TECHNICAL UNIVERISTY OF CLUJ-NAPOCA
FACULTY OF INDUSTRIAL ENGINEERING, ROBOTICS AND PRODUCTION MANAGEMENT

Department of Design Engineering and Robotics

FLORIN POPIŞTER **IOAN BLEBEA**

Mechanical Construction of Industrial Robots

Practical design guide

UTPRESS
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INTRODUCTION

The mechanical construction of industrial robots is a complex field in the field of engineering study and is based on knowledge from disciplines, interconnected specializations, without which the evolution of this large and vast sector depends entirely. Modern and up-to-date engineering, through its simple development, has met the future and current engineers in terms of design, calculation system, design and simulation and physical realization of robotic mechanical equipment.

This design guide, in the form of a MASTER Project, is intended to be a detailed theoretical support, obviously of a practical nature, which is aimed at students and beyond. This material, through the 9 stages, concretely and suggestively defined, which is provided with an explicit content of theoretical information and practical methods, supported by annexes with reference to existing modern products on the industrial market, is a real support for every engineer. becoming, from the point of view of mechanical engineering, in general, but especially of the construction of industrial robots.

All computing approaches, accompanied by theoretical foundations, graphical schemes, constructive and actuation solutions, are developed to the level of numerical calculations necessary for rational choice and verification of functional and active structural elements, around a robot with 5 degrees of freedom, which by its configuration, with obvious practical applicability, can be considered as an analysis model for the design and development of other robotic structures.

Stage 1 aims to initiate the student in the purpose, stages and requirements of the project, the result being to determine the initial data for a concrete scenario of operation of the robot, data obtained by customizing the index mo, nominated in part for each student in a study.

Based on the laws, principles and methods of analysis of theoretical mechanics, through the three major chapters: statics, kinematics and dynamics, all functional subassemblies of the robot are approached in turn, hierarchically and rationally, on each degree of freedom, the objectives being to determine forces and moments of interaction, between the active elements of each functional subassembly and on each kinematic axis, within operating scenarios as close as possible to the real cases.

Each of the next 8 stages of the project has precise professional design goals, up to the level of judicious choice of existing structural and drive components on the industrial market, checking the correct choice based on the required parameters and cataloging them through the supplier order code.

By approaching the student and completing the MASTER Project, developed based on the initiation index $\mathbf{m_o = 12\ kg}$, all design premises, theoretical developments, graphical elements of substantiation, methods of analysis and calculation, edited in the normal color BLACK, remain valid for the approach and development of the STUDENT variant for an introductory index $\mathbf{m_o}$ customized to each one.

Thus, all the theoretical substantiation of each stage is taken over completely and mastered, by the student's goodwill, remaining in its concrete task all the particularizations, development of calculations and numerical results obtained, edited in RED, the completion of each stage being by choosing from the existing catalogs of structural components. and actuating assets, the verification of the rational choice being performed by the parameters proposed in each stage.

We believe that by completing such a project, as proposed and developed in this tutorial, students gain the courage and dexterity necessary to participate in real design teams, where professionalism, competence and engineering responsibility are the strengths of appreciating the value of the individual.

Cluj-Napoca
08.12.2021 AUTHORS

Content

Phase1. Determining the initial design data

A. Project theme statement

Mechanical Construction of Industrial Robots

For the robotic structure, proposed in figure 1, the following design steps and calculations will be carried out, in the order of the sequence of the theory to be taught in the course:

1.) Determination of the cumulative dynamic loads on each functional element,

2.) Calculation of the dimensioning of the longitudinal guidance of the beam,

3.) Calculation of the dimensioning of the vertical guide of the column,

4.) Calculation and dimensioning of the kinematic axis for displacement on the OZ axis,

5.) Choice and verification of the telescopic arm guide,

6.) Choice and verification of the cross roller bearing at the base of the robot,

7.) Calculation of required torque and choice of servo motor for movement along the OX axis,

8.) Calculation of required torque and choice of servo motor for rotation module drive Choice of harmonic reducer for robot shoulder joint,

9.) Calculation and sizing of the robot shoulder joint.

<u>Note1:</u>

1. The project will be initiated from the index **mo** (kg) which is determined according to the student's "n" position in the catalogue of the half-group (group), following the string of "n" numbers in Table 1:

Tab. 1

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
mo																
n	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
mo																
n	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
mo																

1. The **<u>mass of the structural elements</u>** is determined on the basis of correlation relationships with the value of the **mo** index (see Table 2).
2. The choice of components and functional systems shall be made from catalogues valid on the industrial market and their nomination shall be completed by indicating the supplier order code.
3. The nominal durability or service life, as appropriate, shall be calculated as a verification parameter for motion guidance systems.
4. The selection of the servomotors and associated gearboxes respectively shall be based on the average value of the required torque calculated from the dynamic motion conditions.
5. For each servomotor or gear unit selected in the design, the technical data sheet and geometrical data and the torque-torque or torque-speed characteristic diagram shall be provided.
6. The robot shall be considered to be capable of handling, in any possible direction, an equivalent load Ms=1/20 (val. approx.) of the pre-calculated total mass (mt) of the robot.

7. All calculation elements and related schemes will be contained in a personal file, which will be handed in to the subject leader at the end of the semester.

The mass values [kg] of the functional elements of the robot, the names and the mass code of each element

Tab. 2

Name of the element	Masic code	The relationship of the element's mass (kg)	How to obtain the movement of the moving element	Element mass for EXAMPLE **mo=12 [kg]**	Element mass **for (STUDENT) mo=..........** [kg]
BASE	-	-	-		
SERVOMOTOR Sm1	**m1**	m1 =2,5 x mo	-	30	
LONGITUDINAL GUIDE	**m2**	m2=10 x mo	Servomotor - reducer - rack pinion	120	
SERVOMOTOR Sm2	**m3**	m3 =2 x mo	-	24	
ROTATION MODUL OZ	**m4**	m4=5 x mo	Servomotor - reducer1 – reducer 2 – turntable	60	
VERTICAL COLUMN	**m5**	m5=6 x mo	-	72	
SERVOMOTOR Sm3	**m6**	m6 =2 x mo	-	24	
VERTICAL SLEDGE	**m7**	m7=3 x mo	Servomotor – ball screw	36	
SERVOMOTOR Sm4	**m8**	m8 =1,5 x mo	-	18	
ROTATION MODUL OY	**m9**	m9=2 x mo	Servomotor – harmonic reducer – turntable	24	
SERVOMOTOR Sm5	**m10**	m10=mo	-	12	
TELESCOPIC ARM HOUSING	**m11**	m11=2x mo	-	24	
MOBIL ELEMENT TELESCOPIC ARM	**m12**	m12=2x mo	Servomotor – ball screw	24	
ORIENTATION MODULE	**m_0**	**m_0**	-	12	
			Total mass pre-calculated robot, mt:	**480**	
MANIPULATED MASS	**ms**	mt/20		**24**	
			Total cumulative mass, including load, mct:	**504**	

Calculation relationships of initial data

1.The values of velocities, accelerations of movement and axle travels shall be adapted, according to the pre-calculated total mass **mt** (kg) of the whole structure, to the values specified in Table 3.

2. All the values initially set or calculated in the brown boxes are valid for the MASTER example of the project, e.g. **m_o** =12 kg

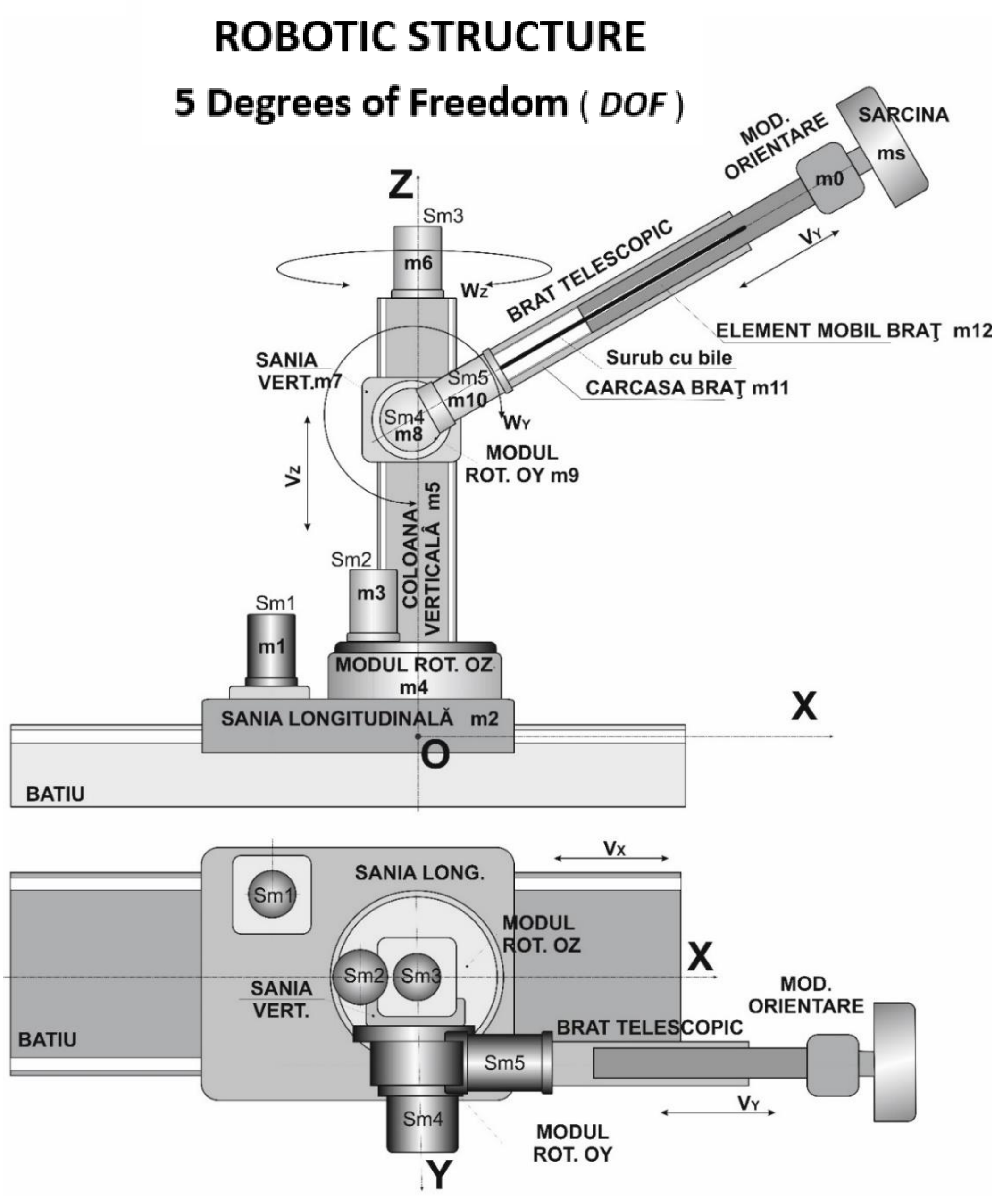
Tab. 3

Total mass of the structure:	Vx, Vy şi Vz:	ax, ay şi az	Wz, Wy	**e**z, **e**y	Size of the axis races [m]		
					OX	OZ	OY
20 – 200 kg	1,0 m/s	4,0 m/s^2	π rad/s	4π rad/s^2	0,5	0,5	0,25
200 – 500 kg	0,5 m/s	2,5 m/s^2	π/2 rad/s	2π rad/s^2	1,0	1,0	0,6
500 – 1000 kg	0,25 m/s	1,5 m/s^2	π/4 rad/s	π rad/s^2	2,0	1,5	1,0
1000 – 2000 kg	0,15 m/s	0,75 m/s^2	π/8 rad/s	π/2 rad/s^2	5,0	2,0	1,5

Values of velocities, accelerations of movement and strokes on the 3 axes
STUDENT project **m₀** =............................

Tab. 4

Name of the working element	Velocity/ acceleration	Size of the guides (Student) [m]		
ARM	-	OX	OZ	OY
LONGITUDNIAL ARM	V_x= m/s a_x= m/s^2			
ROTATION MODULE OZ	W_z= rad/s ε_z= rad/s^2	**-**	**-**	**-**
VERTICAL GUIDE	V_z= m/s a_z= m/s^2			
ROTATION MODULE OY	W_y= rad/s ε_y= rad/s^2	**-**	**-**	**-**
MOBIL ELEMENT TELESCOPIC ARM	V_y= m/s a_y= m/s^2			



B - Determination of cumulative dynamic loads on each functional element

(model for calculating masses according to the value mo=12 kg, taken as an example)

Tab. 5-A

	mci	Cumulative dynamic load on the moving element or on the actuator (kg)	Real value For example mo=12 kg
MASS	ms	ms=24	0
ORIENTATION MODULE	mc0	mc0=ms=24	24
MOBIL ELEMENT TELESCOPIC ARM	mc12	mc12= mc0+m0=24+12	36
TELESCOPIC ARM HOUSING	mc11	mc11=mc12+m12=36+24	60
SERVOMOTOR Sm5	mc10	mc10=mc11+m11=60+24	84
ROTATION MODULE OY	mc9	mc9=mc10+m10=84+12	96
SERVOMOTOR Sm4	mc8	mc8=mc9+m9=96+24	120
VERTICAL GUIDANCE	mc7	mc7=mc8+m8=120+18	138
SERVOMOTOR Sm3	mc6	mc6=mc7+m7=138+36	174
VERTICAL COLUMN	mc5	mc5=mc6+m6=174+24	198
ROTATION MODULE OZ	mc4	mc4=mc5+m5=198+72	270
SERVOMOTOR Sm2	mc3	mc3=mc4+m4=270+60	330
LONGITUDINAL GUIDANCE	mc2	mc2=mc3+m3=330+24	354
SERVOMOTOR Sm1	mc1	mc1=mc2+m2=354+120	474
Check		Servomotor Sm1	30
		Total:	504

Cumulative dynamic loads on each functional element

student's project **mo=…………..** kg

Tab. 5-B

	mci	Cumulative dynamic load on the moving element or on the actuator (kg)	Value mo=……..kg
MASS	**ms**	ms=	0
ORIENTATION MODULE	**mc0**	mc0=ms=	
MOBIL ELEMENT TELESCOPIC ARM	**mc12**	mc12= mc0+m0=	
TELESCOPIC ARM HOUSING	**mc11**	mc11=mc12+m12=	
SERVOMOTOR Sm5	**mc10**	mc10=mc11+m11=	
ROTATION MODULE OY	**mc9**	mc9=mc10+m10=	
SERVOMOTOR Sm4	**mc8**	mc8=mc9+m9=	
VERTICAL GUIDE	**mc7**	mc7=mc8+m8=	
SERVOMOTOR Sm3	**mc6**	mc6=mc7+m7=	
VERTICAL COLUMN	**mc5**	mc5=mc6+m6=	
ROTATION MODULE OZ	**mc4**	mc4=mc5+m5=	
SERVOMOTOR Sm2	**mc3**	mc3=mc4+m4=	
LONGITUDINAL GUIDE	**mc2**	mc2=mc3+m3=	
SERVOMOTOR Sm1	**mc1**	mc1=mc2+m2=	
CHECK		Servomotorul Sm1	
		Total:	

C - Calculation of cumulative dynamic masses on structural sub-assemblies

(**Exemple**, for mo=12 kg)

No. crt.	Functional element name	Mass code	OWN Weight	Rotating elements	The whole arm	Forearm
1.	SERVOMOTOR Sm1	m1	30			
2.	LONGITUDINAL GUIDE	m2	120			
3.	SERVOMOTOR Sm2	m3	24	24		
4.	ROTATION MODULE OZ	m4	60	60		
5.	VERTICAL COLUMN	m5	72	72		
6.	SERVOMOTORUL Sm3	m6	24	24		
7.	SANIA VERTICALA	m7	36	36	36	
8.	SERVOMOTOR Sm4	m8	18	18	18	
9.	ROTATION MODULE OY	m9	24	24	24	24
10.	SERVOMOTOR Sm5	m10	12	12	12	12
11.	TELESCOPIC ARM HOUSING	m11	24	24	24	24
12.	MOBIL ELEMENT TELESCOPIC ARM	m12	24	24	24	24
13.	ORIENTATION MODULE	m0	12	12	12	12
14.	MANIPULATION MODULE	ms	**24**	**24**	**24**	**24**
	TOTAL:		**504**	**354**	**174**	**120**

Calculation of cumulative dynamic masses on structural sub-assemblies

student's project **mo=…………..** kg

Tab. 7

No. crt.	Functional element name	Mass code	OWN Weight	Rotating elements	The whole arm	Forearm
1.	SERVOMOTOR Sm1	m1				
2.	LONGITUDINAL GUIDE	m2				
3.	SERVOMOTOR Sm2	m3				
4.	ROTATION MODULE OZ	m4				
5.	VERTICAL COLUMN	m5				
6.	SERVOMOTOR Sm3	m6				
7.	VERTICAL GUIDE	m7				
8.	SERVOMOTOR Sm4	m8				
9.	ROTATION MODULE OY	m9				
10.	SERVOMOTOR Sm5	m10				
11.	TELESCOPIC ARM HOUSING	m11				
12.	MOBIL ELEMENT TELESCOPIC ARM	m12				
13.	ORIENTATION MODULE	m0				
14.	MANIPULATED MASS	ms				
	TOTAL:					

Note 2: For the calculation of the **equivalent masses** and the **coordinates of the centers of mass**, the values of the functional parameters according to the size of the robot are appreciated from a dimensional point of view. For the **STUDENT** variant, the values of the coordinates of the mass centers on the two axes, as well as the constructively chosen sizes (a, b, c, d) that will be introduced in Tab. 9, will be adjusted as a percentage of the values specified in the orange columns (of the **MASTER** variant), according to the prescriptions in table 8 according to the size of the robot

Total mass of the structure:	Masic center coordinates of the OZ axis	Masic center coordinates of the OX axis	Masic center coordinates of the OY axis	Constructively chosen sizes: a, b, c, d etc
20 – 100 kg	25%	25%	25%	25%
100 – 200 kg	50%	50%	50%	50%
200 – 500 kg	100%	100%	100%	100%
500 – 1000 kg	125%	125%	125%	125%
1000 – 2000 kg	150%	150%	150%	150%

D- Coordinate values of mass centres (in metres)

Tab. 9

No. Crt.	Item name functional	Cod masic	Mass element (exemple mo=12kg	**Coordinates of mass centres** (**exemple mo=12 kg)**			**Mass element (STUDENT mo=...... kg**	**Coordinates of mass centres (STUDENT mo=..... kg)**		
				Zi	**Xi**	**Yi**		**Zi**	**Xi**	**Yi**
1.	**SERVOMOTOR Sm1**	**m1**	30	0,25	0,40	0,0				
2.	**LONGITUDINAL GUIDE**	**m2**	120	0,15	0,0	0,0				
3.	**SERVOMOTOR Sm2**	**m3**	24	0,35	0,20	0,0				
4.	**ROTATION MODULE OZ**	**m4**	60	0,35	0,0	0,0				
5.	**VERTICAL COLUMN**	**m5**	72	0,60	0,0	0,0				
6.	**SERVOMOTOR Sm3**	**m6**	24	1,4	0,0	0,0				
7.	**VERTICAL GUIDE**	**m7**	36	0,7	0,0	0,2				
8.	**SERVOMOTOR Sm4**	**m8**	18	0,7	0,0	0,35				
9.	**ROTATION MODULE OY**	**m9**	24	0,7	0,0	0,3				
10.	**SERVOMOTOR Sm5**	**m10**	12	0,7	0,25	0,3				
11.	**TELESCOPIC ARM HOUSING**	**m11**	24	0,9	0,6	0,3				
12.	**MOBIL ELEMENT TELESCOPIC ARM**	**m12**	24	0,9	**0,9**	0,3				
13.	**ORIENTATION MODULE**	**m0**	12	0,9	**1,2**	0,3				
14.	**MANIPULATED MASS**	**ms**	**24**	0,9	**1,3**	0,3				

E- Calculation of equivalent masses and coordinates of mass centers

Enter the following notations:

MeT - global equivalent mass of the whole robot

MeR - equivalent mass of the rotating structure

MeB - equivalent mass of the integral arm

MeA - equivalent mass of the forearm

The coordinates of the centers of the equivalent masses are determined from the formulae in the formulae:

$$\mathrm{xe} = \frac{\sum mi*xi}{\sum mi}; \qquad \mathrm{ye} = \frac{\sum mi*yi}{\sum mi}; \qquad \mathrm{ze} = \frac{\sum mi*zi}{\sum mi}$$

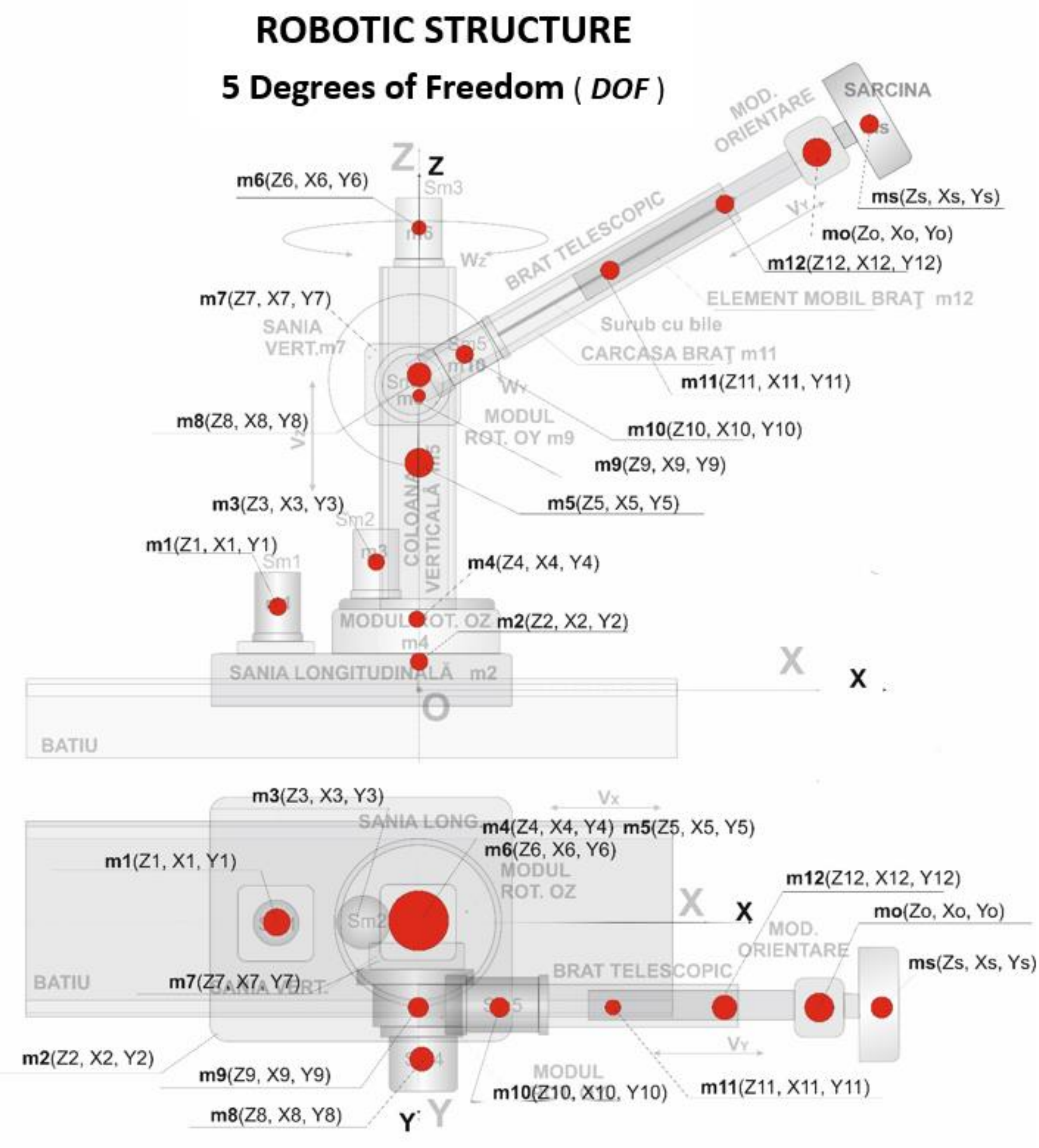


Fig. 2. **Mass centers of the structural elements**

Calculation of the coordinates of the equivalent mass centres of the robot subsystems
(Values according to MASTER model for **mo**=12kg)

THE ENTIRE ROBOT STRUCTURE

Tab. 10 (kg; m)

No. crt.	Element name	CODE	Weight	Zi	Xi	Yi	Mi*Zi	Mi*Xi	Mi*Yi
1	**SERVOMOTOR Sm1**	**m1**	30	0,25	0,4	0	7,5	12	0
2	**LONGITUDINAL GUIDE**	**m2**	120	0,15	0	0	18	0	0
3	**SERVOMOTOR Sm2**	**m3**	24	0,35	0,2	0	8,4	4,8	0
4	**ROTATION MODULE OZ**	**m4**	60	0,35	0	0	21	0	0
5	**VERTICAL COLUMN**	**m5**	72	0,6	0	0	43,2	0	0
6	**SERVOMOTOR Sm3**	**m6**	24	1,4	0	0	33,6	0	0
7	**VERTICAL GUIDE**	**m7**	36	0,7	0	0,2	25,2	0	7,2
8	**SERVOMOTOR Sm4**	**m8**	18	0,7	0	0,35	12,6	0	6,3
9	**ROTATION MODULE OY**	**m9**	24	0,7	0	0,3	16,8	0	7,2
10	**SERVOMOTOR Sm5**	**m10**	12	0,7	0,25	0,3	8,4	3	3,6
11	**TELESCOPIC ARM HOUSING**	**m11**	24	0,9	0,6	0,3	21,6	14,4	7,2
12	**MOBIL ELEMENT TELESCOPIC ARM**	**m12**	24	0,9	0,9	0,3	21,6	21,6	7,2
13	**ORIENTATION MODULE**	**mo**	12	0,9	1,2	0,3	10,8	14,4	3,6
14	**MANIPULATED MASS**	**ms**	24	0,9	1,3	0,3	21,6	31,2	7,2
		MeT	**504**				**270,3**	**101,4**	**49,5**
						ZeT	**0,536**		
						XeT		**0,201**	
						YeT			**0,098**

ROTATING STRUCTURE

Tab. 11 (kg; m)

No. crt.	Element name	CODE	Weight	Zi	Xi	Yi	Mi*Zi	Mi*Xi	Mi*Yi
1	**SERVOMOTOR Sm2**	**m3**	24	0,35	0,2	0	8,4	4,8	0
2	**ROTATION MODULE OZ**	**m4**	60	0,35	0	0	21	0	0
3	**VERTICAL COLUMN**	**m5**	72	0,6	0	0	43,2	0	0
4	**SERVOMOTOR Sm3**	**m6**	24	1,4	0	0	33,6	0	0
5	**VERTICAL GUIDE**	**m7**	36	0,7	0	0,2	25,2	0	7,2
6	**SERVOMOTOR Sm4**	**m8**	18	0,7	0	0,35	12,6	0	6,3
7	**ROTATION MODULE OY**	**m9**	24	0,7	0	0,3	16,8	0	7,2
8	**SERVOMOTOR Sm5**	**m10**	12	0,7	0,25	0,3	8,4	3	3,6
9	**TELESCOPIC ARM HOUSING**	**m11**	24	0,9	0,6	0,3	21,6	14,4	7,2
10	**MOBIL ELEMENT TELESCOPIC ARM**	**m12**	24	0,9	0,9	0,3	21,6	21,6	7,2
11	**ORIENTATION MODULE**	**mo**	12	0,9	1,2	0,3	10,8	14,4	3,6
12	**MANIPULATED MASS**	**ms**	24	0,9	1,3	0,3	21,6	31,2	7,2
13		**MeR**	**354**				**244,8**	**89,4**	**49,5**
14						**ZeR**	**0,691**		
						XeR		**0,252**	
						YeR			**0,139**

THE ENTIRE ROBOT ARM

Tab. 12 (kg; m)

No. crt.	Element name	CODE	Weight	Zi	Xi	Yi	Mi*Zi	Mi*Xi	Mi*Yi
7	**VERTICAL GUIDE**	**m7**	36	0,7	0	0,2	25,2	0	7,2
8	**SERVOMOTOR Sm4**	**m8**	18	0,7	0	0,35	12,6	0	6,3
9	**ROTATION MODULE OY**	**m9**	24	0,7	0	0,3	16,8	0	7,2
10	**SERVOMOTOR Sm5**	**m10**	12	0,7	0,25	0,3	8,4	3	3,6
11	**TELESCOPIC ARM HOUSING**	**m11**	24	0,9	0,6	0,3	21,6	14,4	7,2
12	**MOBIL ELEMENT TELESCOPIC ARM**	**m12**	24	0,9	0,9	0,3	21,6	21,6	7,2
13	**ORIENTATION MODULE**	**mo**	12	0,9	1,2	0,3	10,8	14,4	3,6
14	**MANIPULATED MASS**	**ms**	24	0,9	1,3	0,3	21,6	31,2	7,2
		MeB	**174**				**138,6**	**84,6**	**49,5**
						ZeB	**0,797**		
						XeB		**0,486**	
						YeB			**0,284**

ROBOT FOREARM

Tab. 13 (kg; m)

No. crt.	Element name	CODE	Weight	Zi	Xi	Yi	Mi*Zi	Mi*Xi	Mi*Yi
7	**ROTATION MODULE OY**	**m9**	24	0,7	0	0,3	16,8	0	7,2
8	**SERVOMOTOR Sm5**	**m10**	12	0,7	0,25	0,3	8,4	3	3,6
9	**TELESCOPIC ARM HOUSING**	**m11**	24	0,9	0,6	0,3	21,6	14,4	7,2
10	**MOBIL ELEMENT TELESCOPIC ARM**	**m12**	24	0,9	0,9	0,3	21,6	21,6	7,2
11	**ORIENTATION MODULE**	**mo**	12	0,9	1,2	0,3	10,8	14,4	3,6
12	**MANIPULATED MASS**	**ms**	24	0,9	1,3	0,3	21,6	31,2	7,2
13		**Mea**	**120**				**100,8**	**84,6**	**36**
14						**ZeA**	**0,84**		
						XeA		**0,705**	
						YeA			**0,3**

Mass centers of robot subsystems

Tab. 14, Values in [kg] şi [m]

ROBOT Structure	Symbol	Cumulative mass	Zei		Xei		Yei	
Robot entire (integral)	MeT	504	ZeT	0,536	XeT	0,201	YeT	0,098
Rotation	MeR	354	ZeR	0,691	XeR	0,252	YeR	0,139
Entire robot arm	MeB	174	ZeB	0,797	XeB	0,486	YeB	0,284
Robot Forearm	MeA	120	ZeA	0,840	XeA	0,705	YeA	0,300

Note 3 : Only the tables 10, 11, 12, 13 and 14 of the **STUDENT** project variants will be introduced in the project made by the student, after the calculations have been redone in accordance with the assigned $\mathbf{m_o}$ indicator.

Phase2 - Sizing the longitudinal guide

It is proposed that the linear guidance system be sized to ensure a nominal durability of at least 5,000 km.

a - Determination of the reactions in the movable guideway blocks

Some relations from mechanics:

Centrifugal force: $Fc=mv^2/r=m*\omega^2*r^2/r=m*\omega^2*r$,

Tangential inertia force: $Fit=m*at=m*\varepsilon*r$,

Where: m - equivalent mass of the moving subsystem,

r - radius of the centre of mass relative to the axis of rotation,

ω and ε - velocity and angular acceleration in rotational motion.

1 - The case of accelerated movements in the most unfavourable directions

Motion case: simultaneous accelerated movements in the direction of the OX and OZ axes, as well as rotation of the robot in accelerated motion about the OZ axis).

From Tab. 14 those elements of the calculation corresponding to the motion scenario are taken.

Tab. 15

Direction of movement / robot structure	Symbol	Cumulative mass	Zei		Xei		Yei		Equivalent radius to the axis OZ	
OX – longitudinal/ Integral robot	MeT	504	ZeT	0,536	XeT	0,201	YeT	0,098		-
OZ – rotation / Rotating structure	MeR	354	ZeR	0,691	XeR	0,252	YeR	0,139	reR	0,288
OZ – vertical / Integral arm	MeB	174	ZeB	0,797	XeB	0,486	YeB	0,284		-

- The equilibrium of the longitudinal sled is analysed by writing the equilibrium equations of forces and moments on the three axes: OX, OY and OZ.

- For the probable size of the robot, the distances a=0.8 and b=0.6 m are adopted in advance, which delimit the position of the four movable blocks of the guide in the XOY plane.

- In the case of the MeR rotating structure, the centre of mass zaza reR is determined from the relation: **reR=[(XeR)2+(YeR)2]1/2**

- Based on the notations in Figure 3, the following forces can be identified and calculated:

Tab. 16

Gt	M_{eT}*g	504*10	5040	b=0,6
Fiz	M_{eB}*az	174*2,5	435	a=0,8
Fc	M_{eR}*r_{eR}* ω^2	354*0,288*3,14^2/4	252	r_{eR}=0,288
Fit	M_{eR} * r_{eR}* ε	354*0,288*6,28	640,2	r_{eR}=0,288
Fix	M_{eT} *ax	504*2,5	1260	

Equilibrium equation of moments with respect to the OX axis:

$$Gt \cdot yeT + Fiz \cdot yeB + Fc \cdot zeR = \frac{b}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

Equilibrium equation of moments with respect to the OY axis:

$$Fit \cdot zeR + Fix \cdot zeT = \frac{a}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

Equilibrium equation of moments with respect to the OZ axis:

$$Fit \cdot yeR + Fix \cdot yeT = \frac{a}{2} \cdot (Rt1 + Rt2 + Rt3 + Rt4)$$

Equation of equilibrium of forces with respect to the OY axis:

$$Fc = (Rt1 + Rt2 + Rt3 + Rt4)$$

Force balance equation with respect to the OX axis:

$$Fix + Fit = Fm$$

Numerical calculation:

The symmetry of the system with respect to the three axes will be taken into account, resulting in:

Rn1=Rn2, Rn3=Rn4

Rt1=Rt3, Rt2=Rt4

- Equilibrium equation of moments with respect to the OX axis:

$$Gt \cdot yeT + Fiz \cdot yeB + Fc \cdot zeR = \frac{b}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

$$5040 \cdot 0{,}098 + 435 \cdot 0{,}284 + 252 \cdot 0{,}691 = \frac{b}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

493,9+123,5+174,1=0,3*2*(Rn1+Rn3)

791,6=0,6*(Rn1+Rn3)

Rn1+Rn3=1319,3

- Equilibrium equation of moments with respect to the OY axis:

$$Fit \cdot zeR + Fix \cdot zeT = \frac{a}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

$$640{,}2 \cdot 0{,}691 + 1260 \cdot 0{,}536 = \frac{a}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

442,4+675,4=0,4*2*(Rn1+Rn3)

Rn1+Rn3=1117,7

- The sign in the two relations is compatible:

Rn1-Rn3=1117,7

Rn1+Rn3=1319,3

Rn1=(1319,3+1117,7)/2=1218,5

Rn3=1218,5-1117,7=100,8

- Equilibrium equation of moments with respect to the OZ axis:

$$Fit \cdot yeR + Fix \cdot yeT = \frac{a}{2} \cdot (Rt1 + Rt2 + Rt3 + Rt4)$$

$$640{,}2 \cdot 0{,}139 + 1260 \cdot 0{,}098 = \frac{a}{2} \cdot (Rt1 + Rt2 + Rt3 + Rt4)$$

88,9+123,5=0,4*2*(Rt1+Rt2)

Rt1+Rt2=265,6

- Equation of equilibrium forces with respect to the OY axis:

$$Fc = (Rt1 + Rt2 + Rt3 + Rt4)$$

$$252 = (Rt1 + Rt2 + Rt3 + Rt4)$$

252=2*(Rt1+Rt2)

- The sign in the two relations is compatible:

Rt1+Rt2=265.6

Rt1-Rt2=126

Rt1=(265,6+126)/2=195,8

Rt2=Rt1-126=195,8-126=69,7

- Equilibrium equation of forces about the OX-axis:

Fix+Fit=Fm

Fm=1260+640,2=1900

Fm=1900 N

- Power required to drive in accelerated linear motion along the OX axis:

P=Fm*Vx=1900*0,50=950 W=0,95 kW

P=0,95 kW

For the calculation of the equivalent force on each block, the reactions Rni and Rti are taken only in absolute value.

The values obtained are centralised in a table.

Rn1;Rn2	Rn3;Rn4	Rt1;Rt3	Rt2;Rt4
1257,5	100,8	195,8	69,7

Equivalent forces on each of the 4 movable guide blocks:

Pe1=Rn1+Rt1 = 1257,5+195,8=1397,2

Pe2=Rn1+Rt2 = 1257,5+69,7=1327,2

Pe3=Rn3+Rt1 = 100,8+195,8=296,6

Pe4=Rn3+Rt2 = 100,8+69,8=170,6

Pe1= **1453,3** N

Pe2= **1327,2** N

Pe3= **296,6** N

Pe4= **170,6** N

2- Case of uniform movements (on all axes)

- Equilibrium equation of moments with respect to the OX axis:

$$GT \cdot YeT + Fc \cdot ZeR = \frac{b}{2} \cdot (Rn1 + Rn2 + Rn3 + Rn4)$$

5040*0,098+252*0,691=2*b/2(Rn1+Rn3)

Rn1+Rn3=0,6*668=401

- Equilibrium equation of forces with respect to the OZ axis:

Me_T*g = 2*(Rn1+Rn3)

Rn1+Rn3=5040/2=2520

The sign is compatible in both relationships:

Rn1+Rn3=2520

Rn1-Rn3=401

Rn1=(2520+401)/2=1460,5

Rn3=1460,5-401=1059,5

Rn1=Rn2=1460,5

Rn3=Rn4=1059,5

- Equation of equilibrium of forces with respect to the OY axis:

$$Fc = (Rt1 + Rt2 + Rt3 + Rt4)$$

From symmetry conditions it is estimated:

Rt1=Rt2=Rt3=Rt4

Result: 252=4*Rt1

Rt1=Rt2=Rt3=Rt4=63 N

The values obtained are centralised in a table.

Rn1;Rn2	Rn3;Rn4	Rt1;Rt3	Rt2;Rt4
1460,5	1059,5	63	63

For the calculation of equivalent reactions on each block, the forces Rni and Rti are taken only in absolute value.

- Equivalent reactions on each of the 4 movable blocks of the guide:

P'e1=Pe2= Rn1+Rt1= 1460,5+63=1523,5

P'e3=Pe4= Rn3+Rt2= 1059,5+63=1122,5

P'e1=Pe2=1523,5 N

P'e3=Pe4= 1122,5 N

In the case when the load varies monotonically (fig. 1.44 course material), the relation for calculating the average load is:

$$P_m \cong \frac{1}{3}\left(P_{\min} + 2 \cdot P_{\max}\right),$$

, where:

Pmin is the minimum load

Pmax is the maximum load

This gives the average loads on each movable block:

Mobil block:	1	2	3	4
Pe	1453,3	1327,2	296,6	170,6
P’e	1523,5	1523,5	1122,5	1122,5
Pm	**1500,1**	**1457**	**847**	**748**

The type and size of the guides forming the horizontal guide system at the base of the robot will be chosen according to the average dynamic load (design load) of the most stressed moving block, i.e. the value:

Pm1=1480 N = 1,50 kN

Pm3=859 N = 0,85 kN

b. - Choice and verification of linear guides for longitudinal displacement on the OX axis

1. Specify the initial conditions for the system to be hoisted

Environmental conditions: generally constant temperature (22oC), industrial dust atmosphere and possible humidity.

Easy loading, operation 300 days per year (24 hours/day).

Non-uniform working cycle, depending on the circumstances and the type of production.

Depending on the technical solution to be chosen and the operating conditions, the following values of the factors involved in the guide durability formula are adopted:

- Track hardness factor fH=1

- Temperature factor fT=1

- Contact factor fC=1 (one movable block in each corner of the long sled).

- Load factor fw=2 (medium vibration/shock, speed V<2m/s)

System durability is required to be at least L=5000 km

2. System configuration, number of tracks and system position

- Depending on the kinematic motion system of the robot, a two-axis horizontal guidance system is chosen, (a normal main axis and a secondary axis associated with the rack). The main guide axis is considered to be mounted on the right side of the system, its load finding through reactions Pm1 and Pm2, and the axis associated with the rack is considered to be mounted on the left side of the system, its load finding through reactions Pm3 and Pm4.

- The predominant loading is considered to be in the vertical direction (radial normal and reverse), dynamic conditions with moderate shock and vibration, displacement velocity <2 m/s2.

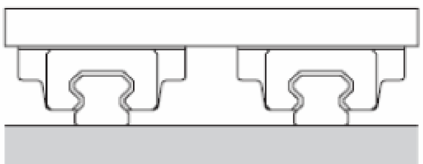


Fig. 4. Guide system configuration

3. Pre-selection of the type and size of guides

- For the longitudinal movement of the sled, it is planned to use a servomotor drive associated with a planetary (or built-in) gearbox, the movement transformation mechanism being a rack and pinion (rack and pinion).
- In view of the relatively low dynamic load of the movable block No. 1 on the right-hand guide (Fig. 3), Pm1=1.50 kN, the HSR-R type (4-way equal load), catalogue THK (ix.pg.1096), will be chosen for this guide.
  - In this case, of the two axes of the system, the right-hand guide will be type HSR-20R and the left-hand guide will be type GSR-V, the column being associated with a rack along its entire length.

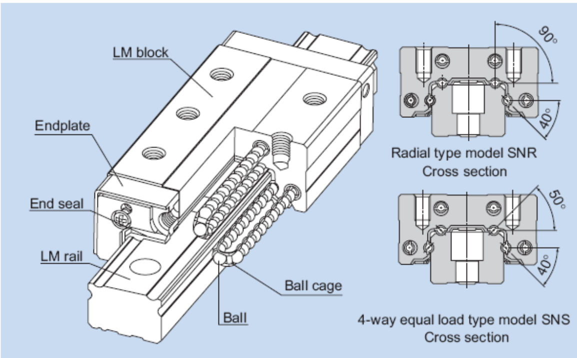


Fig. 4. Normal type guidance HSR-R

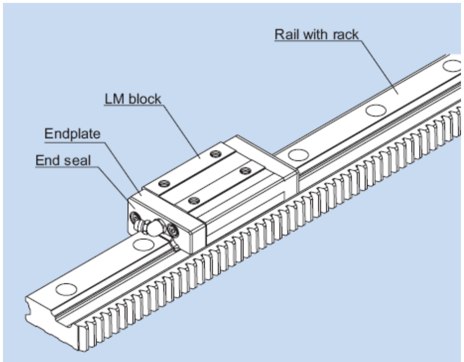


Fig. 5. Secondary guide with zipper type GSR-V

Since all the calculations for determining the reactions in the moving blocks of the two guides have been carried out, one can proceed directly to the choice of the size of each, as follows:

- In choosing the size of each type, the value of the average dynamic loads of the most stressed movable blocks, i.e. block 1 on axis 1 and block 3 on axis 3, is taken into account.

- Pm1=1480 N = 1,50 kN

- Pm3=847 N = 0,85 kN

- From the THK catalogue, (ix.pg.1096) for the HSR-R type guide, choose the size:

HSR-20 R, with the following data: **rated dynamic capacity C=13,8 kN**, rated static capacity Co=**23,8** kN.

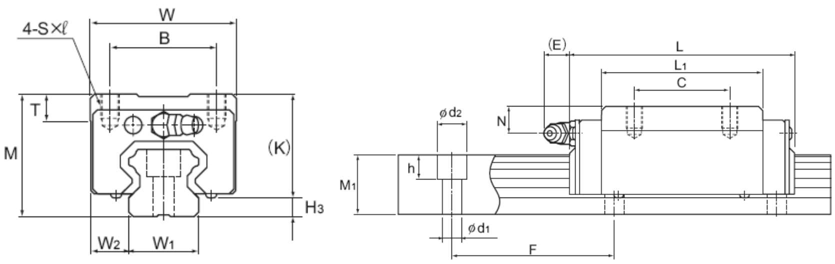


Fig. 6. HSR-20R guide geometry data

Model No.	Outer dimensions Height M	Width W	Length L	LM block dimensions B	C	S×ℓ	L_1	T	K	N	E	Grease nipple	H_3
HSR 15R HSR 15RM	28	34	56.6	26	26	M4×5	38.8	6	23.3	8.3	5.5	PB1021B	3.5
HSR 20R HSR 20RM	30	44	74	32	36	M5×6	50.8	8	26	5	12	B-M6F	4

LM rail dimensions Width W_1 ±0.05	W_2	Height M_1	Pitch F	$d_1 \times d_2 \times h$	Length* Max	Basic load rating C kN	C_0 kN	Static permissible moment kN-m* M_A 1 block	M_A Double blocks	M_B 1 block	M_B Double blocks	M_C 1 block	Mass LM block kg	LM rail kg/m
15	9.5	15	60	4.5×7.5×5.3	3000 (1240)	8.33	13.5	0.0805	0.457	0.0805	0.457	0.0844	0.18	1.5
20	12	18	60	6×9.5×8.5	3000 (1480)	13.8	23.8	0.19	1.04	0.19	1.04	0.201	0.25	2.3

Fig. 7. HSR-20R guide catalogue data

For the HSR-20RM guide, the calculation of the nominal durability will be made for the average equivalent load **Pm1=1,50 kN**,

$L_{1,2}$= $\left(\frac{f_H \cdot f_T \cdot f_C}{f_W}\cdot\frac{C}{P_C}\right)^3 \cdot 50$ =[(1/2)*(13,8/1,50)]^3*50= 4.866 km

From the THK catalogue, (ix.pg.1172) for the GSR-R type guideway choose the size:

GSR 25V, (fig 8 and 8bis) with catalogue data: **rated dynamic capacity C=10,29 kN**, rated static capacity **Co=12,65 kN**.

- for the average equivalent load Pm3=0,859 kN, and the nominal dynamic capacity C=10,29 kN, it results:

- $L_{3,4}$= $\left(\frac{f_H \cdot f_T \cdot f_C}{f_W}\cdot\frac{C}{P_C}\right)^3 \cdot 50$ =[(1/2)*(10,29/0,85)]^3*50=11.088 km

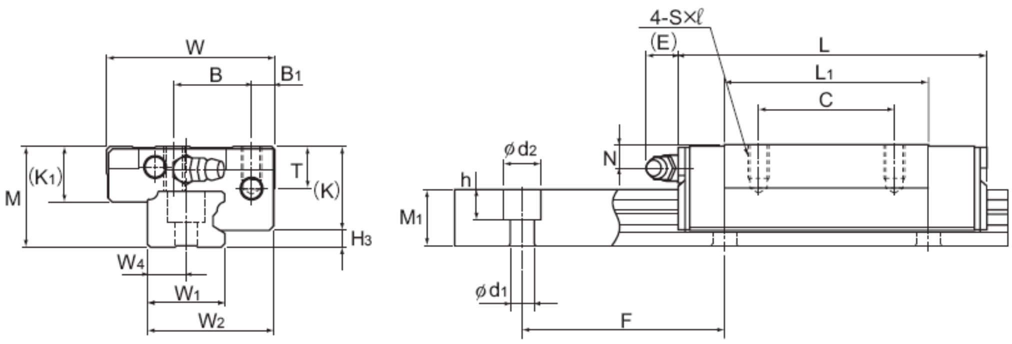


Fig. 8. Geometrical data of the GSR 25V guide

Model No.	Outer dimensions Height M	Width W	Length L	LM block dimensions B_1	B	C	S×ℓ	L_1	T	K	K_1	N	N_1	E	Grease nipple	H_3
GSR 15T GSR 15V	20	32	59.8 47.1	5	15	26 —	M4×7	40.2 27.5	8.25	17.5	12	4.5	3	5.5	PB107	8
GSR 20T GSR 20V	24	43	74 58.1	7	20	30 —	M5×8	50.2 34.3	9.7	20.6	13.6	5	—	12	B-M6F	10.4
GSR 25T GSR 25V	30	50	88 69	7	23	40 —	M6×10	60.2 41.2	12.7	25.5	16.8	7	—	12	B-M6F	13.2

LM rail dimensions Width W_1	W_2	W_4	Height M_1	Pitch F	$d_1 \times d_2 \times h$	Length* Max	Basic load rating C kN	C_0 kN	Static permissible moment kN-m* M_A 1 block	M_A Double blocks	M_B 1 block	M_B Double blocks	Mass LM block kg	LM rail kg/m
15	25	7.5	11.5	60	4.5×7.5×5.3	2000	5.69 4.31	8.43 5.59	0.0525 0.0252	0.292 0.158	0.0452 0.0218	0.252 0.136	0.13 0.08	1.2
20	33	10	13	60	6×9.5×8.5	3000	9.22 7.01	13.2 8.82	0.102 0.0498	0.564 0.307	0.0885 0.0431	0.486 0.265	0.25 0.17	1.8
23	38	11.5	16.5	60	7×11×9	3000	13.5 10.29	19 12.65	0.177 0.0858	0.965 0.522	0.152 0.0742	0.831 0.451	0.5 0.29	2.6

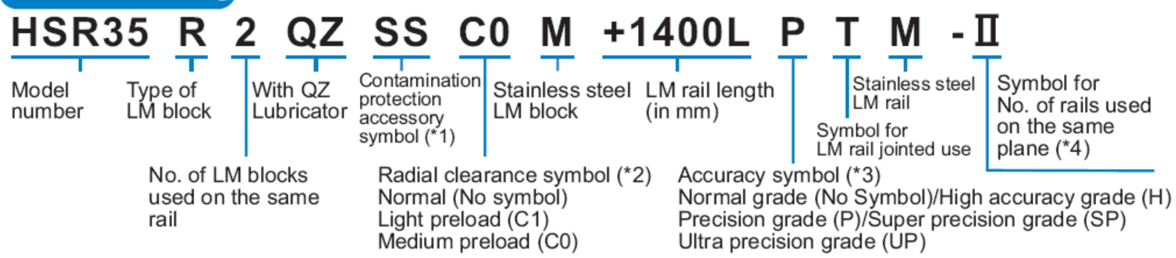
Fig. 8-bis. Catalogue data of the GSR 25V guide

The calculations showed that the durability of the two main guides exceeds the value imposed in the design theme (Ln = 4,500 km).

It can be concluded that both the sizing calculations, the checks performed and the choice of the components were performed correctly.

Order codes SUPPLIER:

Model number coding

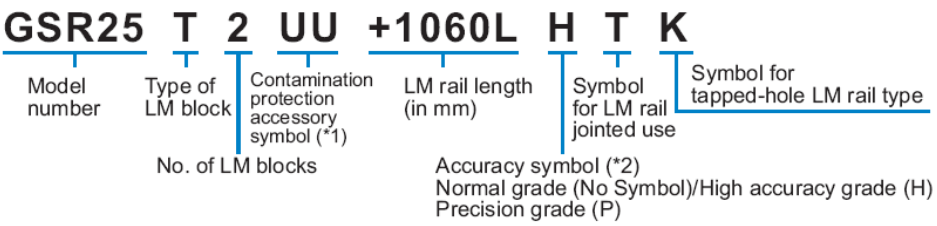


(*1) See contamination protection accessory on A-368. (*2) See A-114. (*3) See A-119. (*4) See A-59.

HSR 20 R 2 QZ DD C0 M +3000L P T M –II

Model number coding

Combination of LM rail and LM block



(*1) See contamination protection accessory on A-368. (*2) See A-124.

GSR 25 V 2 DD +3000L H T K

Phase 3- Dimensions calculus of the vertical guides of the column.

The previously calculated data is stored

a - Determination of reactions in the moving blocks of the guide

To determine the reactions in the moving blocks of the guide, the action of forces and moments will be analyzed according to the scheme in figure 9.

Data from the previous steps are taken over:

$V_x=0,5$ m/s; $a_x= 2,5$ m/s^2; $\omega_z=\pi/2$ rad/s; $\varepsilon_z=2\pi$ rad/s^2; $V_z=0,5$ m/s; $a_z= 2,5$ m/s^2

ROBOT structure	Symbol	Cumulative mass	Zei		Xei		Yei	
The whole arm	MeB	174	ZeB	0,797	XeB	0,486	YeB	0,284

Inventory of the forces involved in the dynamic analysis of the arm

Symbol	Explenantion	Formula	Numeric	Value	Obs
Gb	Weight	Meb *g	174*10	1740	c=0,4
Fiz	Inertia	Meb*az	174*2,5	435	d=0,4
Fc	Centrifugal	Meb*YeB*ωz	$174*0,284*3,14^2/4$	122	ZeB=0,797
Fit	Inerţ. tang.	Meb * YeB *ez	174*0,284*6,28	310	XeB=0,486
Fix	Inertia	Meb*ax	174*2,5	435	YeB=0,284

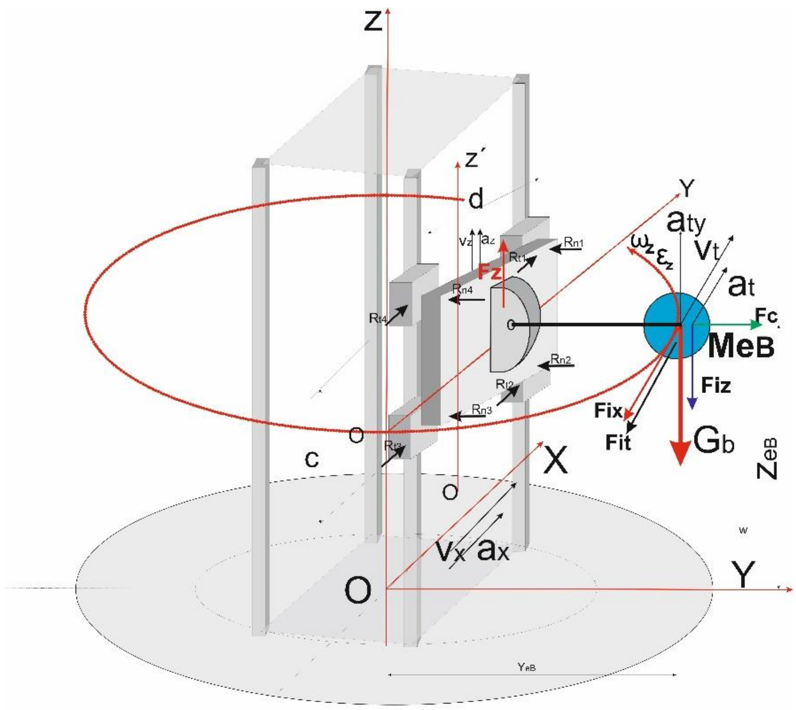


Fig. 9. Diagram of forces acting on the vertical arm

Motion scenario**: simultaneous accelerated movements in the direction of the OX and OZ axes, as well as rotation of the robot in accelerated motion around the OZ axis.**

1 - Case of accelerated movements in the worst-case directions

Analyze the system of forces acting on the robot arm in the worst-case accelerated motion situation (Fig. 9)

It recalls some relationships in mechanics:

Centrifugal force: Fc=mv2/r=m*ω2*r2/r=m* ω2*r,

Tangential inertia force: Fit=m*at=m*ε*r,

Where: m - equivalent mass of the moving subsystem,

r - radius of the center of mass relative to the axis of rotation,

ω and ε - velocity and angular acceleration in rotational motion.

The sizes c=0.4 m and d=0.4 m was chosen constructively according to the size of the robot.

Analyzing the direction of the reactions in the guides, the action of the columns on the moving blocks will be considered. To determine the reactions in the movable blocks of the vertical sled guides, the equations of equilibrium of moments and forces are written as follows:

Balance of forces moments with respect to the OZ axis

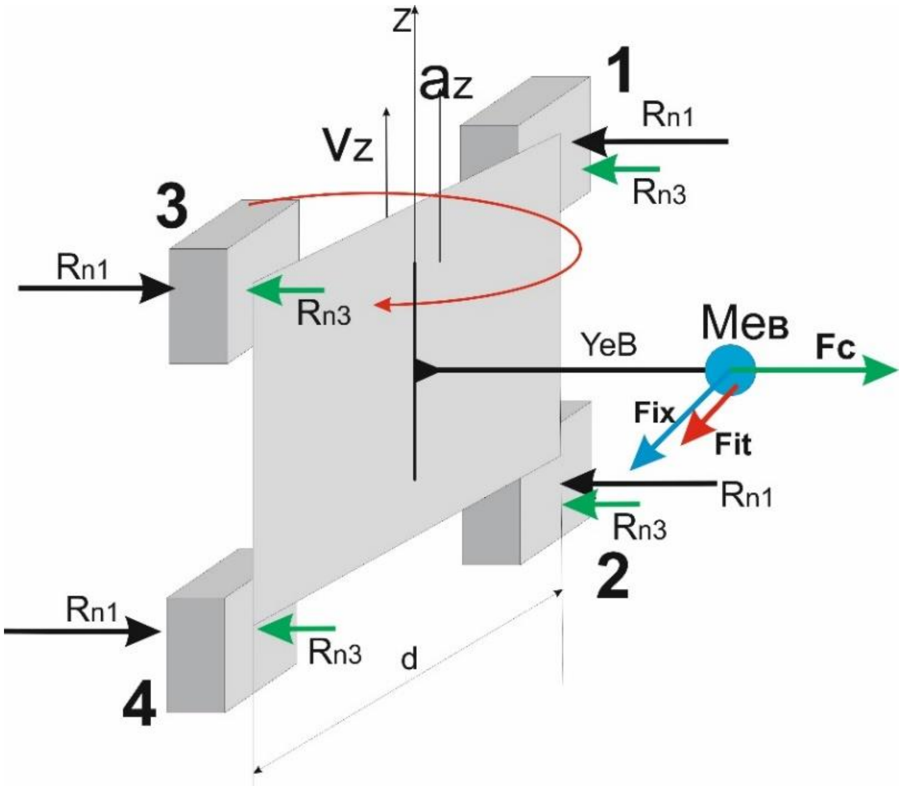


Fig. 10. Sled balance study along the OZ axis

From the symmetrical loading conditions of the 4 movable blocks of the sled guide, choosing the correct direction of the reactions, one can write:

(Fix+Fit)*YeB=4Rn1*d/2

(435+310)*0,284=4*Rn1*0,4/2

Rn1=264,5 N

Force balance on OY axis

Fc=4*Rn3

122=4*Rn3

Rn3=30,5

Balance of forces moments with respect to the OX axis

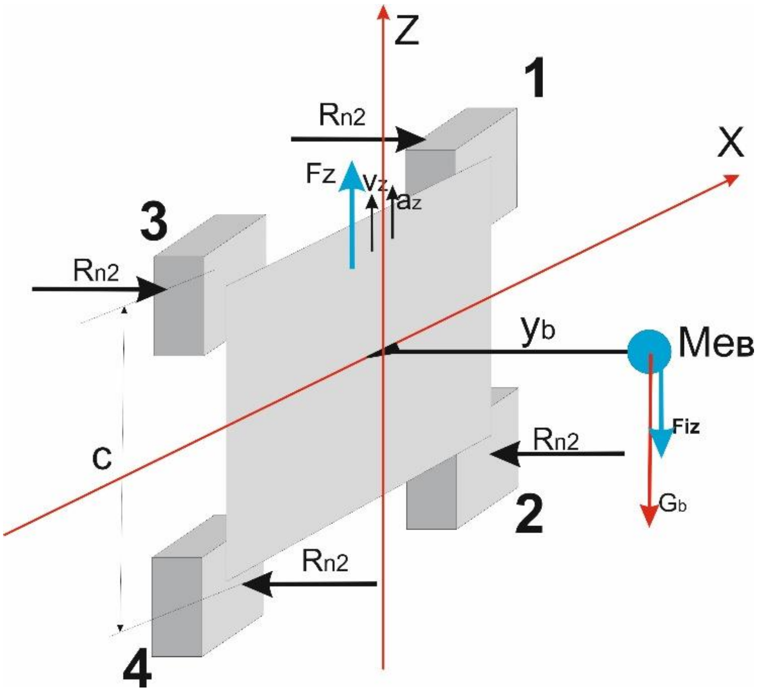


Fig. 11. Study of the sled's balance along the OX axis

(Gb+Fiz)*YeB=4*Rn2*c/2

(1740+435)* 0,284=4*Rn2*0,4/2

Rn2=772,1 N

Equilibrium of the forces on the OZ axis

Fz=Gb+Fiz

Fz=1740+435=2175 N

Fz=2175 N

Based on the value of the vertical force Fz and the travel speed, the required power of the drive motor is obtained in case of uniform movement of the vertical sled.

Pz=Fz*vz=2175*0,50=1087,5 W

Pz=1,09 kW

2 - Case of uniform movement

The moment and force balance equations are repeated, cancelling all inertia forces.

Balance of forces moments with respect to the OZ axis

(Fix+Fit)* YeB =4Rn1*d/2

(0+0)*0,284=4R´n1*d/2

R´n1=0 N

Balance of forces on OY axis

Fc=4*R´n3

R´n3=Fc/4=122/4=30,5 N

R´n3=30,5 N

Balance of forces moments with respect to the OX axis

(Gb+Fiz)*YeB=4R´n2*c/2

(1740+0)* 0,284=4R´n2*0,2

R´n2=494,2/0,8=617,7 N

R´n2=617,7 N

In the first case of accelerated motions on all degrees of freedom, considering the conventional direction chosen for each of the three types of reactions (Fig. 12), the cumulative reactions on each moving block of the guides become:

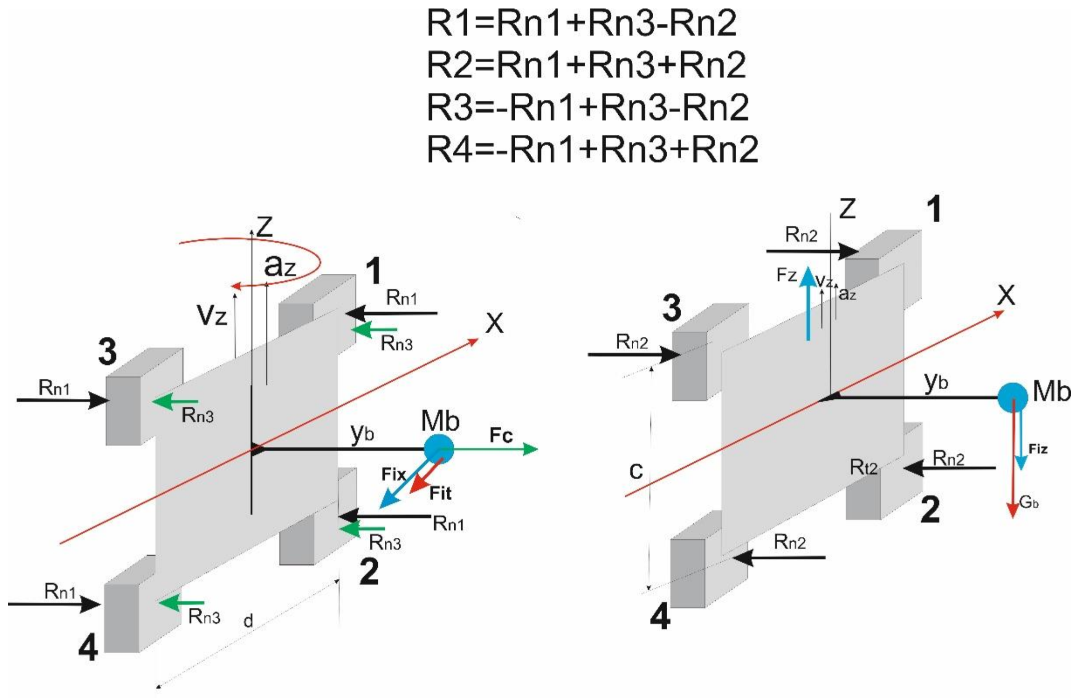


Fig. 12. Study of reaction summation on mobile blocks

Recapitulation of cumulative and equivalent reaction values on each block

Tab. 19

Type of movement	Bloc mob 1	Bloc mob 2	Bloc mob 3	Bloc mob 4
Accelerated movement	**Rn11 =264,5** **Rn31=30,5** **Rn21=-772,1**	**Rn12 =264,5** **Rn32=30,5** **Rn22=772,1**	**Rn13=-264,5** **Rn33=30,5** **Rn23=-772,1**	**Rn14=-264,5** **Rn34=30,5** **Rn24=772,1**
Cumulative reaction	**R1=-477,1**	**R2=1067,1**	**R3=-1006,1**	**R4=538,1**
Uniform movement	**R´n11 =0** **R´n31=30,5** **R´n21=-617,7**	**R´n12 =0** **R´n32=30,5** **R´n22=617,7**	**R´n13 =0** **R´n33=30,5** **R´n23=-617,7**	**R´n14 =0** **R´n34=30,5** **R´n24=617,7**
Reacţinea cumul.	**R´1=-587,2**	**R´2=648,2**	**R´3=-587,2**	**R´4=648,2**
Cumulative reaction Re=1/3*(Rmin+2*Rmax)	**Re1=-550,5**	**Re2=927,5**	**Re3=-866,5**	**Re4=611,5**

b - Choice and verification of the guides for the OZ axis

Next, the type and size of the vertical guide is chosen, considering the maximum equivalent value of the most stressed moving block

Re2=927,5 N = 0,93 kN

1. Specifying the initial loading conditions of the system

When selecting and checking the guidance system for vertical sled movement along the OZ-axis, the same initial conditions are accepted as for longitudinal sled movement along the OX-axis.

The nominal durability of the system is also required to be 5000 km.

2. System configuration, number of paths and position.

- Depending on the kinematic system of the robot arm movement, a vertical guidance system with two identical axes is chosen.

- The predominant loading of the system is on the radial normal and reverse direction, dynamic conditions with moderate shock and vibration, travel speed <2 m/s2.

3. Pre-selection of type and size of guidance systems

- Servo-motor drive is envisaged for the vertical movement of the sled, the motion transformation mechanism being the ball screw.

- In choosing the size of the guides the value of the maximum equivalent reaction is considered:

Re2=927,5 N = 0,93 kN

- From the THK catalogue, (index page:1088) for the HSR type guide choose the size: **HSR** 20AM, with the data shown in figures 13 and 14.

- For the **HSR 20AM** guideway the calculus of the nominal durability will be done for the equivalent mean load Pc=0,93 kN, and the nominal dynamic capacity C=13,8 kN, nominal static capacity Co=23,8 kN, resulting in:

- L= $\left(\frac{f_H \cdot f_T \cdot f_C}{f_W} \cdot \frac{C}{P_C} \right)^3 \cdot 50$ =[(1/2)*(13,8/0,93)]^3*50=20.420 km

The calculations showed that the durability of the system is much higher than the design value (Ln=5.000 km).

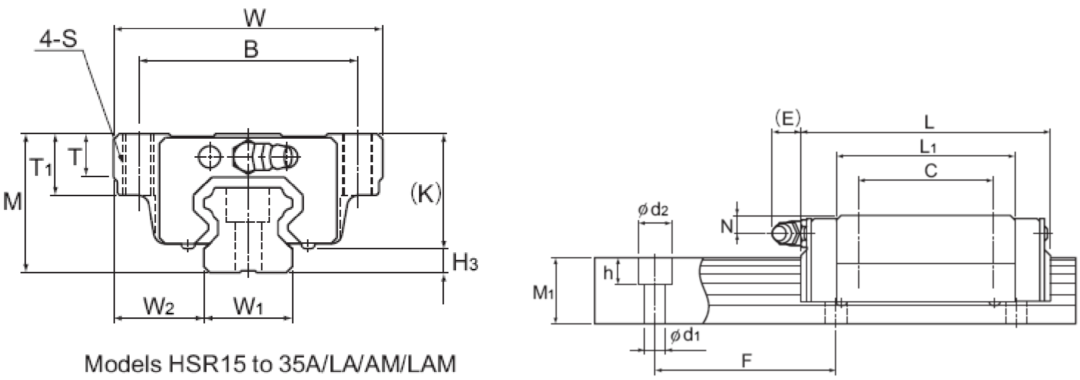


Fig. 13. Geometrical data of HSR guides

Model No.	Outer dimensions			LM block dimensions											
	Height	Width	Length											Grease nipple	
	M	W	L	B	C	S	L_1	t	T	T_1	K	N	E		H_3
HSR 15A HSR 15AM	24	47	56.6	38	30	M5	38.8	—	7	11	19.3	4.3	5.5	PB1021B	3.5
HSR 20A HSR 20AM	30	63	74	53	40	M6	50.8	—	10	9.5	26	5	12	B-M6F	4

LM rail dimensions						Basic load rating		Static permissible moment kN-m*					Mass	
Width		Height	Pitch		Length*	C	C_0	M_A		M_B		M_C	LM block	LM rail
W_1 ±0.05	W_2	M_1	F	$d_1 \times d_2 \times h$	Max	kN	kN	1 block	Double blocks	1 block	Double blocks	1 block	kg	kg/m
15	16	15	60	4.5×7.5×5.3	3000 (1240)	8.33	13.5	0.0805	0.457	0.0805	0.457	0.0844	0.2	1.5
20	21.5	18	60	6×9.5×8.5	3000 (1480)	13.8	23.8	0.19	1.04	0.19	1.04	0.201	0.35	2.3

Fig. 14 catalogue data of HSR 20AM type guides

Order code SUPPLIER:

HSR25 B 2 QZ UU C0 M +1200L P T M -II

- HSR25: Model number
- B: Type of LM block
- 2: No. of LM blocks used on the same rail
- QZ: With QZ Lubricator
- UU: Contamination protection accessory symbol (*1)
- C0: Radial clearance symbol (*2) Normal (No symbol) Light preload (C1) Medium preload (C0)
- M: Stainless steel LM block
- +1200L: LM rail length (in mm)
- P: Accuracy symbol (*3) Normal grade (No Symbol)/High accuracy grade (H) Precision grade (P)/Super precision grade (SP) Ultra precision grade (UP)
- T: Symbol for LM rail jointed use
- M: Stainless steel LM rail
- -II: Symbol for No. of rails used on the same plane (*4)

(*1) See contamination protection accessory on A-368. (*2) See A-114. (*3) See A-119. (*4) See A-59.

HSR20 AM 2 QZ UU C0 M +1480 P T M - II

Phase 4- Calculus and dimensioning of the kinematic axis OZ.

(Selection and check of ball screw and servo motor)

a. Specifying the initial data

We proceed further through the stages of choosing the ball screw for the linear kinematic axis, with vertical operation, (fig. 15), which will satisfy the initial conditions specified above, as well as a series of data proposed at this stage.:

Initial dates:

- robot arm mass: $m1=150$ kg
- mass of manipulated body: $m2=24$ kg
- sled stroke length: $ls=1000$ mm
- maximum linear speed: $Vmax=0.5$ m/s
- acceleration value: $az=\pm 2,5$ m/s2
- dwell time: $t4=10$ s
- number of double strokes/min: $n=5$ min-1
- backlash on reversal: 0,05 mm
- positioning accuracy: 0.1/1000 mm
- repeatability: 0.05 mm
- minimum displacement increment: s=0.01 mm
- service life at 8 hours/day operation: 20,000 h
- electric servomotor type: AC
- rated operating speed nm=3000* min-1
- motor turning moment: Jm=50*x10-5 kg.m2
- motor shaft directly coupled to the screw,
- ball screw efficiency: $\eta=0,92$
- coefficient of friction in guides: $\mu=0.003$
- friction force in sled guides: Fa=50* N
- dynamic load factor fw=2,5

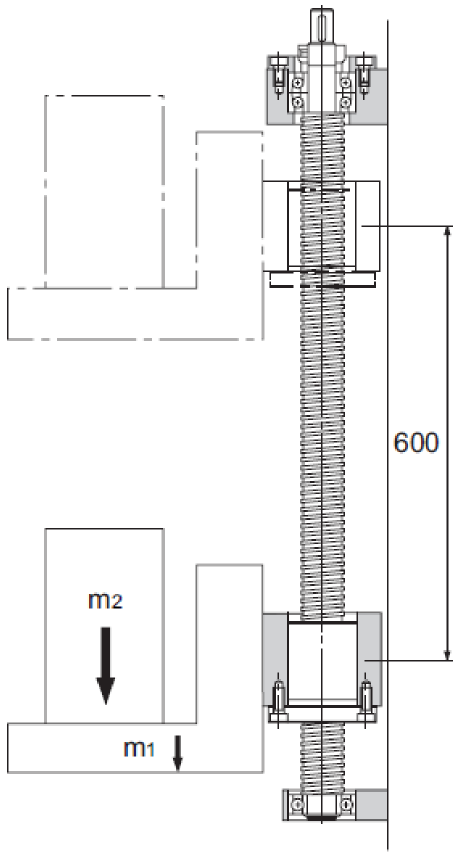


Fig.15 Vertical kinematic axis

with ball screw

Note 1: The values of the indicators: motor turning moment and friction force in the sled guides, will be adjusted percentagewise to other values, correlated to the robot size, as prescribed in Table 8. The numerical speed shall be adjusted inversely in proportion to the size of the robot: between 5000 min-1 - small robots and 2500 min-1 - large robots.

b. Ball screw selection steps:

1. Selection of the accuracy class of the screw:

In order to achieve the proposed accuracy of 0.1mm/1000 mm the approximation is made: $\frac{\pm 0{,}1}{1000} = \frac{\pm 0{,}03}{300}$, based on which the accuracy class that satisfies the calculation value for the reference length of 300 mm is chosen from the manufacturer's catalogue (THK-USA), resulting in Class C3 screws satisfying the requirement, the accuracy of this class being 0.029/300 mm (THK catalogue, Tab. 1, ix.pg. 704).

2. Axial accuracy selection:

Since the action of the load is always directed downwards, there is no problem of backlash when reversing the direction of motion.

3. Choosing the screw shaft design:

Assuming that the length of the screw nut is 100 mm and that the lengths of the screw ends are approximately 200 mm, a screw with a total length of 1400 mm of which the threaded part is at least 1250 mm and the distance between the screw threads is about mm shall be chosen from the manufacturer's catalogue.

Note 2: All values relating to the screw configuration (item 3) shall be adjusted by percentage to values, correlated with the size of the robot as prescribed in Table 8, but in correlation with plausible catalogue data.

4. Screw pitch selection:

At the proposed nominal operating speed: nm=3000 rpm, to achieve the maximum linear speed of the sled: Vmax=0.5 m/s, based on the relation:

$P = \frac{60 \cdot 1000 \cdot V}{n_m}$ (mm), it follows that the screw pitch must be at least 10 mm or larger.

The ball screw with a diameter of 32 mm and a pitch of 10 mm is adopted beforehand (THK catalogue ix.pg. 716 and 718).

Note that the resolution of the kinematic axis is given by the resolution of the encoder with which the servomotor is equipped, this may be: 1000, 1500, 2000, etc. steps/rev. In the case of a screw pitch of 10 mm and encoder resolution of 1000 steps/rev, the proposed minimum displacement increment of 0.01 mm is obtained.

5. Specifying the method of fixing the screw heads

In view of the required precision conditions, it is proposed that the method of fixing the screw ends: "fixed - resilient" (fig. 16) is sufficient.

6.Analysis of permissible axial load.

From the calculation of the dynamic load (**Phase 3, pg.22**) of the vertical sled it resulted that the maximum vertical driving force for driving the robot arm in accelerated motion is:

Fz=2175 N ,

and the force for vertical displacement in uniform motion is equal to the weight of the arm and the load,

Gb=1740 N

Also considering the friction force in the sled guides Fa=50 N,

results in: Fzmax=2225 N and Fzmin= 1790 N

Since the value of the acceleration of motion has been considered when calculating the vertical driving force, it is no longer necessary to calculate the detailed forces on each of the 6 vertical motion sequences.

Thus, the maximum axial load applied to the screw is:

Fa_{max}=Fa_1=2225 N;

7. Verification of the bolt under compression-stretch stress:

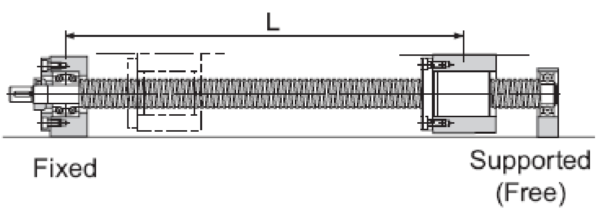


Fig. 16. Recessed - recessed mounting

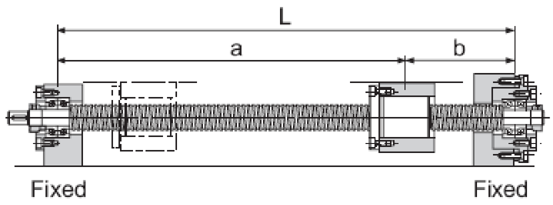


Fig. 17. Recessed - recessed fixing mode

Analyzing the nomogram axial load - screw diameter - distance between bearings (THK catalogue ix.pg. 721) it results that for the screw with a diameter of 32 mm and length between bearings of about 1300 mm, the fastening solution: embedded - resimat, (Fig. 16) is good because the value of the axial permissible load is Fadm=36 kN, is clearly higher than the maximum applied load of 2.23 kN.

8. Calculation of the speed required to achieve the required speed:

For already known data: d=32 mm, pitch p=10 mm, Vmax=0.5 m/s,: the motor speed is Nmax=3000 rpm.

9. Checking the shaft at critical speed:

For the initially proposed method of mounting the screw "recessed - recessed", according to the nomogram critical speed - distance between bearings - fixing mode (catalogue THK ixpg 724 results that the critical speed of the screw shaft with a diameter of 32 mm, is nc=2400 rpm.

Since the check at the critical speed is not confirmed, it follows that the recessed - resilient type of screw head lubrication is not suitable, which is why the fixed-fixed type of lubrication is chosen (fig. 17). In this case, the critical screw speed shall be approx. 4000 rpm. Consequently, the choice of the screw with outside diameter **ds=32 mm** and pitch p=10 mm is correctly made.

Selection of the type and design of the ball screw.

From the THK manufacturer's catalogue (ix.pg.1692), select the **BNFN 3210A-2,5**, (Preload Type of Precision Ball Screw) nut with the following performance:

- diameter of the rolling circle of the ball centres dp=33,75 mm,
- minor diameter dc=26,4 mm,
- number of ball nut rows 1x2.5,
- nominal dynamic capacity: Ca=26,1 kN,
- nominal static capacity: Coa=56,2 kN,
- stiffness K=640 N/µm.
- specific moment of inertia of the shaft Jso=$8,08*10^{-3}$ kg.cm2/mm

11.Calculation of nominal durability

Since the robot as a whole and the robot arm will not execute identical repetitive cycles throughout the service life, the calculation of the average force axially loading the ball screw will be made according to the formula:

Fm= (1/3)*(Fzmin+2*Fzmax),

respectively: Fm= (1/3)*(1790+2*2225)=2079,8 N

This results in the average calculation force:

Fm=2.08 kN

For nominal dynamic capacity: Ca= 26.1 kN, load factor f_W=2.5 and average equivalent load F_m=2.08 kN, the nominal bolt durability is:

$$L=\left(\frac{Ca}{fw\cdot F_m}\right)^3\cdot 10^6=\left(\frac{26.1}{2.5\cdot 2.08}\right)^3\cdot 10^6=126\text{x } 10^6 \text{ rotations}$$

12.Calculation of the duration of service.

Assuming that the vertical sleigh is continuously performing double strokes of average value Lcm=500 mm at a frequency of 5 double strokes/min, calculate the number of complete rotations/hours of the screw:

Note 4: All values relating to the calculation of the service life (item 12) shall be adjusted inversely in proportion to the size of the robot between: Lcm =250 mm/20 cd/min - small robots and Lcm =1500 mm/2 cd/min - large robots.

ns=2*Lcm/ps=100 rev/stroke = 100*5=500 rev/min= 500*60=30.000 rev/hour.

This gives the value of the service life in hours for a normal operating regime (8 hours/day; 300 days/year) of the robot:

$Lh = \frac{L}{ns} =$4200 h, (aprox. 1,75 years) lower value than proposed in the design theme (20,000 hours = 8.33 years).

From this point of view, the choice of the screw does not satisfy the proposed service life criterion, which is why we go through the step of choosing the screw again, whose nominal dynamic capacity must be much higher.

From the THK catalogue pg. 1626 the **BNFN 3210A-5** screw is chosen, with catalogue data:

- diameter of the rolling circle of the ball centres dp=33,7 mm,
- minor diameter dc=26,4 mm,
- number of ball nut rows 2x2.5,
- nominal dynamic capacity: Ca=47,2 kN,
- nominal static capacity: Coa=112,7 kN,
- specific moment of inertia of the shaft Jso=$8,08*10^{-3}$ $kg.cm^2$/ mm

Catalogue data are shown in figures 18 and 19.

Applying the durability formula for the new bolt gives:

L= [47,2/(2,5*2,08)]3*106=$747*10^6$ rot.

The re-calculation of the service life in the new situation results:

$Lh = \frac{L}{ns} =$24.900 hours, (aprox. 10,4 years) higher value than proposed in the design theme (20,000 hours).

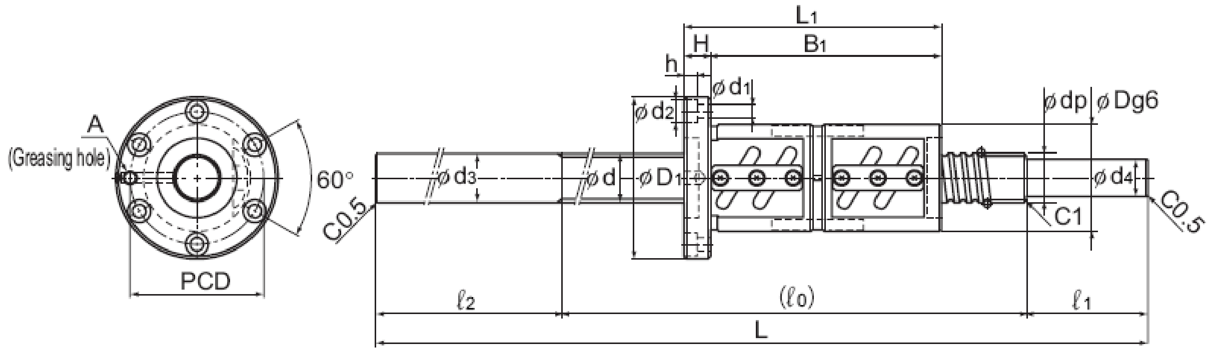


Fig. 18. Geometric data of the screw-nut assembly

Screw shaft outer diameter d	Lead Ph	Model No.	Ball center-to-center diameter dp	Thread minor diameter dc	No. of loaded circuits Rows x turns	Basic load rating Ca kN	Basic load rating C0a kN	Rigidity K N/μm	Outer diameter D	Flange diameter D1	D2
32	8	○ BIF 3208A-5	33.25	27.5	1×2.5	17.8	42.2	610	66	100	—
		○ BIF 3208A-7	33.25	27.5	1×3.5	23.8	59.1	840	66	100	—
		○ BNFN 3208A-2.5	33.25	27.5	1×2.5	17.8	42.2	610	66	100	—
		○ BNFN 3208A-3	33.25	27.5	2×1.5	20.9	50.7	730	66	100	—
		○ BNFN 3208A-4.5	33.25	27.5	3×1.5	29.5	76	1070	66	100	—
		○ BNFN 3208A-5	33.25	27.5	2×2.5	32.3	84.4	1180	66	100	—
	10	DIK 3210-6	33.75	26.4	3×1	25.7	52.2	600	54	87	—
		○ BIF 3210A-5	33.75	26.4	1×2.5	26.1	56.2	640	74	108	—
		○ BNFN 3210A-2.5	33.75	26.4	1×2.5	26.1	56.2	640	74	108	—
		○ BNFN 3210A-3	33.75	26.4	2×1.5	30.5	67.4	750	74	108	—
		○ BNFN 3210A-3.5	33.75	26.4	1×3.5	34.8	78.6	870	74	108	—
		○ BNFN 3210A-5	33.75	26.4	2×2.5	47.2	112.7	1230	74	108	—

Nut dimensions: Overall length L1	H	B1	B2	B3	PCD	d1	d2	h	Tw	N1	Greasing hole A	Screw shaft inertial moment/mm kg•cm²/mm	Nut mass kg	Shaft mass kg/m
82	15	67	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	1.93	5.39
98	15	83	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.21	5.39
106	15	91	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.36	5.39
135	15	120	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.88	5.39
167	15	152	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	3.45	5.39
154	15	139	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	3.21	5.39
110	15	95	25	—	69	9	14	8.5	66	—	M6	8.08×10^{-3}	1.57	4.98
100	15	85	—	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	2.92	4.98

Fig. 19. Catalogue data of Preload Type of Precision Ball Screw

c. Calculus of the drive torque required

During upward travel at constant speed, the amount of torque required is given by the relation:

$T_1 = \frac{Fz_{\min} \cdot Ph}{2\pi \cdot \eta}$ for which the values found before, results:

$$T_1 = \frac{1740 \cdot 0,01}{2\pi \cdot 0,92} = 3,01 Nm$$

13.The amount of torque required to accelerate the motion:

The value of the reduced moment of inertia at the motor shaft due to load acceleration, screw shaft and servo motor rotor is:

$$J = m_b \cdot (\frac{P_h}{2 \cdot \pi})^2 \cdot 10^{-6} + J_s + J_m$$

in which:

MeB=174 kg is the cumulative mass of the robot arm,

Ph= 10 mm is the screw pitch

Js - the turning moment of the screw shaft

Jm =$50x10^{-5}$ kg.m2 - the proper turning moment of the motor rotor

Knowing the unit value of the moment of inertia of the screw shaft: Jso=$8.08*10^{-3}$ kg.cm2/mm, the value of the moment of inertia of the screw shaft, 1400 mm long, is:

Js=$8.08*10^{-3}$ x 1400=11.312 kg.cm2, or 11.31×10^{-4} kg.m2

With the above data, this results in the reduced turning moment at the motor shaft:

$$J = 174 \cdot (\frac{10}{2 \cdot \pi})^2 \cdot 10^{-6} + J_s + J_m = 441 \cdot 10^{-6} + 1131 \cdot 10^{-6} + 500 \cdot 10^{-6} = 2036 \cdot 10^{-6} = 0,002072\ kgm^2$$

The acceleration time of the load in vertical motion, equal to the acceleration time of the servomotor rotor in rotational motion, results from the values of the two parameters Vz=0.5 m/s and az=2.5 m/s2. Respectively: ta=Vz/az= 0.5/2.5=0.2 sec

The angular acceleration of the screw shaft is:

$$\varepsilon = \frac{2 \cdot \pi \cdot N_m}{60 \cdot t_a} = \frac{2 \cdot \pi \cdot 3000}{60 \cdot 0,2} = 1570 \text{ rad/sec}^2$$

Based on the above results, the value of the engine torque required for acceleration is obtained:

$$T_2 = J \cdot \omega' = 0.002072 \times 1570 = 3.253 \text{ Nm}$$

The engine torque required to travel at constant speed:

$$T_1 = 3,01 Nm$$

This results in the value of the maximum engine torque:

$$T_{max}=T1+T2=6{,}26 \text{ Nm} \quad \mathbf{T_{max}=6{,}26 \text{ Nm}}$$

With the two determined required torque values T1 and Tmax the average torque value will be determined according to the formula:

$$T_m=(1/3)*(T1+2*T_{max})= =(1/3)*(3{,}01+2*6{,}26)=5{,}17 \text{ Nm} \quad T_m=5{,}17 \text{ Nm}$$

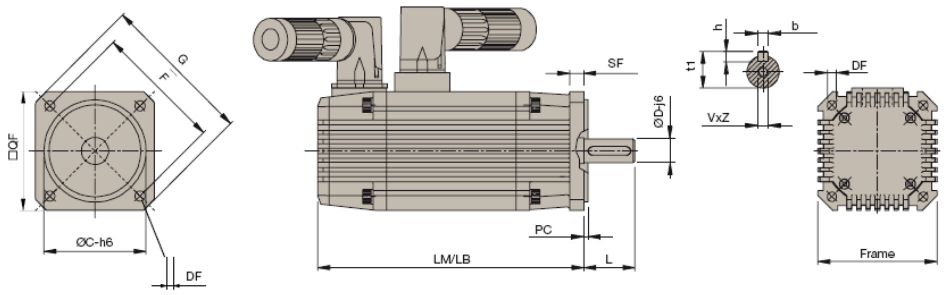
So, the chosen servomotor will have to develop a nominal torque of 5.17 Nm and a maximum torque of 6.26 Nm.

d. Choice of servo motor to drive the vertical displacement on the OZ axis

From the Parker-Hannifin catalogue "Motion Control Products" (index page 128), choose the servomotor type MB/MH , code: M_105 30 06 (fig. 20 and 21) with technical data: **Nominal torque: Tn=5,2 Nm, Maximum torque: 8,3 Nm**, Peak torque: 26,2 Nm, Nominal speed 3000 rpm.

Model	Size	Stall Torque [1]	Stall Current	Nominal Torque [1]	Nominal Speed	Nominal Current	Peak Torque[1]	Inertia No brake	Inertia With brake	Ke [2][3]	Kt [2][3]
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [kgmm²]	J [kgmm²]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 105 50 04	105		7.4	2.7	5000	5.0				0.3	0.58
M_ 105 16 06			3.9	5.9	1600	3.7				1.0	1.65
M_ 105 25 06		6.0	5.6	5.5	2500	5.0	26.2	480	543	0.7	1.15
M_ 105 30 06		(8.3)	7.4	5.2	3000	6.4				0.5	0.87

Dimensions



Motor - Size		LM/LB	Weight	DxL	bxh	t1	VxZ	C	F	DF	G	SF	PC	QF	Order code QF
105	02	186/250	5					95	115	9.5	140	10	3.5	105	5
	04	229/293	7	19x40	6x6	21.5	M6x16	95	115	9.5	140	10	3.5	105	4
	06	273/337	9	24x50	8x7	27	M8x19	80	115	9.5	140	10	3.5	105	9
	08	317/381	11					110	115	9.5	140	10	3.5	105	6

Fig.20. Technical and geometrical data of the servo motor M_105 30 06

3000 min^{-1} 230 V - 6000 min^{-1} 400 V

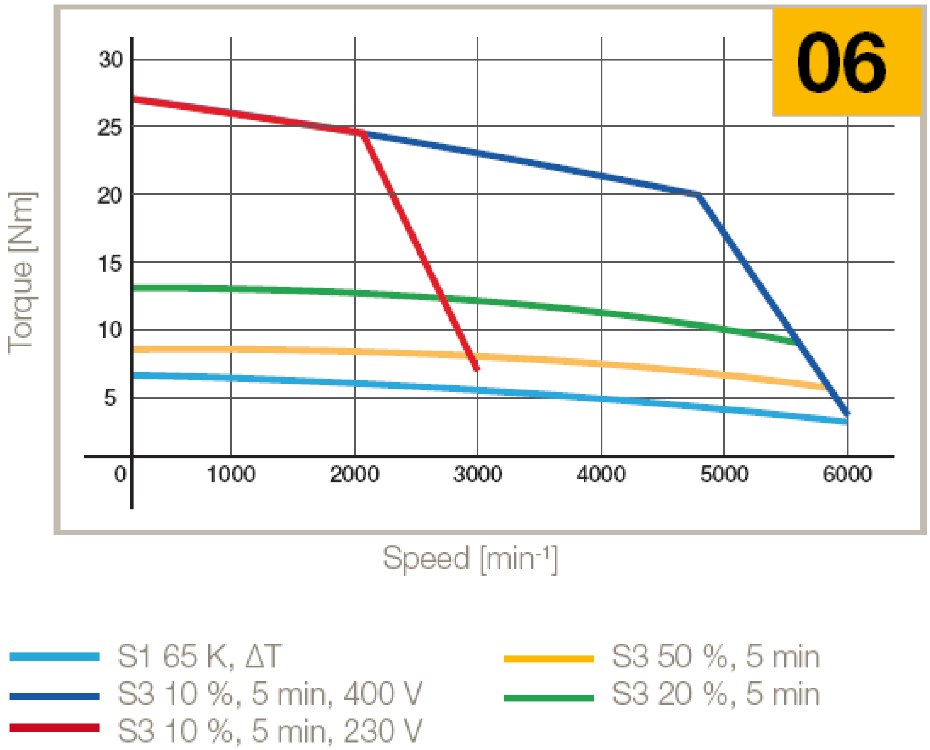


Fig.21. Torque - Speed characteristic of servo motor M_105 30 06

Phase 5- Selecting and checking the telescopic boom guide

a- Determination of reactions in the splined bushings

Adopt the axis OY' along the robot arm, with respect to which the position of the center of mass will be calculated in the two extreme situations of the forearm: retracted arm and extended arm.

Take from Table 8 the Xi values of the elements that change their mass center position with respect to the OZ axis of rotation during arm telescoping, which values on the OY' axis become Yimax.

Considering the value of the stroke Lc of the movable element of the arm (for the calculation model Lc=0.6m), each of the 3 elements composing the forearm will have the radii of the mass centers Yimin and Yimax in the two distinct situations, according to the values in Table 20. The Ymin values of the 3 elements are determined from the Ymax values by subtracting the stroke value.

Tab.20

	Name	Code	Mass	Yimin	Yimax	Mi*Yimin	Mi*Yimax
12	**The mobile element of the tel. arm**	**m12**	**24**	**0,3**	**0,9**	**7,2**	**21,6**
13	**Orientation Module**	**mo**	**12**	**0,6**	**1,2**	**7,2**	**14,4**
14	**Manipulation Mass**	**ms**	**24**	**0,7**	**1,3**	**16,8**	**31,2**
		Me_A	**60**			**31,2**	**67,2**
					YeAmin	**0,52**	
					YeAmax		**1,12**

To choose and check the guidance of the robot's telescopic arm, all the forces acting on the forearm in the following motion scenario are considered:

- accelerated movement of the robot along the OX axis.

- accelerated movement of the vertical sled and arm along the OZ axis.

- accelerated rotation of the robot about the OZ axis.

- accelerated rotation of the robot arm about the OY axis.

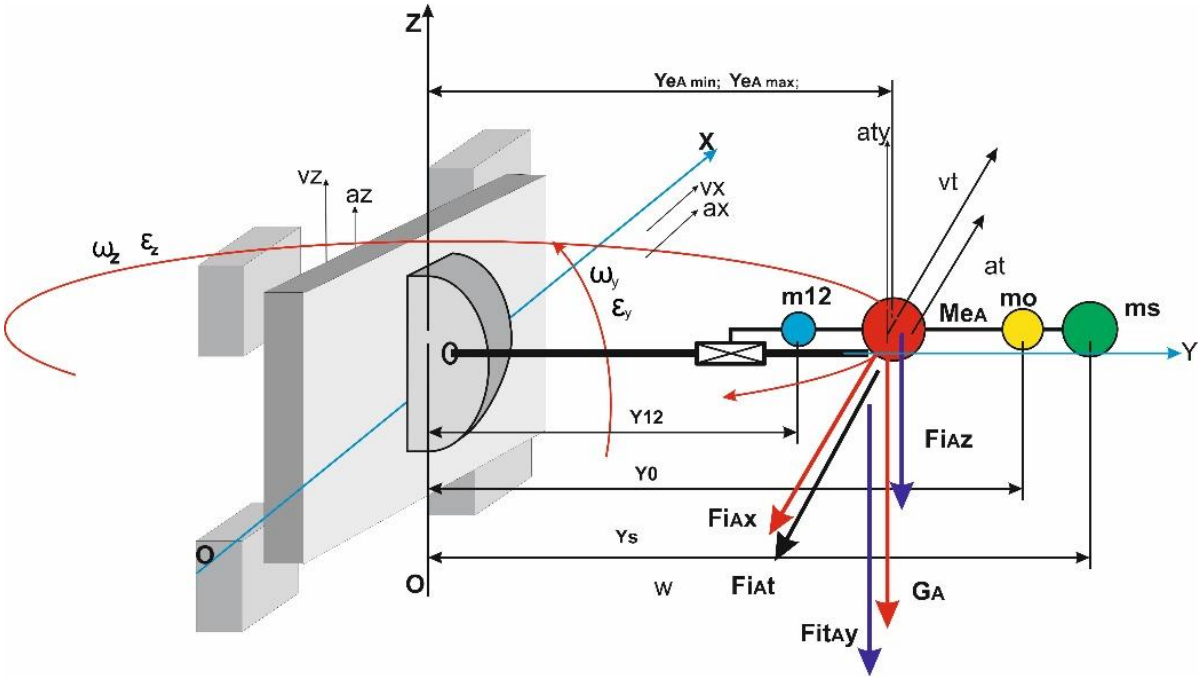


Fig. 22. Study of the forces in the case of accelerated motions of the moving element of the arm

Next the values of the forces acting on the center of mass are calculated.

Dynamic analysis of the robot forearm balance.

Tab. 21

Symbol	Formula	Minimum value (N)		Maximum value (N)	
GA	M_{eA}*g	60*10	600	56*10	600
FiAz	M_{eA} *az	60*2,5	150	60*2,5	150
FiAt	M_{eA} ***e**z * YeA	60*2π *0,52	196	60*2π *1,12	422
FiAx	M_{eA} *ax	60*2,5	150	60*2,5	150
FiAy	M_{eA} * **e**y * YeA	60*2π*0,52	196	60*2π*1,12	422

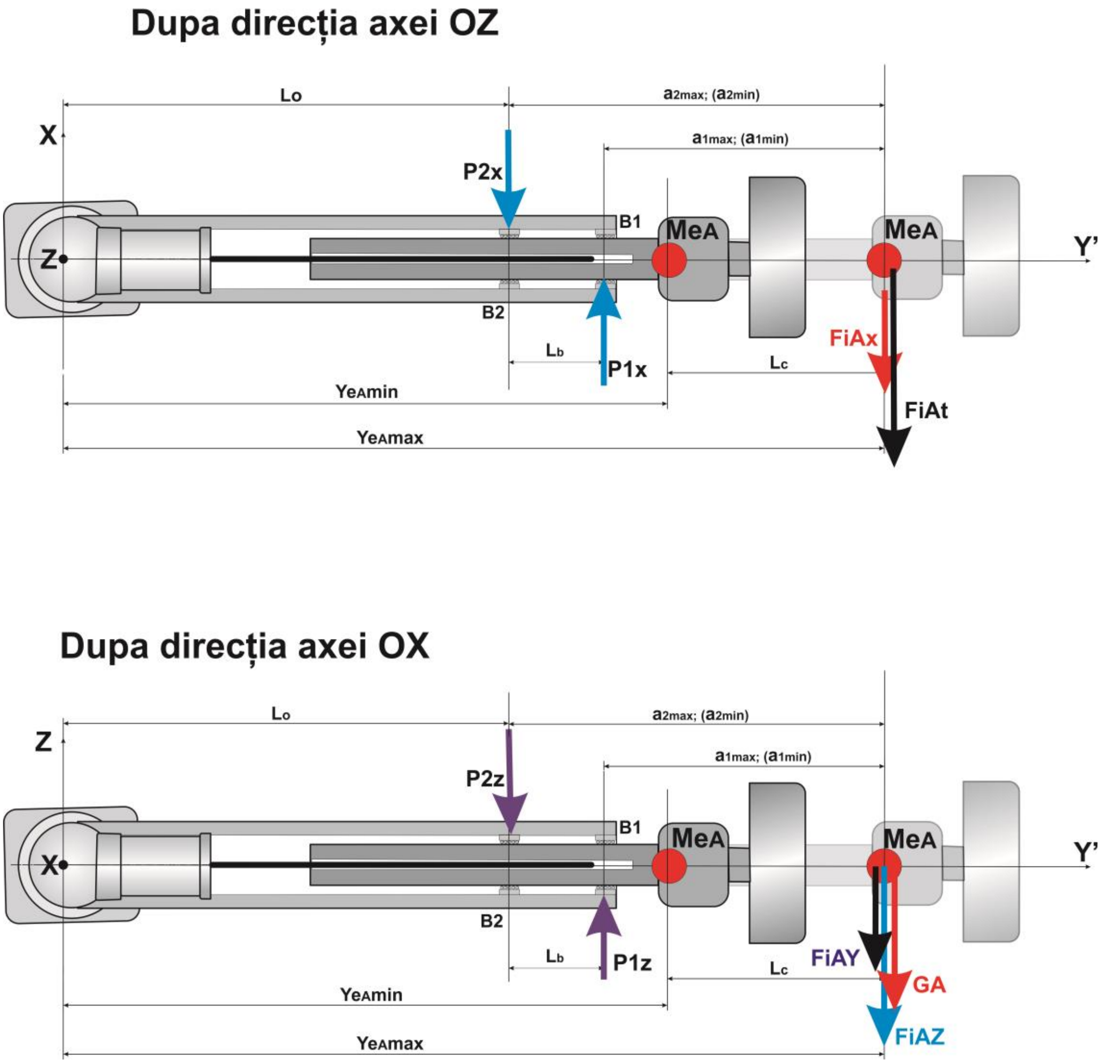


Fig. 23. Dynamic loading of the telescopic arm in the two directions

Since the upper arm (forearm) is considered in the two extreme positions, the radii of the center of mass were calculated in the two distinct situations: Ye_{Amin} and Ye_{Amax}, according to the data inscribed in Table 20.

Ye_{Amin} = 0.52 m

Ye_{Amax} = 1,12 m

Following the analysis of the possible dimensions of the robot arm components (Fig. 24) and based on the value of the required stroke length Lc, the following constructional and functional values (mm), correlated with the robot size, are established:

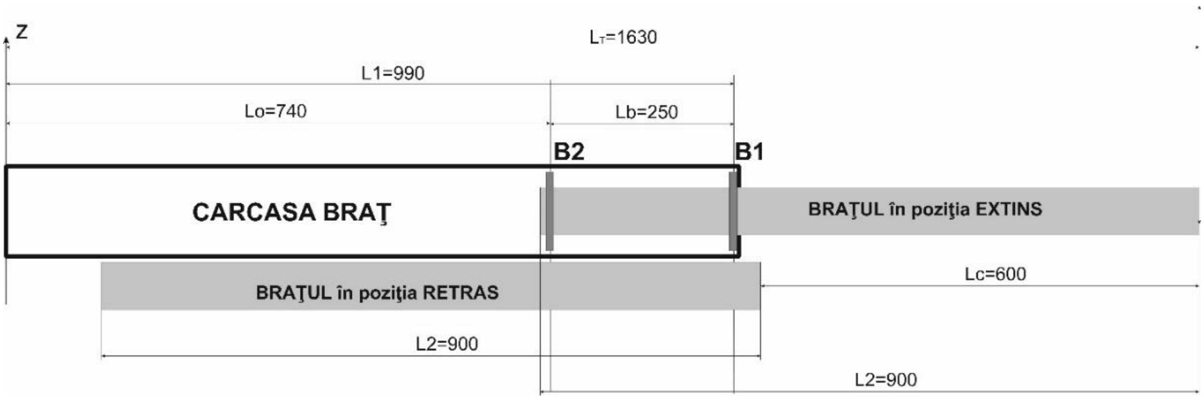


Fig. 24. Correlation of constructive-functional sizes

Lo=0,74 m Distance from axis of rotation OZ to B2 bushing (**value chosen constructively**);

Lc=0,60 m Stroke length established in the design theme,

Lb= 0,25 m Distance between the two ball bushings of the telescopic column,

L1=0,99 m Overall length of the boom housing,

L2=0,90 m Length of the movable arm element,

LT= 1,63 m Total length of the boom in EXTINS configuration.

Note: For the STUDENT version of the project the values of the constructively chosen sizes in the study example will be adjusted by percentage to other values, correlated with the size of the robot, as prescribed in Table 22.

Tab. 22

The total mass of the structure:	**Lo**	**Lc**	**Lb**	**L1**	**L2**	**LT**
20 – 100 kg	40%	40%	40%	40%	40%	40%
100 – 200 kg	60%	60%	60%	60%	60%	60%
200 – 500 kg	100%	100%	100%	100%	100%	100%
500 – 1000 kg	120%	120%	120%	120%	120%	120%
1000 – 2000 kg	140%	140%	140%	140%	140%	140%

Study of the balance of the robot forearm with respect to the two axes: OX and OZ

Table 23 includes both geometric relationships for determining the elevations a_{1max}, a_{1min}, a_{2max}, a_{2min}, as well as the equations of equilibrium of the moments of forces for each of the two axes, the numerical explanation of the equations and the reaction values for each grooved bush and axis.

Tab. 23

	a1max	a2max	a1min	a2min
	YeAmax-(Lo+Lb)	YeAmax- Lo	YeAmin- (Lo+Lb)	YeAmin- Lo
	1,12-0,99	1,12-0,74	0,52-0,99	0,52-0,74
	0,23	0,48	-0,47	-0,22
AXA:OZ	(FiAx+FiAtmax)* a1max=P2x*Lb	(FiAx+FiAtmax)* a2max=P1x*Lb	(FiAx+FiAtmin)* a1min= P'2x*Lb	(FiAx+FiAtmin)* a2min= P'1x*Lb
	(150+422)*0,23= 0,25*P2x	(150+422)*0,48= 0,25*P1x	(150+196)*0,47= -0,25*P'2x	(150+196)*0,22= -0,25*P'1x
	P2x=526,2	**P1x=1098,2**	**P'2x=-650,5**	**P'1x=-304,5**
AXA:OX	(FiAymax+GA+FiAz)* a1max= P2z*Lb	(FiAymax+GA+FiAz)* a2max= P1z*Lb	(FiAymin+GA+FiAz)* a1min= P'2z*Lb	(FiAymin+GA+FiAz)* a2min= P'1z*Lb
	(422+600+150)* 0,23=0,25*P2z	(422+600+150)* 0,48=0,25*P1z	(196+600+150)* 0,47=-0,25*P'2z	(196+600+150)* 0,22=-0,25*'P1z
	P2z=1078,2	**P1z=2250,2**	**P'2z=-1778,5**	**P'1z=-832,5**

Tab. 24

Bratul in poziția minimă		Bratul in poziția maximă	
Axa OZ	Axa OX	Axa OZ	Axa OX
P'_{1xmin}=304,5 N	P'_{1zmin}=832,5 N	P_{1xmax}=1098,2 N	P_{1zmax}=2250,2 N
P'_{2xmin}=650,5 N	P'_{2zmin}=1778,5 N	P_{2xmax}=526,2 N	P_{2zmax}=1078,2 N

The average loads per piece are calculated according to the averaging relationship:

$$P_{med}=1/3*(P_{min}+2*P_{max})$$

Tab. 25

Nut B1	P_{1zmed}	833,6	P_{1xmed}	1777,6
Nut B2	P_{2zmed}	609,1	P_{2xmed}	1545,1

As with ball bearing guides, the equivalent load on each bushing is calculated as the sum of the moduli of all radial loads, resulting:

$$P_{1e}= P_{1xmed}+ P_{1zmed}$$

$$P_{2e}= P_{2xmed}+ P_{2zmed}$$

By replacing the numeric values, the result is:

P_{1e}= 833,6+ 1777,6=2611,3 N

P_{2e}= 609,1+ 1545,1=2154,1 N

P_{1e}= 2611 N=2,61 kN

P_{2e}= 2154=2,15 kN

The way the telescopic arm works, it follows that each movable bushing is loaded only by radial forces, so that the choice of the type and size of the splined transmission from the catalogue will be made only in terms of the nominal dynamic radial load C and the nominal static load Co.

The choice of the splined transmission shall be made according to the load on the most stressed moving bushing, i.e., for the equivalent radial load:

P_{1e}= 2,61 kN

b. Choice of telescopic transmission

It is adopted that the telescopic arm guide shall consist of a telescopic column with two ball bushes, according to the diagram below, specifying the following initial elements:

Proposed nominal durability:	Ln=5,000 km
Temperature factor:	fT =1
Contact factor:	fC =1
Load factor:	fW =1,5 Ca
Splined shaft type:	tubular

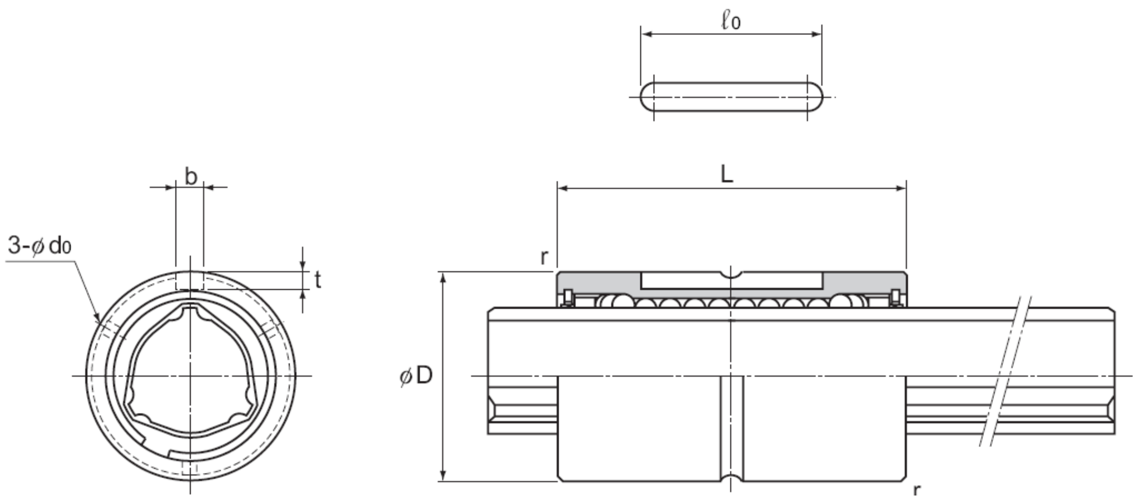


Fig. 25. Elementele geometrice ale trasmisiei telescopice de tip LBST

From the THK catalogue (index pg:1398) select the LBST30 (Heavy Load Type) splined transmission with the catalogue data shown below.

The outer diameter of the splined shaft is d=30 mm

Model No.	Spline nut dimensions								
	Outer diameter		Length		Keyway dimensions				Greasing hole
	D	Tolerance	L	Tolerance	b H8	t +0.05 0	ℓ_0	r	d_0
○● LBST 20	30	0 −0.016	60	0 −0.2	4	2.5	26	0.5	2
○● LBST 25	37		70		5	3	33	0.5	2
○● LBST 30	45		80		7	4	41	1	3

Basic torque rating		Basic load rating (radial)		Static permissible moment		Mass	
C_T N-m	C_{0T} N-m	C kN	C_0 kN	M_{A1}** N-m	M_{A2}** N-m	Spline Nut kg	Spline shaft kg/m
90.2	213	9.4	20.1	103	632	0.17	1.8
176	381	14.9	28.7	171	1060	0.29	2.7
312	657	22.5	41.4	295	1740	0.5	3.8

Fig. 26. Catalogue data of telescopic transmission type LBST30

Calculation of the nominal durability of splined bushes

Based on the values of the factors involved in the formula giving the value of the nominal durability, initially proposed:

Proposed nominal durability: Ln=5.000 km

Temperature factor: f_T =1

Contact factor: f_C =1

Load factor: f_W =1,5

and the catalogue data of the splined shaft model **LBST30**,

C=22,5 kN - nominal radial dynamic capacity

Co=41,4 kN - nominal radial static capacity

This results in the nominal durability of the most required splined bushing B1:

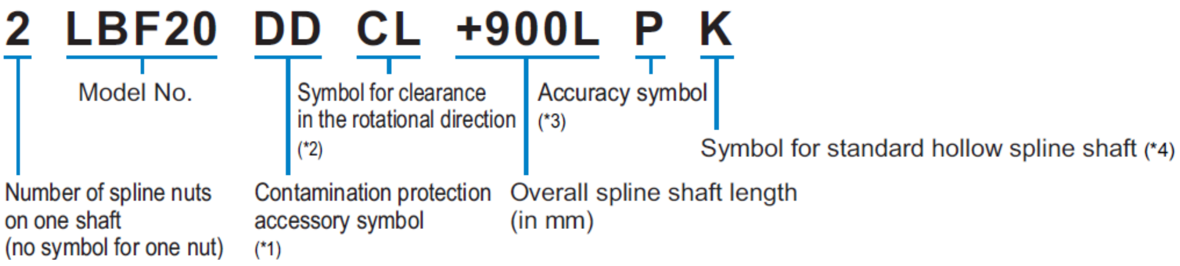
$$L_1 = \left(\frac{f_T \cdot f_C}{f_W} \cdot \frac{C}{P_{1E}} \right)^3 \cdot 50km$$

$$L_1 = \left(\frac{1 \cdot 1}{1{,}5} \cdot \frac{22{,}5}{2{,}61} \right)^3 \cdot 50 = 9491km$$

For cinnamon B2 bushing, the nominal durability is:

$$L_2 = \left(\frac{1 \cdot 1}{1{,}5} \cdot \frac{22{,}5}{2{,}15} \right)^3 \cdot 50 = 16979km$$

From the resulting data it can be concluded that the dimensioning of the telescopic arm guide based on a telescopic transmission type: **LBST 30** is correctly done.



Phase 6- Choosing and checking the cross roller bearing at the base of the robot

- Dynamic analysis of the bearing loads

Optionally it is proposed that the durability of the bearing to be chosen is 1.2 *10^6 rot.

Recall the data determined in the previous steps.

ROBOT Structure	Symbol	Total Mass	Zei		Xei		Yei		Re
Integral robot	MeT	504	ZeT	0,536	XeT	0,201	YeT	0,098	-
Rotative	MeR	354	ZeR	0,691	XeR	0,252	YeR	0,139	ReR= 0,287
Entire arm	MeB	174	ZeB	0,797	XeB	0,486	YeB	0,284	ReB= 0,562
Forearm	MeA	120	ZeA	0,840	XeA	0,705	YeA	0,300	-

For the selection and verification of the cross roller bearing at the base of the robot, all forces acting on the entire rotating structure are considered for the following motion scenario:

- accelerated movement of the robot along the OX axis.
- accelerated movement of the vertical sled and arm along the OZ axis.
- accelerated rotation of the robot about the OZ axis.

In calculating the forces acting on the cross roller bearing at the base of the rotating structure of the robot, the mass of the movable elements supported by the bearing shall be considered.

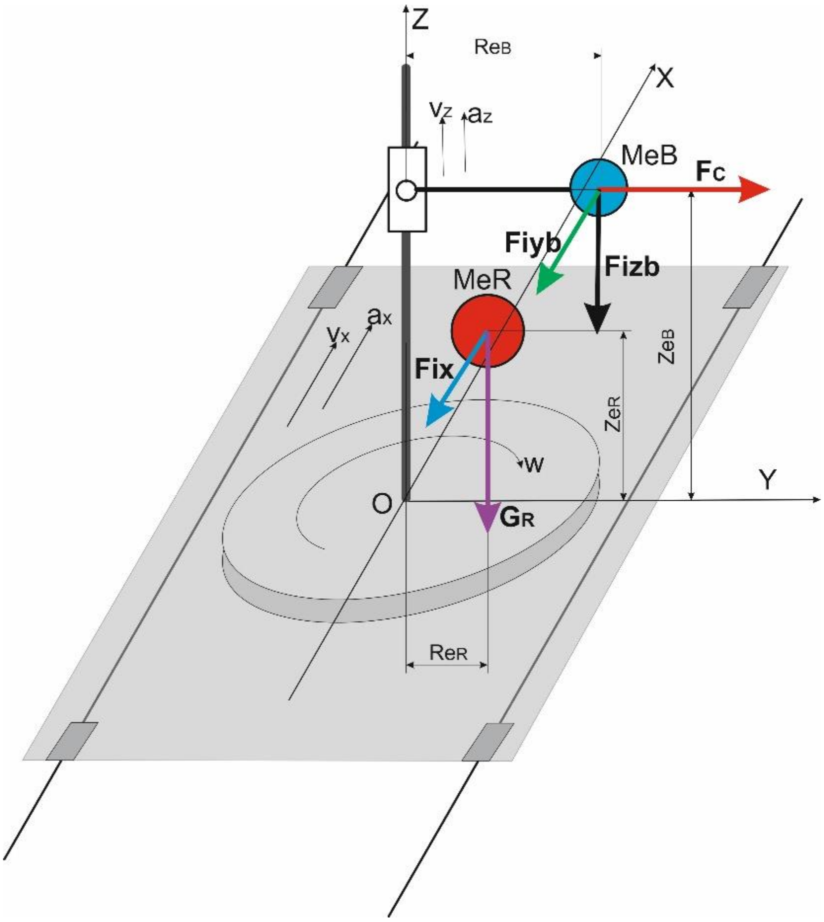


Fig. 27. Inventory of forces acting on the robot base bearing

Based on the notations in figure 27, all the forces involved in the dynamic analysis of the bearing balance are inventoried:

Force	Formula	Numeric	Value
G_R	Me_R*g	354*10	3540
Fix	Me_R *ax	354*2,5	885
Fizb	Me_B*az	174*2,5	435
Fiyb	Me_B * ε_* Ye_B	174*2π*0,562	614
Fc	Me_R *Ye_R*$\pi^2/4$	354*0,287* $\pi^2/4$	250

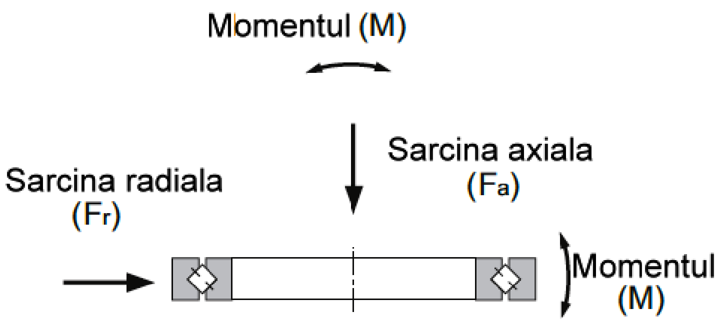


Fig. 28. Bearing loading diagram

Bearing durability of L=1.2*106 rot is proposed.

Based on the forces dynamically loading the cross roller bearing, the following relations can be written:

Axial force

Fa= GR + Fizb

Fa=3540+435= 3975 N

Radial force:

Fr= Fix + Fiyb + Fc

Fr=885+614+250=1749

Tipping moment

M=Fix* ZeR +Fiyb*ZeB+ Fizb* ReB + GR* ReR +Fc* ZeB

M= 885*0,691+614*0,797+435*0,562+3540*0,287+250*0,797=2560 Nm

Equivalent dynamic load

For design reasons the RB45025 series bearing (THK catalogue index pg. 1829) with Dp=0.474 m is proposed in advance.

Depending on the size of the robot, the diameter Dp of the initially proposed bearing will be adjusted according to the indications in the table. 22 - step 5, to a value in correlation with the value string in the catalogue sheet.

When calculating the equivalent dynamic load, account shall be taken of the actual operating and loading conditions of the bearing, using the relationship:

$$P_C = X \cdot \left(F_r + \frac{2M}{d_p} \right) + Y \cdot F_a$$

Then we determine the value of the raport: $\frac{Fa}{Fr + 2M / dp}$

$$\frac{Fa}{Fr + 2M / dp} = \frac{3975}{1749 + 2 \cdot 2560 / 0{,}475} = 0{,}317 < 1{,}5$$

According to the conditions:

Classification	X	Y
$\frac{Fa}{Fr+2M/dp} \le 1.5$	1	0.45
$\frac{Fa}{Fr+2M/dp} > 1.5$	0.67	0.67

It follows that the correction factors X and Y will be:

X=1; Y=0.45

The equivalent radial dynamic load calculation will be:

$$P_C = 1 \cdot \left(1749 + \frac{2 \cdot 2560}{0,475}\right) + 0,45 \cdot 3975 \ = 14.317 \text{ N} = 14,3 \text{ kN}$$

Pc=14,3 kN

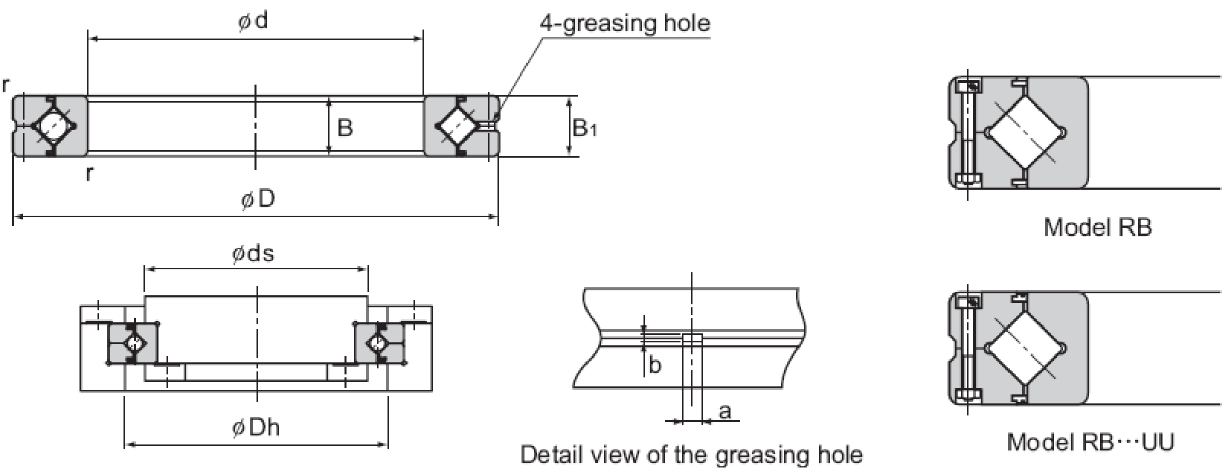


Fig. 29. Geometrical data of the RE 45025 series bearing

Shaft diameter	Model No.	Main dimensions							Shoulder height		Basic load rating (radial)		Mass
		Inner diameter	Outer diameter	Roller pitch circle diameter	Width	Greasing hole					C	C0	
		d	D	dp	B B1	a	b	r_{min}	ds	Dh	kN	kN	kg
400	RE 40035	400	480	440.3	35	5	3	2.5	422	459	156	370	14.5
	RE 40040		510	453.4	40	6	3.5	2.5	428	479	241	531	23.5
450	RE 45025	450	500	476.6	25	3.5	1.6	1	464	484	61.7	182	6.6

Fig. 30. Catalogue sheet of RB series bearings

With the data in the catalogue, as shown in Figures 29 and 30:

dp=0.474 m; C=61.7 kN; Co=182 kN

Calculate the bearing durability:

$$L=\left(\frac{f_T\cdot C}{f_W\cdot P_C}\right)^{\frac{10}{3}}\cdot 10^6 \quad \text{so: } L=\left(\frac{1\cdot 61{,}7}{2.5\cdot 14{,}3}\right)^{\frac{10}{3}}\cdot 10^6=6{,}15*10^6 \text{ rot}$$

In conclusion, the chosen bearing satisfies the required conditions.

The verification of the static safety factor fs is done according to the relation: $f_s=\frac{Co}{Po}$

, where the equivalent **radial static load** is: $P_0=X_0\cdot\left(F_r+\frac{2M}{d_p}\right)+Y_0\cdot F_a$

(Xo=1), (Yo=0,44)

For the determined formulas:

$$P_0=1\cdot\left(1749+\frac{2\cdot 2560}{0{,}474}\right)+0{,}44\cdot 3975=16.048 \text{ kN}=16 \text{ kN}$$

Then results: $f_s=\frac{182}{16}=11{,}37$ value much covering the static safety condition.

Permissible static moment:

$$\text{Mo}=\text{Co}\frac{dp}{2} \text{ kNm}$$

Mo=182*(0,474/2) =43,3 kNm

All checks having been carried out it appears that the cross roller bearing **series RB45025** is properly selected.

Phase 7 - Calculation of the required torque and choice of servo motor to drive the OZ rotation module

Determination of the reduction ratio

For the choice of the servomotor that will drive the rotation module for rotating the robot around the OZ axis, the maximum angular velocity to be developed: ωz = π/2 rad/sec, and the angular acceleration εz=2π rad/s2 must be considered.

It results that the maximum speed to be reached in the rotational movement of the robot is:

$$N_r=60*\omega_z/2\pi=60/4=15 \text{ rpm}$$

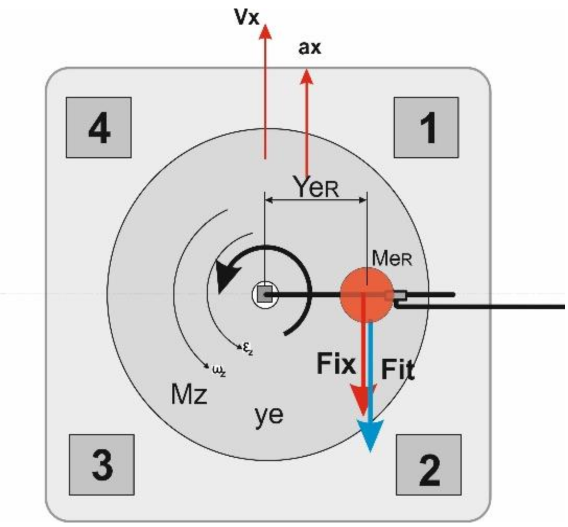


Fig. 31 Schematic of the forces determining the maximum value of the driving moment at the turntable axis of the module

Assuming that the servomotor will be associated with a planetary gearbox with a ratio of ir=1/50, for the speed at the servomotor shaft of Nm=4000 rpm, the speed at the gearbox shaft will be about 80 rpm.

In order to achieve a speed of Nr=15 rpm on the rotary plate axis of the module, it follows that, in addition to the reduction ratio of ir=1/50 of the gearbox, it is necessary to further reduce the speed to a ratio of i_m=1/5.33 (80/15), which will be ensured by the kinematics and internal construction of the rotary module.

Choosing the associated gearbox

Recall some of the previously calculated data:

ROBOT structure	Symbol	Mass cumulate	Zei		Xei		Yei		reR
Rotating	MeR	354	ZeR	0,691	XeR	0,252	YeR	0,139	0,287

Movement scenario:

- Accelerated unpacking, of the whole robot, along the OX axis.

- Accelerated rotation of the rotating structure around the OZ axis.

Force inventory:

Fit	MeR*ReR*ε	354*0,287*2,5*3,14	798
Fix	MeR *ax	354*2,5	885

Considering the value of the two forces Fit=797 N and Fix=885 N, the value of the maximum resisting moment at the plate axis results:

Mr_{max}=(Fit +Fix)*ReR, respectiv:

Mr_{max}= 1682*0,287=483 Nm

Mr_{max}= 483 Nm

Considering the additional reduction ratio achieved by the rotation module im=1/5.33, the value of the motor torque at the gearbox shaft will be:

$Mred_{max}$=Mr_{max}* im=483*1/5,33=90,6 Nm

$Mred_{max}$= 90,6 Nm

In the situation where the two forces are in different directions, the resistive torque at the platter shaft will have the value:

Mr_{min} = (Fix –Fit)*ReR

Mr_{min} =87*0,284=24,7 Nm

$Mred_{min}$=Mr_{min}* im=24,7*1/5,33=4,63 Nm

$Mred_{min}$=4,63 Nm

In this case, the average shaft resisting torque is calculated according to the formula:

$Mred_{med}$=($Mred_{min}$+2*$Mrde_{max}$)*1/3

$Mred_{med}$= (4,63+2*90,6)*1/3=62 Nm

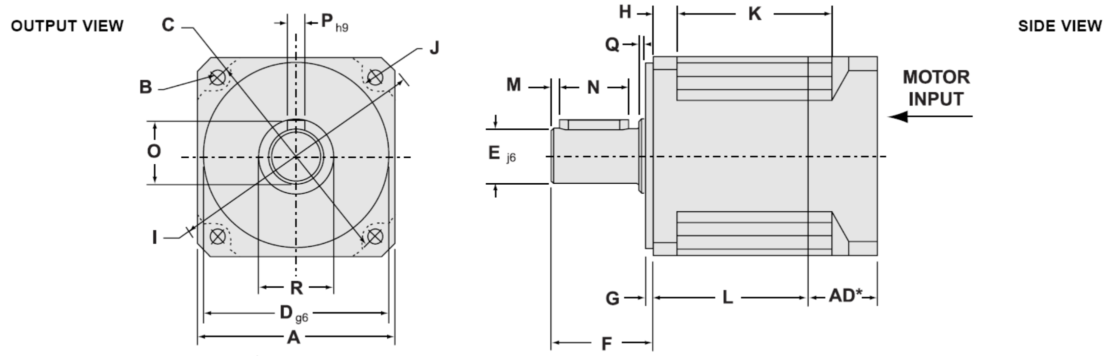
$Mred_{med}$= 62 Nm

The choice of the reducer will be made based on the value of the determined average hub **$Mred_{med}$= 62 Nm.**

From the Parker - Hannifin catalogue "Gearheads Servomotors", (index page 28), the planetary gearbox code: **PS90** is chosen, with the following catalogue data (fig. 36 and 37):

- Nominal torque: **Mr**=107 Nm; (a 3% deviation from the calculated value is allowed)
- Maximum torque: 130 Nm.
- Breakdown torque: 299 Nm;
- Rated speed: 3,800 rpm.
- Reduction ratio: 50

Dimensions



Frame Size	A Square Flange		B Bolt Hole		C Bolt Circle		D Pilot Diameter		E Output Shaft Diameter		F Output Shaft Length		G Pilot Thickness		H Flange Thickness		I Housing Diameter		J Housing Recess	
	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)
PS40	**42**	1.654	**3.4**	0.134	**50**	1.969	**35**	1.378	**13**	0.512	**26**	1.024	**5.5**	0.217	**5**	0.197	**56**	2.205	**3.5**	0.138
PS60	**60**	2.362	**5.5**	0.217	**70**	2.756	**50**	1.969	**16**	0.630	**37**	1.457	**8**	0.315	**8**	0.315	**80**	3.150	**5**	0.197
PS90	**90**	3.543	**6.5**	0.256	**100**	3.937	**80**	3.150	**22**	0.866	**48**	1.890	**11**	0.433	**10**	0.394	**116**	4.567	**6.5**	0.256

Frame Size	K1 Recess Length (For Ratio ≤ 10:1)		K2 Recess Length (For Ratio > 10:1)		L1 Length (For Ratio ≤ 10:1)		L2 Length (For Ratio > 10:1)		M Dist. From Shaft End		N Keyway Length		O Key Height		P Keyway Width		Q Shoulder Height		R Shoulder Diameter	
	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)
PS40	**32**	1.260	**53**	2.087	**30**	1.181	**50.7**	1.996	**2**	0.079	**16**	0.630	**15**	0.591	**5**	0.197	1	0.039	**15**	0.591
PS60	**37**	1.457	**67**	2.638	**36.7**	1.445	**66.7**	2.626	**2**	0.079	**25**	0.984	**18**	0.709	**5**	0.197	**0.5**	0.020	**22**	0.866
PS90	**48**	1.890	**88**	3.465	**49.5**	1.949	**89**	3.504	**3**	0.118	**32**	1.260	**24.5**	0.965	**6**	0.236	**0.5**	0.020	**35**	1.378

Fig. 32. Catalogue geometrical data of the PS 90 (Parker - Hannifin) gearbox

	Units	Ratio	Frame Size							
			PS40	PS60	PS90	PS115	PS142	PS180	PS220	PS300
Nominal Output Torque, $T_{nom\ r}$	Nm	3-10	**5**	**25**	**74**	**170**	**294**	**735**	**1,413**	**3,616**
	in lb		42	220	650	1,500	2,600	6,500	12,500	32,000
	Nm	15-50	**9**	**34**	**107**	**226**	**396**	**1,017**	**1,808**	**4,520**
	in lb		75	300	950	2,000	3,500	9,000	16,000	40,000
	Nm	70-100	**8**	**28**	**90**	**203**	**339**	**893**	**1,582**	**4,181**
	in lb		67	250	800	1,800	3,000	7,900	14,000	37,000
Maximum Acceleration Output Torque, $T_{acc\ r}$	Nm	3-10, 70-100	**8**	**34**	**105**	**232**	**367**	**972**	**1,763**	**4,825**
	in lb		74	300	930	2,050	3,250	8,600	15,600	42,700
	Nm	15-50	**10**	**42**	**130**	**283**	**452**	**1,198**	**2,011**	**5,492**
	in lb		92	370	1,150	2,500	4,000	10,600	17,800	48,600
Emergency(1) Stop Output Torque, $T_{em\ r}$	Nm	3-10, 70-100	**19**	**78**	**243**	**537**	**853**	**2,237**	**4,068**	**11,119**
	in lb		170	690	2,150	4,750	7,550	19,800	36,000	98,400
	Nm	15-50	**24**	**96**	**299**	**655**	**1,040**	**2,757**	**4,520**	**12,656**
	in lb		210	850	2,650	5,800	9,200	24,400	40,000	112,000
Nominal Input Speed, $N_{nom\ r}$	RPM	3-5	3,600	3,200	2,800	2,400	2,000	1,600	1,200	1,000
	RPM	7-10	4,100	3,700	3,300	2,900	2,500	2,000	1,500	1,250
	RPM	15-50	4,600	4,200	3,800	3,400	3,000	2,400	1,800	1,500
	RPM	70-100	5,100	4,700	4,300	3,900	3,500	2,800	2,100	1,750
Max. Input Speed, N_{maxr}	RPM	3-100	6,000	6,000	5,300	4,500	3,800	3,000	2,300	1,900
Standard Backlash (2)	arc min	3-10	10	6	6	4	4	4	4	4
	arc min	15-100	14	8	8	6	6	6	6	6
Low Backlash (2)	arc min	3-10	—	4	4	3	3	3	3	3
	arc min	15-100	—	6	6	5	5	5	5	5
Efficiency at Nominal Torque	%	3-10	97	97	97	97	97	97	97	97
	%	15-100	94	94	94	94	94	94	94	94
Noise Level(3) at:										
3,000 RPM	dB	3-100	68	68	68	68	70	—	—	—
2,000 RPM	dB	3-100	—	—	—	—	—	70	70	70
Torsional Stiffness	Nm / arc min	3-100	**2**	**3**	**12**	**23**	**44**	**110**	**210**	**360**
	in lb / arc min		16	26	106	204	389	973	1,858	3,185
Maximum Weight	kg	3-10	**0.4**	**1.3**	**3**	**7**	**14**	**26**	**49**	**103**
	lb		1.0	2.8	7	15	30	57	108	228
	kg	15-100	**0.6**	**1.7**	**5**	**10**	**20**	**35**	**71**	**149**
	lb		1.4	3.7	10	22	43	77	157	330
Maximum Allowable Case Temperature	°C	3-100	← 100 → For applications requiring lower case temperature, consult factory							

Fig. 33. Catalogue sheet of PS type gearboxes (Parker - Hannifin)

Gearbox purchase code: PS090-050-XXX-LV

Choosing the servo motor

When choosing the servomotor, consider the data of the associated gearbox, which, according to the catalogue sheet shown above, are:

Rated torque: VMnred=**107** Nm,

Maximum acceleration torque: **130 Nm**,

Peak torque: **299 Nm**,

Rated speed: **3800** rpm

Based on the gearbox own ratio ir=1/50, the rated torque of the servomotor should be:

Mmn= Mnred* ir=107/50=2,14 Nm

Mmn= 2,14 **Nm**

Mmmax=Mredmax* ir=130 /50=2,6 Nm

Mmmax=2,6 **Nm**

Peak torque:

Mmvf= Mredvf * ir =299/50=5,98 Nm

From the Parker - Hannifin - "Motion Control Products" catalogue, (index page 106), choose the servomotor code **SM_82 33 03**, with the following catalogue data:

Rated torque: Mn=2.4 Nm,

Maximum rated torque: 3 (3.7) Nm,

Peak torque: 9 Nm,

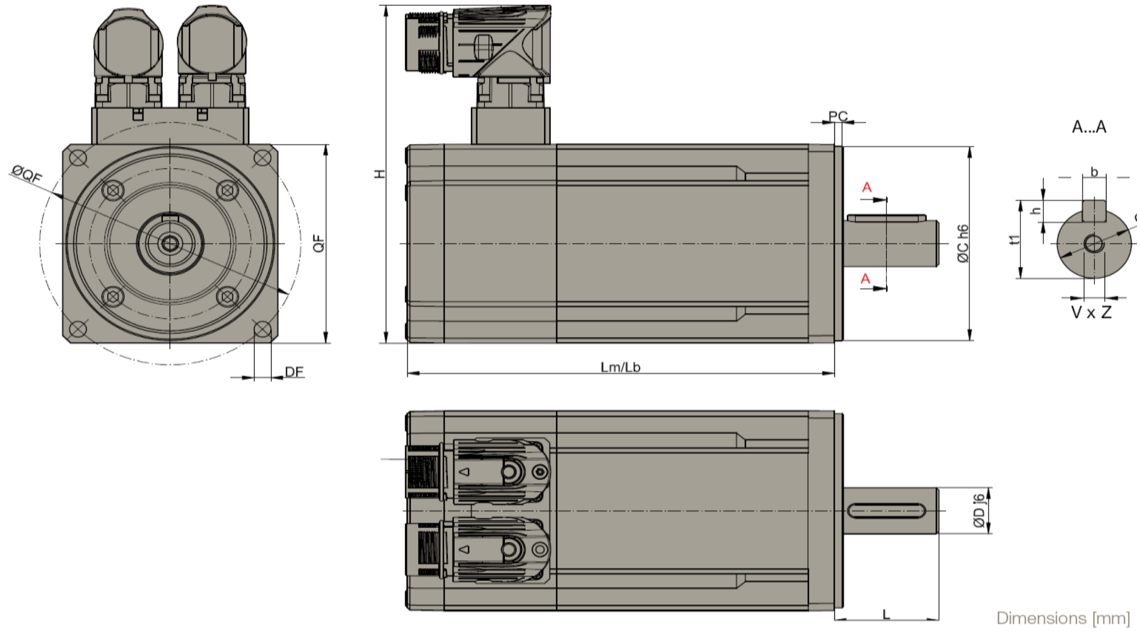
Engine speed 3,300 rpm.

230 VAC supply voltage

Model (4)	Size	Stall (1)		Nominal (1)			Peak (1)	Inertia		Ke (2) (3)	Kt (2) (3)
		Torque	Current	Torque	Speed	Current	Torque	No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [$kgmm^2$]	J [$kgmm^2$]	Ke [Vs]	Kt [Nm/A_{rms}]
SM_42 60 0,35	42	0.35 0.45	0.78	0.15	6000	0.38	0.9	13	n.a.	0.29	0.46
SM_60 30 0,55			0.7	0.50	3000	0.66				0.44	0.76
SM_60 45 0,55		0.55 (0.68)	1.0	0.39	4500	0.74	1.7	18	30.5	0.30	0.53
SM_60 60 0,55			1.4	0.24	6000	0.60				0.23	0.40
SM_60 16 1,4	60		0.95	1.35	1600	0.91				0.85	1.48
SM_60 30 1,4			1.73	1.20	3000	1.50				0.47	0.81
SM_60 45 1,4		1.4 (1.7)	2.37	1.00	4500	1.69	4.4	30	42.5	0.34	0.59
SM_60 60 1,4			2.98	0.80	6000	1.70				0.27	0.47
SM_60 75 1,4			3.85	0.15	7500	0.41				0.21	0.36
SM_82 10 03			1.2	2.9	1000	1.2				1.43	2.48
SM_82 16 03			1.8	2.9	1600	1.7				0.96	1.66
SM_82 30 03			3.1	2.7	3000	2.8				0.55	0.96
SM_82 33 03	82	3 (3.7)	3.5	2.4	3300	2.8	9	140	183	0.49	0.85

Fig. 34. SM servomotors catalogue sheet (Parker - Hannifin)

Dimensions of Standard Motors with Resolver Feedback



Motors Size			LM LB	Weight [kg]	DxL	bxh	t1	VxZ	H	C	ØQF	F	DF	PC	QF	Order Code QF
SMB /H	42	0,35	110	0.85	9x25	-	-	M3x9	66	30		50	3.2	2.5	42	5
SMB /H	60	0,55	88 137	- 1	9x20 11x23	3x3 4x4	10.2 12.5	- M4x10	111.5	40	63	63	5.5	-	60	8
										60	75	75	6	2.5	70	5
SMB /H	60	1,4	129.5 161	1.5	9x20 11x23	3x3 4x4	10.2 12.5	M4x10		40	63	63	5.5	2.5	60	8
										60	75	75	6	2.5	70	5
SMB /H	82	03	159 202	3.6	11x23(2) 14x30	4x4	12.5	M4x12	140	60	75	75	6	3.5	70	7
SMB /H	82	03	163.5 206.5	3.6	11x23(2) 14x30 19x40(1)	5x5 6x6	16 21.5	M4x12 M5x12.5 M6x16		80	100	100	6.5	3.5	82	8
										95	115	115	9	3.5	100	5

Fig. 35. Geometrical data of SM servomotors (Parker - Hannifin)

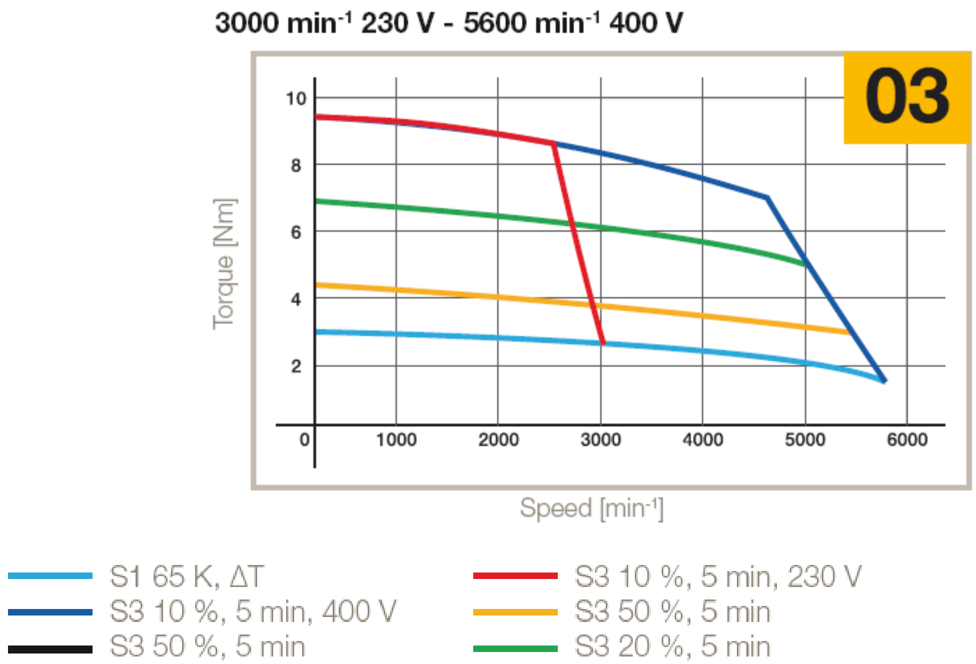


Fig. 36. Dynamic torque - speed performance of the SM servo motor_82 33 03

Phase 8. Choosing the harmonic gearbox and associated servomotor for the robot shoulder joint

Determination of the transfer ratio and choice of the harmonic gearbox.

For the choice of the harmonic reducer that will drive the shoulder joint for the rotation of the robot arm around the axis OY', the maximum angular velocity to be developed shall be considered: $\omega y = \pi/2$ rad/sec, as well as the angular acceleration $\varepsilon z = 2\pi$ rad/s^2.

It results that the maximum speed to be reached in the rotational movement of the robot arm is:

$$Nr = 60 * \omega y / 2\pi = 60/4 = 15 \text{ rot/min}$$

For the speed of the servo motor shaft Nm=2500 rpm, with which the gearbox will be associated, the gearbox transfer ratio must be ir=1/166.

According to the catalogue data of gearboxes on the market, it is normal to choose a gearbox with ratio ir=1/160.

The cumulative mass of the rotating arm Meb is equal to the mass of the integral arm **MeB**=174 kg minus the masses of the vertical sled m7=36 kg, the servomotor m8=18 kg and the rotation module m9=24 kg. **This gives Meb=96 kg**

Recalculate the coordinates of the center of mass of the arm for the two extreme positions of the forearm:

ROBOT structure	Symbol	Mass cumulate	Yei		Σmi*yimin	Σmi*yimax
Rotative robot	Meb	96	YeB	0,284	27,26	27,26
Forearm pos retracted	MeA	60	YeAmin	0,520	31,2	-
Extended forearm position	MeA	60	YeAmax	1,120	-	67,2
				Σmi*yi	58,5	94,5
	Meb	**96**		**Yeвmin**	**0,61**	
				Yeвmax		**0,98**

Determination of maximum, average and nominal torque.

Considering the position of the mass center of the robot arm in the two extreme situations:

Yb_{min}= 0.61 m **Yb_{max}= 0,98 m**

For the motion scenario:

- Accelerated vertical motion on the OZ axis,
- Accelerated rotation about the shoulder joint (OY' axis).

This gives the inventory of forces acting on the mass center of the arm:

		Minimum value (N)		Maximum value (N)	
Gb	Meb*g	96*10	960	96*10	960
Fiz	Meb *az	96*2,5	240	96*2,5	240
Fity	Meb * e* YeB	96*2π*0,61	368	96*2π*0,98	590
Force's sum			1568		1790

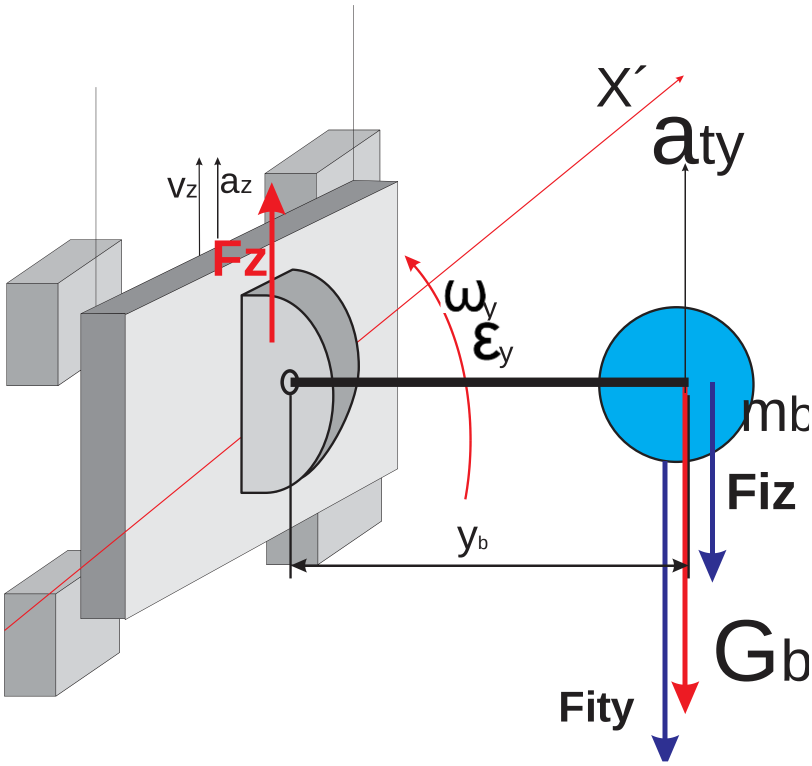


Fig. 37. Study of forces dynamically loading the harmonic reducer

A.) Considering the robot arm in accelerated motion situation on both degrees of freedom OZ and OY, all forces are directed downwards (as shown in figure 37).

a) Torque required at the output shaft of the gearbox, <u>arm in retracted position</u>:

$Mr_{min}=(Fity_{min}+Gb+Fiz)'Yb_{min}$, result:

$Mr_{min}=1568*0,61=956$ Nm

$Mr_{min}=956$ Nm

b) Torque required at the output shaft of the gearbox, <u>arm in extended position</u>:

$Mr_{max}=(Fity_{max}+Gb+Fiz)*Yb_{max}$, rezultă:

$Mr_{max}=(1790)*0,98=1754$ Nm

$Mr_{max}=1754$ Nm

B.) Considering the robot arm in the state of uniform motion on both the OY and OZ axes, it follows that only the weight of the arm Gb participates in the calculation of the required gearbox moment.

In this case:

(c) Torque required at the output shaft of the gearbox, arm in retracted position:

$$M'r_{min}=(Gb)*Yb_{min}, \text{ rezultă:}$$

$$M'r_{min}=960*0,61=586 \text{ Nm}$$

$$\mathbf{M'r_{min}=586 \text{ Nm}}$$

d) Torque required at the output shaft of the gear unit, arm in extended position:

$$M'r_{max}=(Gb)Yb_{max}, \text{ rezultă:}$$

$$M'r_{max}=960*0,98=941 \text{ Nm}$$

$$\mathbf{M'r_{max}=941 \text{ Nm}}$$

To determine the value of the average torque required by the harmonic gearbox, the following averaging formulae are applied:

$$Mr_{med}=(Mr_{min}+2*Mr_{max})/3 \text{ , for motion A.}$$

$$Mr_{med}=(956+2*1754)/3=\mathbf{1488 \text{ Nm}}$$

$$M'r_{med}=(M'r_{min}+2*M'r_{max})/3 \text{ , for motion B.}$$

$$M'r_{med}=(568+2*941)/3=\mathbf{817 \text{ Nm}}$$

Between the two distinct motion situations the averaging formula is applied:

$$Mr=(M_{min}+2*M_{max})/3=(817+2*1488)/3=1264 \text{ Nm}$$

The harmonic reducer shall be chosen according to the average value of the required torque, respectively:

Mr=1264 Nm

From the Harmonic Drive Gear catalogue "csf-cgh-catalogue" (index page 11) the harmonic gear is chosen: CSF 80 with reduction ratio 160, and torque values:

Nominal torque: Mnred=1990 Nm; Repetitive peak torque limit: 4910 Nm; Average torque limit: 3130 Nm; Momentary peak torque limit: 7910 Nm; Maximum input speed: 2900 rpm; Average speed limit: 2200 rpm.

Size	Ratio	Rated Torque at 2000 rpm Tr		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed rpm		Limit for Average Input Speed rpm		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil	Grease	Oil	Grease	$\times10^{-4}$kg·m²	$\times10^{-5}$kgf·…
65	50	490	4337	1420	12567	720	6372	2830	25046	3500	2800	2400	1900	46.8	47.8
	80	745	6593	2110	187	1040	9204	3720	32922						
	100	951	8416	2300	20355	1520	13452	4750	42038						
	120	951	8416	2510	22214	1570	13895	4750	42038						
	160	951	8416	2630	23276	1570	13895	4750	42038						
80	50	872	7717	2440	21594	1260	11151	4870	43100	2900	2300	2200	1500	122	124
	80	1320	11682	3430	30356	1830	16196	6590	58322						
	100	1700	15045	4220	37347	2360	20886	7910	70004						
	120	1990	17612	4590	40622	3130	27701	7910	70004						
	160	1990	17612	4910	43454	3130	27701	7910	70004						

Fig. 38. Catalogue data of CSF gearboxes -

Table 9 (mm)

	45	50	58	65	80	90	100
ØA h6	155	170	195	215	265	300	330
B	$58.5^{0}_{-1.2}$	$64^{0}_{-1.3}$	$75.5^{0}_{-1.3}$	$83^{0}_{-1.3}$	$101^{0}_{-1.3}$	$112.5^{0}_{-1.4}$	$125^{0}_{-1.6}$
C_1	$38^{+0.6}_{0}$	$41^{+0.6}_{0}$	$48^{+0.6}_{0}$	$52.5^{+0.6}_{0}$	$64^{+0.6}_{0}$	$71.5^{+0.8}_{0}$	$79^{+1.0}_{0}$
C_2	20.5	23	27.5	30.5	37	41	46
D	4.5	5	5.8	6.5	8	9	10
E	4	4	5	5	6	6	6
F	19	22	25	29	36	41	46
CSF	3.7	4.2	4.8	5.8	6.6	7.5	8.3
CSG	6.3	7	8.2	9.5	–	–	–
$^{0}_{-0.1}$ CSF	27.9	32	34.9	40.9	49.1	48.2	56.7
CSG	30.5	34.8	38.3	44.6	–	–	–
H_2	–	0.8	–	2.2	3.1	–	4.5
h6 1/30 except	124	135	156	177	218	245	272
1/30	–	–	–	–	–	–	–
ØJ	72	80	92.8	104	128	144	160
ØK H6	36	40	46	52	65	72	80
CSF	12	12	12	12	16	16	16
CSG	16	16	16	16	–	–	–
ØM	9	9	11	11	11	14	14
N_C	M8	M8	M10	M10	M10	M12	M12
N_F	M6	M8	M8	M8	M8	M12	M10
O	12	13	15	15	15	18	20
ØP	9	9	11	11	11	14	14
Q(PCD)	140	150	175	195	240	270	300
R	8	8	8	8	10	8	12
ØS	13.5	15.5	15.5	18	18	22	22
T_1 (PCD)	54	60	70	80	100	110	130
T_2 (PCD)	61	68	79	90	114	120	142
$ØU_1$	32	32	40	48	55	60	65
$ØU_2$	–	32	–	48	55	–	65
(H7)Standard	19	19	22	24	28	28	28
Maximum	20	20	25	30	35	37	40
WJs9	6	6	6	8	8	8	8
X	$21.8^{+0.1}_{0}$	$21.8^{+0.1}_{0}$	$24.8^{+0.1}_{0}$	$27.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$
Y	C0.4	C0.8	C0.8	C0.8	C0.8	C0.8	C0.8
$ØZ_1$	0.5	0.5	0.5	0.5	0.5	1.0	1.0
$ØZ_2$	0.75	0.75	0.75	1.0	1.0	1.0	1.0
$ØZ_3$	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	119	133	154	172	212	239	265
Minimum housing clearance	36.5	39	46.2	50	61	68.5	76
	2	2	2.5	2.5	3	3	3
Øcc H7	6	8	8	8	8	12	10
d_1	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4
d_2	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4
d_3	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5
e	–	–	–	–	–	–	–
f	–	–	–	–	–	–	–
eight (kg)	2.3	3.2	4.7	6.7	12.4	17.6	23.5

Fig. 39. Geometrical data of the CSF 80 harmonic reducer

Choice of servo motor associated with the harmonic gearbox

Considering the dynamic catalogue data of the harmonic gearbox:

Nominal torque: Mnred=1990 Nm; Peak repetitive torque limit: 4910 Nm; Average torque limit: 3130 Nm; and Reduction ratio Ir=160, This gives the required nominal torque of the servomotor:

Mnm=1990/160=12,43 Nm

Mnm=12,5 Nm

For the average gearbox torque limit (3130 Nm), the maximum value of the motor torque will be:

Mmax.m =3130/160 Nm = 19,6 Nm

Mmax.m=20 Nm

For the gearbox peak torque limit (4910 Nm), the peak motor torque will be:

Mv.m=4910/160=30,7 Nm

From the Parker - Hannifin "Motion Control_Products" catalogue (index page 132) choose the servo motor type: MB/MH, code: M_205 30 15.

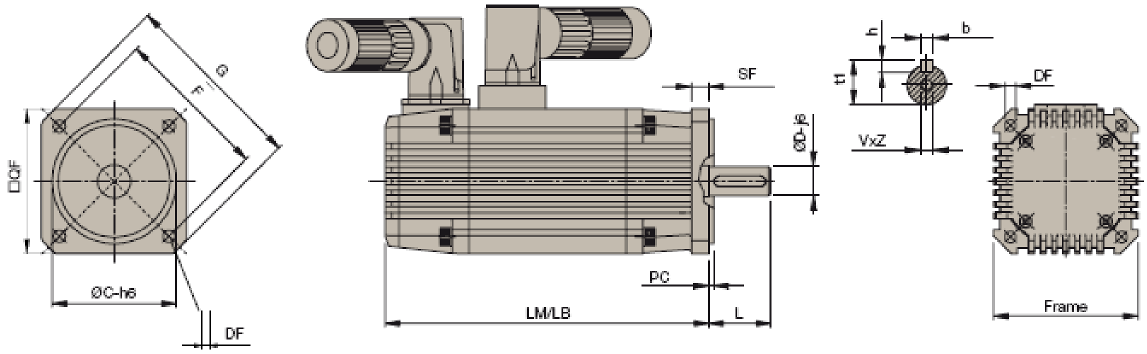
With the following dynamic data: Nominal torque: Mn=13,4 Nm, Starting torque: 15 (22) Nm, Peak torque: 69 Nm, Nominal speed: 3000 rpm.

400 VAC

Model	Size	Stall		Nominal			Peak	Inertia		Ke (2)(3)	Kt (2)(3)
		Torque (1)	Current	Torque (1)	Speed	Current	Torque(1)	No brake	With brake		
		T_{o65} (T_{105}) [Nm]	I_{o65} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [$kgmm^2$]	J [$kgmm^2$]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 205 20 15	205	15 (22)	6.3	14.1	2000	5.9	69	3500	4035	1.4	2.38
M_ 205 30 15			8.6	13.4	3000	7.7				1	1.74
M_ 205 10 28		28 (39)	6.9	28.2	1000	6.8	123	5000	5535	2.5	4.35
M_ 205 20 28			13.0	27.3	2000	12.3				1.3	2.31
M_ 205 30 28			20.1	25.7	3000	18.0				0.9	1.50
M_ 205 10 50		50 (70)	12.4	50.4	1000	12.1	222	8000	8535	2.5	4.35
M_ 205 20 50			22.1	47.0	2000	20.1				1.4	2.45
M_ 205 30 50			33.1	41.7	3000	26.8				0.9	1.63
M_ 205 10 70		70 (98)	16.8	69.4	1000	16.1	310	11 000	11 535	2.6	4.49
M_ 205 20 70			30.7	62.9	2000	26.9				1.4	2.45
M_ 205 30 70			46.1	52.3	3000	33.7				0.9	1.63
M_ 205 10 90		90 (126)	22.1	88.2	1000	21.2	398	14 000	14 535	2.5	4.35
M_ 205 20 90			44.3	78.3	2000	37.7				1.3	2.18
M_ 205 30 90			59.0	61.6	3000	39.7				0.9	1.63

Fig. 40. Catalogue sheet of M 205 type servomotors

Dimensions



Motor - Size		LM/LB	Weight	DxL	bxh	t1	VxZ	C	F	DF	G	SF	PC	QF	Order code QF
205	15	239/338	20	38x80 42x110	10x8 12x8	41 45	M12x32 M16x40	180	215	14	250	18	4	205	5
	28	273/372	29												
	50	342/441	44												
	70	411/510	59												
	90	480/579	74												

Fig. 41. Geometrical data of servo motor M_205 30 15

MB/MH205

1700 min^{-1} 230 V - 3000 min^{-1} 400 V

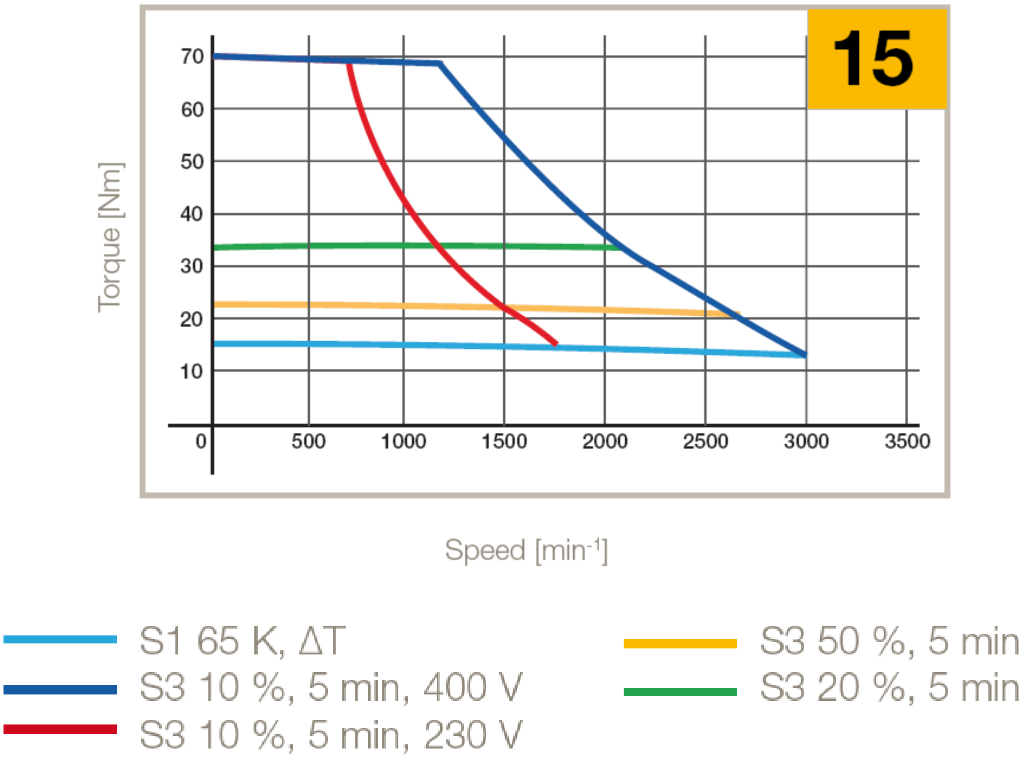


Fig. 42. Torque - Speed characteristic of servo motor M_205 30 15

Phase 9. Calculation of required torque and choice of servomotor for longitudinal displacement along the OX axis

- Determination of the required torque at the pinion of the mechanism

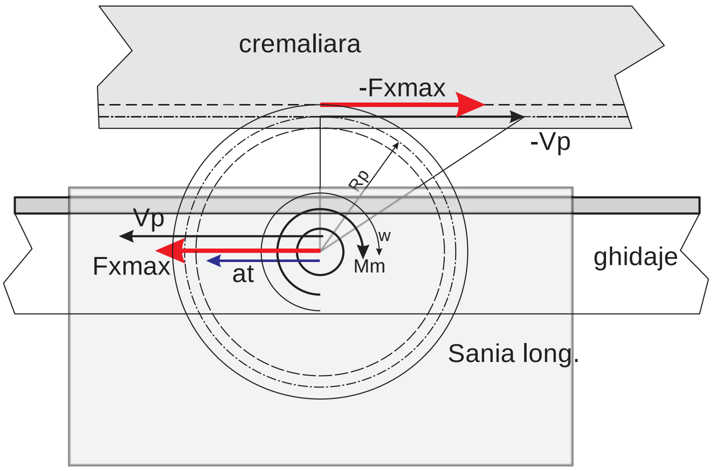


Fig. 43. Diagram of the longitudinal sled drive mechanism

Assuming that the force required for the accelerated movement of the longitudinal sled on the beater gravels has been calculated previously, for the proposed rack-and-pinion drive to be applied (Fig. 43), the following relations can be written:

$$Fx_{max}=MeT*ax + MeT*g*\mu_o = 504*2,5 + 5040*0,03 = 1411 \text{ N},$$

MeT = 504 kg - overall mass of the whole robot, including the manipulated load,

ax = 2,5 m/s2 - the linear acceleration of the sled, proposed in the design theme.

μ_o = 0,03 - friction coefficient in longitudinal guides

From the catalogue data of the longitudinal guide type **GSR 25T-R**, associated with the rack and pinion, the following items are taken for the rack and pinion gearing:

tooth modulus m=1.91; tooth pitch, p=6 mm.

The number of teeth of the pinion zp= 24 is chosen in advance.

This gives the radius of the pinion that meshes with the rack belonging to the intermediate guide,

$$Rp=(1/2)*m*zp=0,5*1,91*24=22,92 \text{ mm}=0,02292 \text{ m}$$

For the sled operating speed: Vx= 0.5 m/s, this gives the required sled drive servo motor speed:

Vx=2π*(Nm/60)*Rp, from which the required servomotor shaft speed is calculated:

Nm=(Vx.60)/ 2π*Rp, resulting in: Nm =(60*0.5)/ 2π*0.02292

Nm=208 rpm

The power required by the servomotor to develop the acceleration ax=2,5 m/s2

is given by the relation:

Pnec= Fxmax*Vx=1411*0,5=705 W (indicative value)

From the known relationship:

$$F \cdot v = \frac{M_m}{r} \cdot \frac{2 \cdot \pi \cdot N_m}{60} \cdot r = \frac{2 \cdot \pi \cdot M_m \cdot N_m}{60}$$

results in the maximum required motor torque of the servomotor:

$$M_m = \frac{60 \cdot F \cdot v}{2 \cdot \pi \cdot N_m} \cdot r$$

Mm= 60*Fxmax*Vx/2π Nm

After inputting the data it follows:

Mm=60*1411*0,5/(2π*208)=32,40 Nm,

The motor moment developed by the pinion in case of accelerated motion is:

Mmax=32,40 Nm

For linear movement with constant speed of the longitudinal sled, the peripheral force in the rack and pinion gear is reduced to the frictional force in the guides.

For the coefficient of friction in the running guides, of value µ0=0.03 and the overall mass of the robot (including the manipulated load), Me=504 kg, the force in the gear becomes:

Fxo=Me*g*μ_0=5040*0,03=151,2 N, for which the minimum motor torque required for uniform movement is:

Mmo=60*151,2*0,5/2π*208=3,47 Nm

Mno=3,47 Nm

Under these conditions, the nominal torque of the engine is calculated based on the averaging relationship:

Mn=1/3*(Mmo+2 Mm)= 1/3*(3,47+2 *32,40)=22,75 Nm

Mn=22,75 Nm

Choice of servomotor for actuating the longitudinal displacement.

Consequently, choose the servo motor associated with the gearbox that develops:

the minimum nominal torque of 22,75 Nm and the maximum torque of 32,40 Nm.

From the Parker-Hannifin catalogue "Parker Gearheads Servomotors".

http://www.parkermotion.com/literature/precision_cd/CD-EM/daedal/cat/english/Gearheads.pdf)

(index pg.15) choose the servo gear associated with planetary gearbox: GM 115-7:1 - Single Stack with technical data shown below in figures 43, 44, 45 and 46. The gear ratio of the associated gearbox is 7:1

Performance Specifications (six step / trapezoidal commutation)

Mechanical Specifications

Frame Size	Stack Length	Weight without Brake		Maximum Radial Load		Torsional Stiffness		Standard Backlash	Low Backlash
		(kg)	(lb)	(N)	(lb)	(Nm/arc min)	(in lb/arc min)	(arc min)	(arc min)
GM115	Single	8.4	18.5	3,900	876	20	177	15	10
GM115	Double	10.6	23.4	3,900	876	20	177	15	10

Single Stack Specifications

Frame Size	Ratio	Max. Speed[1] (RPM)	Cont. Stall Torque [1] T_C (Nm)	(in lb)	Peak Torque[1] T_P (Nm)	(in lb)	Winding C:160 Vdc D:300 Vdc	Voltage Constant[1][3] K_{EL-L} (V/kRPM)	Torque Constant[1][3] K_{TL-L} (Nm/amp)	(in lb/amp)	Induct L_{L-L} (mH)	Cold Resistance R_{L-L} (ohms)	Cont. Current I_C (amps)	Peak Current I_P (amps)	Inertia [2] (gm cm sec^2)	(lb in sec^2)
GM115	5:1	700	18.2	162	54.7	486	C	228.0	2.15	19.5	2.9	1.2	8	25	4.33	0.00375
GM115	5:1	680	18.2	162	54.7	486	D	438.0	4.15	37.0	10.7	4.7	4	13	4.33	0.00375
GM115	7:1	500	25.4	227	76.6	681	C	319.2	3.01	27.3	2.9	1.2	8	25	3.54	0.00306
GM115	7:1	480	25.4	227	76.6	681	D	613.2	5.81	51.8	10.7	4.7	4	13	3.54	0.00306
GM115	10:1	350	36.5	324	109.4	972	C	456.0	4.30	39.0	2.9	1.2	8	25	3.54	0.00306
GM115	10:1	340	36.5	324	109.4	972	D	876.0	8.30	74.0	10.7	4.7	4	13	3.54	0.00306

Fig. 44. Catalogue data of servomotors type GM115 (Parker - Hannifin)

<u>Technical data of the servomotor</u>: GM 115-7:1 - Single Stack

Nominal motor torque: Mnm 25,4 Nm

Maximum motor torque: 76,6 Nm

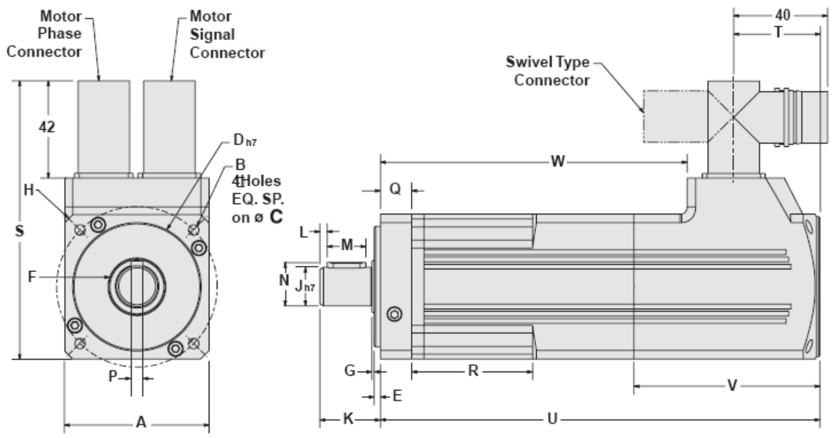
Reduction ratio: 7:1

Engine speed: 500 rpm

Eigen-rotating torque: $3.54.10^{-5}$ [kg.m.sec2]

With these values fully satisfying the dynamic conditions for OX axis actuation, the choice of servomotor is considered correct.

Dimensions



METRIC SIZES

Frame Size	A Square Flange (mm)	(in)	B Bolt Hole (mm)	(in)	C Bolt Circle Diameter (mm)	(in)	D Pilot Diameter (mm)	(in)	E Pilot Thick. (mm)	(in)	F Shoulder Diameter (mm)	(in)	G Shoulder Height (mm)	(in)	H Housing Diameter (mm)	(in)	J Shaft Diameter (mm)	(in)
GM060	60	2.36	5.5	0.22	70	2.756	50	1.969	2.5	0.1	23	0.91	1.0	0.04	80	3.15	16	0.63
GM090	90	3.54	6.5	0.26	100	3.94	80	3.15	3.0	0.12	36	1.42	1.0	0.04	116	4.57	20	0.79
GM115	115	4.53	8.5	0.33	130	5.12	110	4.33	3.5	0.14	36	1.42	1.5	0.6	152	5.95	24	0.94

Frame Size	K Shaft Length		L Dist From Shaft End		M Keyway Length		N Keyway Height		P Keyway Width		Q Flange Thick.		R Recess Length		S Height		T Connector Location	
	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)	(mm)	(in)
GM060	25.0	0.98	3	0.118	16	0.630	18.0	0.709	5	0.20	13	0.51	50.0	1.969	117	4.60	37	1.457
GM090	40.0	1.57	5	0.20	28	1.10	22.5	0.886	6	0.24	17	0.67	54.5	2.15	147	5.79	39	1.535
GM115	50.0	1.97	7	0.28	32	1.26	27.0	1.063	8	0.32	20	0.79	55.5	2.18	175	6.89	46	1.811

Fig. 45. Geometric data of the GM 115-7:1 - Single Stack servo motor(Parker - Hannifin)

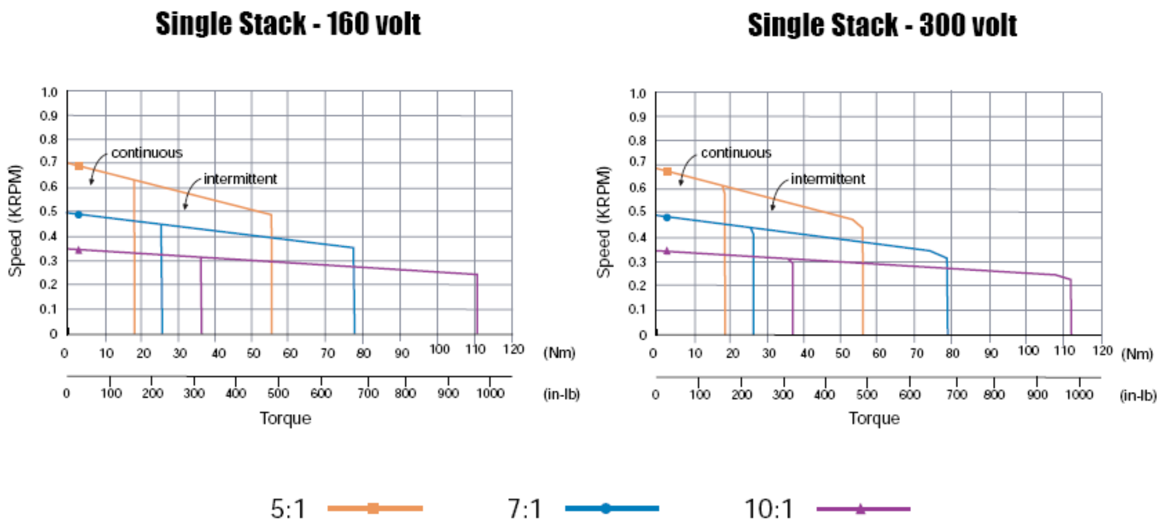


Fig. 46. Torque - speed characteristics for GM115 family servomotors (Parker - Hannifin)

OPIS

LIST OF COMPONENTS TO BE PURCHASED FROM EXTERNAL SUPPLIERS

Product name / code in the project	Vendor order code	SUPPLIER/ PROVIDER
Linear ball guide HSR-20 RM,	HSR 20 R 2 QZ DD C0 M +3000L P T M -II	THK Manufacturing of Europe S.A.S. Parc d' Activités la Passerelle, 68190 Ensisheim France Phone:+33-3-8983-4400 / Fax:+33-3-8983-4409
Linear ball guide GSR 25V	GSR 25 V 2 DD +3000L H T K	
Linear ball guide HSR 20AM	HSR20 AM 2 QZ UU C0 M +1480 P T M - II	
Ball screw BNFN 3210A-5	BNFN 3210°-5 RR G0 + 1400 L C5 A	
Servomotor M_105 30 06	M_105 30 06	Parker Hannifin Sales CEE s.r.o. sp.z o.o. Oddział w Polsce Równoległa 8 Warszawa Poland 02-235
Ball telescopic shaft LBST30	2 LBST30 UU CM + 900L H K	THK Manufacturing of Europe S.A.S. Parc d' Activités la Passerelle, 68190 Ensisheim France, Phone:+33-3-8983-4400
Cross roller bearing RB45025	RE45025 UU CC0 P6	
Reducing PS 90	P S 90 - 0 50 - X X X L D	Parker Hannifin Sales CEE s.r.o. sp.z o.o. Oddział w Polsce, Równoległa 8 Warszawa Poland 02-235
Servomotor SM_82 33 03	SM_82 33 03	Parker Hannifin Sales CEE s.r.o. sp.z o.o. Oddział w Polsce,Równoległa 8 Warszawa,Poland 02-235
Harmonic reducer CSF 80-160	CSF 80-160	Servo Drive AG Hoenbergstrasse, 14, D-6555 Limburg/Lahn Germany
Haronic Drive AGServomotor M_205 30 15	M_205 30 15	Parker Hannifin Sales CEE s.r.o. sp.z o.o. Oddział w Polsce, Równoległa 8 Warszawa Poland 02-235
Servomotor GM 115–7:1 – Single Stack	GM 115–7:1 – Single Stack	Parker Hannifin Sales CEE s.r.o. sp.z o.o. Oddział w Polsce Równoległa 8 Warszawa, Poland 02-235

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Precision Gearhead & Gearmotor
for the Motion Control Industry. www.baysidemotion.com

Motion Control Products
Drives, Motors and Controller Products. www.parker.com

THK - Linear Motion Systems – Genaral Catalogue.
https://www.thk.com/catalog

ANNEXES

GHIDAJE LINIARE

Ghid de alegere a preciziei în funcţie de aplicaţia industrială

Table14 Guideline for Accuracy Grades by Machine Type

Type of machine		Accuracy grades						
		Ct7	Ct5	Normal	H	P	SP	UP
Machine tool	Machining center					●	●	
	Lathe					●	●	
	Milling machine					●	●	
	Boring machine					●	●	
	Jig borer						●	●
	Grinding machine						●	●
	Electric discharge machine					●	●	●
	Punching press				●	●		
	Laser beam machine				●	●	●	
	Woodworking machine	●	●	●	●	●		
	NC drilling machine				●	●		
	Tapping center				●	●		
	Palette changer			●				
	ATC	●	●	●				
	Wire cutting machine					●	●	
	Dressing machine						●	●
Industrial robot	Cartesian coordinate			●	●	●		
	Cylindrical coordinate			●	●			
Semiconductor manufacturing equipment	Wire bonding machine					●	●	
	Prober						●	●
	Electronic component inserter				●	●		
	Printed circuit board drilling machine				●	●	●	
Other equipment	Injection molding machine			●	●			
	3D measuring instrument						●	●
	Office equipment	●	●	●	●			
	Conveyance system	●	●	●	●			
	XY table				●	●	●	
	Coating machine	●	●	●	●			
	Welding machine	●	●	●	●			
	Medical equipment			●	●			
	Digitizer				●	●	●	
	Inspection equipment					●	●	●

Ct7 : Grade Ct7
Ct5 : Grade Ct5
Normal : Normal grade
H : High accuracy grade
P : Precision Grade
SP : Super precision grade
UP : Ultra precision grade

LM Guide

Ghid de alegere a preciziei în funcție de aplicația industrială

Since the radial clearance of an LM Guide greatly affects the running accuracy, load carrying capacity and rigidity of the LM Guide, it is important to select an appropriate clearance according to the application. In general, selecting a negative clearance (i.e., a preload* is applied) while taking into account possible vibrations and impact generated from reciprocating motion favorably affects the service life and the accuracy.

For specific radial clearances, contact THK. We will help you select the optimal clearance according to the conditions.

The clearances of all LM Guide models (except model HR, GSR and GSR-R, which are separate types) are adjusted as specified before shipment, and therefore they do not need further preload adjustment.

Preload is an internal load applied to the rolling elements (balls, rollers, etc.) of an LM block in advance in order to increase its rigidity.

Table13 Types of Radial Clearance

	Normal Clearance	Clearance C1 (Light Preload)	Clearance C0 (Medium Preload)
Condition	● The loading direction is fixed, impact and vibrations are minimal and 2 rails are installed in parallel. ● Very high precision is not required, and the sliding resistance must be as low as possible.	● An overhang load or moment load is applied. ● LM Guide is used in a single-rail configuration. ● Light load and high accuracy are required.	● High rigidity is required and vibrations and impact are applied. ● Heavy-cutting machine tool
Examples of applications	• Beam-welding machine • Book-binding machin • Automatic packaging machine • XY axes of general industrial machinery • Automatic sash-manufacturing machine • Welding machine • Flame cutting machine • Tool changer • Various kinds of material feeder	• Grinding machine table feed axis • Automatic coating machine • Industrial robot • various kinds of material high speed feeder • NC drilling machine • Vertical axis of general industrial machinery • Printed circuit board drilling machine • Electric discharge machine • Measuring instrument • Precision XY table	• Machining center • NC lathe • Grinding stone feed axis of grinding machine • Milling machine • Vertical/horizontal boring machine • Tool rest guide • Vertical axis of machine tool

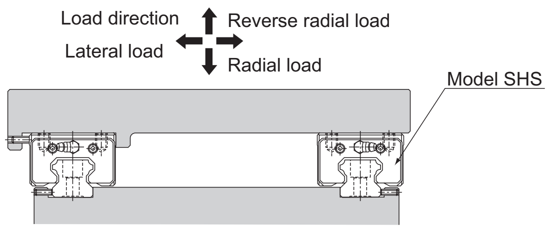
Soluţii de proiectare a sistemelor de ghidaje

THK offers various types of LM Guides in order to meet diversified conditions. Supporting ordinary horizontal mount, vertical mount, inverted mount, slant mount, wall mount and single-axis mount, the wide array of LM Guide types makes it easy to achieve a linear guide system with a long service life and high rigidity while minimizing the required space for installation.

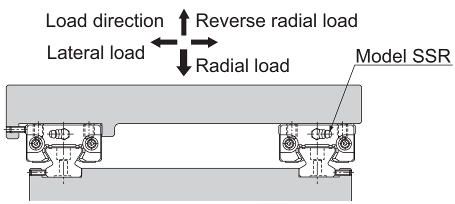
Examples of Arrangements of the Guide System

The following are representative guide systems and arrangements when installing the LM Guide. (For indication of the reference surface, see A-338.)

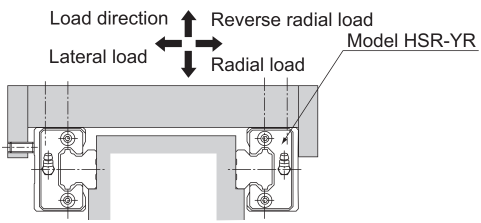
Double-rail configuration when high rigidity is required in all directions



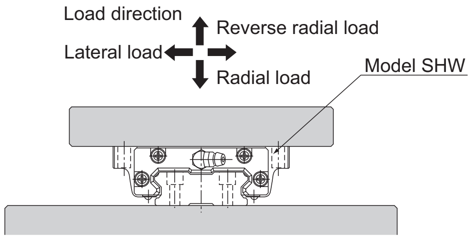
Double-rail configuration when high rigidity is required in the radial direction



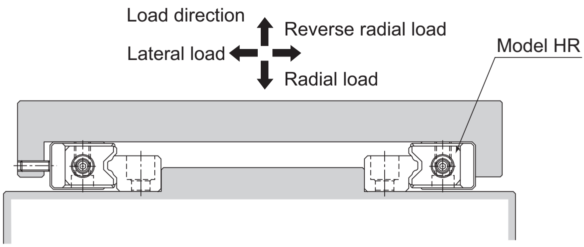
When high rigidity is required in all directions and the installation space is limited in height



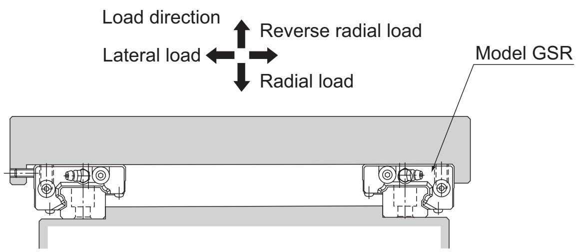
Single-rail configuration

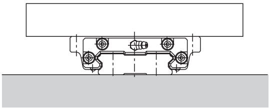
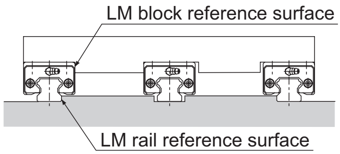


When the minimum possible height of the equipment is allowed (Adjustable preload type)

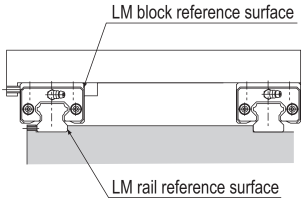


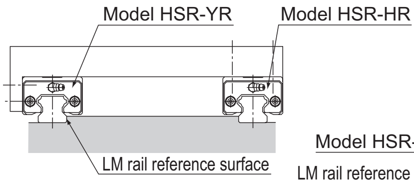
When a medium load is applied and the mounting surface is rough (Preload, self-adjusting type)

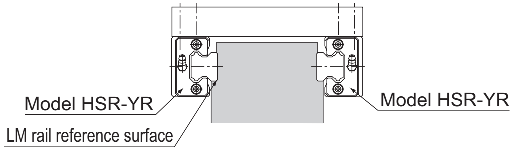


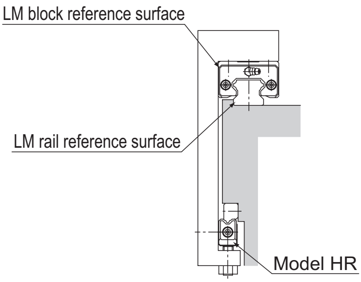
Single-rail configuration	Triple-rail configuration
	

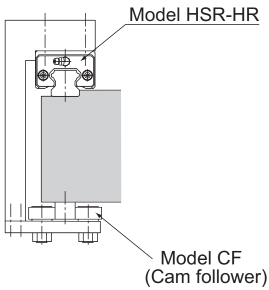
Double-rail configuration

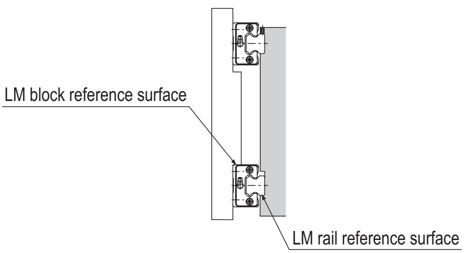


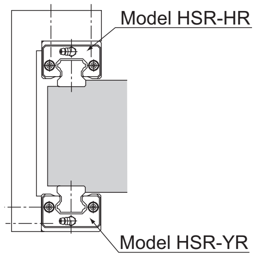




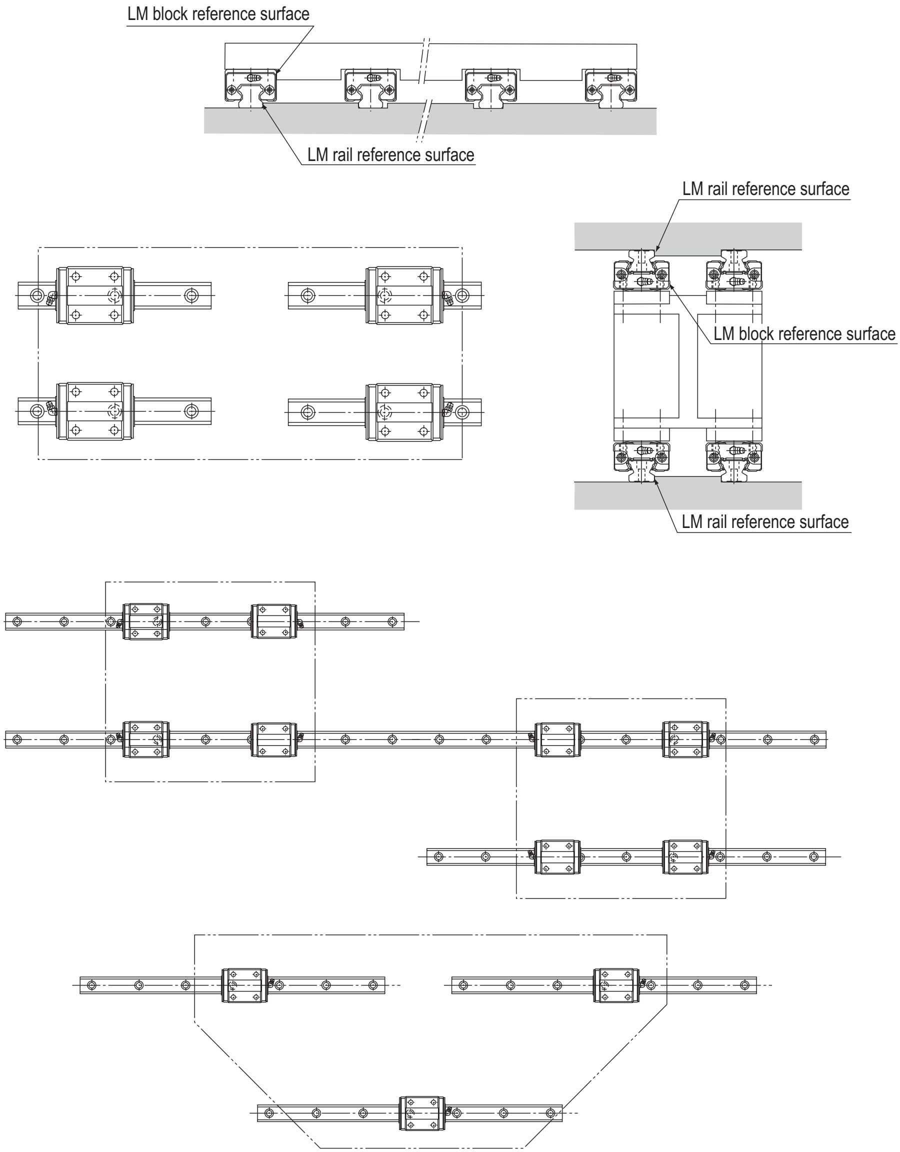








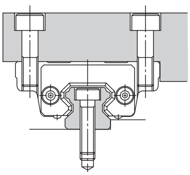
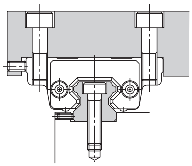
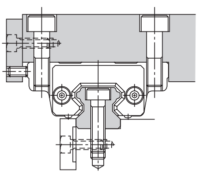
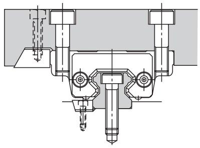
4-rail configuration



Metode de fixare şi asigurare a elementelor ghidajelor liniare

LM Guides are categorized into groups of types by mounting space and structure: a group of types to be mounted with bolts from the top, and another of types to be mounted from the bottom. LM rails are also divided into types secured with bolts and those secured with clamps (model JR). This wide array of types allows you to make a choice according to the application.
There are several ways of mounting the LM Guide as shown in Table1. When the machine is subject to vibrations that may cause the LM rail(s) or LM blocks to loosen, we recommend the securing method indicated by Fig.1 on A-323. (If 2 or more rails are used in parallel, only the LM block on the master rail should be secured in the crosswise direction.) If this method is not applicable for a structural reason, hammer in knock pins to secure the LM block(s) as shown in Table2 on A-323 When using knock pins, machine the top/bottom surfaces of the LM rail by 2 to 3 mm using a carbide end mill before drilling the holes since the surfaces are hardened.

Table1 Major Securing Methods on the Master-rail Side

(a) Secured only with side reference surfaces	(b) Secured with set screws
	
(c) Secured with a presser plate	**(d) Secured with tapered gibs**
	

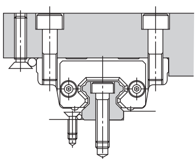
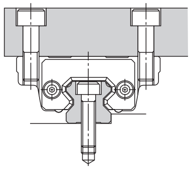
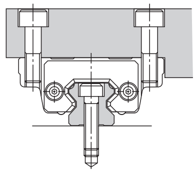
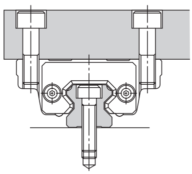
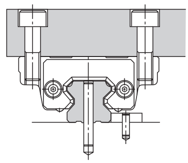
(e) Secured with pins


Table2 Major Securing Methods on the Subsidiary-rail Side

(a) Secured only with the side reference surface of the rail	(b) Secured only with the side reference surface of the block
	
(c) Secured without a side reference surface	**(d) Secured with dowel pins**
	

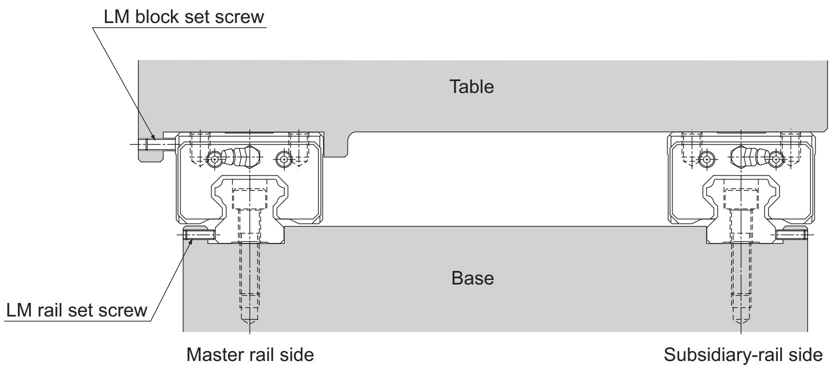
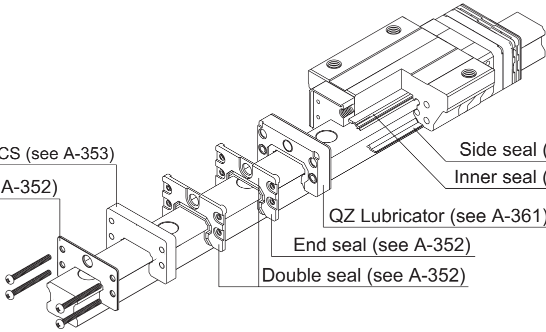


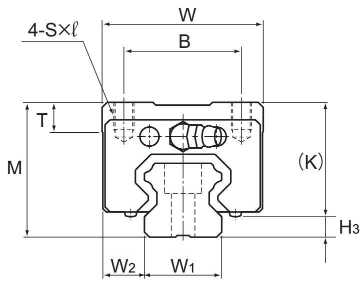
Fig.1 When the Machine Receives Vibrations or Impact

Lista simbolurilor elementelor componente



Symbol	Lubrication and Dust Prevention Accessories
UU	End seal
SS	With end seal + side seal + inner seal
DD	With double seals + side seal + inner seal
ZZ	With end seal + side seal + inner seal + metal scraper
KK	With double seals + side seal + inner seal + metal scraper
GG	LiCS
PP	With LiCS + side seal + inner seal
SSHH	With end seal + side seal + inner seal + LaCS
DDHH	With double seals + side seal + inner seal + LaCS
ZZHH	With end seal + side seal + inner seal + metal scraper + LaCS
KKHH	With double seals + side seal + inner seal + metal scraper + LaCS
QZUU	With end seal + QZ
QZSS	With end seal + side seal + inner seal + QZ
QZDD	With double seals + side seal + inner seal + QZ
QZZZ	With end seal + side seal + inner seal + metal scraper + QZ
QZKK	With double seals + side seal + inner seal + metal scraper + QZ
QZGG	With LiCS + QZ
QZPP	With LiCS + side seal + inner seal + QZ
QZSSHH	With end seal + side seal + inner seal + LaCS + QZ
QZDDHH	With double seals + side seal + inner seal + LaCS + QZ
QZZZHH	With end seal + side seal + inner seal + metal scraper + LaCS + QZ
QZKKHH	With double seals + side seal + inner seal + metal scraper + LaCS + QZ

Exemple fişe de catalog pentru ghidaje liniare, utilizate în proiect



Model No.	Outer dimensions			LM block dimensions									
	Height M	Width W	Length L	B	C	S×ℓ	L_1	T	K	N	E	Grease nipple	H_3
HSR 15R HSR 15RM	28	34	56.6	26	26	M4×5	38.8	6	23.3	8.3	5.5	PB1021B	3.5
HSR 20R HSR 20RM	30	44	74	32	36	M5×6	50.8	8	26	5	12	B-M6F	4
HSR 20LR HSR 20LRM	30	44	90	32	50	M5×6	66.8	8	26	5	12	B-M6F	4
HSR 25R HSR 25RM	40	48	83.1	35	35	M6×8	59.5	9	34.5	10	12	B-M6F	5.5
HSR 25LR HSR 25LRM	40	48	102.2	35	50	M6×8	78.6	9	34.5	10	12	B-M6F	5.5
HSR 30R HSR 30RM	45	60	98	40	40	M8×10	70.4	9	38	10	12	B-M6F	7
HSR 30LR HSR 30LRM	45	60	120.6	40	60	M8×10	93	9	38	10	12	B-M6F	7
HSR 35R HSR 35RM	55	70	109.4	50	50	M8×12	80.4	11.7	47.5	15	12	B-M6F	7.5
HSR 35LR HSR 35LRM	55	70	134.8	50	72	M8×12	105.8	11.7	47.5	15	12	B-M6F	7.5
HSR 45R HSR 45LR	70	86	139 170.8	60	60 80	M10×17	98 129.8	15	60	20	16	B-PT1/8	10
HSR 55R HSR 55LR	80	100	163 201.1	75	75 95	M12×18	118 156.1	20.5	67	21	16	B-PT1/8	13
HSR 65R HSR 65LR	90	126	186 245.5	76	70 120	M16×20	147 206.5	23	76	19	16	B-PT1/8	14
HSR 85R HSR 85LR	110	156	245.6 303	100	80 140	M18×25	178.6 236	29	94	23	16	B-PT1/8	16

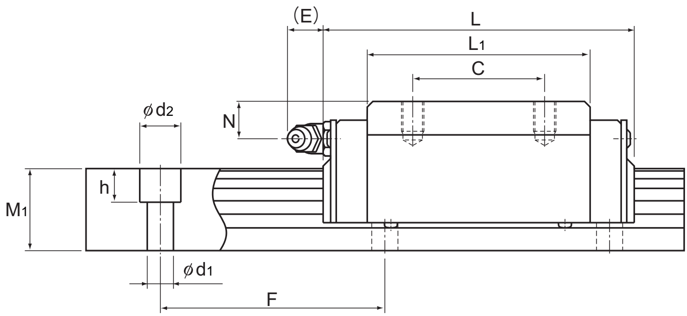
Model number coding

HSR35 R 2 QZ SS C0 M +1400L P T M -Ⅱ

- HSR35: Model number
- R: Type of LM block
- 2: No. of LM blocks used on the same rail
- QZ: With QZ Lubricator
- SS: Contamination protection accessory symbol (*1)
- C0: Radial clearance symbol (*2) Normal (No symbol) Light preload (C1) Medium preload (C0)
- M: Stainless steel LM block
- +1400L: LM rail length (in mm)
- P: Accuracy symbol (*3) Normal grade (No Symbol)/High accuracy grade (H) Precision grade (P)/Super precision grade (SP) Ultra precision grade (UP)
- T: Symbol for LM rail jointed use
- M: Stainless steel LM rail
- -Ⅱ: Symbol for No. of rails used on the same plane (*4)

(*1) See contamination protection accessory on A-368. (*2) See A-114. (*3) See A-119. (*4) See A-59.

Note) This model number indicates that a single-rail unit constitutes one set. (i.e., required number of sets when 2 rails are used in parallel is 2 at a minimum.)
Those models equipped with QZ Lubricator cannot have a grease nipple.

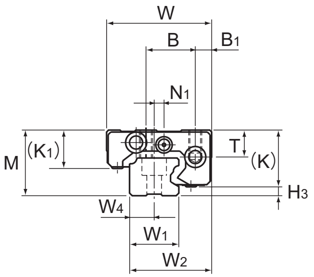


Unit: mm

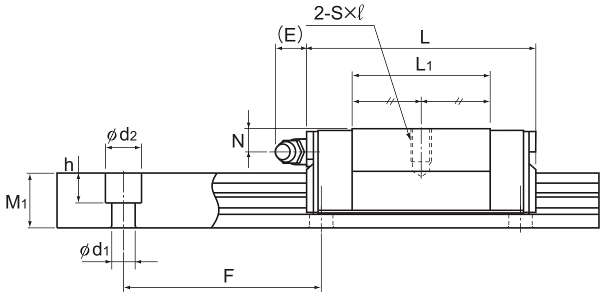
	LM rail dimensions						Basic load rating		Static permissible moment kN-m*					Mass	
	Width W_1 ±0.05	W_2	Height M_1	Pitch F	$d_1 \times d_2 \times h$	Length* Max	C kN	C_0 kN	M_A 1 block	M_A Double blocks	M_B 1 block	M_B Double blocks	M_C 1 block	LM block kg	LM rail kg/m
	15	9.5	15	60	4.5×7.5×5.3	3000 (1240)	8.33	13.5	0.0805	0.457	0.0805	0.457	0.0844	0.18	1.5
	20	12	18	60	6×9.5×8.5	3000 (1480)	13.8	23.8	0.19	1.04	0.19	1.04	0.201	0.25	2.3
	20	12	18	60	6×9.5×8.5	3000 (1480)	21.3	31.8	0.323	1.66	0.323	1.66	0.27	0.35	2.3
	23	12.5	22	60	7×11×9	3000 (2020)	19.9	34.4	0.307	1.71	0.307	1.71	0.344	0.54	3.3
	23	12.5	22	60	7×11×9	3000 (2020)	27.2	45.9	0.529	2.74	0.529	2.74	0.459	0.67	3.3
	28	16	26	80	9×14×12	3000 (2520)	28	46.8	0.524	2.7	0.524	2.7	0.562	0.9	4.8
	28	16	26	80	9×14×12	3000 (2520)	37.3	62.5	0.889	4.37	0.889	4.37	0.751	1.1	4.8
	34	18	29	80	9×14×12	3000 (2520)	37.3	61.1	0.782	3.93	0.782	3.93	0.905	1.5	6.6
	34	18	29	80	9×14×12	3000 (2520)	50.2	81.5	1.32	6.35	1.32	6.35	1.2	2	6.6
	45	20.5	38	105	14×20×17	3090	60 80.4	95.6 127	1.42 2.44	7.92 12.6	1.42 2.44	7.92 12.6	1.83 2.43	2.6 3.1	11
	53	23.5	44	120	16×23×20	3060	88.5 119	137 183	2.45 4.22	13.2 21.3	2.45 4.22	13.2 21.3	3.2 4.28	4.3 5.4	15.1
	63	31.5	53	150	18×26×22	3000	141 192	215 286	4.8 8.72	23.5 40.5	4.8 8.72	23.5 40.5	5.82 7.7	7.3 9.3	22.5
	85	35.5	65	180	24×35×28	3000	210 282	310 412	8.31 14.2	45.6 72.5	8.31 14.2	45.6 72.5	11 14.7	13 16	35.2

Note) Symbol M indicates that stainless steel is used in the LM block, LM rail and balls. Those models marked with this symbol are therefore highly resistant to corrosion and environment.
The maximum length under "Length*" indicates the standard maximum length of an LM rail. (See B-82.)
Static permissible moment*: 1 block: static permissible moment value with 1 LM block
Double blocks: static permissible moment value with 2 blocks closely contacting with each other

Models GSR-T and GSR-V



Model GSR15T/V



Models GSR15 to 25V

Model No.	Outer dimensions			LM block dimensions												
	Height M	Width W	Length L	B_1	B	C	S×ℓ	L_1	T	K	K_1	N	N_1	E	Grease nipple	H_3
GSR 15T GSR 15V	20	32	59.8 47.1	5	15	26 —	M4×7	40.2 27.5	8.25	17.5	12	4.5	3	5.5	PB107	8
GSR 20T GSR 20V	24	43	74 58.1	7	20	30 —	M5×8	50.2 34.3	9.7	20.6	13.6	5	—	12	B-M6F	10.4
GSR 25T GSR 25V	30	50	88 69	7	23	40 —	M6×10	60.2 41.2	12.7	25.5	16.8	7	—	12	B-M6F	13.2
GSR 30T	33	57	103	8	26	45	M8×12	70.3	14.6	28.5	18	7	—	12	B-M6F	15
GSR 35T	38	68	117	9	32	50	M8×15	80.3	15.6	32.5	20.5	8	—	12	B-M6F	17.5

Model number coding

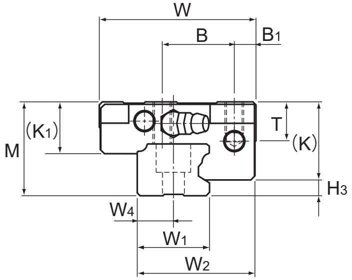
Combination of LM rail and LM block

GSR25 T 2 UU +1060L H T K

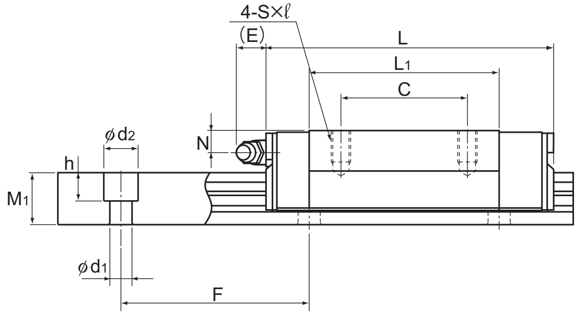
- GSR25: Model number
- T: Type of LM block
- 2: No. of LM blocks
- UU: Contamination protection accessory symbol (*1)
- +1060L: LM rail length (in mm)
- H: Accuracy symbol (*2) Normal grade (No Symbol)/High accuracy grade (H) Precision grade (P)
- T: Symbol for LM rail jointed use
- K: Symbol for tapped-hole LM rail type

(*1) See contamination protection accessory on A-368. (*2) See A-124.

Note) One set of model GSR: This model number indicates that a single-rail unit constitutes one set.



Models GSR20 to 35T, Models GSR20V and 25V



Models GSR15 to 35T

Unit: mm

LM rail dimensions							Basic load rating		Static permissible moment kN-m*				Mass	
Width			Height	Pitch		Length*	C	C_0	M_A		M_B		LM block	LM rail
W_1	W_2	W_4	M_1	F	$d_1 \times d_2 \times h$	Max	kN	kN	1 block	Double blocks	1 block	Double blocks	kg	kg/m
15	25	7.5	11.5	60	4.5×7.5×5.3	2000	5.69 4.31	8.43 5.59	0.0525 0.0252	0.292 0.158	0.0452 0.0218	0.252 0.136	0.13 0.08	1.2
20	33	10	13	60	6×9.5×8.5	3000	9.22 7.01	13.2 8.82	0.102 0.0498	0.564 0.307	0.0885 0.0431	0.486 0.265	0.25 0.17	1.8
23	38	11.5	16.5	60	7×11×9	3000	13.5 10.29	19 12.65	0.177 0.0858	0.965 0.522	0.152 0.0742	0.831 0.451	0.5 0.29	2.6
28	44.5	14	19	80	9×14×12	3000	18.8	25.9	0.282	1.54	0.243	1.32	0.6	3.6
34	54	17	22	80	11×17.5×14	3000	25.1	33.8	0.421	2.28	0.362	1.96	1	5

Note) A moment in the direction M_C can be received if two rails are used in parallel. However, since it depends on the distance between the two rails, the moment in the direction M_C is omitted here.
The maximum length under "Length*" indicates the standard maximum length of an LM rail. (See B-148.)
Static permissible moment*: 1 block: static permissible moment value with 1 LM block
Double blocks: static permissible moment value with 2 blocks closely contacting with each other

Model number coding

LM block

GSR25 T UU

- GSR25: Model number
- T: Type of LM block
- UU: Contamination protection accessory symbol (*1)

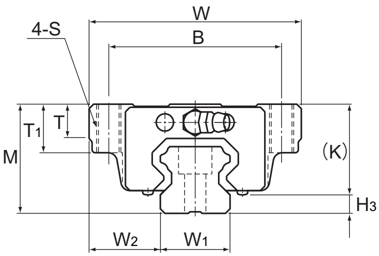
LM rail

GSR25 -1060L H K

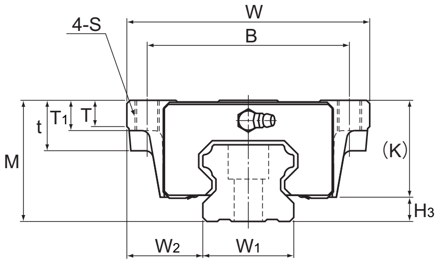
- GSR25: Model number
- -1060L: LM rail length (in mm)
- H: Accuracy symbol (*2) Normal grade (No Symbol) High accuracy grade (H) Precision grade (P)
- K: Symbol for tapped-hole LM rail type

(*1) See contamination protection accessory on A-368. (*2) See A-124.

Models HSR-A and HSR-AM, Models HSR-LA and HSR-LAM



Models HSR15 to 35A/LA/AM/LAM



Models HSR45 to 85A/LA

Model No.	Outer dimensions			LM block dimensions											
	Height M	Width W	Length L	B	C	S	L_1	t	T	T_1	K	N	E	Grease nipple	H_3
HSR 15A HSR 15AM	24	47	56.6	38	30	M5	38.8	—	7	11	19.3	4.3	5.5	PB1021B	3.5
HSR 20A HSR 20AM	30	63	74	53	40	M6	50.8	—	10	9.5	26	5	12	B-M6F	4
HSR 20LA HSR 20LAM	30	63	90	53	40	M6	66.8	—	10	9.5	26	5	12	B-M6F	4
HSR 25A HSR 25AM	36	70	83.1	57	45	M8	59.5	—	11	16	30.5	6	12	B-M6F	5.5
HSR 25LA HSR 25LAM	36	70	102.2	57	45	M8	78.6	—	11	16	30.5	6	12	B-M6F	5.5
HSR 30A HSR 30AM	42	90	98	72	52	M10	70.4	—	9	18	35	7	12	B-M6F	7
HSR 30LA HSR 30LAM	42	90	120.6	72	52	M10	93	—	9	18	35	7	12	B-M6F	7
HSR 35A HSR 35AM	48	100	109.4	82	62	M10	80.4	—	12	21	40.5	8	12	B-M6F	7.5
HSR 35LA HSR 35LAM	48	100	134.8	82	62	M10	105.8	—	12	21	40.5	8	12	B-M6F	7.5
HSR 45A HSR 45LA	60	120	139 170.8	100	80	M12	98 129.8	25	13	15	50	10	16	B-PT1/8	10
HSR 55A HSR 55LA	70	140	163 201.1	116	95	M14	118 156.1	29	13.5	17	57	11	16	B-PT1/8	13
HSR 65A HSR 65LA	90	170	186 245.5	142	110	M16	147 206.5	37	21.5	23	76	19	16	B-PT1/8	14
HSR 85A HSR 85LA	110	215	245.6 303	185	140	M20	178.6 236	55	28	30	94	23	16	B-PT1/8	16

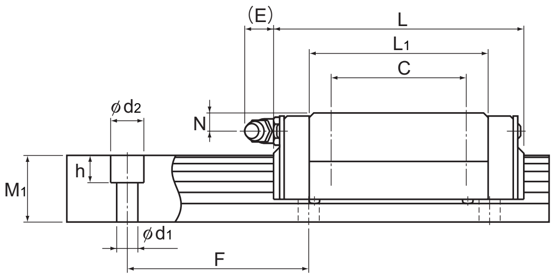
Model number coding

HSR25 A 2 QZ UU C0 M +1200L P T M -II

- HSR25: Model number
- A: Type of LM block
- 2: No. of LM blocks used on the same rail
- QZ: With QZ Lubricator
- UU: Contamination protection accessory symbol (*1)
- C0: Radial clearance symbol (*2) Normal (No symbol) Light preload (C1) Medium preload (C0)
- M: Stainless steel LM block
- +1200L: LM rail length (in mm)
- P: Accuracy symbol (*3) Normal grade (No Symbol)/High accuracy grade (H) Precision grade (P)/Super precision grade (SP) Ultra precision grade (UP)
- T: Symbol for LM rail jointed use
- M: Stainless steel LM rail
- -II: Symbol for No. of rails used on the same plane (*4)

(*1) See contamination protection accessory on A-368. (*2) See A-114. (*3) See A-119. (*4) See A-59.

Note) This model number indicates that a single-rail unit constitutes one set. (i.e., required number of sets when 2 rails are used in parallel is 2 at a minimum.)
Those models equipped with QZ Lubricator cannot have a grease nipple.



Unit: mm

	LM rail dimensions						Basic load rating		Static permissible moment kN-m*					Mass	
	Width		Height	Pitch		Length*	C	C_0	M_A		M_B		M_C	LM block	LM rail
	W_1 ±0.05	W_2	M_1	F	$d_1 \times d_2 \times h$	Max	kN	kN	1 block	Double blocks	1 block	Double blocks	1 block	kg	kg/m
	15	16	15	60	4.5×7.5×5.3	3000 (1240)	8.33	13.5	0.0805	0.457	0.0805	0.457	0.0844	0.2	1.5
	20	21.5	18	60	6×9.5×8.5	3000 (1480)	13.8	23.8	0.19	1.04	0.19	1.04	0.201	0.35	2.3
	20	21.5	18	60	6×9.5×8.5	3000 (1480)	21.3	31.8	0.323	1.66	0.323	1.66	0.27	0.47	2.3
	23	23.5	22	60	7×11×9	3000 (2020)	19.9	34.4	0.307	1.71	0.307	1.71	0.344	0.59	3.3
	23	23.5	22	60	7×11×9	3000 (2020)	27.2	45.9	0.529	2.74	0.529	2.74	0.459	0.75	3.3
	28	31	26	80	9×14×12	3000 (2520)	28	46.8	0.524	2.7	0.524	2.7	0.562	1.1	4.8
	28	31	26	80	9×14×12	3000 (2520)	37.3	62.5	0.889	4.37	0.889	4.37	0.751	1.3	4.8
	34	33	29	80	9×14×12	3000 (2520)	37.3	61.1	0.782	3.93	0.782	3.93	0.905	1.6	6.6
	34	33	29	80	9×14×12	3000 (2520)	50.2	81.5	1.32	6.35	1.32	6.35	1.2	2	6.6
	45	37.5	38	105	14×20×17	3090	60 80.4	95.6 127	1.42 2.44	7.92 12.6	1.42 2.44	7.92 12.6	1.83 2.43	2.8 3.3	11
	53	43.5	44	120	16×23×20	3060	88.5 119	137 183	2.45 4.22	13.2 21.3	2.45 4.22	13.2 21.3	3.2 4.28	4.5 5.7	15.1
	63	53.5	53	150	18×26×22	3000	141 192	215 286	4.8 8.72	23.5 40.5	4.8 8.72	23.5 40.5	5.82 7.7	8.5 10.7	22.5
	85	65	65	180	24×35×28	3000	210 282	310 412	8.31 14.2	45.6 72.5	8.31 14.2	45.6 72.5	11 14.7	17 23	35.2

Note) Symbol M indicates that stainless steel is used in the LM block, LM rail and balls. Those models marked with this symbol are therefore highly resistant to corrosion and environment.
The maximum length under "Length*" indicates the standard maximum length of an LM rail. (See B-82.)
Static permissible moment*: 1 block: static permissible moment value with 1 LM block
Double blocks: static permissible moment value with 2 blocks closely contacting with each other

A-15

Combinaţiile standard între diametrele şi pasul şuruburilor cu bile

Table16 Standard Combinations of Screw Shaft and Lead (Precision Ball Screw)   Unit: mm

Screw shaft outer diameter	Lead																					
	1	2	4	5	6	8	10	12	15	16	20	24	25	30	32	36	40	50	60	80	90	100
4	●																					
5	●																					
6	●																					
8	●	●					●	○														
10		●	●				●		○													
12		●		●		●																
13											○											
14		●	●	●		●																
15							●				●			○			○					
16			○	●	○		○			●												
18							●															
20			○	●	○	○	●	○			●						○		○			
25			○	●	○	○	●	○		○	●		○					○				
28				○	●	○	○															
30																			○		○	
32			○	●	●	○	●	○			○				○							
36					○	○	●	○		○	○	○				○						
40				○	○	○	●	●		○	○			○			○			○		
45					○	○	○	○		○	○											
50				○		○	●	○		○	○			○		○		○				○
55							○	○		○	○			○		○						
63							○	○		○	○											
70							○	○			○											
80							○	○			○											
100											○											

●: off-the-shelf products [standard-stock products equipped with the standardized screw shafts (with unfinished shaft ends/finished shaft ends)]
○: Semi-standard stock

Table17 shows the standard combinations of shaft diameter and lead for the rolled Ball Screw.

Table17 Standard Combinations of Screw Shaft and Lead (Rolled Ball Screw)

Unit: mm

Screw shaft outer diameter	Lead																			
	1	2	4	5	6	8	10	12	16	20	24	25	30	32	36	40	50	60	80	100
6	●																			
8		●																		
10		●			○															
12		●				○														
14			●	●																
15							●			●			●							
16				●					●											
18						●														
20				●			●			●						●				
25				●			●					●					●			
28					●															
30																		●		
32							●							●						
36							●			●	●				●					
40							●									●			●	
45								●												
50									●								●			●

●: Standard stock
○: Semi-standard stock

CRITERI DE VERIFICARE A ŞURUBULUI CU BILE ÎN FUNCŢE DE PARAMETRI FUNCŢIONALI

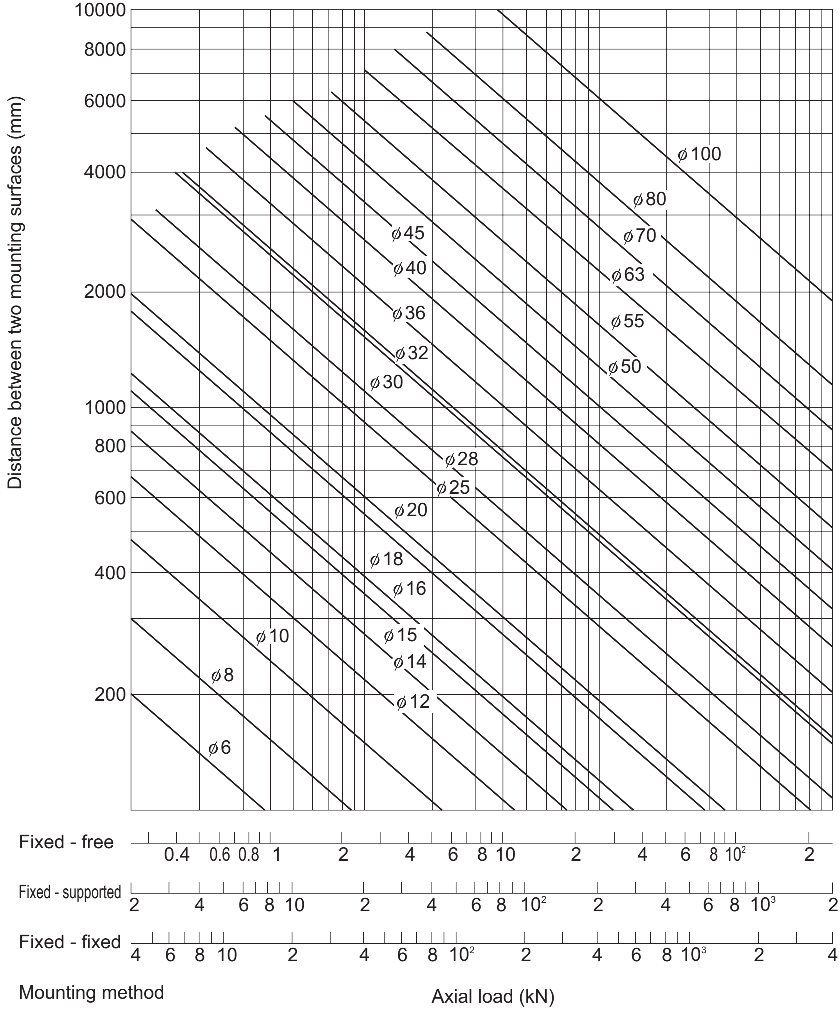


Fig.8 Permissible Tensile Compressive Load Diagram

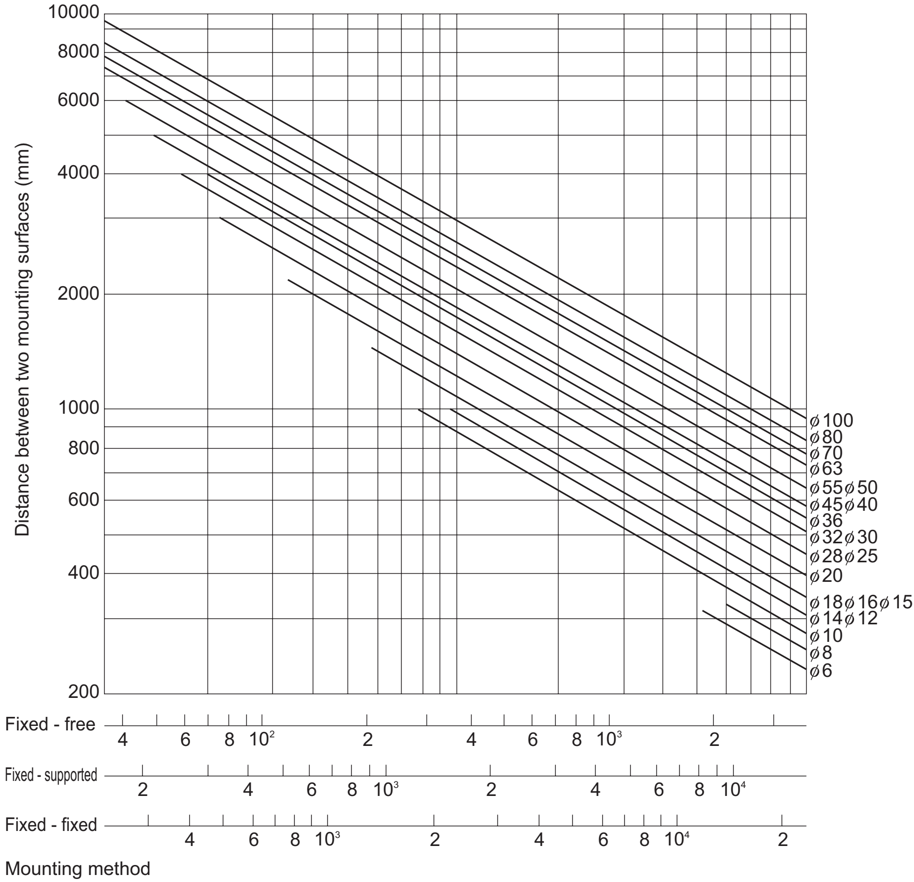


Fig.9 Permissible Rotational Speed Diagram

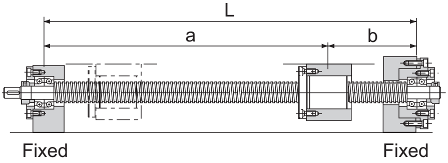
● **For Fixed-Fixed Configuration**

$$K_S = \frac{A \cdot E \cdot L}{1000 \cdot a \cdot b} \quad \cdots\cdots\cdots(34)$$

K_S becomes the lowest and the elastic displacement in the axial direction is the greatest at the position of $a = b = \frac{L}{2}$.

$$K_S = \frac{4A \cdot E}{1000L}$$

Fig.11 on A-709 shows an axial rigidity diagram of the screw shaft in this configuration.



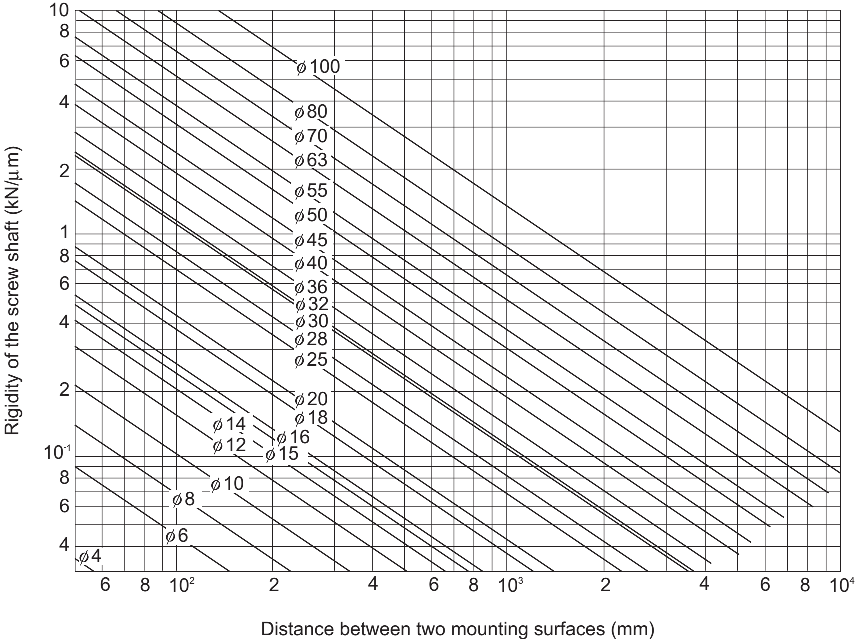


Fig.10 Axial Rigidity of the Screw Shaft (Fixed-Free, Fixed-Supported)

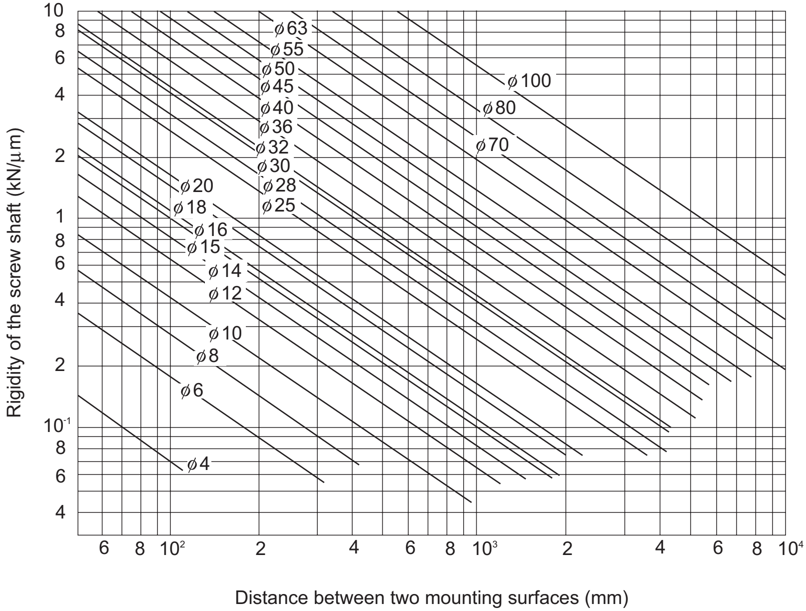


Fig.11 Axial Rigidity of the Screw Shaft (Fixed-Fixed)

[Axial rigidity of the nut]

The axial rigidity of the nut varies widely with preloads.

● No Preload Type

The logical rigidity in the axial direction when an axial load accounting for 30% of the basic dynamic load rating (Ca) is applied is indicated in the specification tables of the corresponding model number. This value does not include the rigidity of the components related to the nut-mounting bracket. In general, set the rigidity at roughly 80% of the value in the table.

The rigidity when the applied axial load is not 30% of the basic dynamic load rating (Ca) is calculated using the equation (35) below.

$$K_N = K\left(\frac{Fa}{0.3Ca}\right)^{\frac{1}{3}} \times 0.8 \quad \cdots\cdots\cdots(35)$$

K_N	: Axial rigidity of the nut	(N/µm)
K	: Rigidity value in the specification tables	(N/µm)
Fa	: Applied axial load	(N)
Ca	: Basic dynamic load rating	(N)

Selecţia tipului piuliţelor şuruburilor cu bile

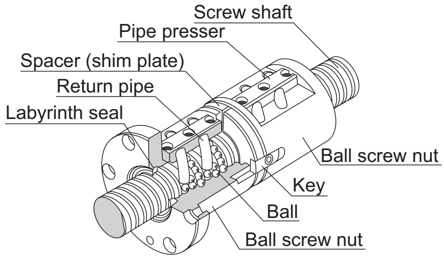
Types of Nuts

The nuts of the Ball Screws are categorized by the ball circulation method into the return-pipe type, the deflector type and end the cap type. These three nut types are described as follows.
In addition to the circulation methods, the Ball Screws are categorized also by the preloading method.

[Types by Ball Circulation Method]

- **Return-pipe Type**
  (Models SBN, BNF, BNT, BNFN, BIF and BTK)
  Return-piece Type (Model HBN)

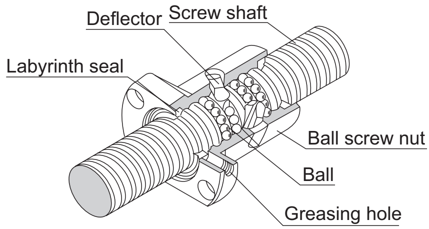
These are most common types of nuts that use a return pipe for ball circulation. The return pipe allows balls to be picked up, pass through the pipe, and return to their original positions to complete infinite motion.



Example of Structure of Return-Pipe Nut

- **Deflector Type**
  (Models DK, DKN, DIK, JPF and DIR)

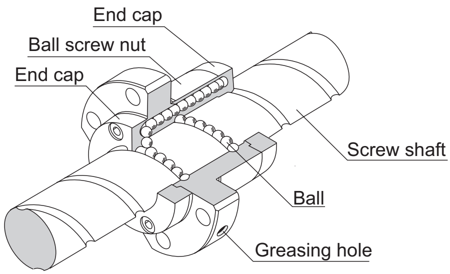
These are the most compact type of nut. The balls change their traveling direction with a deflector, pass over the circumference of the screw shaft, and return to their original positions to complete an infinite motion.



Example of Structure of Simple Nut

- **End-cap Type: Large lead Nut**
  (Models SBK, BLK, WGF, BLW, WTF, CNF and BLR)

These nuts are most suitable for the fast feed. The balls are picked up with an end cap, pass through the through hole of the nut, and return to their original positions to complete an infinite motion.



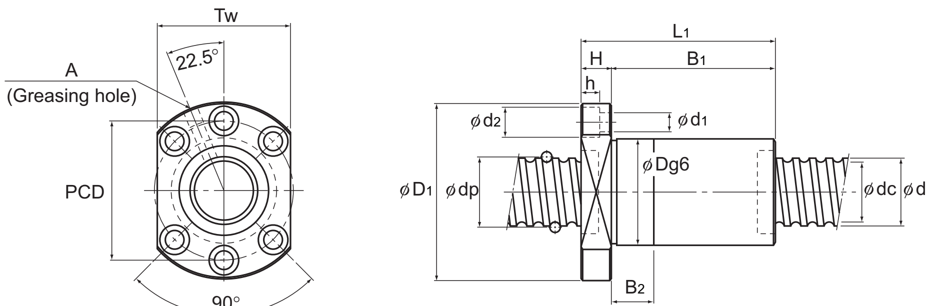
Example of Structure of Large lead Nut

Recomandări a clasei de precizie a şuruburilor cu bile în funcţie de aplicaţie

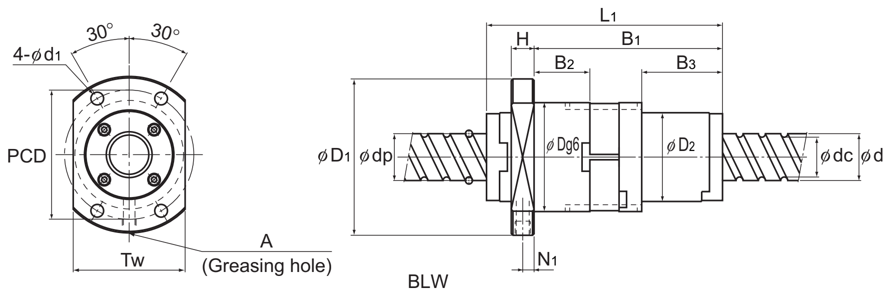
Applications		Shaft	Accuracy grades							
			C0	C1	C2	C3	C5	C7	C8	C10
NC machine tools	Lathe	X		●	●	●	●			
		Z				●	●			
	Machining center	XY			●	●	●			
		Z			●	●	●			
	Drilling machine	XY				●	●			
		Z					●	●		
	Jig borer	XY	●	●						
		Z	●	●						
	Surface grinder	X				●	●			
		Y		●	●	●	●			
		Z		●	●	●	●			
	Cylindrical grinder	X	●	●	●					
		Z		●	●	●				
	Electric discharge machine	XY	●	●	●					
		Z		●	●	●	●			
	Electric discharge machine Wire cutting machine	XY	●	●	●					
		Z	●	●	●	●				
		UV		●	●	●				
	Punching press	XY				●	●	●		
	Laser beam machine	X				●	●	●		
		Z				●	●	●		
	Woodworking machine						●	●	●	●
General-purpose machine; dedicated machine						●	●	●	●	●
Industrial robot	Cartesian coordinate	Assembly				●	●	●	●	
		Other					●	●	●	●
	Vertical articulated type	Assembly					●	●	●	
		Other						●	●	
	Cylindrical coordinate					●	●	●		
Semiconductor manufacturing machine	Photolithography machine		●	●						
	Chemical treatment machine				●	●	●	●	●	●
	Wire bonding machine			●	●					
	Prober		●	●	●	●				
	Printed circuit board drilling machine			●	●	●	●	●		
	Electronic component inserter				●	●	●	●		
3D measuring instrument			●	●	●					
Image processing machine			●	●	●					
Injection molding machine								●	●	●
Office equipment							●	●	●	●

Exemplu fişă de catalog pentru şurubul cu bile utilizat în proiect

Screw shaft outer diameter	32
Lead	8 to 32



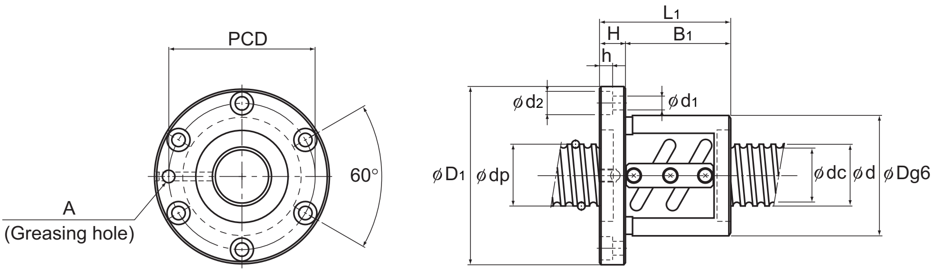
DIK (2805 to 6312)



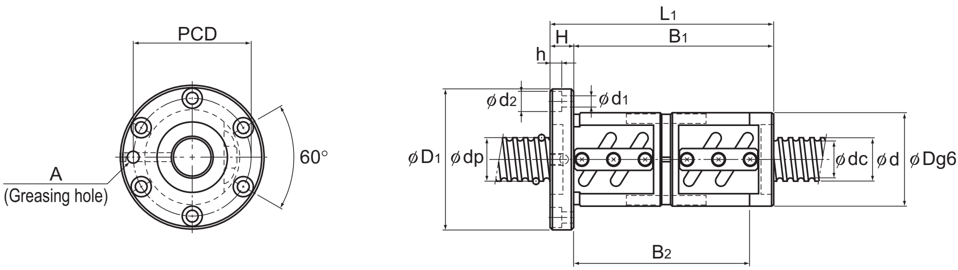
BLW

Screw shaft outer diameter d	Lead Ph	Model No.	Ball center-to-center diameter dp	Thread minor diameter dc	No. of loaded circuits Rows x turns	Basic load rating Ca kN	Basic load rating C_{0a} kN	Rigidity K N/μm	Outer diameter D	Flange diameter D_1	D_2
32	8	○ BIF 3208A-5	33.25	27.5	1×2.5	17.8	42.2	610	66	100	—
		○ BIF 3208A-7	33.25	27.5	1×3.5	23.8	59.1	840	66	100	—
		○ BNFN 3208A-2.5	33.25	27.5	1×2.5	17.8	42.2	610	66	100	—
		○ BNFN 3208A-3	33.25	27.5	2×1.5	20.9	50.7	730	66	100	—
		○ BNFN 3208A-4.5	33.25	27.5	3×1.5	29.5	76	1070	66	100	—
		○ BNFN 3208A-5	33.25	27.5	2×2.5	32.3	84.4	1180	66	100	—
	10	DIK 3210-6	33.75	26.4	3×1	25.7	52.2	600	54	87	—
		○ BIF 3210A-5	33.75	26.4	1×2.5	26.1	56.2	640	74	108	—
		○ BNFN 3210A-2.5	33.75	26.4	1×2.5	26.1	56.2	640	74	108	—
		○ BNFN 3210A-3	33.75	26.4	2×1.5	30.5	67.4	750	74	108	—
		○ BNFN 3210A-3.5	33.75	26.4	1×3.5	34.8	78.6	870	74	108	—
		○ BNFN 3210A-5	33.75	26.4	2×2.5	47.2	112.7	1230	74	108	—
	12	DIK 3212-4	33.75	26.4	2×1	18.8	37	430	54	87	—
		○ BNFN 3212-3.5	34	26.1	1×3.5	40.4	88.5	890	76	121	—
	32	BLW 3232-3.6	33.25	28.3	2×1.8	23.7	59.5	880	68	99	58

Note) The model numbers in dimmed type indicate semi-standard types. If desiring them, contact THK.
Those models marked with ○ can be attached with QZ Lubricator or the wiper ring.
For dimensions of the ball screw nut with either accessory being attached, see B-778.
Model BLW cannot be attached with seal.



BIF



BNFN

Unit: mm

Nut dimensions												Screw shaft inertial moment/mm	Nut mass	Shaft mass
Overall length L_1	H	B_1	B_2	B_3	PCD	d_1	d_2	h	Tw	N_1	Greasing hole A	kg・cm²/mm	kg	kg/m
82	15	67	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	1.93	5.39
98	15	83	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.21	5.39
106	15	91	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.36	5.39
135	15	120	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	2.88	5.39
167	15	152	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	3.45	5.39
154	15	139	—	—	82	9	14	8.5	—	—	M6	8.08×10^{-3}	3.21	5.39
110	15	95	25	—	69	9	14	8.5	66	—	M6	8.08×10^{-3}	1.57	4.98
100	15	85	—	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	2.92	4.98
130	15	115	99	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	3.64	4.98
167	15	152	136	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	4.53	4.98
150	15	135	119	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	4.12	4.98
190	15	175	159	—	90	9	14	8.5	—	—	M6	8.08×10^{-3}	5.08	4.98
98	15	83	25	—	69	9	14	8.5	66	—	M6	8.08×10^{-3}	1.43	5.2
170	18	152	—	—	98	11	17.5	11	—	—	M6	8.08×10^{-3}	5.26	4.9
155	15	127	42.4	55.4	81	9	—	—	70	6	M6	8.08×10^{-3}	3.19	5.83

For model number coding, see B-718.

Servomotoare- seriile MB/MH
catalog Parker Motion Control
Products

Motors
MB / MH Series

MB / MH Motors, Size 105 - 2.2...8 Nm

Model	Size	Stall Torque [1] T_{065} (T_{105}) [Nm]	Stall Current I_{065} [A]	Nominal Torque [1] T_{n065} [Nm]	Nominal Speed n [min^{-1}]	Nominal Current I_{n065} [A]	Peak Torque[1] T_{max} [Nm]	Inertia No brake J [$kgmm^2$]	Inertia With brake J [$kgmm^2$]	Ke [2][3] Ke [Vs]	Kt [2][3] Kt [Nm/A_{rms}]
M_ 105 16 02	105	2.2 (3.5)	1.5	2.2	1600	1.4	11.0	190	253	0.9	1.63
M_ 105 25 02			2.1	2.1	2500	2.0				0.6	1.11
M_ 105 30 02			2.8	2.1	3000	2.6				0.5	0.83
M_ 105 50 02			4.3	1.8	5000	3.5				0.3	0.55
M_ 105 16 04		4.0 (6.1)	2.6	4.0	1600	2.5	19.5	340	403	1.0	1.65
M_ 105 25 04			3.8	3.7	2500	3.5				0.7	1.13
M_ 105 30 04			5.0	3.6	3000	4.4				0.5	0.85
M_ 105 50 04			7.4	2.7	5000	5.0				0.3	0.58
M_ 105 16 06		6.0 (8.3)	3.9	5.9	1600	3.7	26.2	480	543	1.0	1.65
M_ 105 25 06			5.6	5.5	2500	5.0				0.7	1.15
M_ 105 30 06			7.4	5.2	3000	6.4				0.5	0.87
M_ 105 50 06			11.2	3.6	5000	6.7				0.3	0.58
M_ 105 16 08		8.0 (10.0)	5.2	7.8	1600	5.0	31.7	620	683	1.0	1.65
M_ 105 25 08			7.5	7.2	2500	6.6				0.7	1.15
M_ 105 30 08			9.7	6.8	3000	8.2				0.5	0.88
M_ 105 50 08			14.2	4.4	5000	7.9				0.4	0.61

400 VAC

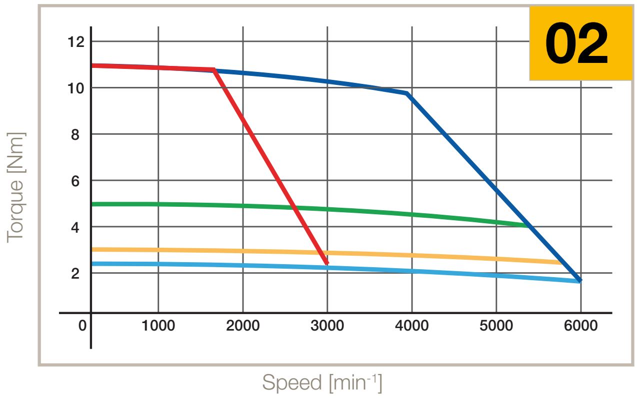
Model	Size	Stall Torque [1] T_{065} (T_{105}) [Nm]	Stall Current I_{065} [A]	Nominal Torque [1] T_{n065} [Nm]	Nominal Speed n [min^{-1}]	Nominal Current I_{n065} [A]	Peak Torque[1] T_{max} [Nm]	Inertia No brake J [$kgmm^2$]	Inertia With brake J [$kgmm^2$]	Ke [2][3] Ke [Vs]	Kt [2][3] Kt [Nm/A_{rms}]
M_ 105 30 02	105	2.2 (3.5)	1.5	2.1	3000	1.4	11.0	190	253	0.9	1.63
M_ 105 45 02			2.1	1.9	4500	1.8				0.6	1.11
M_ 105 60 02			2.8	1.7	6000	2.2				0.5	0.83
M_ 105 30 04		4.0 (6.1)	2.6	3.6	3000	2.3	19.5	340	403	1.0	1.65
M_ 105 45 04			3.8	3.0	4500	2.8				0.7	1.13
M_ 105 60 04			5.0	2.4	6000	3.0				0.5	0.85
M_ 105 30 06		6.0 (8.3)	3.9	5.3	3000	3.4	26.2	480	543	1.0	1.65
M_ 105 45 06			5.6	4.1	4500	3.8				0.7	1.15
M_ 105 60 06			7.4	3.0	6000	3.7				0.5	0.87
M_ 105 30 08		8.0 (10.0)	5.2	6.9	3000	4.4	31.7	620	683	1.0	1.65
M_ 105 45 08			7.5	5.2	4500	4.9				0.7	1.15
M_ 105 60 08			9.7	3.6	6000	4.4				0.5	0.88

(1) Data referred to motor suspend in horizontal position in free still air, 20 °C ambient temperature
(2) Data measured at 20 °C. When "hot" consider 5 % derating
(3) Tolerance data ±10 %

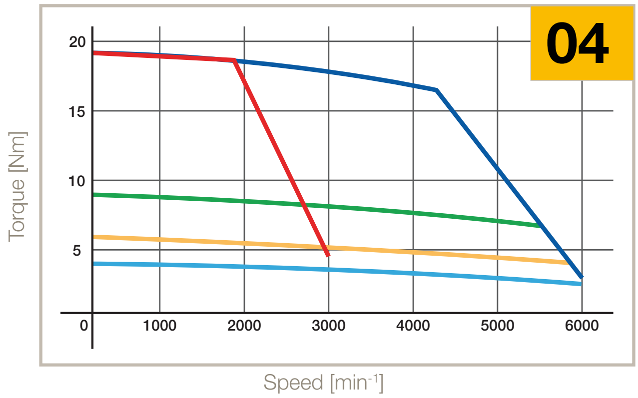
Speed Torque Curves

MB/MH105

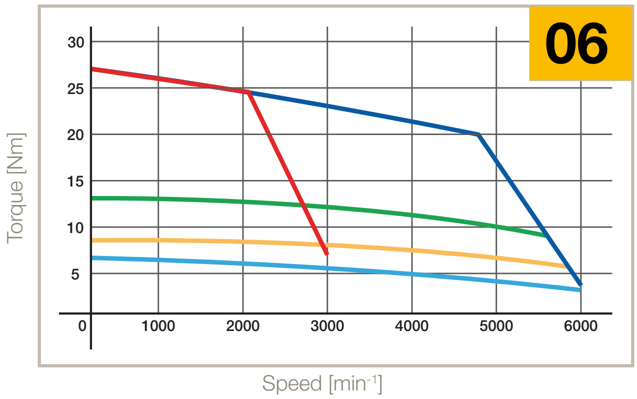
3000 min^{-1} 230 V - 6000 min^{-1} 400 V



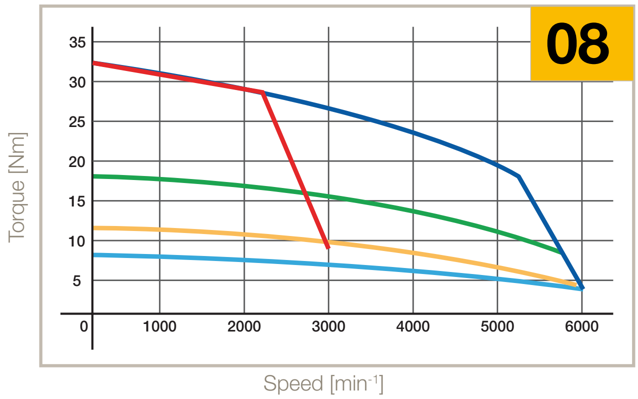
3000 min^{-1} 230 V - 6000 min^{-1} 400 V



3000 min^{-1} 230 V - 6000 min^{-1} 400 V



3000 min^{-1} 230 V - 6000 min^{-1} 400 V



S1 65 K, ΔT
S3 10 %, 5 min, 400 V
S3 10 %, 5 min, 230 V
S3 50 %, 5 min
S3 20 %, 5 min

Motors
MB / MH Series

A-27

Fişe de catalog pentru servomotoare
seriile MB/MH din catalogul Parker
Motion Control Products

Model	Size	Stall		Nominal			Peak Torque[1]	Inertia		Ke [2][3]	Kt [2][3]
		Torque [1]	Current	Torque [1]	Speed	Current		No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [kgmm^2]	J [kgmm^2]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 145 5,5 04	145	4.5 (9)	1.1	4.6	550	1.1	28	780	975	2.1	3.65
M_ 145 11 04			2.3	4.6	1100	2.4				1.2	2.03
M_ 145 16 04			3.4	4.5	1600	3.3				0.8	1.42
M_ 145 25 04			4.7	4.3	2500	4.5				0.6	1.01
M_ 145 40 04			8.1	4.1	4000	7.2				0.4	0.60
M_ 145 5,5 08		8.7 (16)	2.0	8.7	550	2.0	49	1050	1245	2.7	4.69
M_ 145 11 08			3.7	8.7	1100	3.6				1.4	2.49
M_ 145 16 08			5.4	8.6	1600	5.2				1.0	1.70
M_ 145 25 08			8.2	8.1	2500	7.4				0.7	1.14
M_ 145 40 08			12.3	7.0	4000	9.7				0.4	0.76
M_ 145 5,5 15		15.0 (27)	3.3	15.0	550	3.2	86	1600	1795	2.9	4.94
M_ 145 11 15			6.2	14.7	1100	5.9				1.5	2.59
M_ 145 16 15			9.1	14.3	1600	8.5				1.0	1.78
M_ 145 25 15			14.2	13.6	2500	12.5				0.7	1.14
M_ 145 40 15			21.3	10.9	4000	15.0				0.4	0.76
M_ 145 5,5 22		22.0 (37)	4.7	21.9	550	4.6	117	2150	2345	2.9	5.03
M_ 145 11 22			8.9	21.3	1100	8.4				1.5	2.65
M_ 145 16 22			13.1	20.8	1600	12.1				1.0	1.80
M_ 145 25 22			20.8	19.1	2500	17.6				0.7	1.13
M_ 145 40 22			31.1	13.4	4000	18.6				0.4	0.76
M_ 145 5,5 28		28.0 (45)	5.9	27.8	550	5.8	143	2700	2895	2.9	5.07
M_ 145 11 28			11.3	26.9	1100	10.6				1.5	2.65
M_ 145 16 28			17.0	26.2	1600	15.5				1.0	1.78
M_ 145 25 28			26.5	23.2	2500	21.4				0.7	1.13
M_ 145 40 28			39.6	14.1	4000	19.7				0.4	0.76

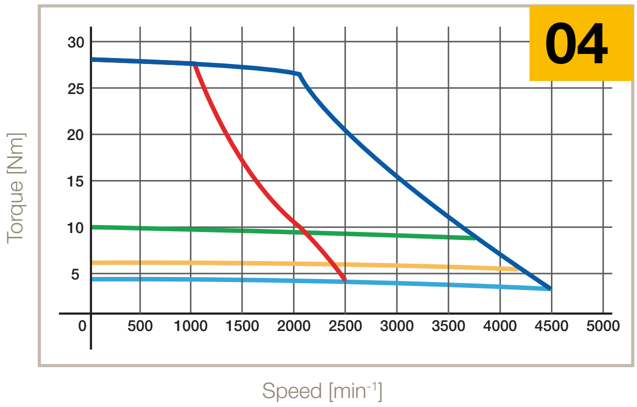
400 VAC

Model	Size	Stall		Nominal			Peak Torque[1]	Inertia		Ke [2][3]	Kt [2][3]
		Torque [1]	Current	Torque [1]	Speed	Current		No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [kgmm^2]	J [kgmm^2]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 145 10 04	145	4.5 (9)	1.1	4.5	1000	1.1	28	780	975	2.1	3.65
M_ 145 20 04			2.3	4.5	2000	2.3				1.2	2.03
M_ 145 30 04			3.4	4.3	3000	3.2				0.8	1.42
M_ 145 45 04			4.7	3.9	4500	4.0				0.6	1.01
M_ 145 10 08		8.7 (16)	2.0	8.7	1000	1.9	49	1050	1245	2.7	4.69
M_ 145 20 08			3.7	8.4	2000	3.5				1.4	2.49
M_ 145 30 08			5.4	7.9	3000	4.8				1.0	1.70
M_ 145 45 08			8.2	7.1	4500	6.6				0.7	1.14
M_ 145 10 15		15.0 (27)	3.3	14.8	1000	3.1	86	1600	1795	2.9	4.94
M_ 145 20 15			6.2	13.7	2000	5.5				1.5	2.59
M_ 145 30 15			9.1	12.7	3000	7.5				1.0	1.78
M_ 145 45 15			14.2	9.8	4500	9.1				0.7	1.14
M_ 145 10 22		22.0 (37)	4.7	21.4	1000	4.5	117	2150	2345	2.9	5.03
M_ 145 20 22			8.9	19.4	2000	7.6				1.5	2.65
M_ 145 30 22			13.1	17.3	3000	10.1				1.0	1.80
M_ 145 45 22			20.8	11.6	4500	10.8				0.7	1.13
M_ 145 10 28		28.0 (45)	5.9	27.1	1000	5.6	143	2700	2895	2.9	5.07
M_ 145 20 28			11.3	23.9	2000	9.4				1.5	2.65
M_ 145 30 28			17.0	21.1	3000	12.5				1.0	1.78
M_ 145 45 28			26.5	10.0	4500	9.4				0.7	1.13

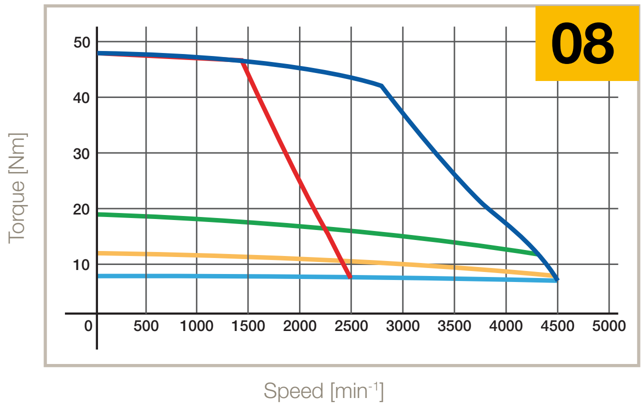
Speed Torque Curves

MB/MH145

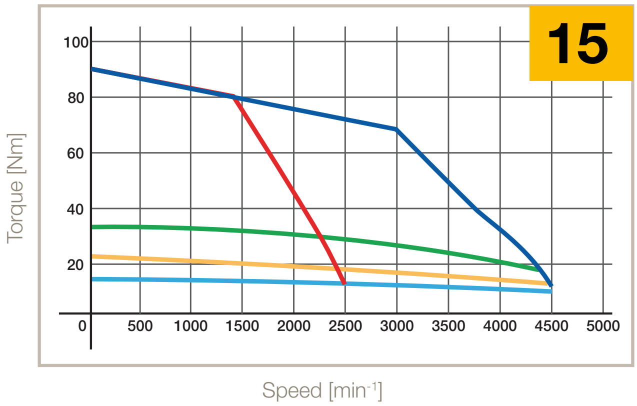
2500 min^{-1} 230 V - 4500 min^{-1} 400 V



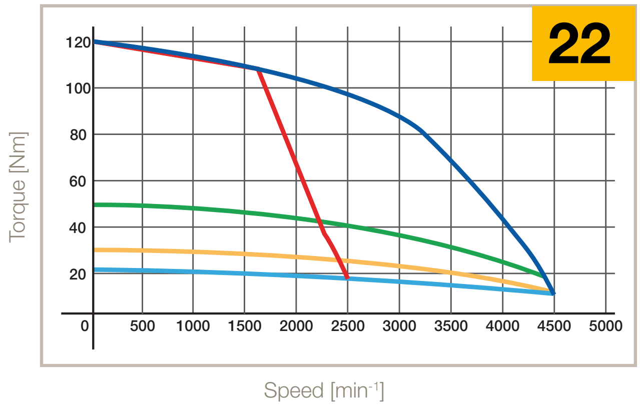
2500 min^{-1} 230 V - 4500 min^{-1} 400 V



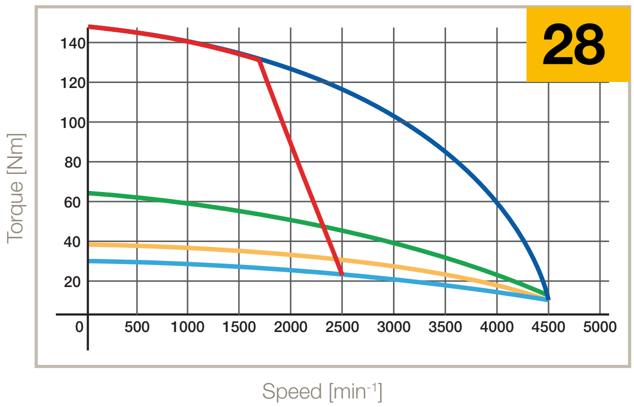
2500 min^{-1} 230 V - 4500 min^{-1} 400 V



2500 min^{-1} 230 V - 4500 min^{-1} 400 V



2500 min^{-1} 230 V - 4500 min^{-1} 400 V



- S1 65 K, ΔT
- S3 10 %, 5 min, 400 V
- S3 10 %, 5 min, 230 V
- S3 50 %, 5 min
- S3 20 %, 5 min

(1) Data referred to motor suspend in horizontal position in free still air, 20 °C ambient temperature
(2) Data measured at 20 °C. When "hot" consider 5 % derating
(3) Tolerance data ±10 %

Ffişe de catalog pentru servomotoare
seriile MB/MH din catalogul Parker Motion
Control Producrs

Model	Size	Stall		Nominal			Peak Torque(1)	Inertia		Ke (2)(3)	Kt (2)(3)
			Current	Torque (1)	Speed	Current		No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [$kgmm^2$]	J [$kgmm^2$]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 205 11 15	205	15 (22)	6.3	14.7	1150	6.2	69	3500	4035	1.4	2.38
M_ 205 17 15			8.6	14.4	1700	8.3				1	1.74
M_ 205 5,5 28		28 (39)	6.9	28.6	550	6.9	123	5000	5535	2.5	4.35
M_ 205 11 28			13.0	28.2	1150	12.7				1.3	2.31
M_ 205 17 28			20.1	27.6	1700	19.3				0.9	1.50
M_ 205 5,5 50		50 (70)	12.4	51.3	550	12.3	222	8000	8535	2.5	4.35
M_ 205 11 50			22.1	50.0	1150	21.3				1.4	2.45
M_ 205 17 50			33.1	48.0	1700	30.8				0.9	1.63
M_ 205 5,5 70		70 (98)	16.8	71.1	550	16.5	310	11 000	11 535	2.6	4.49
M_ 205 11 70			30.7	68.6	1150	29.3				1.4	2.45
M_ 205 17 70			46.1	65.0	1700	41.7				0.9	1.63
M_ 205 5,5 90		90 (126)	22.1	90.9	550	21.8	398	14 000	14 535	2.5	4.35
M_ 205 11 90			44.3	87.0	1150	41.8				1.3	2.18
M_ 205 17 90			59	81.7	1700	52.4				0.9	1.63

400 VAC

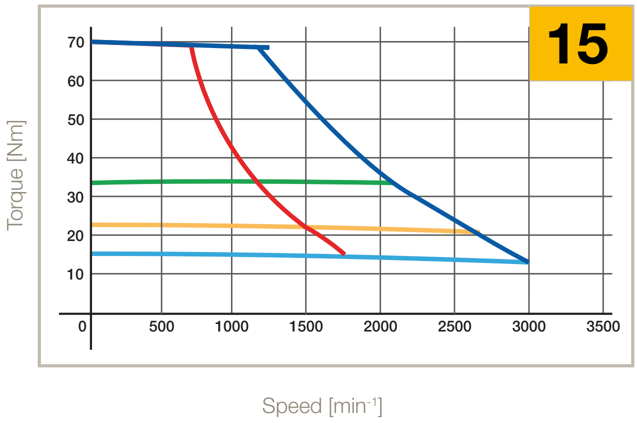
Model	Size	Stall		Nominal			Peak Torque(1)	Inertia		Ke (2)(3)	Kt (2)(3)
		Torque (1)	Current	Torque (1)	Speed	Current		No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [$kgmm^2$]	J [$kgmm^2$]	Ke [Vs]	Kt [Nm/A_{rms}]
M_ 205 20 15	205	15 (22)	6.3	14.1	2000	5.9	69	3500	4035	1.4	2.38
M_ 205 30 15			8.6	13.4	3000	7.7				1	1.74
M_ 205 10 28		28 (39)	6.9	28.2	1000	6.8	123	5000	5535	2.5	4.35
M_ 205 20 28			13.0	27.3	2000	12.3				1.3	2.31
M_ 205 30 28			20.1	25.7	3000	18.0				0.9	1.50
M_ 205 10 50		50 (70)	12.4	50.4	1000	12.1	222	8000	8535	2.5	4.35
M_ 205 20 50			22.1	47.0	2000	20.1				1.4	2.45
M_ 205 30 50			33.1	41.7	3000	26.8				0.9	1.63
M_ 205 10 70		70 (98)	16.8	69.4	1000	16.1	310	11 000	11 535	2.6	4.49
M_ 205 20 70			30.7	62.9	2000	26.9				1.4	2.45
M_ 205 30 70			46.1	52.3	3000	33.7				0.9	1.63
M_ 205 10 90		90 (126)	22.1	88.2	1000	21.2	398	14 000	14 535	2.5	4.35
M_ 205 20 90			44.3	78.3	2000	37.7				1.3	2.18
M_ 205 30 90			59.0	61.6	3000	39.7				0.9	1.63

(1) Data referred to motor suspend in horizontal position in free still air, 20 °C ambient temperature
(2) Data measured at 20 °C. When "hot" consider 5 % derating
(3) Tolerance data ±10 %

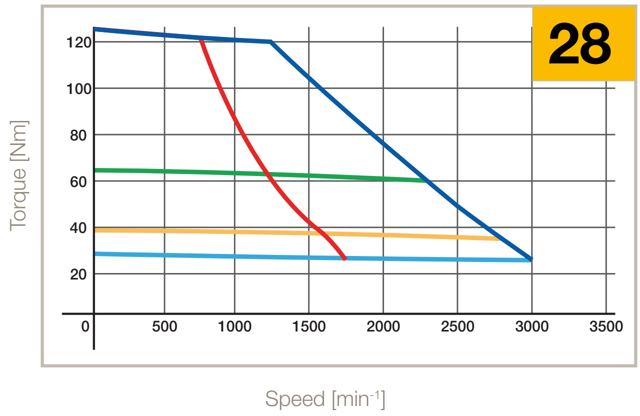
Speed Torque Curves

MB/MH205

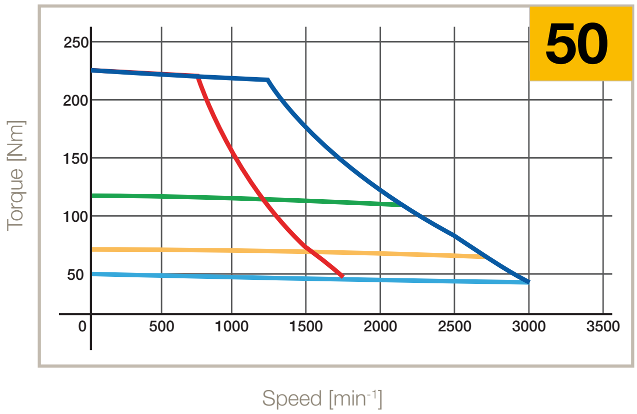
1700 min^{-1} 230 V - 3000 min^{-1} 400 V



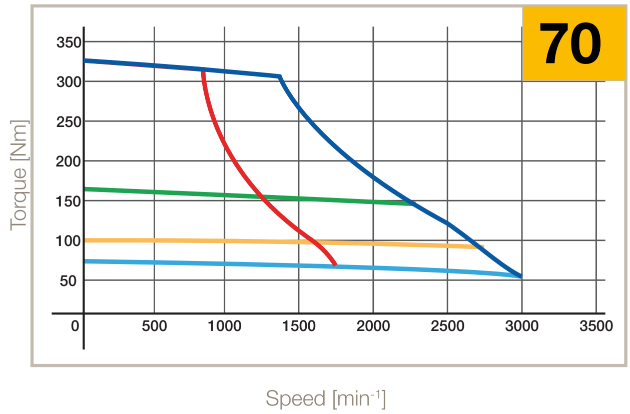
1700 min^{-1} 230 V - 3000 min^{-1} 400 V



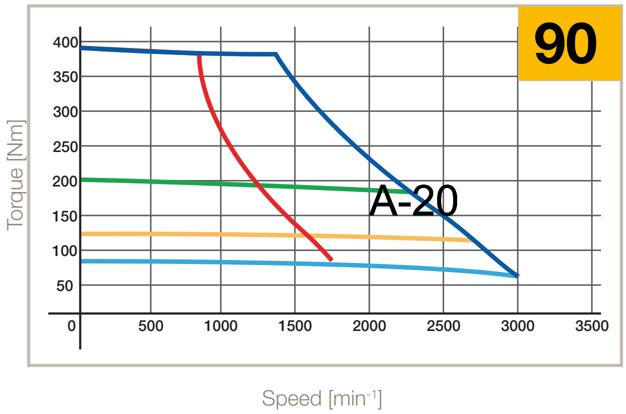
1700 min^{-1} 230 V - 3000 min^{-1} 400 V



1700 min^{-1} 230 V - 3000 min^{-1} 400 V

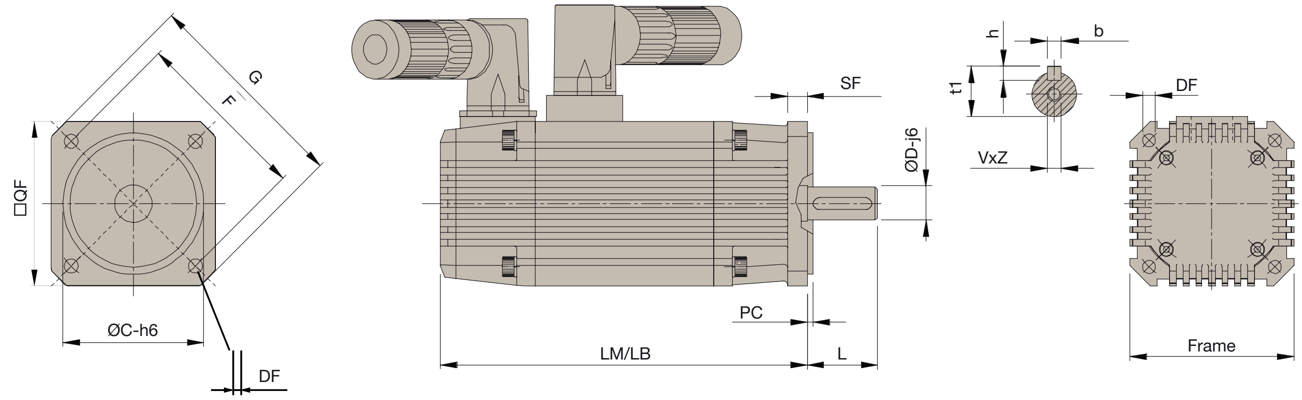


1700 min^{-1} 230 V - 3000 min^{-1} 400 V



S1 65 K, ΔT
S3 10 %, 5 min, 400 V
S3 10 %, 5 min, 230 V
S3 50 %, 5 min
S3 20 %, 5 min

Dimensions



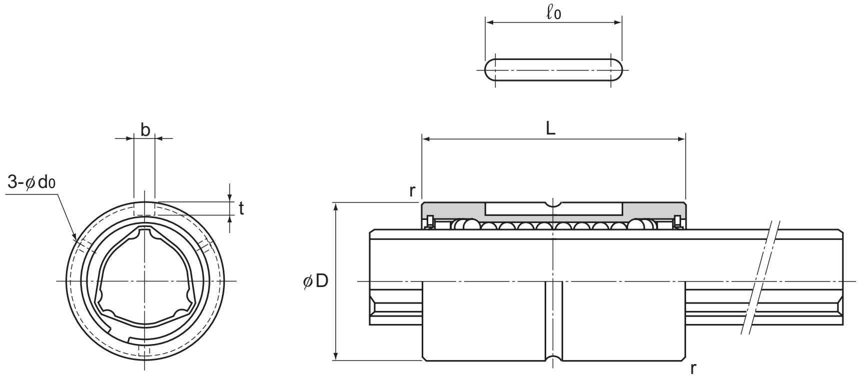
Motor - Size			LM/LB	Weight	DxL	bxh	t1	VxZ	C	F	DF	G	SF	PC	QF	Order code QF
MB / MH	56	0,2	130.5/181.5	0.7	9x20 11x23	3x3 4x4	10.2 12.5	M4x10	40	63	5.5	74	6.5	2.5	56	5
		0,4	150.5/201.5	1												
		0,6	170.5/221.5	1.3												
	70	0,5	158/214	2	11x23 14x30	4x4 5x5	12.5 16	M4x10 M4x12.5	60	75	6	90	8.5	2.5	70	5
		01	188/244	2.8												
		1,5	218/274	3.5												
		02	248/304	4.3												
		2,5	278/334	5.1												
	105	02	186/250	5	19x40 24x50	6x6 8x7	21.5 27	M6x16 M8x19	95	115	9.5	140	10	3.5	105	5
		04	229/293	7					95	115	9.5	140	10	3.5	105	4
		06	273/337	9					80	115	9.5	140	10	3.5	105	9
		08	317/381	11					110	115	9.5	140	10	3.5	105	6
	145	04	200/274	8	19x40 24x50 28x60	6x6 8x7	21.5 27 31	M6x16 M8x19 M10x22	130	165	11.5	200	12	3.5	145	5
		08	231/305	12												
		15	292/366	18					130	165	11.5	200	12	3.5	145	4
		22	354/428	23												
		28	416/490	28												
	205	15	239/338	20	38x80 42x110	10x8 12x8	41 45	M12x32 M16x40	180	215	14	250	18	4	205	5
		28	273/372	29												
		50	342/441	44												
		70	411/510	59												
		90	480/579	74												
	265	75	340/475	89	48X110	14x9	51.5	M16x40	250	300	19	342	35	4	264	5
		150	447/582	126												
		220	554/689	164												
		285	661/796	203												

LM: Motor length without brake with resolver
LB: Motor length with brake with resolver
DxL: Shaft
bxh: Key
t1: Overall shaft height
VxZ: Shaft hole depth

mm for dimensions, kg for weight

C: Center
F: Distance between center of holes clamp
DF: Fixing holes
G: Dimension in diagonal
SF: Flange thickness
PC: Centering depht
QF: Flange square

Fişă de catalog pentru transmisi canelate cu bile



Model No.	Spline nut dimensions								
	Outer diameter		Length		Keyway dimensions				Greasing hole
	D	Tolerance	L	Tolerance	b H8	t ${}^{+0.05}_{0}$	ℓ_0	r	d_0
○● LBST 20	30		60	${}^{0}_{-0.2}$	4	2.5	26	0.5	2
○● LBST 25	37	${}^{0}_{-0.016}$	70		5	3	33	0.5	2
○● LBST 30	45		80		7	4	41	1	3
○● LBST 40	60	${}^{0}_{-0.019}$	100	${}^{0}_{-0.3}$	10	4.5	55	1	3
○● LBST 50	75		112		15	5	60	1.5	4
○ LBST 60	90		127		18	6	68	1.5	4
○● LBST 70	100	${}^{0}_{-0.022}$	135		18	6	68	2	4
○● LBST 85	120		155	${}^{0}_{-0.4}$	20	7	80	2.5	5
○● LBST 100	140	${}^{0}_{-0.025}$	175		28	9	93	3	5
○ LBST 120	160		200	${}^{0}_{-0.5}$	28	9	123	3.5	6
○ LBST 150	205	${}^{0}_{-0.029}$	250		32	10	157	3.5	6

Note) ○: indicates model numbers for which high temperature types are available (with metal retainer; service temperature: up to 100℃).

(Example) LBST25 A CM+400L H
A — High temperature symbol

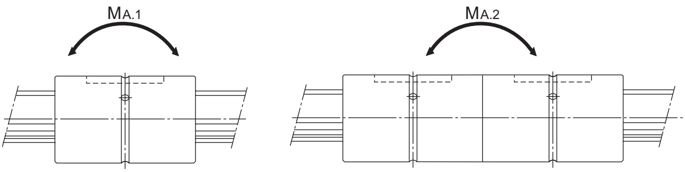
●: indicates model numbers for which felt seal types are available (see A-509).
A felt seal cannot be attached to Ball Spline models using metal retainer.

Model number coding

2 LBST50 UU CM +800L H K

- 2 — Number of spline nuts on one shaft (no symbol for one nut)
- LBST50 — Model No.
- UU — Contamination protection accessory symbol (*1)
- CM — Symbol for clearance in the rotational direction (*2)
- +800L — Overall spline shaft length (in mm)
- H — Accuracy symbol (*3)
- K — Symbol for standard hollow spline shaft (*4)

(*1) See A-509. (*2) See A-481. (*3) See A-482. (*4) See B-381.



Ball Spline

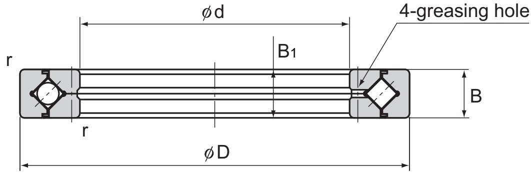
Unit: mm

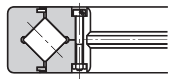
Basic torque rating		Basic load rating (radial)		Static permissible moment		Mass	
C_T N-m	C_{0T} N-m	C kN	C_0 kN	$M_{A.1}$** N-m	$M_{A.2}$** N-m	Spline Nut kg	Spline shaft kg/m
90.2	213	9.4	20.1	103	632	0.17	1.8
176	381	14.9	28.7	171	1060	0.29	2.7
312	657	22.5	41.4	295	1740	0.5	3.8
696	1420	37.1	66.9	586	3540	1.1	6.8
1290	2500	55.1	94.1	941	5610	1.9	10.6
1870	3830	66.2	121	1300	8280	3.3	15.6
3000	6090	90.8	164	2080	11800	3.8	21.3
4740	9550	119	213	3180	17300	6.1	32
6460	14400	137	271	4410	25400	10.4	45
8380	19400	148	306	5490	32400	12.9	69.5
13900	32200	196	405	8060	55400	28	116.6

Note) **$M_{A.1}$ indicates the permissible moment value in the axial direction when a single spline nut is used, as shown in the figure above.
**$M_{A.2}$ indicates the permissible moment value in the axial direction when two spline nuts in close contact with each other are used, as shown in the figure above.
For details on the maximum lengths of ball spline shafts by accuracy, please see B-410.

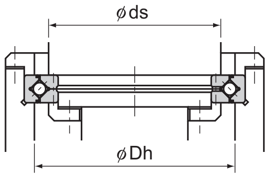
Description of Each Option⇒A-509

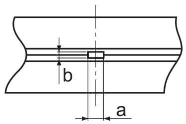
Fişă de catalog pentru rulmenţi cu role în cruce



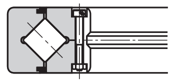


Model RE





Detail view of the greasing hole



Model RE···UU

Unit: mm

Shaft diameter	Model No.	Main dimensions: Inner diameter d	Outer diameter D	Roller pitch circle diameter dp	Width B B_1	Greasing hole a	Greasing hole b	r_{min}	Shoulder height ds	Shoulder height Dh	Basic load rating (radial) C kN	C_0 kN	Mass kg
400	RE 40035	400	480	440.3	35	5	3	2.5	422	459	156	370	14.5
	RE 40040		510	453.4	40	6	3.5	2.5	428	479	241	531	23.5
450	RE 45025	450	500	476.6	25	3.5	1.6	1	464	484	61.7	182	6.6
500	RE 50025	500	550	526.6	25	3.5	1.6	1	514	534	65.5	201	7.3
	RE 50040		600	548.8	40	6	3	2.5	526	572	239	607	26
	RE 50050		625	561.6	50	6	3.5	2.5	536	587	267	653	41.7
600	RE 60040	600	700	650	40	6	3	3	627	673	264	721	29

Note) The model number of a type with seals attached is RE···UU.
If a certain level of accuracy is required, this model is used for outer ring rotation.

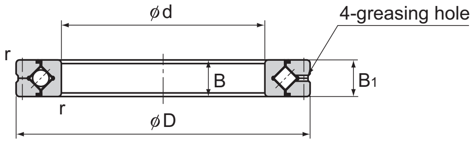
Model number coding

RE45025 UU CC0 P6

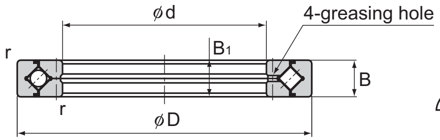
- RE45025 — Model number
- UU — Seal attached on both ends (seal attached on either end: U)
- CC0 — Radial clearance symbol (*1)
- P6 — Accuracy symbol (*2)

(*1) See A-870. (*2) See A-866.

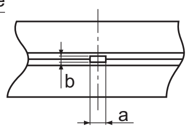
USP-Grade Models RB and RE



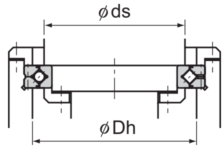
RB-USP（RB…UU-USP）



RE-USP（RE…UU-USP）



Detail view of the greasing hole



Unit: mm

Model No.	Main dimensions								Shoulder height		Basic load rating (radial)		Mass
	Inner diameter	Outer diameter	Roller pitch circle diameter dp		Width	Greasing hole					C	C_0	
	d	D	RB	RE	B B_1	a	b	r_{min}	ds	Dh	kN	kN	kg
RB 10020USP RE 10020USP	100	150	123	127	20	3.5	1.6	1	113	133	33.1	50.9	1.45
RB 12025USP RE 12025USP	120	180	148.7	152	25	3.5	2	1.5	133	164	66.9	100	2.62
RB 15025USP RE 15025USP	150	210	178	182	25				164	194	76.8	128	3.16
RB 20030USP RE 20030USP	200	280	240	240	30	4.5	3	2	221	258	114	200	6.7
RB 25030USP RE 25030USP	250	330	287.5	287.5	30			2.5	269	306	126	244	8.1
RB 30035USP RE 30035USP	300	395	345	345	35	5	3		322	368	183	367	13.4
RB 40040USP RE 40040USP	400	510	453.4	453.4	40	6	3.5		428	479	241	531	23.5
RB 50040USP RE 50040USP	500	600	548.8	548.8	40	6	3		526	572	239	607	26
RB 60040USP RE 60040USP	600	700	650	650	40			3	627	673	264	721	29

Note) The model number of a type with seals attached is RB…UU-USP or RE…UU-USP.
If a certain level of rotational accuracy is required for the inner ring, select model RB; if a certain level of rotational accuracy is required for the outer ring, select model RE.

Model number coding

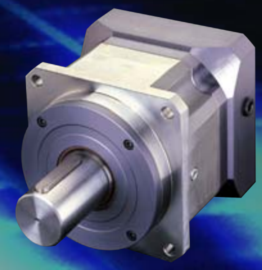
RB50040 UU CC0 USP

- RB50040: Model number
- UU: Seal attached on both ends (seal attached on either end: U)
- CC0: Radial clearance symbol (*1)
- USP: Accuracy symbol (Ultra precision grade)

(*1) See A-870.

FIŞE DE CATALOG PENTRU REDUCTOARE

Stealth® PS Advanced Series



Performance Specifications

	Units	Ratio	PS40	PS60	PS90	PS115	PS142	PS180	PS220	PS300
			Frame Size							
Nominal Output Torque, $T_{nom\ r}$	**Nm**	3-10	**5**	**25**	**74**	**170**	**294**	**735**	**1,413**	**3,616**
	in lb		42	220	650	1,500	2,600	6,500	12,500	32,000
	Nm	15-50	**9**	**34**	**107**	**226**	**396**	**1,017**	**1,808**	**4,520**
	in lb		75	300	950	2,000	3,500	9,000	16,000	40,000
	Nm	70-100	**8**	**28**	**90**	**203**	**339**	**893**	**1,582**	**4,181**
	in lb		67	250	800	1,800	3,000	7,900	14,000	37,000
Maximum Acceleration Output Torque, $T_{acc\ r}$	**Nm**	3-10, 70-100	**8**	**34**	**105**	**232**	**367**	**972**	**1,763**	**4,825**
	in lb		74	300	930	2,050	3,250	8,600	15,600	42,700
	Nm	15-50	**10**	**42**	**130**	**283**	**452**	**1,198**	**2,011**	**5,492**
	in lb		92	370	1,150	2,500	4,000	10,600	17,800	48,600
Emergency(1) Stop Output Torque, $T_{em\ r}$	**Nm**	3-10, 70-100	**19**	**78**	**243**	**537**	**853**	**2,237**	**4,068**	**11,119**
	in lb		170	690	2,150	4,750	7,550	19,800	36,000	98,400
	Nm	15-50	**24**	**96**	**299**	**655**	**1,040**	**2,757**	**4,520**	**12,656**
	in lb		210	850	2,650	5,800	9,200	24,400	40,000	112,000
Nominal Input Speed, $N_{nom\ r}$	RPM	3-5	3,600	3,200	2,800	2,400	2,000	1,600	1,200	1,000
	RPM	7-10	4,100	3,700	3,300	2,900	2,500	2,000	1,500	1,250
	RPM	15-50	4,600	4,200	3,800	3,400	3,000	2,400	1,800	1,500
	RPM	70-100	5,100	4,700	4,300	3,900	3,500	2,800	2,100	1,750
Max. Input Speed, N_{maxr}	RPM	3-100	6,000	6,000	5,300	4,500	3,800	3,000	2,300	1,900
Standard Backlash (2)	arc min	3-10	10	6	6	4	4	4	4	4
	arc min	15-100	14	8	8	6	6	6	6	6
Low Backlash (2)	arc min	3-10	—	4	4	3	3	3	3	3
	arc min	15-100	—	6	6	5	5	5	5	5
Efficiency at Nominal Torque	%	3-10	97	97	97	97	97	97	97	97
	%	15-100	94	94	94	94	94	94	94	94
Noise Level(3) at:										
3,000 RPM	dB	3-100	68	68	68	68	70	—	—	—
2,000 RPM	dB	3-100	—	—	—	—	—	70	70	70
Torsional Stiffness	**Nm / arc min**	3-100	**2**	**3**	**12**	**23**	**44**	**110**	**210**	**360**
	in lb / arc min		16	26	106	204	389	973	1,858	3,185
Maximum Weight	**kg**	3-10	**0.4**	**1.3**	**3**	**7**	**14**	**26**	**49**	**103**
	lb		1.0	2.8	7	15	30	57	108	228
	kg	15-100	**0.6**	**1.7**	**5**	**10**	**20**	**35**	**71**	**149**
	lb		1.4	3.7	10	22	43	77	157	330
Maximum Allowable Case Temperature	°C	3-100	← 100 → For applications requiring lower case temperature, consult factory							

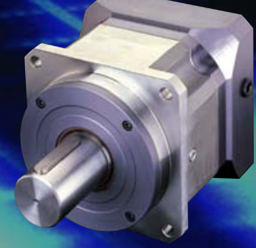
(1) Maximum of 1,000 stops
(2) Measured at 2% of rated torque
(3) Measured at 1 meter

(4) PS40 is available in Ratios of: 4, 5, 7, 10, 16, 20, 25, 40, 50, 70 & 100:1
PS300 is available in Ratios of: 4, 5, 7, 10, 20, 50, 70 & 100:1

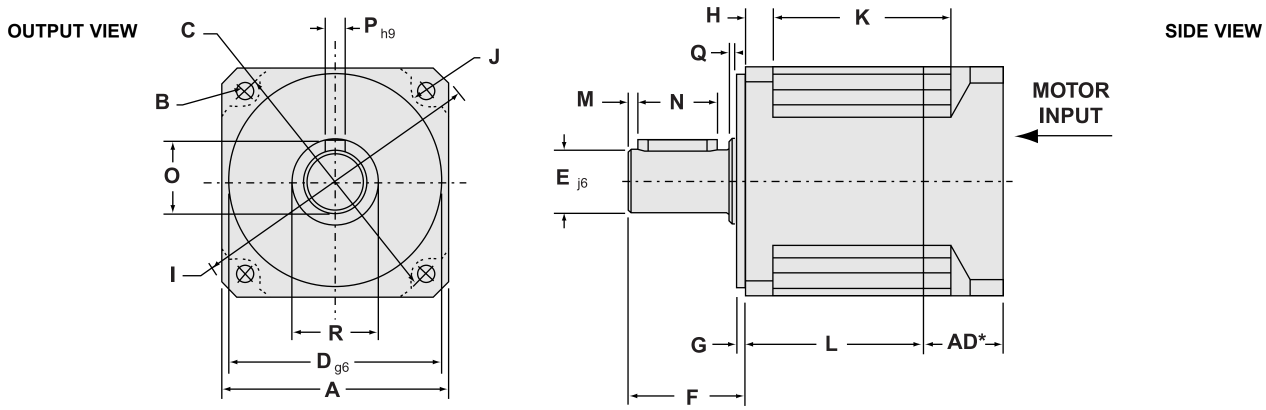
Specification are subject to change without notice

Gearmotors & Gearheads

Stealth® PS Advanced Series



Dimensions



Frame Size	A Square Flange (mm)	(in)	B Bolt Hole (mm)	(in)	C Bolt Circle (mm)	(in)	D Pilot Diameter (mm)	(in)	E Output Shaft Diameter (mm)	(in)	F Output Shaft Length (mm)	(in)	G Pilot Thickness (mm)	(in)	H Flange Thickness (mm)	(in)	I Housing Diameter (mm)	(in)	J Housing Recess (mm)	(in)
PS40	42	1.654	3.4	0.134	50	1.969	35	1.378	13	0.512	26	1.024	5.5	0.217	5	0.197	56	2.205	3.5	0.138
PS60	60	2.362	5.5	0.217	70	2.756	50	1.969	16	0.630	37	1.457	8	0.315	8	0.315	80	3.150	5	0.197
PS90	90	3.543	6.5	0.256	100	3.937	80	3.150	22	0.866	48	1.890	11	0.433	10	0.394	116	4.567	6.5	0.256
PS115	115	4.528	8.5	0.335	130	5.118	110	4.331	32	1.260	65	2.559	13	0.512	14	0.551	152	5.984	7.5	0.295
PS142	142	5.591	11	0.433	165	6.496	130	5.118	40	1.575	97	3.819	15	0.591	15	0.591	185	7.283	10	0.394
PS180	182	7.165	13	0.512	215	8.465	160	6.299	55	2.165	105	4.134	20	0.787	16	0.630	240	9.449	16	0.630
PS220	220	8.661	17	0.669	250	9.843	180	7.087	75	2.953	138	5.433	30	1.181	22	0.866	290	11.417	16	0.630
PS300	305	12.008	21	0.827	350	13.780	250	9.843	100	3.937	190	7.480	35	1.378	26	1.024	400	15.748	18	0.709

Frame Size	K1 Recess Length (For Ratio ≤ 10:1) (mm)	(in)	K2 Recess Length (For Ratio > 10:1) (mm)	(in)	L1 Length (For Ratio ≤ 10:1) (mm)	(in)	L2 Length (For Ratio > 10:1) (mm)	(in)	M Dist. From Shaft End (mm)	(in)	N Keyway Length (mm)	(in)	O Key Height (mm)	(in)	P Keyway Width (mm)	(in)	Q Shoulder Height (mm)	(in)	R Shoulder Diameter (mm)	(in)
PS40	32	1.260	53	2.087	30	1.181	50.7	1.996	2	0.079	16	0.630	15	0.591	5	0.197	1	0.039	15	0.591
PS60	37	1.457	67	2.638	36.7	1.445	66.7	2.626	2	0.079	25	0.984	18	0.709	5	0.197	0.5	0.020	22	0.866
PS90	48	1.890	88	3.465	49.5	1.949	89	3.504	3	0.118	32	1.260	24.5	0.965	6	0.236	0.5	0.020	35	1.378
PS115	62	2.441	110	4.331	61.7	2.429	109.5	4.311	5	0.197	40	1.575	35	1.378	10	0.394	1	0.039	45	1.772
PS142	82	3.228	143	5.630	76.5	3.012	138	5.433	5	0.197	63	2.480	43	1.693	12	0.472	3	0.118	55	2.165
PS180	88	3.465	158	6.220	83.5	3.287	153.5	6.043	6	0.236	70	2.756	59	2.323	16	0.630	3	0.118	70	2.756
PS220	116	4.567	218	8.583	108	4.252	210.5	8.287	6	0.236	90	3.543	79.5	3.130	20	0.787	3	0.118	95	3.740
PS300	160	6.299	332	13.071	158	6.220	292	11.496	7	0.276	140	5.512	106	4.173	28	1.102	3	0.118	140	5.512

*AD=Adapter Length. Adapter will vary, depending on motor.
Consult Internet (www.baysidemotion.com) for details or call Bayside.

Specifications are subject to change without notice.

How to Order

1. Pick frame size and ratio.
2. Pick backlash and orientation.
3. Specify motor make and model for mounting kit.

P S 1 4 2 - 0 0 3 - X X X L H

FRAME SIZE
40** 142
60 180
90 220
115 300***

RATIO
003 010 030
004 015 040
005 020 050
007 025 070
100

SPECIAL
(Factory Issued)

BACKLASH
L = Low
S = Standard

ORIENTATION
H = Horizontal orientation
U = Output shaft pointing up
D = Output shaft pointing down

(For other orientations consult the factory)

PS Gearheads are supported by a worldwide network of offices and local distributors. Call **1-800-305-4555** for application engineering assistance or for the name of your local distributor. Information can also be obtained at **www.baysidemotion.com**.

** PS40 is available in Ratios of : 4, 5, 7, 10, 16, 20, 25, 40, 50, 70 & 100:1*** PS300 is available in Ratios of: 4, 5, 7, 10, 20, 50, 70 & 100:1

Fişe de catalog pentru servomotoare
seriile SM din catalogul Parker Motion
Control Products

Technical Data

230 VAC supply voltage

Model [4]	Size	Stall [1] Torque T_{065} (T_{105}) [Nm]	Stall [1] Current I_{065} [A]	Nominal [1] Torque T_{n065} [Nm]	Nominal [1] Speed n [min^{-1}]	Nominal [1] Current I_{n065} [A]	Peak [1] Torque T_{max} [Nm]	Inertia No brake J [kgmm²]	Inertia With brake J [kgmm²]	Ke [2] [3] Ke [Vs]	Kt [2] [3] Kt [Nm/A_{rms}]
SM_42 60 0,35	42	0.35 0.45	0.78	0.15	6000	0.38	0.9	13	n.a.	0.29	0.46
SM_60 30 0,55	60	0.55 (0.68)	0.7	0.50	3000	0.66	1.7	18	30.5	0.44	0.76
SM_60 45 0,55			1.0	0.39	4500	0.74				0.30	0.53
SM_60 60 0,55			1.4	0.24	6000	0.60				0.23	0.40
SM_60 16 1,4		1.4 (1.7)	0.95	1.35	1600	0.91	4.4	30	42.5	0.85	1.48
SM_60 30 1,4			1.73	1.20	3000	1.50				0.47	0.81
SM_60 45 1,4			2.37	1.00	4500	1.69				0.34	0.59
SM_60 60 1,4			2.98	0.80	6000	1.70				0.27	0.47
SM_60 75 1,4			3.85	0.15	7500	0.41				0.21	0.36
SM_82 10 03			1.2	2.9	1000	1.2				1.43	2.48
SM_82 16 03			1.8	2.9	1600	1.7				0.96	1.66
SM_82 30 03			3.1	2.7	3000	2.8				0.55	0.96
SM_82 33 03	82	3 (3.7)	3.5	2.4	3300	2.8	9	140	183	0.49	0.85
SM_82 45 03			4.7	2.2	4500	3.4				0.37	0.64
SM_82 60 03			6.1	1.5	6000	3.1				0.28	0.49
SM_82 75 03			7.5	0.6	7500	1.6				0.23	0.40
SM_100 16 06	100	6 (9)	3.7	5.8	1600	3.6	18	336	440	0.92	1.60
SM_100 30 06			5.9	5.0	3000	4.9				0.59	1.02
SM_100 45 06			9.4	3.5	4500	5.5				0.37	0.64
SM_100 55 06			11.8	2.6	5500	5.1				0.29	0.51
SM_100 75 06			14.7	0.6	7500	1.5				0.24	0.41
SM_115 16 10	115	10 (12.5)	6.0	9.0	1600	5.4	32	900	1000	0.96	1.66
SM_115 30 10			10.5	8.0	3000	8.4				0.55	0.95
SM_115 40 10			14.7	7.6	4000	11.2				0.39	0.68
SM_115 54 10			18.2	7.1	5400	12.9				0.32	0.55
SM_142 18 15	142	15 (19)	9.7	13.3	1800	8.6	47	1400	1600	0.89	1.54
SM_142 30 15			16.0	12.5	3000	13.4				0.54	0.94

[1] Data referred to motor mounted on a steel flange in horizontal position with dim. 200x230x20 mm (for SM_60,82), dim. 200x270x20 mm (for SM_100,115,142). Stall torques refer to motor turning at 100 min^{-1}
[2] Data measured at 20 °C. When "hot" consider -0.09 %/K derating
[3] Tolerance data ±10 %
[4] SMB: for Drives TPD-M, SLVD-N, Twin-N, SPD-N, Hi-Drive
SMH: for Drive Compax3

400 VAC power supply

Model [4]	Size	Stall [1]		Nominal [1]			Peak [1]	Inertia		Ke [2] [3]	Kt [2] [3]
		Torque	Current	Torque	Speed	Current	Torque	No brake	With brake		
		T_{065} (T_{105}) [Nm]	I_{065} [A]	T_{n065} [Nm]	n [min^{-1}]	I_{n065} [A]	T_{max} [Nm]	J [$kgmm^2$]	J [$kgmm^2$]	Ke [Vs]	Kt [Nm/A_{rms}]
SM_60 30 1,4	60	1.4 (1.7)	0.95	1.2	3000	0.81	4.4	30	42.5	0.81	1.48
SM_60 45 1,4			1.37	1.0	4500	0.98				0.59	1.02
SM_60 60 1,4			1.73	0.8	6000	0.99				0.68	0.81
SM_60 75 1,4			2.15	0.15	7500	0.23				0.38	0.65
SM_82 30 03	82	3 (3.7)	1.8	2.7	3000	1.6	9	140	183	0.96	1.66
SM_82 45 03			2.7	2.2	4500	2.0				0.64	1.11
SM_82 56 03			3.1	1.6	5600	1.7				0.55	0.96
SM_82 60 03			3.5	1.7	6000	2.0				0.49	0.85
SM_82 75 03			4.4	0.6	7500	0.9				0.39	0.68
SM_100 30 06	100	6 (9)	3.7	5.0	3000	3.1	18	336	440	0.92	1.60
SM_100 45 06			5.6	3.5	4500	3.3				0.62	1.07
SM_100 56 06			5.9	2.5	5600	2.4				0.59	1.02
SM_100 75 06			9.4	0.6	7500	0.9				0.37	0.64
SM_115 20 10	115	10 (12.5)	4.5	9.0	2000	4.06	32	900	1000	1.28	2.22
SM_115 30 10			6.0	8.0	3000	4.82				0.96	1.66
SM_115 40 10			8.0	7.6	4000	6.05				0.73	1.26
SM_115 56 10			10.5	6.0	5600	6.30				0.55	0.95
SM_142 20 15	142	15 (19)	6.4	13.0	2000	5.5	47	1400	1600	1.36	2.35
SM_142 30 15			9.7	12.5	3000	8.1				0.89	1.54
SM_142 45 15			14.4	10.9	4500	10.5				0.60	1.04
SM_142 56 15			16.0	9.2	5600	9.8				0.54	0.94
SM_142 10 17		17 (21)	3.5	16.4	1000	3.4	54			2.83	4.90
SM_142 30 17			9.6	14.0	3000	8.1				1.02	1.77
SM_142 56 17			15.8	10.6	5600	9.8				0.62	1.08
SM_170 10 36	170	available on request									
SM_170 27 36											

[1] Data referred to motor mounted on a steel flange in horizontal position with dim. 200x230x20 mm (for SM_60,82), dim. 200x270x20 mm (for SM_100,115,142). Stall torques refer to motor turning at 100 min^{-1}
[2] Data measured at 20 °C. When "hot" consider -0.09 %/K derating
[3] Tolerance data ±10 %
[4] SMB: for Drives TPD-M, SLVD-N, Twin-N, SPD-N, Hi-Drive
SMH: for Drive Compax3

STANDARDS

In compliance with: 2006/95 EC

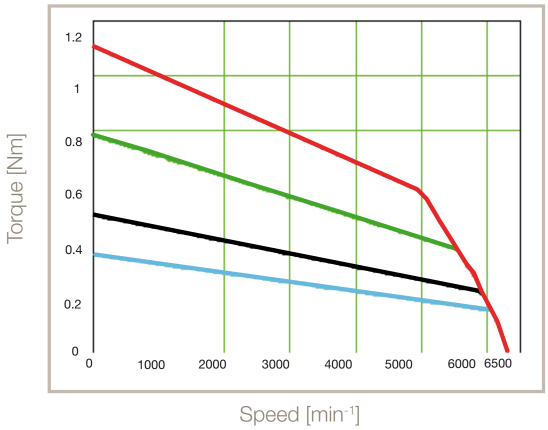
- EN60034-1
- EN60034-5
- EN60034-5/A1

Marked CE **Marked** cULus (execept SM_42)

Speed Torque Curves

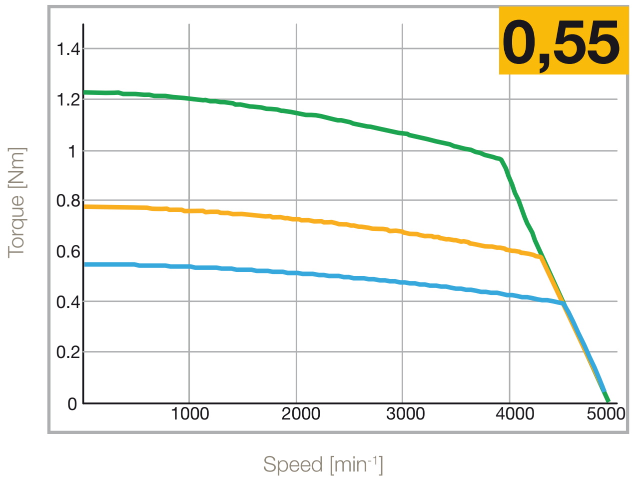
SMB/H42

6000 min^{-1} 230 V

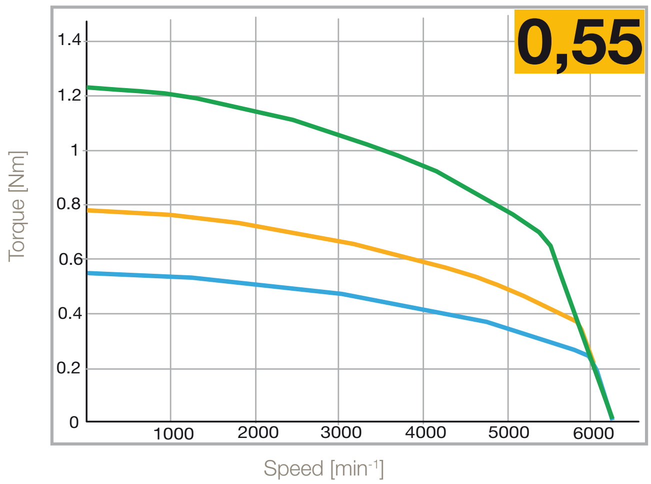


SMB/H60

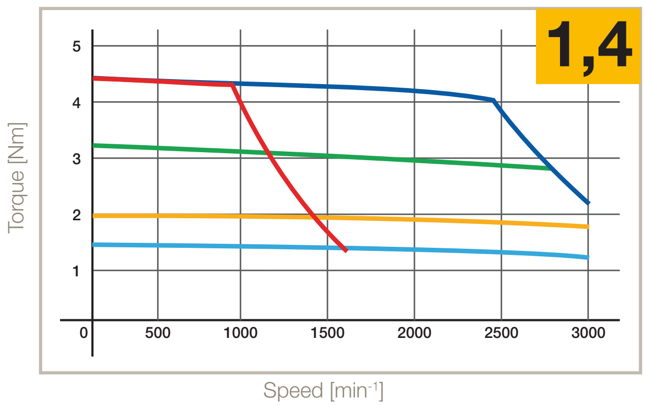
4500 min^{-1} 230 V



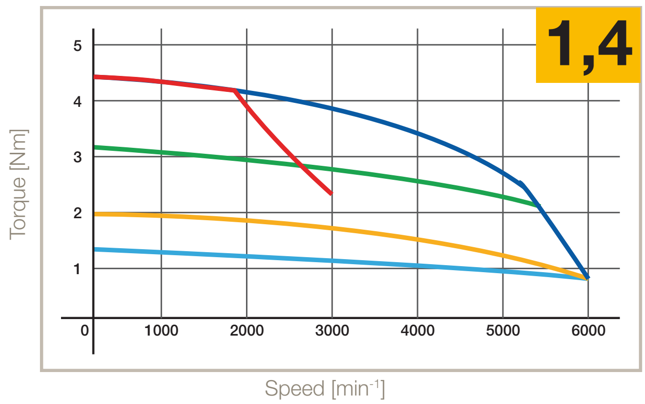
6000 min^{-1} 230 V



1600 min^{-1} 230 V - 3000 min^{-1} 400 V



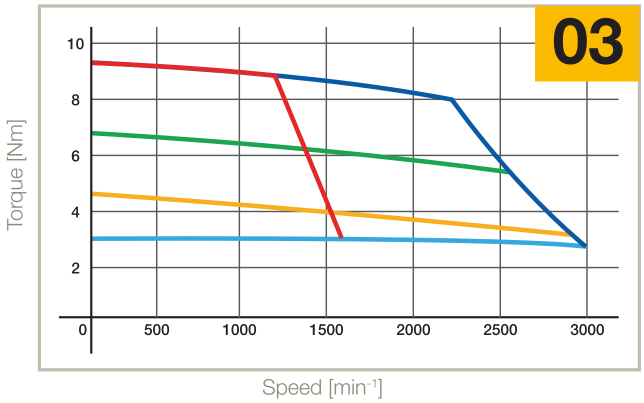
3000 min^{-1} 230 V - 6000 min^{-1} 400 V



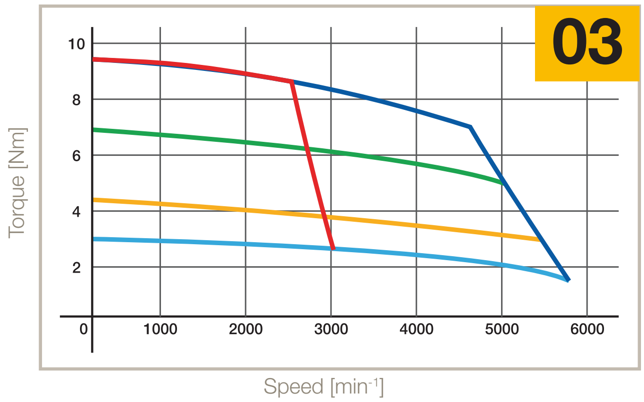
S1 65 K, ΔT
S3 10 %, 5 min, 400 V
S3 50 %, 5 min
S3 10 %, 5 min, 230 V
S3 50 %, 5 min
S3 20 %, 5 min

SMB/H82

1600 min^{-1} 230 V - 3000 min^{-1} 400 V

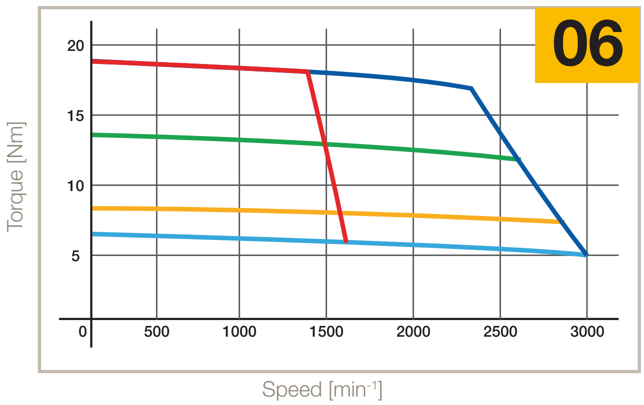


3000 min^{-1} 230 V - 5600 min^{-1} 400 V

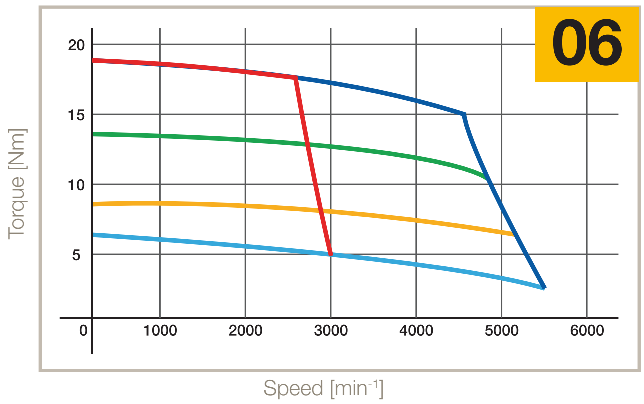


SMB/H100

1600 min^{-1} 230 V - 3000 min^{-1} 400 V

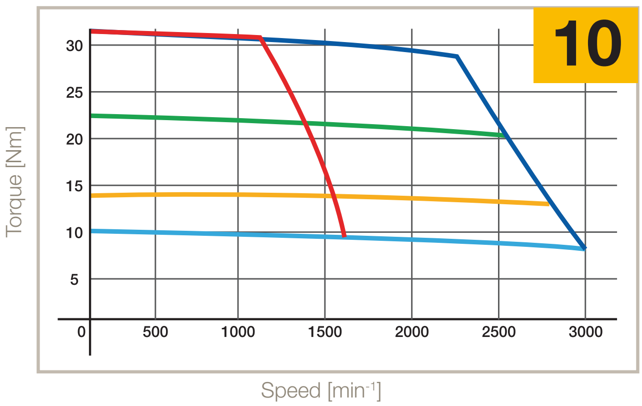


3000 min^{-1} 230 V - 5600 min^{-1} 400 V

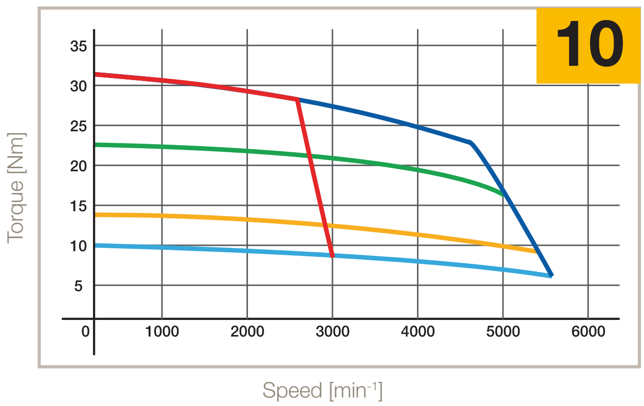


SMB/H115

1600 min^{-1} 230 V - 3000 min^{-1} 400 V



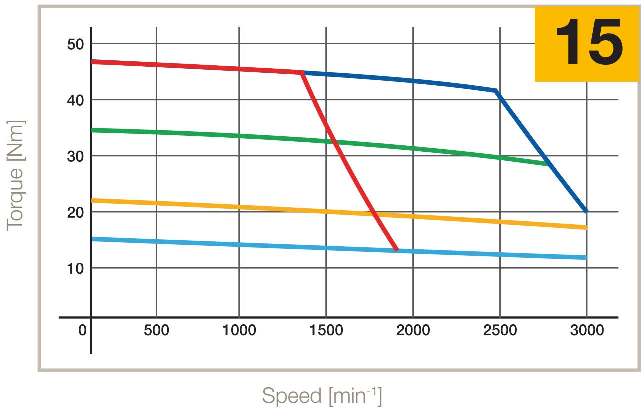
3000 min^{-1} 230 V - 5600 min^{-1} 400 V



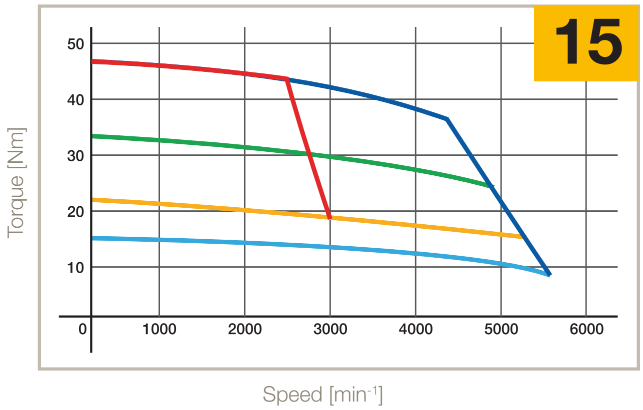
- S1 65 K, ΔT
- S3 10 %, 5 min, 400 V
- S3 50 %, 5 min
- S3 10 %, 5 min, 230 V
- S3 50 %, 5 min
- S3 20 %, 5 min

SMB/H142

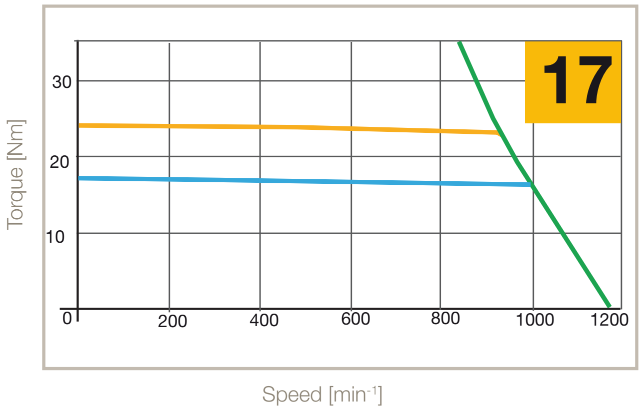
1800 min^{-1} 230 V - 3000 min^{-1} 400 V



3000 min^{-1} 230 V - 5600 min^{-1} 400 V

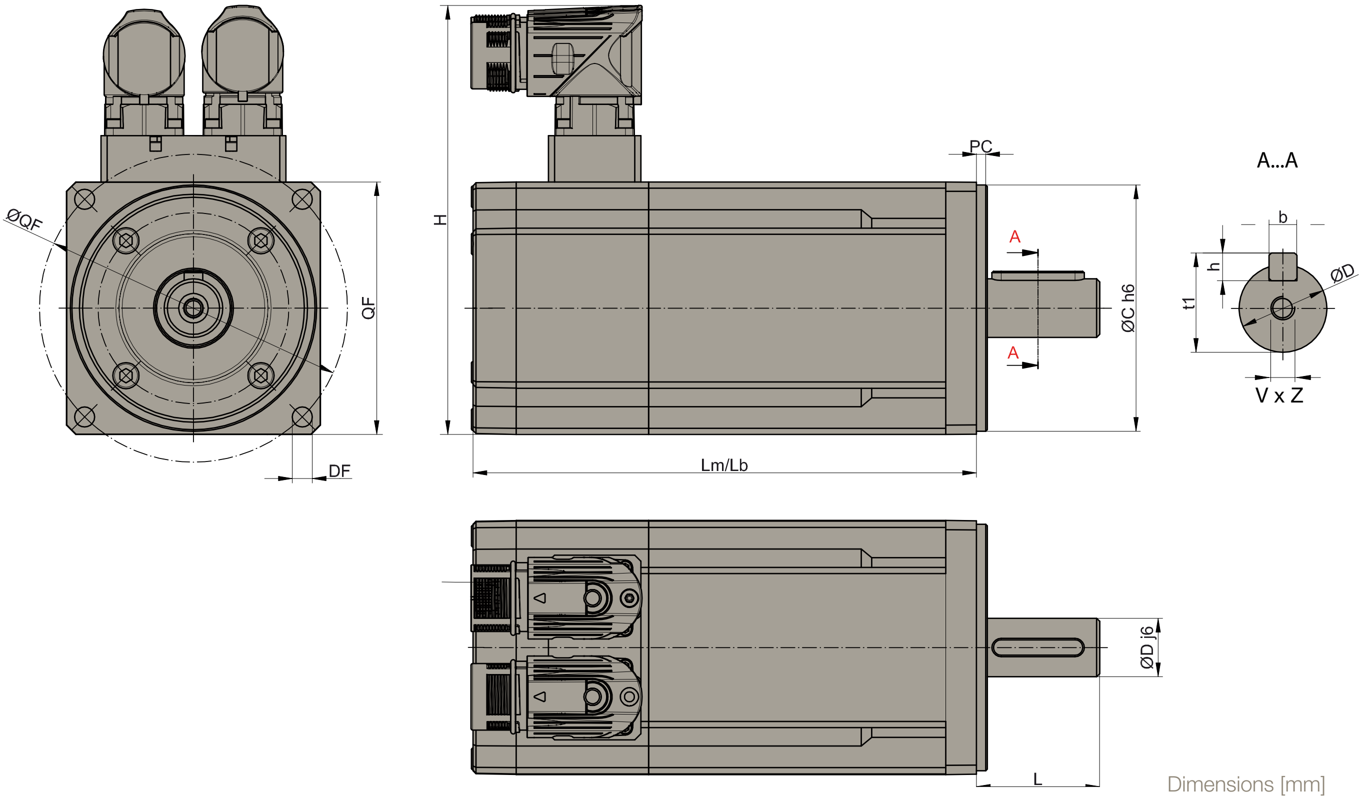


1000 min^{-1} 400 V



S1 65 K, ΔT
S3 10 %, 5 min, 400 V
S3 50 %, 5 min
S3 10 %, 5 min, 230 V
S3 50 %, 5 min
S3 20 %, 5 min

Dimensions of Standard Motors with Resolver Feedback



Dimensions [mm]

Motors Size			LM LB	Weight [kg]	DxL	bxh	t1	VxZ	H	C	ØQF	F	DF	PC	QF	Order Code QF
SMB / H	42	0,35	110	0.85	9x25	-	-	M3x9	66	30		50	3.2	2.5	42	5
SMB / H	60	0,55	88 137	- 1	9x20 11x23	3x3 4x4	10.2 12.5	- M4x10	111.5	40	63	63	5.5	-	60	8
										60	75	75	6	2.5	70	5
SMB / H	60	1,4	129.5 161	1.5	9x20 11x23	3x3 4x4	10.2 12.5	M4x10	111.5	40	63	63	5.5	2.5	60	8
										60	75	75	6	2.5	70	5
SMB / H	82	03	159 202	3.6	11x23[2] 14x30	4x4	12.5	M4x12	140	60	75	75	6	3.5	70	7
SMB / H	82	03	163.5 206.5	3.6	11x23[2] 14x30 19x40[1]	5x5 6x6	16 21.5	M4x12 M5x12.5 M6x16	140	80	100	100	6.5	3.5	82	8
										95	115	115	9	3.5	100	5
SMB / H	100	06	191.5 238.5	4.7	19x40 24x50	6x6 8x7	21.5 27	M6x16 M8x19	157.5	80	100	100	7	3.5	100	8
										95	115	115	9	3.5	100	5
SMB / H	115	10	220 265	7.7	19x40 24x50 28x60	6x6 8x7 8x7	21.5 27 31	M6x16 M8x19 M10x22	172	95	115	115	9	3.5	115	9
										95	130	130	9	3.5	115	8
										110	130	130	9	3.5	130	7
										130	165	165	11	3.5	145	5
SMB / H	142	15	243 293	13	19x40 24x50 28x60	6x6 8x7 8x7	21.5 27 31	M6x16 M8x19 M10x22	199	130	165	165	11	3.5	142	5

LM: Motor's length without brake and with resolver
LB: Motor's length with brake and resolver
DxL: Shaft
bxh: Key
T1: Overall shaft height
VxZ: Shaft hole depth
H: Height

C: Center
DF: Fixing holes
QF: Mounting flange
F: Pitch circle diameter
PC: Centre Depth
[1] not available with flange 7
[2] only for torque <2 Nm

Table 1

Size	Ratio	Rated Torque at 2000 T_r rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed rpm		Limit for Average Input Speed rpm		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil	Grease	Oil	Grease	$x10^{-4}kg \cdot m^2$	$x10^{-5}kgf \cdot m \cdot s^2$
	30	0.9	8	1.8	16	1.4-	12	3.3	29						
8	50	1.8	16	3.3	29	2.3-	20	6.6	58	14000	8500	6500	3500	0.003	0.0031
	100	2.4	18	4.8	42	3.3-	29	9.0	80						
	30	2.2	19	4.5	40	3.4-	30	8.5	75						
11	50	3.5	31	8.3	73	5.5-	49	17	150	14000	8500	6500	3500	0.012	0.012
	100	5.0	44	11	97	8.9-	79	25	221						
	30	4.0	35	9.0	80	6.8	60	17	150						
14	50	5.4	48	18	159	6.9	61	35	310	14000	8500	6500	3500	0.033	0.034
	80	7.8	69	23	204	11	97	47	416						
	100	7.8	69	28	248	11	97	54	478						
	30	8.8	78	16	142	12	106	30	266						
	50	16	142	34	301	26	230	70	620						
17	80	22	195	43	381	27	239	87	770	10000	7300	6500	3500	0.079	0.081
	100	24	212	54	478	39	345	108	956						
	120	24	212	54	478	39	345	86	761						
	30	15	133	27	239	20	177	50	443						
	50	25	221	56	496	34	301	98	867						
20	80	34	301	74	655	47	411	127	1124	10000	6500	6500	3500	0.193	0.197
	100	40	354	82	726	49	434	147	1301						
	120	40	354	87	770	49	434	147	1301						
	160	40	354	92	814	49	434	147	1301						
	30	27	239	50	443	38	336	95	841						
	50	39	345	98	868	55	487	186	1646						
25	80	63	558	137	1212	87	770	255	2257	7500	5600	5600	3500	0.413	0.421
	100	67	593	157	1389	108	956	284	2513						
	120	67	593	167	1478	108	956	304	2690						
	160	67	593	176	1558	108	956	314	2779						
	30	54	478	100	885	75	664	200	1770						
	50	76	673	216	1912	108	956	382	3381						
32	80	118	1044	304	2690	167	1478	568	5027	7000	4800	4600	3500	1.69	1.72
	100	137	1212	333	2947	216	1912	647	5726						
	120	137	1212	353	3124	216	1912	686	6071						
	160	137	1212	372	3292	216	1912	686	6071						
	50	137	1212	402	3558	196	1735	686	6071						
	80	206	1823	519	4593	284	2513	980	8673						
40	100	265	2345	568	5027	372	3292	1080	9558	5600	4000	3600	3000	4.50	4.59
	120	294	2602	617	5460	451	3991	1180	10443						
	160	294	2602	647	5726	451	3991	1180	10443						
	50	176	1558	500	4425	265	2345	950	8408						
	80	313	2770	706	6248	390	3452	1270	11240						
45	100	353	3124	755	6682	500	4425	1570	13895	5000	3800	3300	3000	8.68	8.86
	120	402	3558	823	7284	620	5487	1760	15576						
	160	402	3558	882	7806	630	5576	1910	16904						
	50	245	2168	715	6328	350	3098	1430	12656						
	80	372	3292	941	8328	519	4593	1860	16461						
50	100	470	4160	980	8673	666	5894	2060	18231	4500	3500	3000	2500	12.5	12.8
	120	529	4682	1080	9558	813	7195	2060	18231						
	160	529	4682	1180	10443	843	7461	2450	21683						
	50	353	3124	1020	9027	520	4602	1960	17346						
	80	549	4859	1480	13098	770	6815	2450	21683						
58	100	696	6160	1590	14072	1060	9381	3180	28143	4000	3000	2700	2200	27.3	27.9
	120	745	6593	1720	15222	1190	10532	3330	29471						
	160	745	6593	1840	16284	1210	10709	3430	30356						

Table 2

Size	Ratio	Rated Torque at 2000 Tr rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed rpm		Limit for Average Input Speed rpm		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil	Grease	Oil	Grease	$x10^{-4}kg{\cdot}m^2$	$x10^{-5}kgf{\cdot}m{\cdot}s^2$
65	50	490	4337	1420	12567	720	6372	2830	25046	3500	2800	2400	1900	46.8	47.8
	80	745	6593	2110	187	1040	9204	3720	32922						
	100	951	8416	2300	20355	1520	13452	4750	42038						
	120	951	8416	2510	22214	1570	13895	4750	42038						
	160	951	8416	2630	23276	1570	13895	4750	42038						
80	50	872	7717	2440	21594	1260	11151	4870	43100	2900	2300	2200	1500	122	124
	80	1320	11682	3430	30356	1830	16196	6590	58322						
	100	1700	15045	4220	37347	2360	20886	7910	70004						
	120	1990	17612	4590	40622	3130	27701	7910	70004						
	160	1990	17612	4910	43454	3130	27701	7910	70004						
90	50	1180	10443	3530	31241	1720	15222	6660	58941	2700	2000	2100	1300	214	218
	80	1550	13718	3990	35312	2510	22214	7250	64163						
	100	2270	20090	5680	50268	3360	29736	9020	79827						
	120	2570	22745	6160	54516	4300	38055	9800	86730						
	160	2700	23895	6840	60534	4300	38055	11300	100005						
100	50	1580	13983	4450	39383	2280	20178	8900	78765	2500	1800	2000	1200	356	363
	80	2380	21063	6060	53631	3310	29294	11600	102660						
	100	2940	26019	7350	65048	4630	40976	14100	124785						
	120	3180	28143	7960	70446	5720	50622	15300	135405						
	160	3550	31418	9180	81243	5720	50622	15500	137175						

CSG Rating Table

Table 3

Size	Ratio	Rated Torque at 2000 Tr rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed rpm		Limit for Average Input Speed rpm		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil	Grease	Oil	Grease	$x10^{-4}kg{\cdot}m^2$	$x10^{-5}kgf{\cdot}m{\cdot}s^2$
14	50	7.0	62	23	204	9	80	46	407	14000	8500	6500	3500	0.033	0.0034
	80	10	89	30	266	14	124	61	540						
	100	10	89	36	319	14	124	70	620						
17	50	21	186	44	390	34	301	91	805	10000	7300	6500	3500	0.079	0.081
	80	29	257	56	496	35	310	113	1000						
	100	31	274	70	620	51	451	143	1266						
	120	31	274	70	620	51	451	112	991						
20	50	33	292	73	646	44	389	127	1124	10000	6500	6500	3500	0.193	0.197
	80	44	389	96	850	61	540	165	1460						
	100	52	460	107	947	64	566	191	1690						
	120	52	460	113	1000	64	566	191	1690						
	160	52	460	120	1062	64	566	191	1690						
25	50	51	451	127	1124	72	637	242	2142	7500	5600	5600	3500	0.413	0.421
	80	82	726	178	1575	113	1000	332	2938						
	100	87	770	204	1805	140	1239	369	3266						
	120	87	770	217	1920	140	1239	395	3496						
	160	87	770	229	2027	140	1239	408	3611						
32	50	99	876	281	2487	140	1239	497	4399	7000	4800	4600	3500	1.69	1.72
	80	153	1354	395	3496	217	1920	738	6531						
	100	178	1575	433	3832	281	2487	841	7443						
	120	178	1575	459	4062	281	2487	892	7894						
	160	178	1575	484	4283	281	2487	892	7894						
40	50	178	1575	523	4629	255	2257	892	7894	5600	4000	3600	5000	4.50	4.59
	80	268	2372	675	5974	369	3266	1270	11240						
	100	345	3053	738	6531	484	4283	1400	12390						
	120	382	3381	802	7098	586	5186	1530	13541						
	160	382	3381	841	7443	586	5186	1530	13541						

Table 4

Size	Ratio	Rated Torque at 2000 Tr rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed rpm		Limit for Average Input Speed rpm		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil	Grease	Oil	Grease	$\times10^{-4}$kg•m^2	$\times10^{-5}$kgf•m•s^2
45	50	229	2,027	650	5,753	345	3,053	1,235	10,930	5,000	3,800	3,300	3,000	8.68	8.86
	80	407	3,602	918	8,124	507	4,487	1,651	14,611						
	100	459	4,062	982	8,691	650	5,753	2,041	18,063						
	120	523	4,629	1,070	9,470	806	7,133	2,288	20,249						
	160	523	4,629	1,147	10,151	819	7,248	2,483	21,975						
50	80	484	4,283	1,223	10,824	675	5,974	2,418	21,399	4,500	3,500	3,000	2,500	12.5	12.8
	100	611	5,407	1,274	11,275	866	7,664	2,678	23,700						
	120	688	6,089	1,404	12,425	1,057	9,354	2,678	23,700						
	160	688	6,089	1,534	13,576	1,096	9,700	3,185	28,187						
58	80	714	6,319	1,924	17,027	1,001	8,859	3,185	28,187	4,000	3,000	2,700	2,200	27.3	27.9
	100	905	8,009	2,067	18,293	1,378	12,195	4,134	36,586						
	120	969	8,576	2,236	19,789	1,547	13,691	4,329	38,312						
	160	969	8,576	2,392	21,169	1,573	13,921	4,459	39,462						
65	80	969	8,576	2,743	24,276	1,352	11,965	4,836	42,799	3,500	2,800	2,400	1,900	46.8	47.8
	100	1,236	10,939	2,990	26,462	1,976	17,488	6,175	54,649						
	120	1,236	10,939	3,263	28,878	2,041	18,063	6,175	54,649						
	160	1,236	10,939	3,419	30,258	2,041	18,063	6,175	54,649						

SERVOMOTOARE

Stealth® GM Gearmotors Series:

Performance Specifications (six step / trapezoidal commutation)

Mechanical Specifications

Frame Size	Stack Length	Weight without Brake		Maximum Radial Load		Torsional Stiffness		Standard Backlash	Low Backlash
		(kg)	(lb)	**(N)**	(lb)	**(Nm/arc min)**	(in lb/arc min)	(arc min)	(arc min)
GM115	Single	**8.4**	18.5	**3,900**	876	**20**	177	15	10
GM115	Double	**10.6**	23.4	**3,900**	876	**20**	177	15	10

* Measured at 2% of rated torque

Single Stack Specifications

Frame Size	Ratio	Max. Speed(1)	Cont. Stall Torque (1) T_C		Peak Torque(1) T_P		Winding C:160 Vdc D:300 Vdc	Voltage Constant(1)(3) K_{EL-L}	Torque Constant(1)(3) K_{TL-L}		Induct L_{L-L}	Cold Resistance R_{L-L}	Cont. Current I_C	Peak Current I_P	Inertia (2)	
		(RPM)	**(Nm)**	(in lb)	**(Nm)**	(in lb)		(V/kRPM)	**(Nm/amp)**	(in lb/amp)	(mH)	(ohms)	(amps)	(amps)	**(gm cm sec²)**	(lb in sec²)
GM115	5:1	700	**18.2**	162	**54.7**	486	C	228.0	**2.15**	19.5	2.9	1.2	8	25	**4.33**	0.00375
GM115	5:1	680	**18.2**	162	**54.7**	486	D	438.0	**4.15**	37.0	10.7	4.7	4	13	**4.33**	0.00375
GM115	7:1	500	**25.4**	227	**76.6**	681	C	319.2	**3.01**	27.3	2.9	1.2	8	25	**3.54**	0.00306
GM115	7:1	480	**25.4**	227	**76.6**	681	D	613.2	**5.81**	51.8	10.7	4.7	4	13	**3.54**	0.00306
GM115	10:1	350	**36.5**	324	**109.4**	972	C	456.0	**4.30**	39.0	2.9	1.2	8	25	**3.54**	0.00306
GM115	10:1	340	**36.5**	324	**109.4**	972	D	876.0	**8.30**	74.0	10.7	4.7	4	13	**3.54**	0.00306

Double Stack Specifications

Frame Size	Ratio	Max. Speed(1)	Cont. Stall Torque (1) T_C		Peak Torque(1) T_P		Winding C:160 Vdc D:300 Vdc	Voltage Constant(1)(3) K_{EL-L}	Torque Constant(1)(3) K_{TL-L}		Induct L_{L-L}	Cold Resistance R_{L-L}	Cont. Current I_C	Peak Current I_P	Inertia (2)	
		(RPM)	**(Nm)**	(in lb)	**(Nm)**	(in lb)		(V/kRPM)	**(Nm/amp)**	(in lb/amp)	(mH)	(ohms)	(amps)	(amps)	**(gm cm sec²)**	(lb in sec²)
GM115	5:1	570	**30.1**	267	**90.2**	801	C	280.5	**2.70**	23.5	2.2	0.73	11	34	**6.28**	0.00544
GM115	5:1	650	**30.1**	267	**90.2**	801	D	455.5	**4.35**	38.5	5.8	1.9	7	21	**6.28**	0.0054
GM115	7:1	400	**42.0**	373	**125.9**	1,119	C	392.7	**3.78**	32.9	2.2	0.73	11	34	**5.50**	0.00475
GM115	7:1	470	**42.0**	373	**125.9**	1,119	D	637.7	**6.09**	53.9	5.8	1.9	7	21	**5.50**	0.00475
GM115	10:1	280	**60.0**	533	**179.9**	1,599	C	561.0	**5.40**	47.0	2.2	0.73	11	34	**5.50**	0.00475
GM115	10:1	320	**60.0**	533	**179.9**	1,599	D	911.0	**8.70**	77.0	5.8	1.9	7	21	**5.50**	0.00475

Note: Pole Count for GM115 is 12

Thermal Resistance for GM115 is 0.95 °C/W

Stator winding thermal resistance (winding to ambient) is for the unit, mounted to a 254mm x 254mm x 12.7mm (10in x 10in x 0.5in) aluminum plate.

(1) These specifications refer to the output of the GM assembly.
When programming a digital amplifier for use with a GM assembly, these specifications must be adjusted by the ratio to create actual motor performance

(2) Inertia = Motor Rotor + Gear Selection. External Inertia must be divided by the square of the ratio.

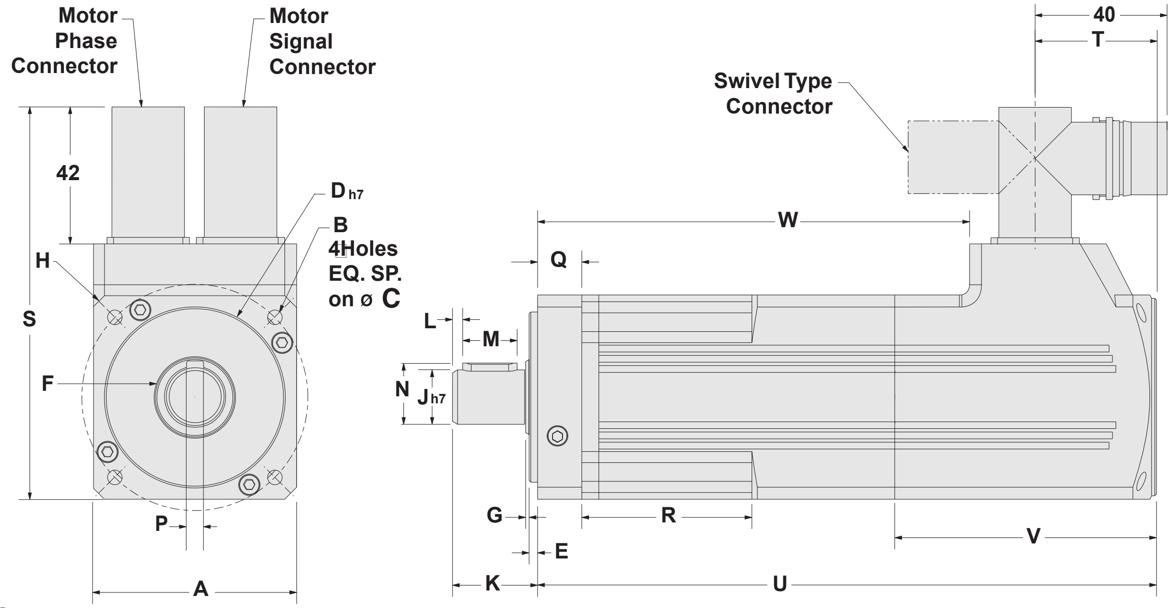
(3) Peak of sine wave

* For Motor Selection calculations see page 194

Gearmotors & Gearheads

Stealth® GM Gearmotors Series

Dimensions



METRIC SIZES

Frame Size	A Square Flange (mm)	A (in)	B Bolt Hole (mm)	B (in)	C Bolt Circle Diameter (mm)	C (in)	D Pilot Diameter (mm)	D (in)	E Pilot Thick. (mm)	E (in)	F Shoulder Diameter (mm)	F (in)	G Shoulder Height (mm)	G (in)	H Housing Diameter (mm)	H (in)	J Shaft Diameter (mm)	J (in)
GM060	**60**	2.36	**5.5**	0.22	**70**	2.756	**50**	1.969	**2.5**	0.1	**23**	0.91	**1.0**	0.04	**80**	3.15	**16**	0.63
GM090	**90**	3.54	**6.5**	0.26	**100**	3.94	**80**	3.15	**3.0**	0.12	**36**	1.42	**1.0**	0.04	**116**	4.57	**20**	0.79
GM115	**115**	4.53	**8.5**	0.33	**130**	5.12	**110**	4.33	**3.5**	0.14	**36**	1.42	**1.5**	0.6	**152**	5.95	**24**	0.94

Frame Size	K Shaft Length (mm)	K (in)	L Dist From Shaft End (mm)	L (in)	M Keyway Length (mm)	M (in)	N Keyway Height (mm)	N (in)	P Keyway Width (mm)	P (in)	Q Flange Thick. (mm)	Q (in)	R Recess Length (mm)	R (in)	S Height (mm)	S (in)	T Connector Location (mm)	T (in)
GM060	**25.0**	0.98	**3**	0.118	**16**	0.630	**18.0**	0.709	**5**	0.20	**13**	0.51	**50.0**	1.969	**117**	4.60	**37**	1.457
GM090	**40.0**	1.57	**5**	0.20	**28**	1.10	**22.5**	0.886	**6**	0.24	**17**	0.67	**54.5**	2.15	**147**	5.79	**39**	1.535
GM115	**50.0**	1.97	**7**	0.28	**32**	1.26	**27.0**	1.063	**8**	0.32	**20**	0.79	**55.5**	2.18	**175**	6.89	**46**	1.811

NEMA SIZES

Frame Size	B Bolt Hole (in)	B (mm)	C Bolt Circle (in)	C (mm)	D Pilot Diameter (in)	D (mm)	J Output Shaft Diameter (in)	J (mm)	K Output Shaft Length (in)	K (mm)	M Keyway Length (in)	M (mm)	N Keyway Height (in)	N (mm)	P Keyway Width (in)	P (mm)
GM023	**0.195**	5.0	**2.625**	66.7	**1.500**	38.1	**0.375**	9.5	**1.000**	25.4	**0.750** flat	19.1 flat	**0.015** flat	0.4 flat	—	—
GM034	**0.218**	5.5	**3.875**	98.4	**2.875**	73.0	**0.500**	12.7	**1.250**	31.8	**1.063**	27.0	**0.072**	1.8	**0.125**	3.2
GM042	**0.281**	7.1	**4.950**	125.7	**2.187**	55.5	**0.625**	15.9	**1.500**	38.1	**1.130**	28.7	**0.108**	2.7	**0.188**	4.8