GOVERNMENT OF
WESTERN AUSTRALIA

TAFE WA South Metropolitan

LATHE AUTOMATION

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Advance diploma of mechanical engineering

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Contents

Introduction

Lathe has been an important tool for the industrial revolution. It has been considered as a must-have tool for the manufacturing industry offering reliable and accurate result. However, in the last decade automatic lathes have taken over this process due to its low cost, manufacturing errors reduction and human safety benefits. Furthermore, the intent of stepping into this technology is fundamental giving basic comprehension and skills required by today's challenges.

This report consists of four sections:

1. Modelling
2. Calculations.
3. Manufacturing.
4. Assembly.

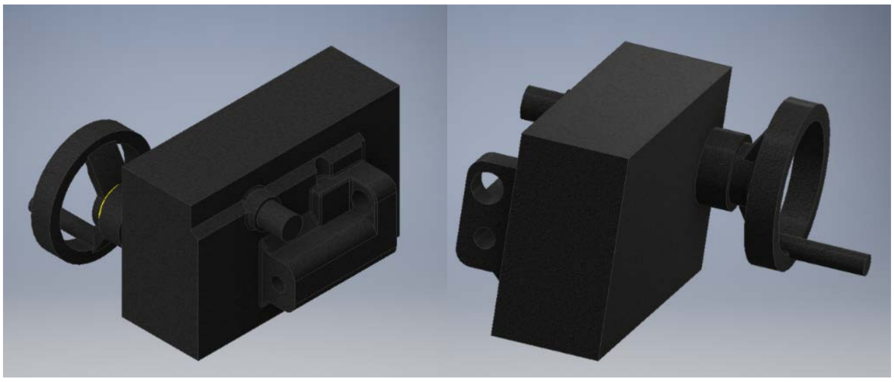
In this order, modelling refers to the process of digitalizing a physical component into a computational 3D model while calculations will involve some research and force analysis develop during operation. These two sections will be carried out individually where every person will have a different task while the manufacturing process will be operated by an authorised machinist. Moreover, assembly, wiring and programmable set up sections will be done in collaboration.

By the end of this project, operators should be able to machine a material by giving it a specific drawing file which will be then translated and transformed into GCODE files and lastly be readable by the motor controllers.

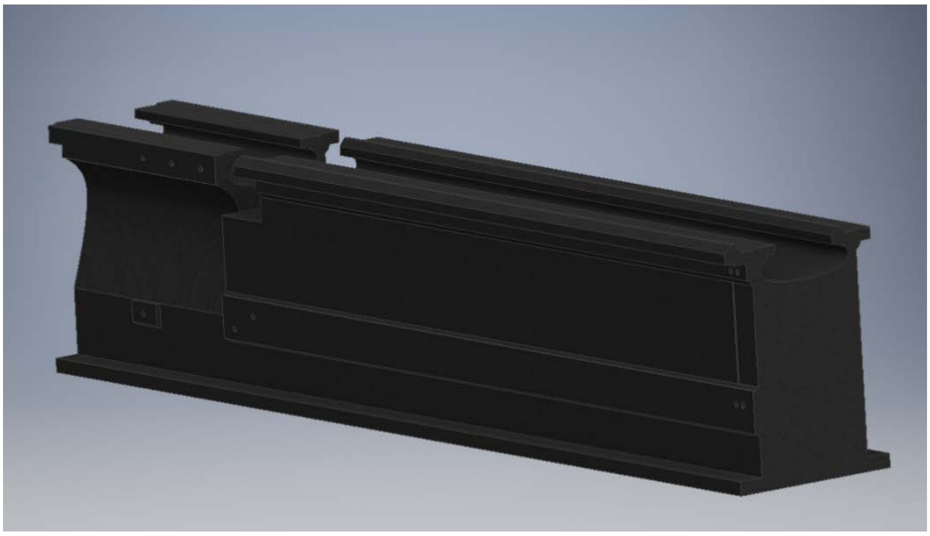
Modelling

The following components were part of my collaboration to the team.

Apron



Bed



Calculations

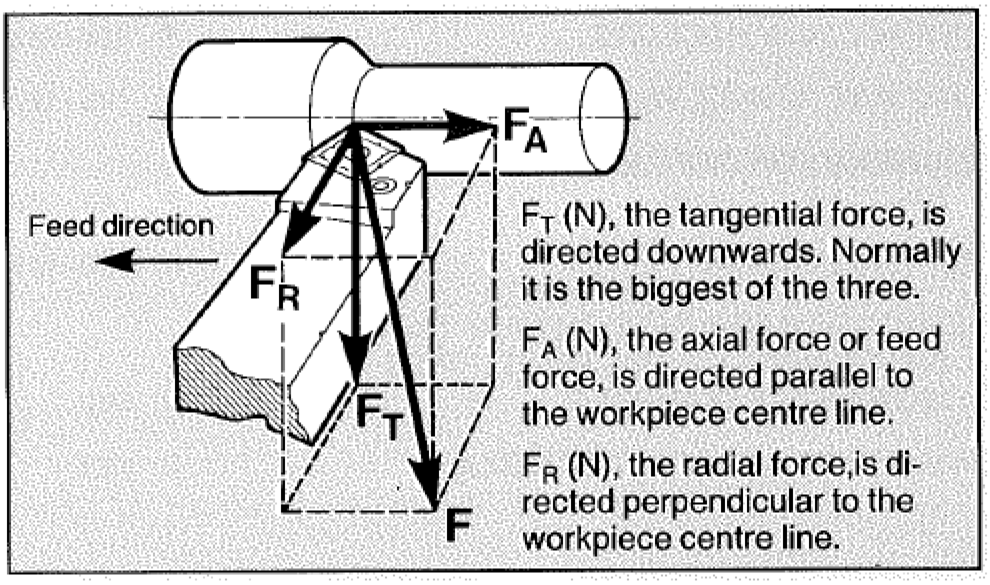
Torques and forces exerted by the lathe were calculated in order to select both motors and ball screws.

Initial stablished parameters:

Predominantly material for workpiece	High Carbon Steel	N/A
Depth of cut (max)	6	mm
Feed rate (max)	0.5	mm/rev
Chuck angular velocity (max)	22 - 1800	RPM
Coefficient of friction metal-metal	0.16 (The Engineering ToolBox, 2017)	N/A
Z-axis weight	50	Kg
X-axis weight	25	Kg
Manual angular velocity	120	RPM
Lead angle accuracy	0.05	mm
Ball screw length to be used for the Z-axis	1100	mm

CNC lathe is required to be driven by ball screws and servo motors for their lowest factors of frictions and accuracy respectively. Therefore all following calculations are aimed at selecting a ball screw and a servo motor that can overcome the maximum torque, velocity and forces developed by the lathe.

For cutting force calculation:



The approximate relationship of these components to each other is: $F_T : F_A : F_R = 4:2:1$

Tangential cutting force (F_t) may be determined by:

$$F_T(N) = k_s \times \mathrm{a} \times s$$

Where	k_s	=	specific cutting force (N/mm^2)
	a	=	depth of cut (mm)
	s	=	feed (mm/rev)

As k_s = 2300 N/mm^2 for a workpiece of high carbon steel, it need to be corrected by three (3) factors which are insert geometry, entering angle of the tool and the feed rate chosen. See appendix 1 for more information.

Assuming all these factors are equal to one, k_s is:

$$k_s = 2300 \times 1 \times 1 \times 1 = \mathbf{2300\ N/mm^2}$$

Thus,

$$F_T = 2300\ N/mm^2 \times 6\ mm \times 0.5\ mm/rev = \mathbf{6900\ N}$$

And:

$$F_A = \frac{F_T}{2} = \frac{6900\ N}{2} = \mathbf{3450\ N}$$

$$F_R = \frac{F_T}{4} = \frac{6900\ N}{4} = \mathbf{1725\ N}$$

Since the lead angle accuracy is 0.05 mm and the effective thread length is greater than 1000 mm, the accuracy grade for the ball screw will be **C5 Precision Ball Screw.** Furthermore, most ball screw can provide an efficiency of 95%.

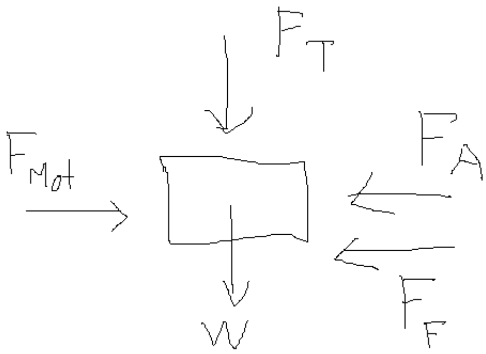
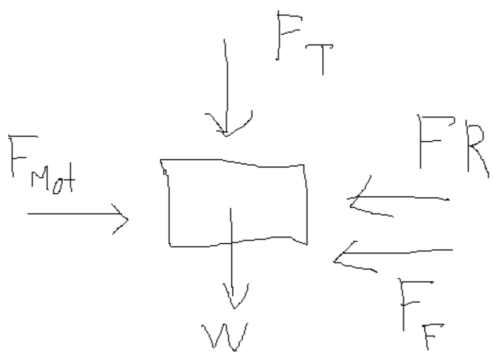
Additionally, the ball screw lead may be obtained as follow:

$$Lead = \frac{Chuck\ angular\ velocity\ (RPM) \times Feed\ rate\ \left(\frac{mm}{rev}\right)}{Manual\ angular\ velocity\ (RPM)} = \frac{1800 \times 0.5}{120}$$

$$= \mathbf{7.5\ mm/rev}$$

Rounding up the theoretical lead to match a standard lead screw ball from manufactures, lead is equal to **10 mm/rev.**

Once cutting forces and ball screw's lead have been calculated, forces due to friction and lathe's components weight must be included for both X and Z axes. Thus,

Z-axis (Apron)	X-axis (Tool post)
	
$W = 50Kg \times 9.81\ m/s^2 = \mathbf{490.5\ N}$	$W = 25Kg \times 9.81\ m/s^2 = \mathbf{245.5\ N}$
$F_F = (6900N + 490.5N) \times 0.16 = \mathbf{1182.5N}$	$F_F = (6900N + 245.5\ N) \times 0.16 = \mathbf{1143.2N}$
$F_{mot} = F_F + F_A = 1182.5N + 3450\ N = \mathbf{4632.5N}$	$F_{mot} = F_F + F_R = 1143.2N + 1725\ N = \mathbf{2868.2N}$

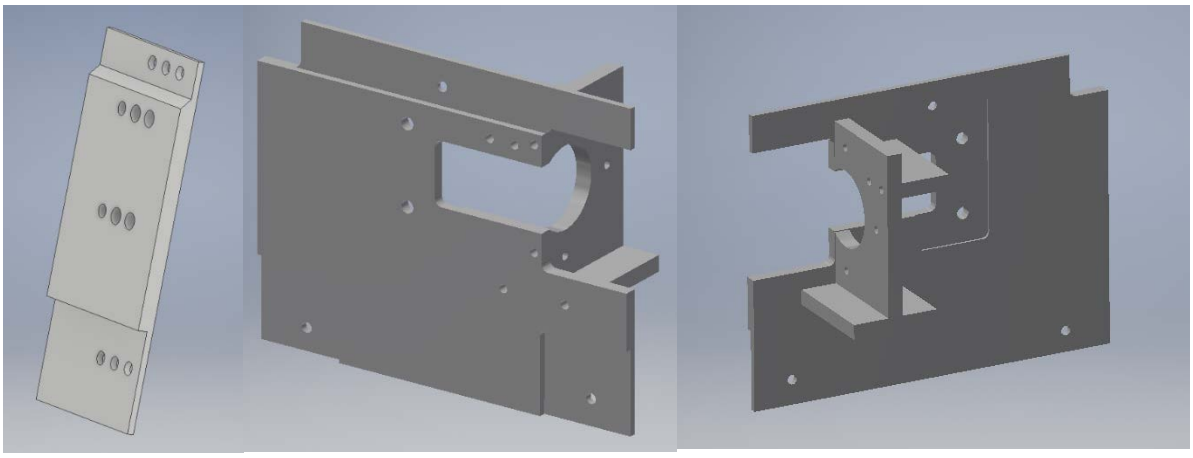
$T_{ball\,screw} = \dfrac{F_{mot} \times Lead}{2\pi \times \eta_{ball\,screw} \times 1000}$ $= \dfrac{4632.5N \times 10\text{ mm/rev}}{2\pi \times 0.9 \times 1000} = \mathbf{8.2\ Nm}$	$T_{ball\,screw} = \dfrac{F_{mot} \times Lead}{2\pi \times \eta_{ball\,screw} \times 1000}$ $= \dfrac{2868.2N \times 10\text{ mm/rev}}{2\pi \times 0.9 \times 1000} = \mathbf{5.1\ Nm}$

Considering all the previous values and space limits, the ball screw selected could be found on appendix 2. Furthermore, a 3D representation of the ball screw was drawn by using the dimensions shown on the appendix 2.

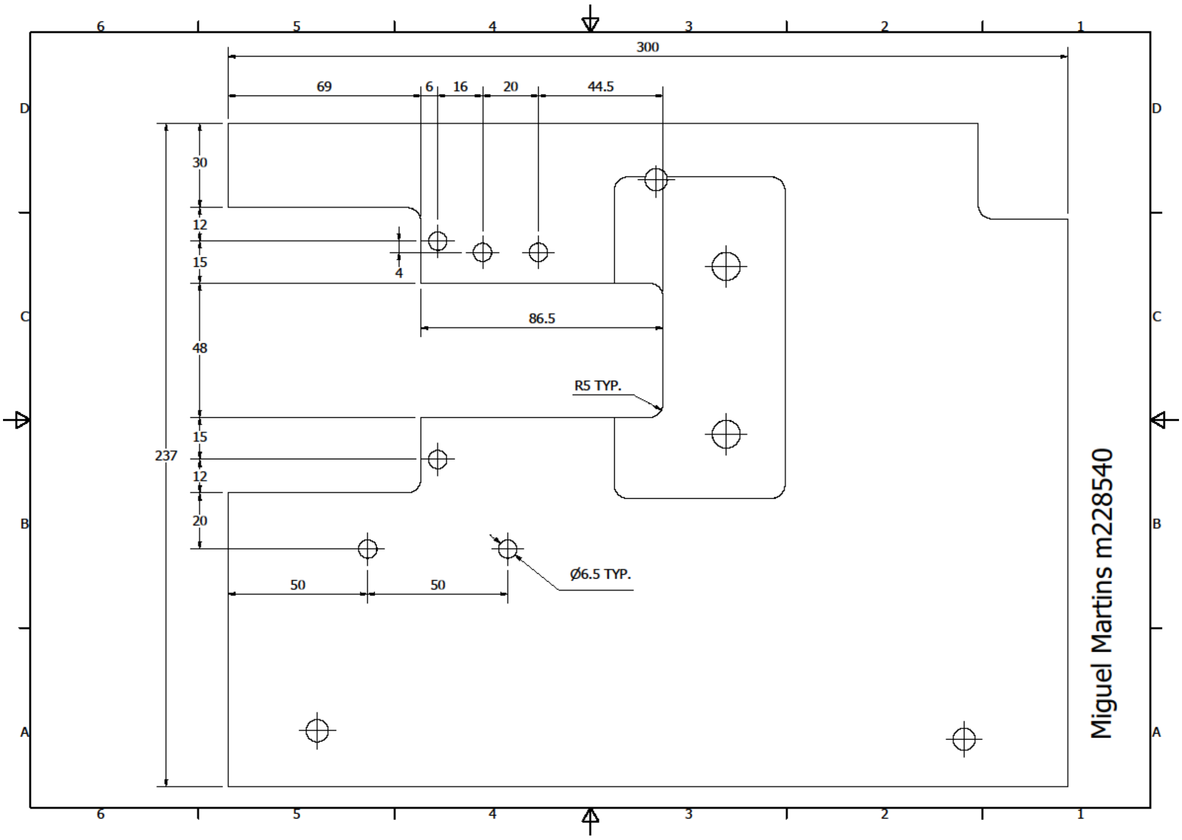
Finally, selecting the motor is done by using the maximum torque calculated previously and the assumed rotational speed. The motor details are shown on appendix 3. (Ocean Controls, 2017)

Manufacturing

Having all the dimensions for the ball screw and the motor to be used, supports can be designed and adapted to the lathe in a convenience manner.



Then, manufacturing drawing were created and handed to the machinist.


300
69
6
16
20
44.5
30
12
15
4
86.5
48
R5 TYP.
237
15
12
20
50
50
Ø6.5 TYP.
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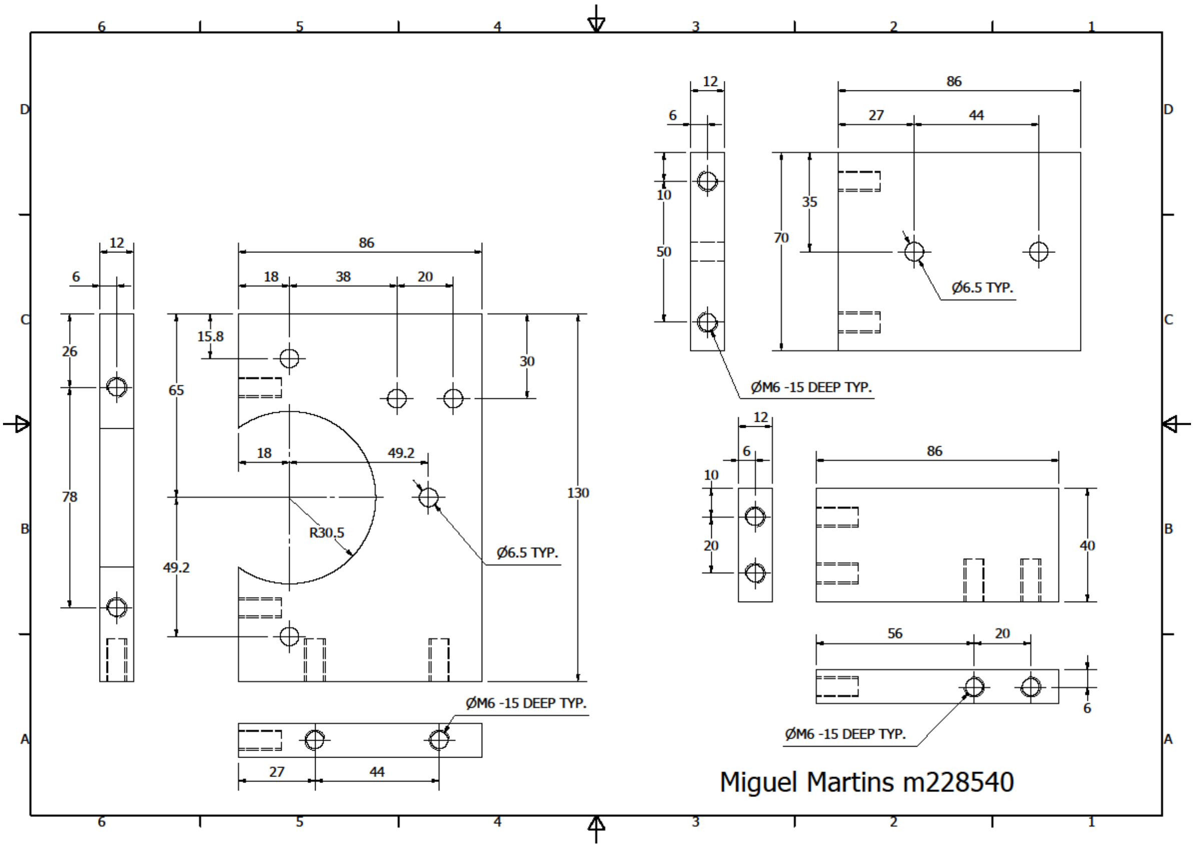
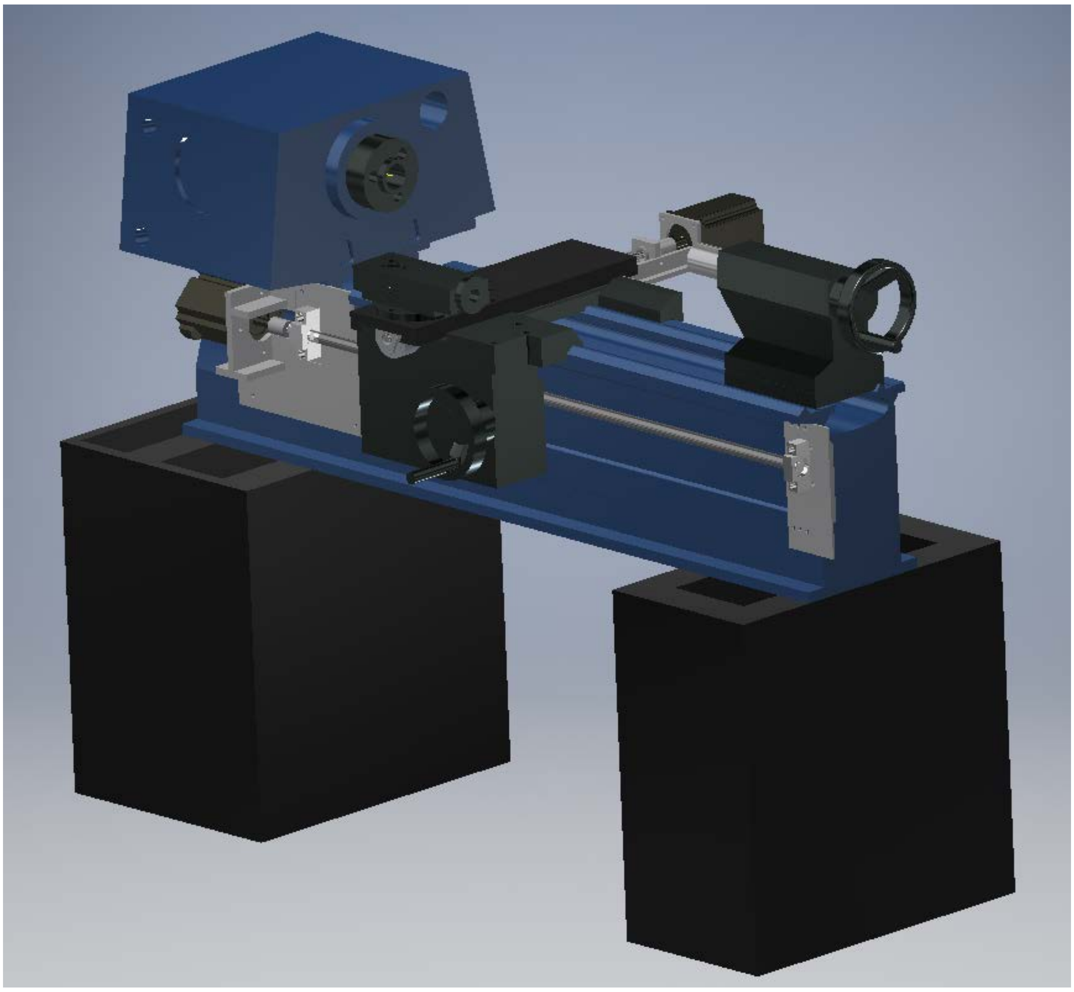

12
6
26
78
86
18
38
20
15.8
65
30
18
49.2
R30.5
Ø6.5 TYP.
130
49.2
ØM6 -15 DEEP TYP.
27
44
12
6
10
50
86
27
44
35
70
Ø6.5 TYP.
ØM6 -15 DEEP TYP.
12
6
10
20
86
40
56
20
6
ØM6 -15 DEEP TYP.
Miguel Martins m228540

Assembly

Unfortunately, this section was only accomplished on a 3D model because machinists and lectures were unavailable. However, supports were machined partially and some modifications were added to it afterwards due to some discrepancy on the flexible couplings.

In addition, the final 3D model was designed to allow movements and test the maximum possible displacements after all components being assembled. Finally, the 3D representation of the final assembly is:



Conclusion

Although we finished off the virtual representation of the final assembly, the physical assembly could not be done due to circumstances out of our control. Furthermore, all the basic selections like motor and ball screw were carried out without major difficulties. As mention previously, what was done of the supports was also tested on the bed and fitted correctly with aligned holes and proper dimensions.

Regarding the z-axis configuration which was my task, there was not need of modifying neither the apron nor the bed for the nut or ball screw's supports to fit in. This was accomplished by selecting the most suitable ball screw and playing around with the design of its supports. As it can be seen, these supports were machined on both front and rear surfaces which avoided us modifying the apron or bed.

Finally, all the calculations were proven to be the most suitable for our application due to a interactive spread sheet on Excel were initial values can be changed and see the result right away. It is worth mentioning these initial values were obtained from machinist and lecture's experiences and used as a starting point or initial reference.

Recommendations

In order to complete this project, ball screw's supports must be finished off as indicated on manufacturing drawings.

Motors must be place in a convenience way where cables go towards the motor controllers

References

Ocean Controls. (2017, July 18). *NEMA 34 Easy Servo Motor 8.0 N.m*. Retrieved from oceancontrol.com.au: https://oceancontrols.com.au/MOT-184.html

The Engineering ToolBox. (2017, July 18). *Friction and Friction Coefficients*. Retrieved from Enginnering ToolBox: https://www.engineeringtoolbox.com/friction-coefficients-d_778.html

Appendices

Appendix 1

k_sCORRECTION FACTORS FOR INSERT GEOMETRIES

	T-MAX P + NEGATIVE/POSITIVE										T-MAX U NEUTRAL			T-MAX COPYING	
INSERT GEOMETRY	TNMG CNMG SNMG DNMG 61	TNMG CNMG SNMG DNMG 15	TNMM CNMM DNM 71	CNMM 62 TNMM 31	TNMM SNMM SNMG 41	TNMG CNMG DNMG VNMG	RNMG SNMN	TNMM CNMM SNMA DNMM	TNMA CNMA DNMA VNMA RNMA	RCMX SCMN	TCMM CCMN SCMN DCMN RCMN 52	TCMN CCMN SCMA DCMN VDMN 53	TCMA -71 KNOX DCMA VBMA	KNMX -12 -11	KNUX
Correction Factor	.95	.95	.85	.87	.85	.97	1.00	1.10	.90	.83	.95	.85	.80		

k_sCORRECTION FACTORS FOR ENTERING ANGLES

ENTERING ANGLE	90°	75°	72°	60°	45°	93° 95°	ROUND
Correction Factor	1.0	.96	.94	.86	.70	1.0	

ROUND:

a/D	Factor
.05	.22
.10	.32
.20	.43
.30	.52
.40	.59
.50	.63

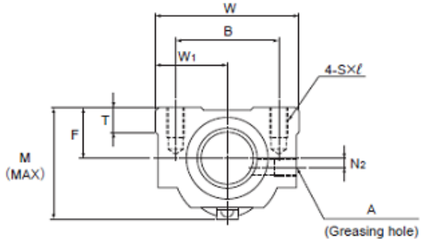
k_sCORRECTION FACTORS FOR FEED RATES

Feed rate	0.1	0.15	0.2	0.25	0.3	0.35	0.4
Correction Factor	1.49	1.32	1.22	1.14	1.08	1.03	1.00
Feed rate	0.5	0.6	0.7	0.8	1.0	102	1.4
Correction rate	.94	.89	.85	.82	.77	.72	.69

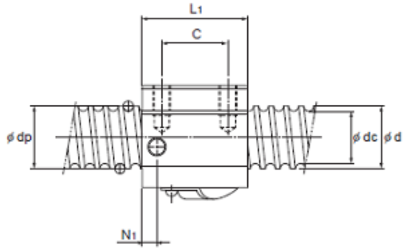
Appendix 2

No Preload Type of Precision Ball Screw (Square Nut)

Screw shaft outer diameter	14 to 45
Lead	4 to 12



BNT



BNT

Unit: mm

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
14	4	BNT 1404-3.6	14.4	11.5	1×3.65	6.8	12.6	190
	5	BNT 1405-2.6	14.5	11.2	1×2.65	7.2	12.6	150
16	5	BNT 1605-2.6	16.75	13.5	1×2.65	7.8	14.7	170
18	8	BNT 1808-3.6	19.3	14.4	1×3.65	18.2	34.4	270
20	5	BNT 2005-2.6	20.5	17.2	1×2.65	8.7	18.3	200
	10	BNT 2010-2.6	21.25	16.4	1×2.65	14.7	27.8	220
25	5	BNT 2505-2.6	25.5	22.2	1×2.65	9.6	23	240
	10	BNT 2510-5.3	26.8	20.2	2×2.65	43.4	92.8	520
28	6	BNT 2806-2.6	28.5	25.2	1×2.65	10.1	25.8	270
		BNT 2806-5.3	28.5	25.2	2×2.65	18.3	51.6	510
32	10	BNT 3210-2.6	33.75	27.2	1×2.65	27.3	59.5	330
		BNT 3210-5.3	33.75	27.2	2×2.65	49.6	118.9	640
36	10	BNT 3610-2.6	37	30.5	1×2.65	28.7	65.6	360
		BNT 3610-5.3	37	30.5	2×2.65	52.1	131.2	700
45	12	BNT 4512-5.3	46.5	39.2	2×2.65	68.1	186.7	860

Model No.	Nut dimensions: Width W	Center height F	Overall length L_1	Mounting hole B	Mounting hole C	Mounting hole S×ℓ	W_1	T	M	N_1	N_2	Greasing hole A	Screw shaft inertial moment/mm kg•cm²/mm	Nut mass kg	Shaft mass kg/m
BNT 1404-3.6	34	13	35	26	22	M4×7	17	6	30	6	2	M6	2.96×10^{-4}	0.15	0.93
BNT 1405-2.6	34	13	35	26	22	M4×7	17	6	31	6	2	M6	2.96×10^{-4}	0.15	0.92
BNT 1605-2.6	42	16	36	32	22	M5×8	21	21.5	32.5	6	2	M6	5.05×10^{-4}	0.3	1.24
BNT 1808-3.6	48	17	56	35	35	M6×10	24	10	44	8	3	M6	8.09×10^{-4}	0.47	1.46
BNT 2005-2.6	48	17	35	35	22	M6×10	24	9	39	5	3	M6	1.23×10^{-3}	0.28	2.06
BNT 2010-2.6	48	18	58	35	35	M6×10	24	9	46	10	2	M6	1.23×10^{-3}	0.5	1.99
BNT 2505-2.6	60	20	35	40	22	M8×12	30	9.5	45	7	5	M6	3.01×10^{-3}	0.41	3.35
BNT 2510-5.3	60	23	94	40	60	M8×12	30	10	55	10	—	M6	3.01×10^{-3}	1.18	2.79
BNT 2806-2.6	60	22	42	40	18	M8×12	30	10	50	8	—	M6	4.74×10^{-3}	0.81	4.42
BNT 2806-5.3	60	22	67	40	40	M8×12	30	10	50	8	—	M6	4.74×10^{-3}	0.78	4.42
BNT 3210-2.6	70	26	64	50	45	M8×12	35	12	62	10	—	M6	8.08×10^{-3}	1.3	4.98
BNT 3210-5.3	70	26	94	50	60	M8×12	35	12	62	10	—	M6	8.08×10^{-3}	2.0	4.98
BNT 3610-2.6	86	29	64	60	45	M10×16	43	17	67	11	—	M6	1.29×10^{-2}	1.8	6.54
BNT 3610-5.3	86	29	96	60	60	M10×16	43	17	67	11	—	M6	1.29×10^{-2}	2.4	6.54
BNT 4512-5.3	100	36	115	75	75	M12×20	50	20.5	80	13	—	M6	3.16×10^{-2}	4.1	10.56

For model number coding, see A15-248.

Ball Screw

Options⇒A15-351

Appendix 3

Leadshine

Datasheet of the Easy Servo Motor

ES-M Series

Stepper Motor with Encoder, 0.9 - 8 Nm

Version 1.3

http://www.Leadshine.com

Motor Specifications

Part Number	Phase	Step Angle (°)	Leads	Holding Torque (N.m)	Phase Current (A)	Phase Resistance (Ohm)	Phase Inductance (mH)	Rotor Inertia ($kg.cm^2$)	Weight (Kg)	Shaft Diameter (mm)
ES-M32309	3	1.2°	3	0.9	5.8	0.37	0.92	0.3	0.9	8
ES-M32320	3	1.2°	3	2.0	5.8	0.62	1.85	0.5	1.35	8
ES-M22430	2	1.8°	4	3.0	3	0.39	1.71	0.52	1.5	8
ES-M23440	2	1.8°	4	4.0	5.5	0.46	4.0	1.5	2.5	14
ES-M23480	2	1.8°	4	8.0	6.0	0.44	3.73	2.7	4.0	14