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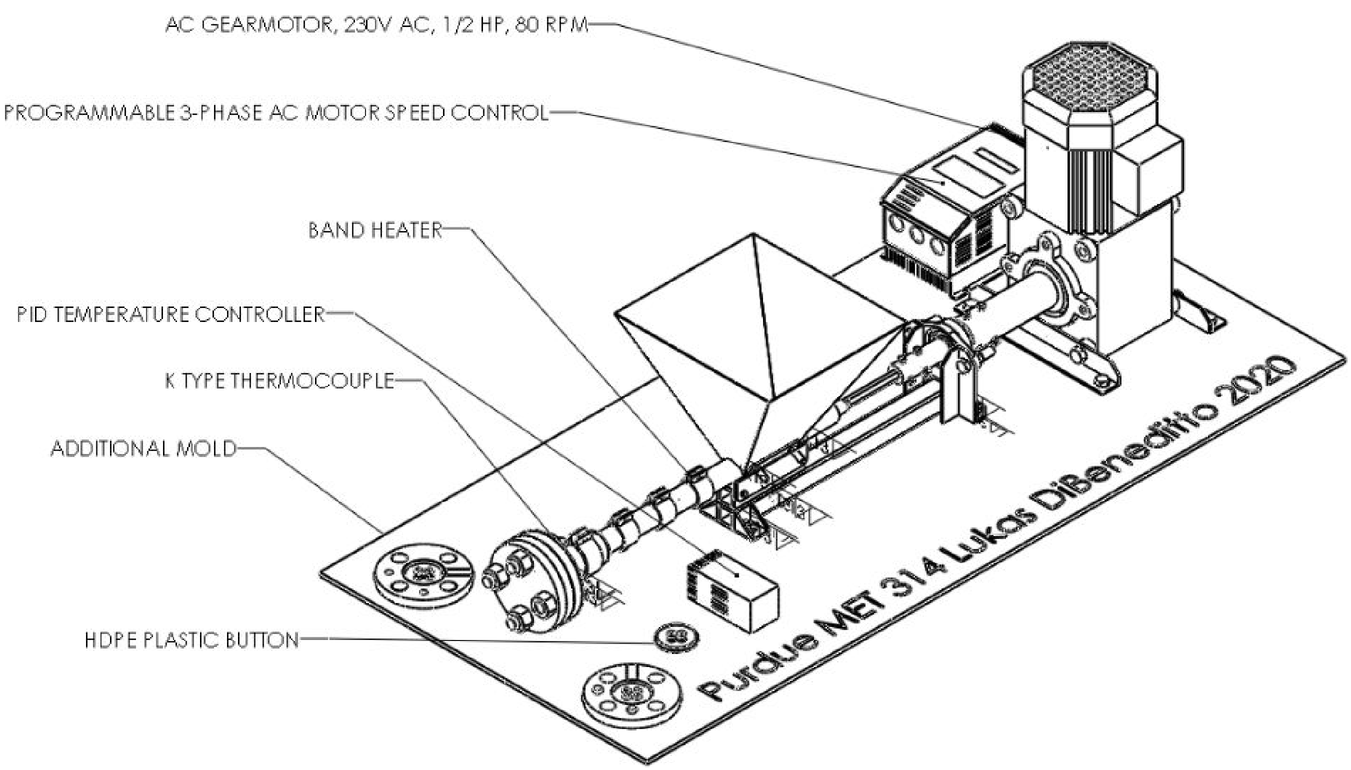
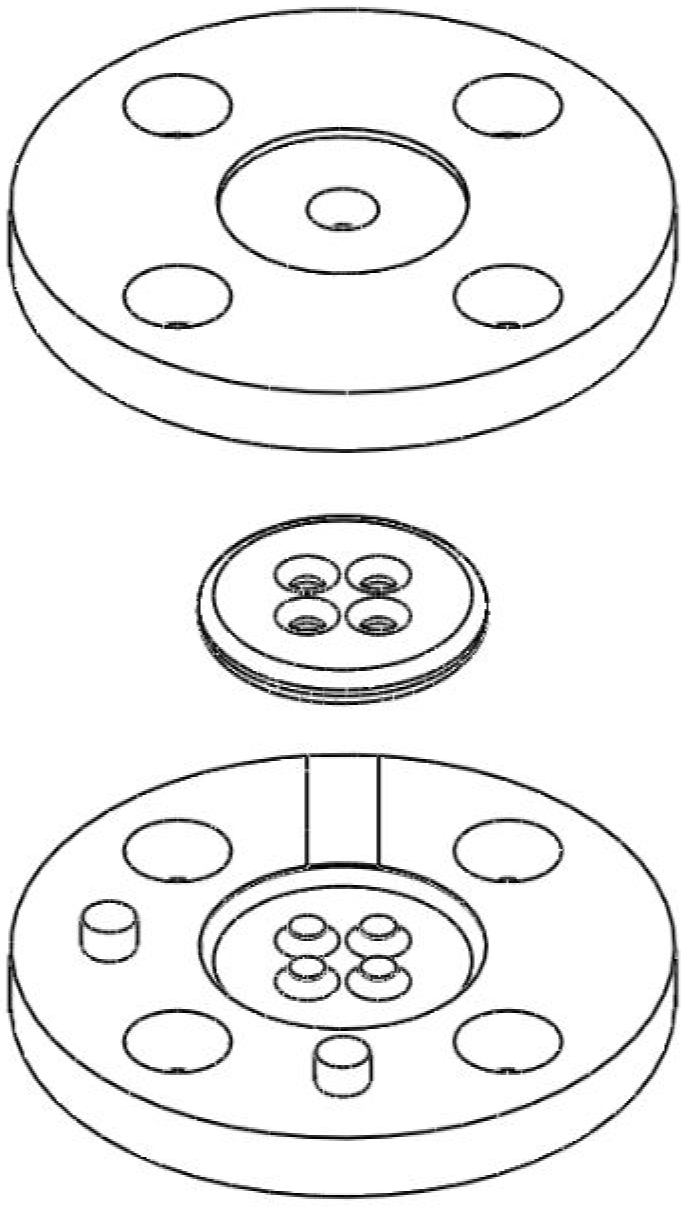
MET 314 Application of Machine Elements
05 May 2020

Final Project: Precious Plastic Extruder



Complete system with annotations of some components.



Aluminum mold for making recycled HDPE plastic buttons.

2020-05-04
MET 314
Lukas DiBenedetto
Professor Sisk

Final Project

Precious Plastic

From Brightspace Course Webpage

"Work with your groups to design and build one of the machines developed by Precious Plastics. You must design at least 3 machine elements using the methods learned in class. Some ideas are: bearings, belts, shafts, brakes, tolerances, gears, keys, springs, etc."

"In addition you must design a plastic part, and any molds / forming tools needed to create the part. Your mold must be compatible with one of the machines built by the class; it does not have to be compatible with your machine."

"Your grade will be based on the:

Design computation of 3 elements 50%

Complete Solidworks design of your machine 40%

Detailed solidworks design of mold for part 10%"

Note: Modified due to the Pandemic, making in person ~~classes~~ classes not possible.

Additional Instructions Per Professor Sioh

Solidworks design

Not required

Drawings

Wires

Solid State Relay

Every nut and Bolt

Ex: The Bolts and Nuts on the heating elements.

Required

Holes for Bolts

Rotating shaft

Note I based some designs on [PPGH], and the toolbox, and McMaster Carr 660N530 key shaft, (I modled the motor). So of the 45 CAD files, I personally drew 39 of them for a total of approximately 120 hours of CAD work.

Allowed

written calculations, formal document not required, for example a word document is not required.

→ Calculated machine elements do not have to match elements in solidworks if an reasonable equivalent is used.

Sources:

[IMH] Injection molding Handbook pp151-220
Dominick V. Rosato, Marlene G. Rosato

link.springer.com/chapter/10.1007%2F978-1-4615-4597-2_3

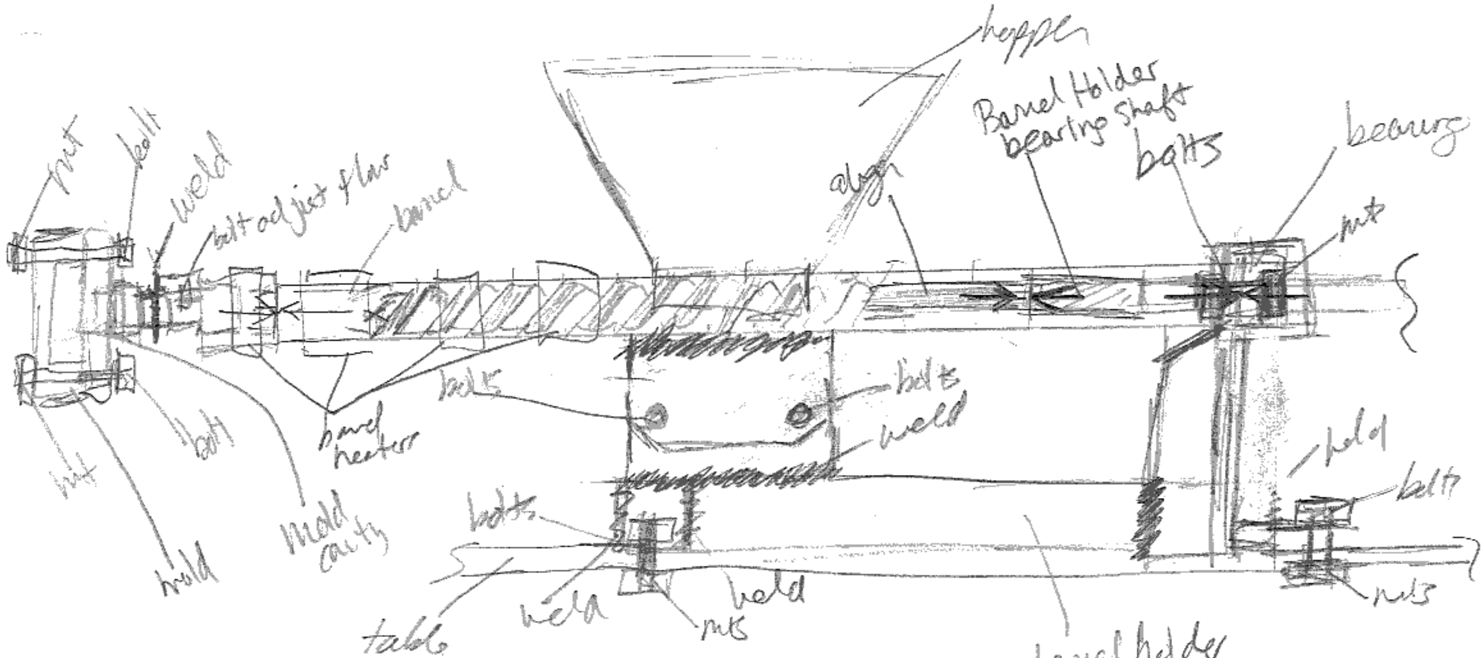
Single stage reciprocating screw
plastic fed through screw to shot chamber (front of screw), ... screw motion generates controllable low pressure (usually 50 to 300 psi, 0.34 to 2.07 MPa)

[DYNISCO] The Dynisco Extrusion Processors Handbook 2nd Edition by John Goff and Tony Whelan
Edited by Tim Delaney

www.dynisco.com/userfiles/files/27429_Legacy_Txt.pdf

[Textbook] Machine Elements in Mechanical Design Fifth Edition
Robert L. Mott (2014) Pearson.

[PPGH] Precious Plastic kit 3.Build 4. Extrusion master
ONE ARMY Github.
github.com/ONEARMY/precious-plastic-kit/tree/master/3.%20Build/4.%20Extrusion



For Referance Only
Not to Scale

Forces from Auger and Backpressure from HDPE plastic Injecting into mold, find Force

Assuming motor is rotating shaft at ~80 rpm

Viscosity of HDPE plastic at optimal melt temperature of ~240°C [dynisco], and acting as non-newtonian fluid

pressure range 0.34 mPa to 2.07 mPa [Im H]

Given

Motor from [PP6H] and McMaster model AC Gearmotor model #6660N530 mcmaster.com/6660n53

Inner Diameter of Barrel ID = 20.1168 mm

Pressure $P = \frac{\text{Force } F}{\text{Area } A}$

$$P = \frac{F}{A} \longrightarrow F = P \cdot A$$

$$P = P_{AVG.} = \frac{P_1 + P_2}{2} = \frac{(0.34\,mPa + 2.07\,mPa)}{2} = 1.205\,mPa$$

$$A = \frac{\pi D^2}{4} = \frac{\pi (ID)^2}{4} = \frac{\pi\,(20.1168\,mm)^2}{4} \cong 317.8394\,mm^2$$

$$\therefore F = 1.205\,mPa \cdot 317.8394\,mm^2$$

$$= 1.205 \times 10^6\,Pa \cdot 3.178394 \times 10^{-4}\,m^2$$

$$\cong 382.9965\,Pa \cdot m^2 \cdot \frac{N/m^2}{1\,Pa}$$

$$\boxed{F = 382.9965\,N}$$

QED

The Motor that was selected for this system is a McMaster-Carr AC Gearmotor, that Fits 1-1/4" Diameter Shaft, 230V AC, 1/2 hp, 80 rpm

https://mcmaster.com/6660n57

Since the Force calculation was in metric and the motor is in english I must choose to convert either English to metric or Metric to English.

Power P $1\,hp \cong 745.7\,W$

$$P = \text{Given } 1/2\,hp \cdot \frac{745.7\,W}{1\,hp} = 372.85\,W = \boxed{372.85\,N \cdot \frac{m}{s}}$$

Rotational Speed n, $1\,rev = 2\pi\,rad$, $1\,min = 60s$

pg20 $$n = 80\,rpm = 80\,\frac{rev}{min} \cdot \frac{2\pi\,rad}{1\,rev}\,\frac{1\,min}{60s} = 8.3776\,\frac{rad}{s}$$

pg 92 $$\text{Torque } T = \frac{\text{Power } P}{\text{Speed } n} \rightarrow T = \frac{P}{n} = \frac{372.85\,N \cdot \frac{m}{s}}{8.3776\,\frac{rad}{s}}$$

$$\boxed{T = 44.5235\,N \cdot m}$$

$T = 32.8388\,ft \cdot lbf$

$T \cong 394.07\,in \cdot lbf$

QED

I.) Machine Element <u>Bearing</u>

Select a Bearing.

<u>Given</u> Force acting axial on a shaft

$F = 382.9965\,N$

Assumptions Per Prof. Sisk Instructions

No Inertia of Signifigance

System operating at Steady State

Constant Rotational Velocity

No radial loads

There is not a procedure in the textbook that specifies what to do when there are No radial loads. Hence procedure specified on pg 517 for "Procedure for selecting a bearing - radial and thrust load" has been adapted for use, because it is the closest procedure.

See Note Next page

Step 1.) Value of $Y = 1.50$ assumed

Step 2.) Compute $P = VXR + YT$

where P = equivalent load
V = rotation factor
R = applied radial load
Y = thrust factor
T = applied thrust load

→

Since $VXR = 0$

$$P = VXR + YT \rightarrow P = YT$$

$$P = YT = 1.50 \cdot 382.9965\,N$$

$$\boxed{P \cong 574.4948\,N}$$

Note: I understand that equation 14-5 from pg 516

$$P = VXR + YT$$

that it is used "when both radial and thrust loads are exerted on a bearing, the equivalent load is the constant radial load that would produce the same rated life for the bearing as the combined loading."

Hence assuming the design of the bearing or thrust bearing can be selected by thrust loads and comparing Dynamic C Basic load ratings would be sufficient, I am still going to follow the design procedure in the book as no other design procedure were specified by Professor Sisk, for only thrust loads.

Dynamic C from pg 512 to 514 table.

→

Step 3. Compute required basic dynamic load rating C
eq 14-3 pg 515

$$C = P_d \left(\frac{L_d}{10^6}\right)^{1/k}$$

where C = basic dynamic load rating

P_d = given design load

L_d = design Life

$k = 3.00$ for ball bearings as per pg 515

Recommended Design Life for Bearings
table 14-4 pg 515
general industrial machine

$L_{10,h}$ = 20 000 to 30000 hours

$L_{10,h} = 20000\,h$ Selected

Using $P = 574.4948N$ rpm = 80rpm
and setting $P_d = P$ $L_{10h} = h$

The "number of design revolution for the bearing" pg 515

$$L_d = (h)(rpm)\left(60\left(\frac{min}{h}\right)\right)$$

$$L_d = (20{,}000)(80rpm)\left(60\left(\frac{min}{h}\right)\right)$$

$$L_d = 9.6 \times 10^7 rev$$

$$C = 574.4948N\left(\frac{9.6 \times 10^7 rev}{10^6}\right)^{1/3}$$

$$C \triangleq 2630.5295\,N \cong 2.630\,kN$$

→

Step 4. Select a candidate bearing having a value of C at least equal to the required value from pg 512 to 514

Pg 512 The closest Dynamic C value to 2.630 kN is Bearing number 6300 with a Dynamic C of 3.40 kN

$$2.630\,kN < 3.40\,kN \checkmark$$

$$\frac{2.630\,kN}{3.40\,kN} = 0.7735 = 77.35\%$$

Step 5. For the selected bearing, determine C_o

pg 512 Bearing number 6300 has a Basic load rating $C_o = 8.06\,kN$

Step 6. Compute $\frac{T}{C_o}$ where $T = 382.9965\,N \cong 0.3830\,kN$

$$\frac{T}{C_o} = \frac{0.3830\,kN}{8.06\,kN} = 0.0475 \quad (ND)$$

Step 7. From table 14-5 determine e pg 517

Interpolating

e_{table}	$T/C_{o\,table}$
0.22	0.028
e	0.0475
0.26	0.056

Interpolated

$e \cong 0.2479$

→

Step 8. If $T/R > e$ then determine Y from table 14-5

$$\frac{T}{R} = \frac{0.3830\,kN}{0\,kN}$$ is undefined because you cannot divide by zero.

As per Professor Fisk webex on 5/4/2020 ~@3:30pm
Cannot do step 8., cannot substitute 0kN for 1kN

Therefor
Interpolating Y from table 14-5 is the only thing I can do, since other procedure has not been specified.

Y_{table}	$\frac{T}{C_0}$ table
1.99	0.028
Y	0.0475
1.71	0.056

Interpolated
$Y = 1.795$

Step 9. If the new value of Y is different from that assumed in step 1, repeat the process

→ Step. 1 $Y = 1.795$

Step. 2 $P = VXR + YT \rightarrow P = YT$
$P = 1.795 \cdot 382.4948\,N$
$P \cong 686.5782\,N$

Step 3. $C = 2.630\,kN$ no change

Step 4. Again closest is still Bearing number 6300
$C = 3.40\,kN$
$C_0 = 8.06\,kN$

Step 6. $\frac{T}{C_0} = 0.0475$

→

↳ Step 7. $e = 0.2479$ still

Step 8. $\frac{T}{R} > e$ is still not possible

Step 9. $Y = 1.795$ still

Step 10. $T/R < e$ doesn't make sense to do

equation 14-4 but OK

$P = VR$ $V = 1.0$ pg 516 $R = \emptyset N$

$P = 1.0 \cdot \emptyset N$

$P = \emptyset N$

Hence my original Note: Selecting a bearing based on Dynamic C alone is sufficient.

Per the ~~Design~~ Procedure instructions

Bearing 6300 Single row, deep grove ball bearing

Thrust Bearing

Mounted in a Pillow Block

Bearing material SAE 52100 pg 509 recommendation

Note no metric equivalent could be found online or in the textbook to my knowledge.

However per pg. 527 Section 14-17

Bearing 51000 Ball thrust Bearing may also be selected.

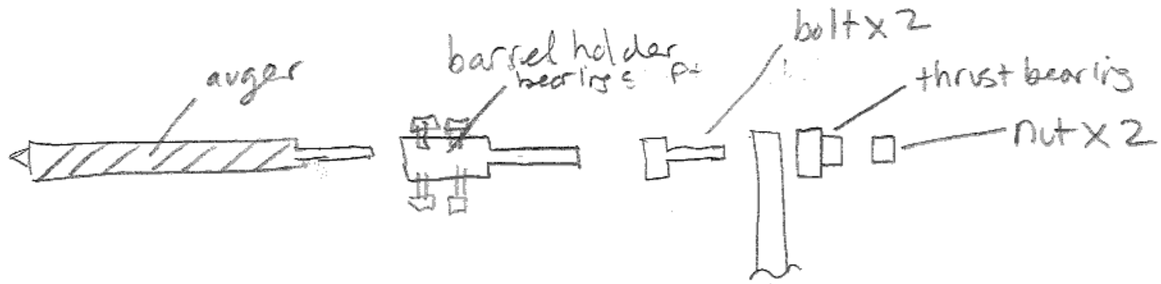
Professor Sish, if you provide me with another procedure I will use that. To my knowledge you have not.

QED

II. Machine Element Fastener

Per professor Sioh

Assume 100% of the force from the HDPE plastic to the auger to the barrel holder bearing shaft to the thrust bearing to the barrel holder frame



For Reference Only, Not to scale

Given $F = 382.9965N$

Since the load is shared equally between 2 bolts.

$$F_{PB} = \frac{382.9965N}{2} \cong 191.4983\,N$$

From pg 632 table 19-3 metric grades of steels for Bolts grade 4.6 selected for Bolt size M5 to M36

T = Tensile Strength 400 mPa

Yield Strength 240 mPa approximate since not in the standard

Proof Strength 225 mPa

→

Using the procedure ...

From pg 635 ex 19-1 since no other design procedures have been specified by Professor Sisk to my recollection:

If each bolt is to be stressed to 75% of its proof strength, compute the tightening torque.

$$\sigma_a = 0.75(225 mPa)$$

$$\sigma_a = 168.75 MPa = 1.6875 \times 10^8 Pa = 1.6875 \times 10^8 N/m^2$$

$$A_t = \frac{load}{\sigma_a} = \frac{F_{PB}}{\sigma_a} = \frac{191.4983 N}{1.6875 \times 10^8 N/m^2}$$

$$A_t = 1.1348 \times 10^{-6} m^2 = 1.1348 mm^2$$

Sanity check $1.1348 mm^2 \cong 0.0017593 in^2$ while extremely small the force which was verified as correct by Professor Sisk on webex 5/4/2020 this calculation does seem to be correct, which is derived from Injection molding hand book [IMH] of 0.34 to 2.07 MPa for screw motion.

From pg 634 table 19-5 metric sizes of screw threads M1 x 0.25 has a tensile area of $0.460 mm^2$ for coarse threads, which is the smallest listed on the table.

Therefore D = 1mm from pg 634 table 19-5 M1x0.25 Basic major diameter.

→

Professor Sesh Instructed me to solve for the k value even though in class we have been using $k = 0.15$ as per pg 635, using the Tensile strength of the material pg 635 eq 19-3 Tightening Torque for general mechanical design, and $T = 400$ MPa from table 19-3 pg 632

$$T = kDP$$

$$k = \frac{T}{DP} = \frac{T}{D\,F_{PB}} = \frac{400\text{ MPa}}{1\text{mm} \cdot 191{,}4983\text{N}}$$

$$k = \frac{4 \times 10^{8}\ \text{N/m}^2}{0.001\text{ m} \cdot 191.4983\text{ N}}$$

$$\frac{N/m^2}{m\ N} = \frac{1}{m^3} = m^{-3}$$

$$k = 2.0888 \times 10^{9}\ m^{-3}$$

Also Professor Sesh requested I find length

pg 638 eq 19-14 where we are assuming equal strength for Nut and bolt Material. Testing M1 x 0,25

L_e = length of engagement

A_{tB} = tensile stress area of bolt

D_{nom} = nominal diameter

pg 624 table 19-5
$A_{tB} = 0{,}460\text{ mm}^2$

$$L_e = \frac{4A_{tB}}{\pi P D_{nom}} = \frac{4A_{tB}}{\pi F_{PB} \cdot D}$$

$$L_e = \frac{4(0.460\text{mm}^2)}{\pi(191.4983\text{N})(1\text{mm})}$$

$$L_e = \frac{4(4.6 \times 10^{-7}\ m^2)}{\pi(191.4983\text{N})(0.001\text{m})}$$

$$L_e \cong 3.0585 \times 10^{-6}\ \frac{m}{N}$$

L_e represents the required length of engagement to develop at least full strength of the bolt

→

Pg 638 eq 19-15

The shear stress for the nut or bolt threads is

$$A_S = \pi P D_{nom} \frac{L_e}{2} = \pi F_{PB} D_{nom} \frac{L_e}{2}$$

$$A_S = \pi (191.4983N)(1mm)\left(3.0585 \times 10^{-6} \frac{m}{N}\right)/2$$

$$A_S = \pi (191.4983N)(0.001m)\left(3.0585 \times 10^{-6} \frac{m}{N}\right)/2$$

$$A_S = 9.2001 \times 10^{-7} m^2$$

$$A_S = 0.92 \ mm^2$$

Sanity check $0.92 mm^2 = 0.001426 \ in^2$, again while extremely small based upon available inputs this does seem to be correct.

Pg 634 table 19-5 metric sizes of screw thread.

M1.6 X 0.35 has a tensile stress area of $1.27 \ mm^2$ whereas the M1 X 0.25 has a tensile stress area of $0.460 \ mm^2$ therefore resizing to M1.6 X 0.35 is sufficient

$$\frac{A_{S,Required}}{A_{S,provided}} = \frac{0.92 \ mm^2}{1.27 mm^2} = 0.7244 = 72.44\%$$

Selection

M1.6 X 0.35. Grade 4.6 Steel
for both nut and bolt combination.

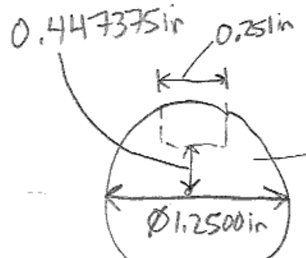
QED

III.) Machine Element Parallel Key

Even though the othe problems in this assignment are in metric, Professor Suh asked me to repeat this problem in English.

From pg 429 Design Procedure for Parallel Keys

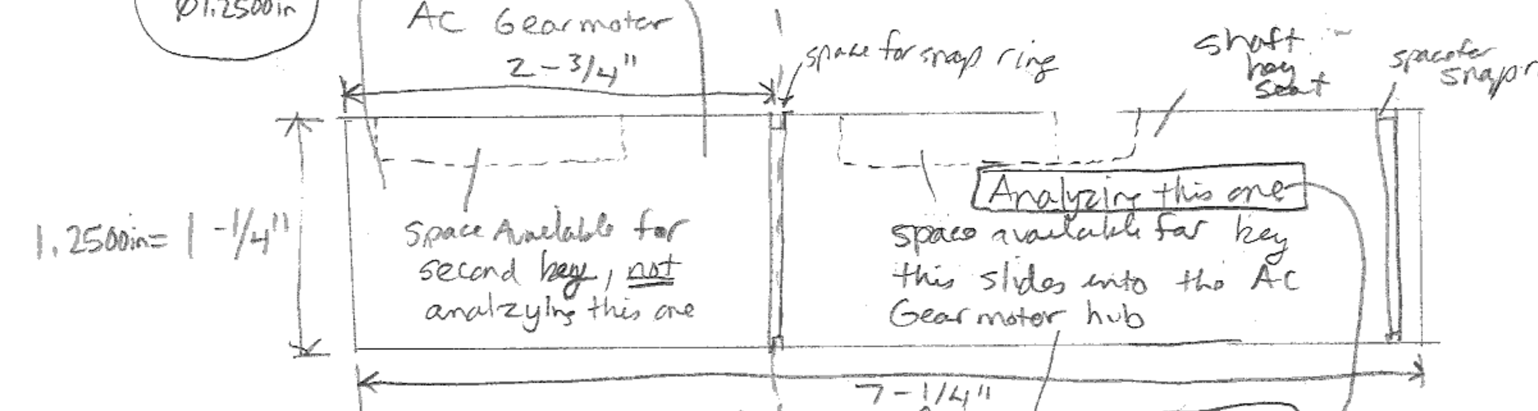
<u>Step 1.</u> Complete the design of the shaft into which the key will be installed, and specify the actual diameter at the location of the keyseat.



This is based on McMaster-Carr part number 6660N53

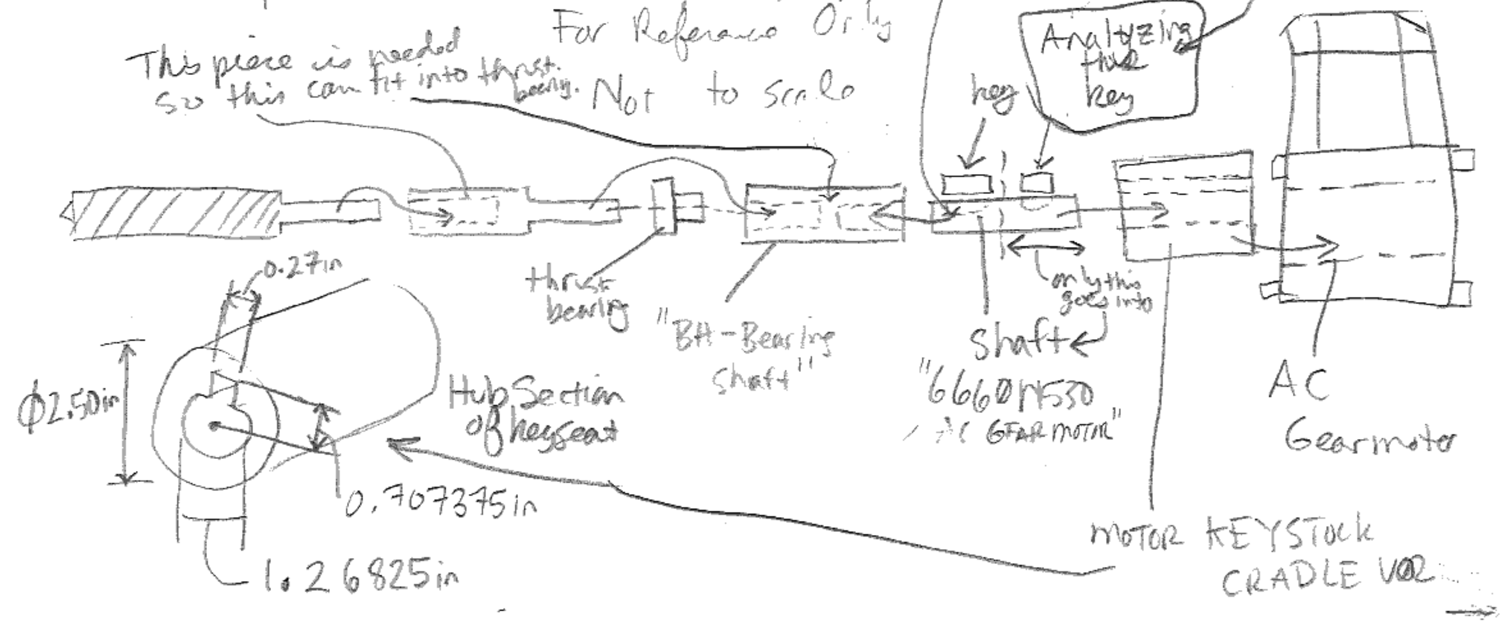
mcmaster.com/6660n53

Keyed shaft 1-1/4" Diameter, with key stock, for AC Gearmotor



For Reference Only

Not to Scale



pg 429

Step 2. Select the size of the key from table 11-1 pg 425

Key dimensions

Width $W = 0.2500$ in

height $H = 0.2500$ in

pg 429

Step 3. Specify a suitable design factor N. In typical industrial application $N=3$ is adequate to accomodate accidental overloads and shock.

$N = 3$

pg 429

Step 4. Specify the material for the key, usually SAE 1018 steel. A higher strength material can be used.

key material SAE 1018

Step 5. Determine the yield strength of the materials for the key, the shaft, and the hub.

per example 11-1 pg 430

Key material SAE 1018 $S_y = 54\,000$ psi table 11-4 pg 428

shaft material SAE 1040 cold drawn steel $S_y = 71\,000$ psi Appendix 3 pg. 725

Hub material SAE 8650 OQT 1000 steel $S_y = 155\,000$ psi Appendix 3 pg 726

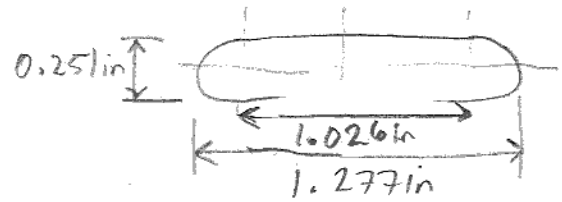
Step 6. If a square key is used ✓ and the key material has the lowest strength. ✓ Use equation 11-5 to compute the minimum required length of the key. This length will be satisfactory for both shear and bearing stress.

→

<u>Step 6.</u> cont.1 pg 429 eq. 11-5

$$L_{min} = \frac{4TN}{DWS_y}$$

The key is the weakest material of the key, shaft, and hub.

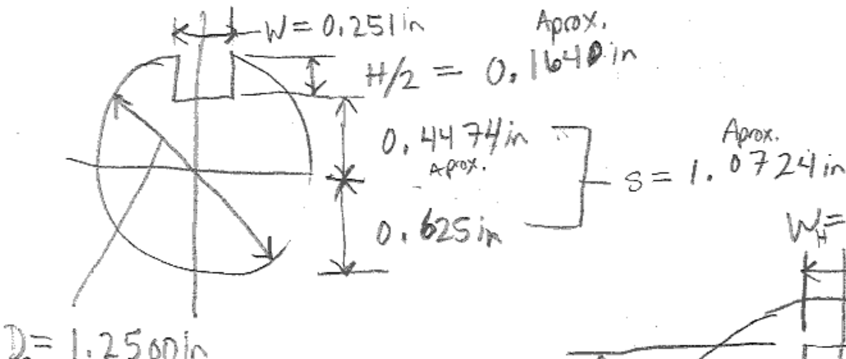


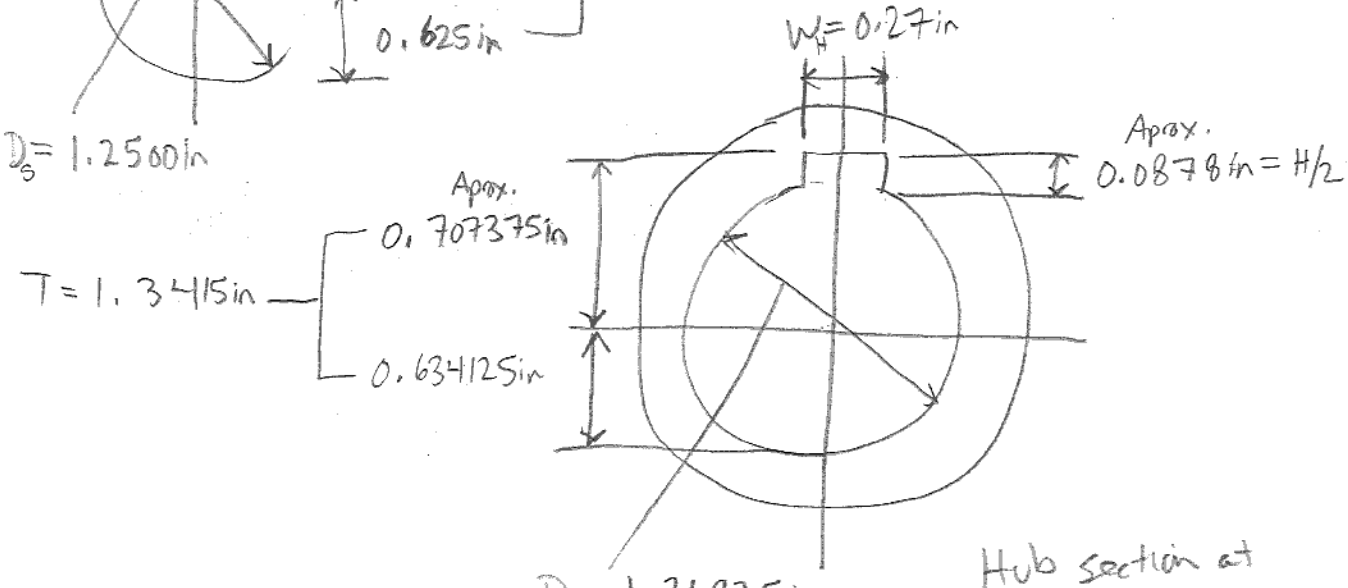
Top view of keyseat in shaft

From pg 6 of this assignment

Torque $T = 394.07$ in·lbf

Shaft section at keyseat





Hub section at keyseat

→

Step 6. Cont. 2

Used to calculate the minimum required length of the key

$$L_{min} \cong \frac{4TN}{D_s W S_y} \cong \frac{4(394.07\ in \cdot lb_f)(3)}{(1.25\ in)(0.251\ in)\left(54\,000\ \frac{lb_f}{in^2}\right)}$$

$L_{min} \cong 0.2791\ in$

Step 7.

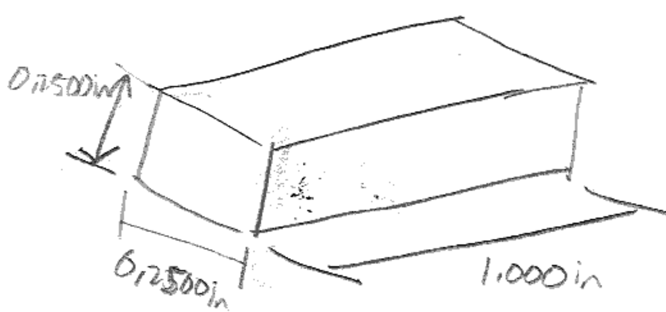
Eq. 11-2, 11-3, 11-4 pg 428-429 Not required

This length is significantly below the width available for a keyseat, since it could move inside the keyseat a design decision has been made to specify the length of the key at 1 in.

Step 8. Specify the actual length of the key

$L = 1.0000\ in$

0.2500 in × 0.2500 in × 1.0000 in



Note on precision

Per Class instructions 4 decimal places. However I would Normally specify this on prints to 3 decimal places.

Also per Step 8.

" The key should extend over all or a substantial part of the length of the hub. But the keyseat should not run into other stress raisers such as shoulders or grooves."

→

Step 9. Complete the design of the keyseat in the shaft and the keyway in the hub using the equations in fig 11-2 pg 426. ANSI Standard B17.1 should be consulted for standard tolerances on dimensions for the key and keyseats.

Chordal Height

Hub $$Y = \frac{D - \sqrt{D^2 - W^2}}{2}$$

$$Y = \frac{1.26825in - \sqrt{(1.26825in)^2 - (0.27in)^2}}{2} \cong 0.0145$$

Depth of shaft keyseat

Shaft $$S = D - Y - \frac{H}{2} = \frac{D - H + \sqrt{D^2 - W^2}}{2}$$

$$S = D - (H/2/2) - \frac{H}{2}$$

$$S = 1.25in - \left(\frac{0.1640in}{2}\right) - 0.1640in$$

$$S = 1.0040$$

Depth of hub keyseat

hub $$T = D - Y + \frac{H}{2} + C = \frac{D + H + \sqrt{D^2 - W^2}}{2} + C$$

$$T = D - (H/2/2) + \frac{H}{2} + C$$

$$T = 1.26825in - \left(\frac{0.0878in}{2}\right) + 0.0878in + 0.005in$$

$$T \cong 1.3172in$$

Where C = Allowance + 0.005in Clearance for parallel keys

→

Step 9 Cont. 1

Per ASME B17.1 - 1967
pg 426 table 11-2

$\frac{H}{2}$ keyseat depth $= \frac{H}{2}_{shaft} = 0.1640$ in

therefore Fillet radius $= 1/32$
45° chamfer $= 3/64$

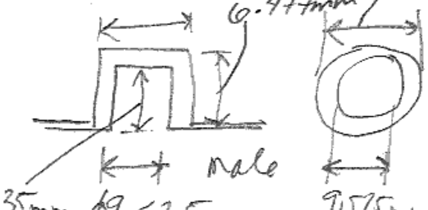
Step 10.

Selected

Parallel Square Key
Material: SAE 1018
Width: 0.250 in ± 0.0005 in
Height: 0.250 in ± 0.0005 in
Length: 1.000 in ± 0.0005 in
Fillet radius 1/32 in
45° Chamfer 3/64 in

QED

Ferrole ϕ 9,1755mm Φ9,7155mm



IV.) Tolerance and Fit in mold of registration marks

pg 496

Temperature increase required to produce a given increase for assembly

pg 496 eq 13-1

$$\delta = \alpha L(\Delta t)$$

δ = total deformation desired mm

α = coefficient of thermal expansion $\frac{mm}{mm} \cdot {}^\circ C$

L = nominal length of marks being heated in mm

Δt = temperature difference °C

Since same material they expand at the same rate in all directions causing no issue.

However

Assume Ambient temperature = 70°F → 21.11°C

Assume mold Aluminum 6061

$$\alpha = 23.4 \times 10^{-6} \frac{mm}{mm \cdot {}^\circ C}$$

Assume mold at optimal 240°C even though there will be a thermal gradient wave front propagation, assume enough time has passed to allow mold. thermal equalize at steady state

$$\delta = 23.41 \times 10^{-6} \frac{mm}{mm \cdot {}^\circ C} \; 6.35\,mm \cdot (240^\circ C - 21.11^\circ C)$$

$$\delta = 0.03252\ mm$$

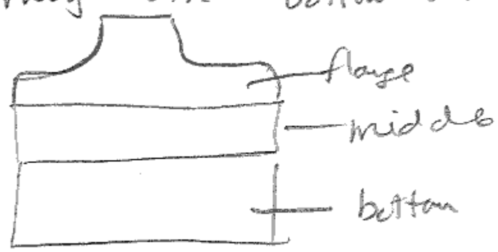
Assuming worse case non uniform thermal expansion

Clearance vertical = 6.477mm − 6.35mm = 0.127mm

Clearance round = 9.7155 mm − 9.525mm = 0.1905mm

→

Assuming Both Bottom and Middle mold



6061 Aluminum pg 734
modulus of Elasticity
$E = 69.0\ GPa = 69.0 \times 10^9\ Pa$

Tolerance for IT Grade pg 489
Assuming Eq 13-1 can be used for metric

$$T = \left[0.045\ D^{1/3} + 0.001\ D\right]\left[10^{(0.2(ITG-1))}\right]$$

T = tolerance in mm
D = mean dimension in mm of the range of nominal sizes in Table 13-2m
ITG = International Tolerance Grade Number 1 to 14

pg 489 specify Range of nominal size 6 - 10 mm

Tolerance Grade 4

Mean dimension Reference

8 mm

$$T = \left[0.045(8\ mm)^{1/3} + 0.001(8\ mm)\right]\left[10^{(0.2(4-1))}\right]$$

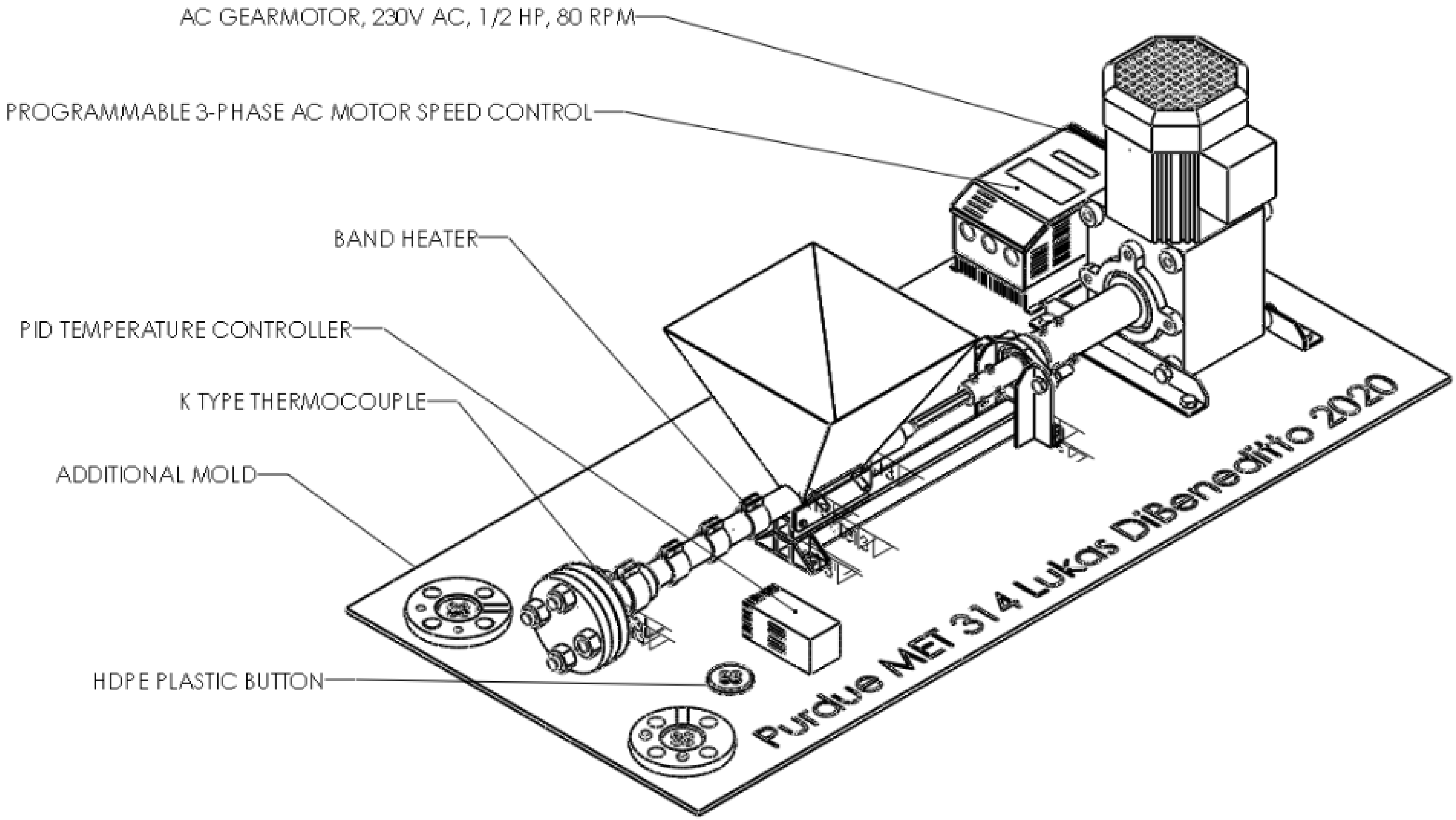
$$T = 0.3901\ mm$$

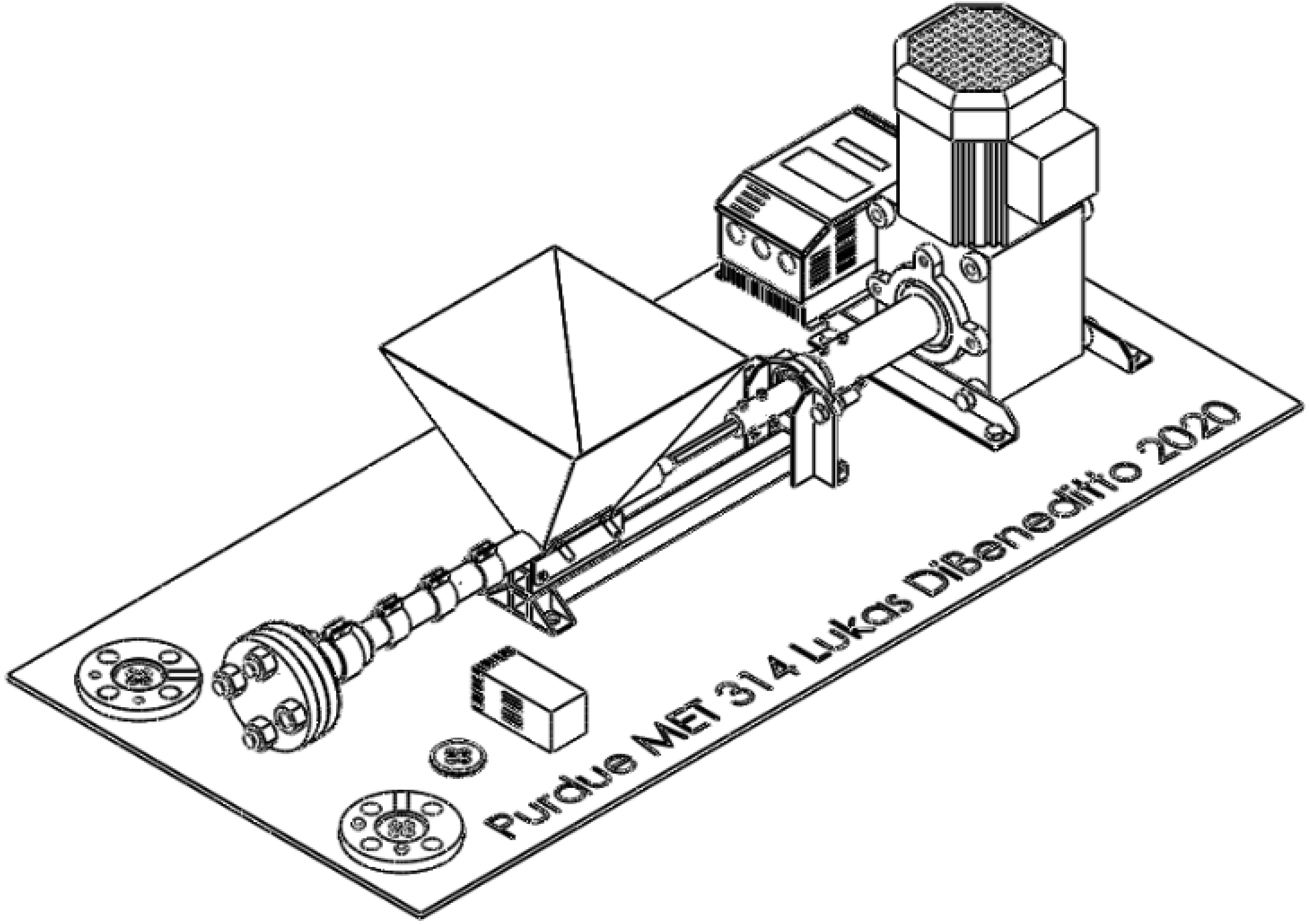
Grade 4

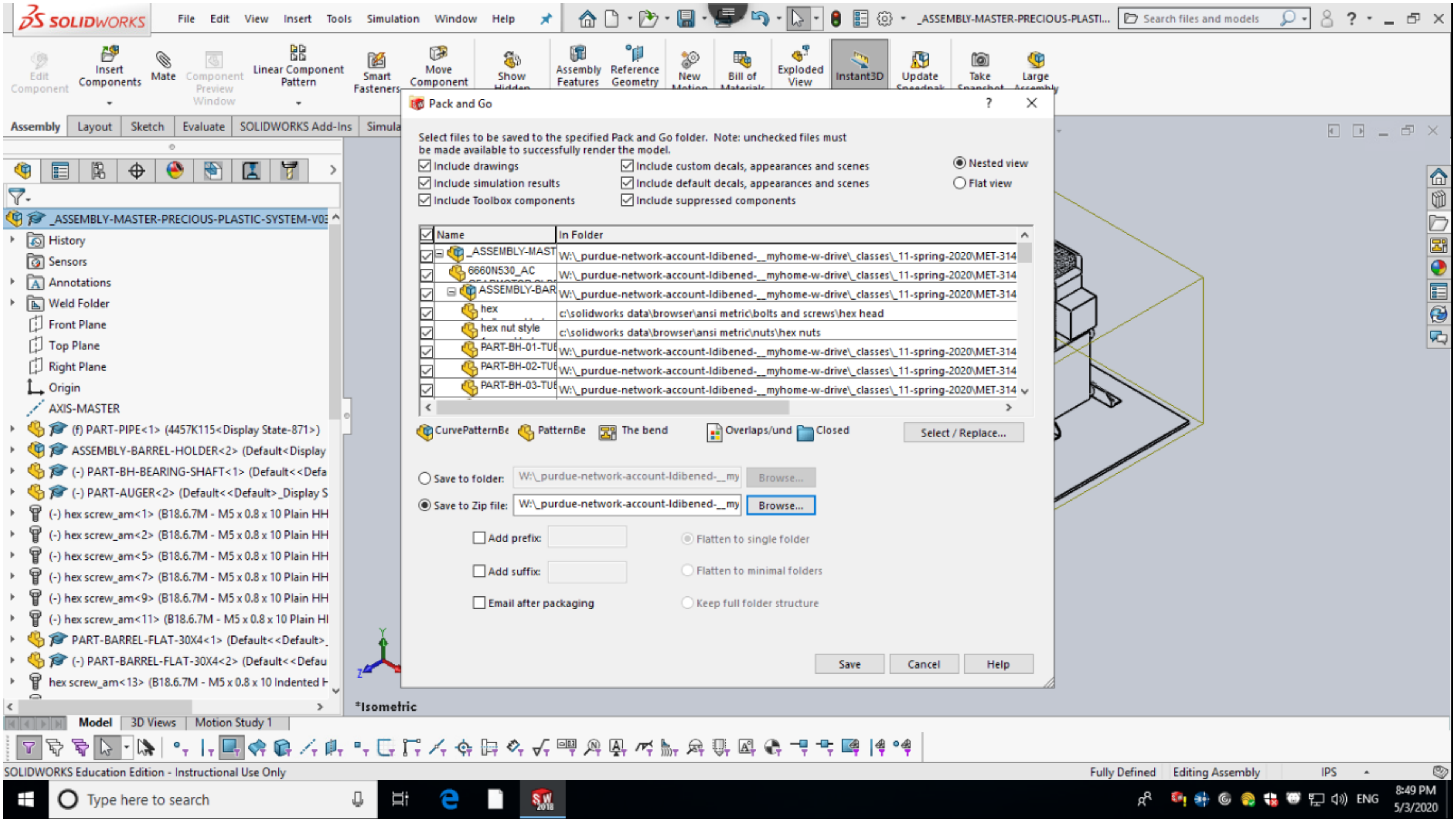
ϕ 9.525 mm $\pm$ 0.3901 mm , 6.35 mm $\pm$ 0.3901 mm

ϕ 9.1755 mm $\pm$ 0.3901 mm , 6.477 mm $\pm$ 0.3901 mm

QED


AC GEARMOTOR, 230V AC, 1/2 HP, 80 RPM
PROGRAMMABLE 3-PHASE AC MOTOR SPEED CONTROL
BAND HEATER
PID TEMPERATURE CONTROLLER
K TYPE THERMOCOUPLE
ADDITIONAL MOLD
HDPE PLASTIC BUTTON
Purdue MET 314 Lukas DiBeneditto 2020


Purdue MET 314 Lukas DiBeneditto 2020



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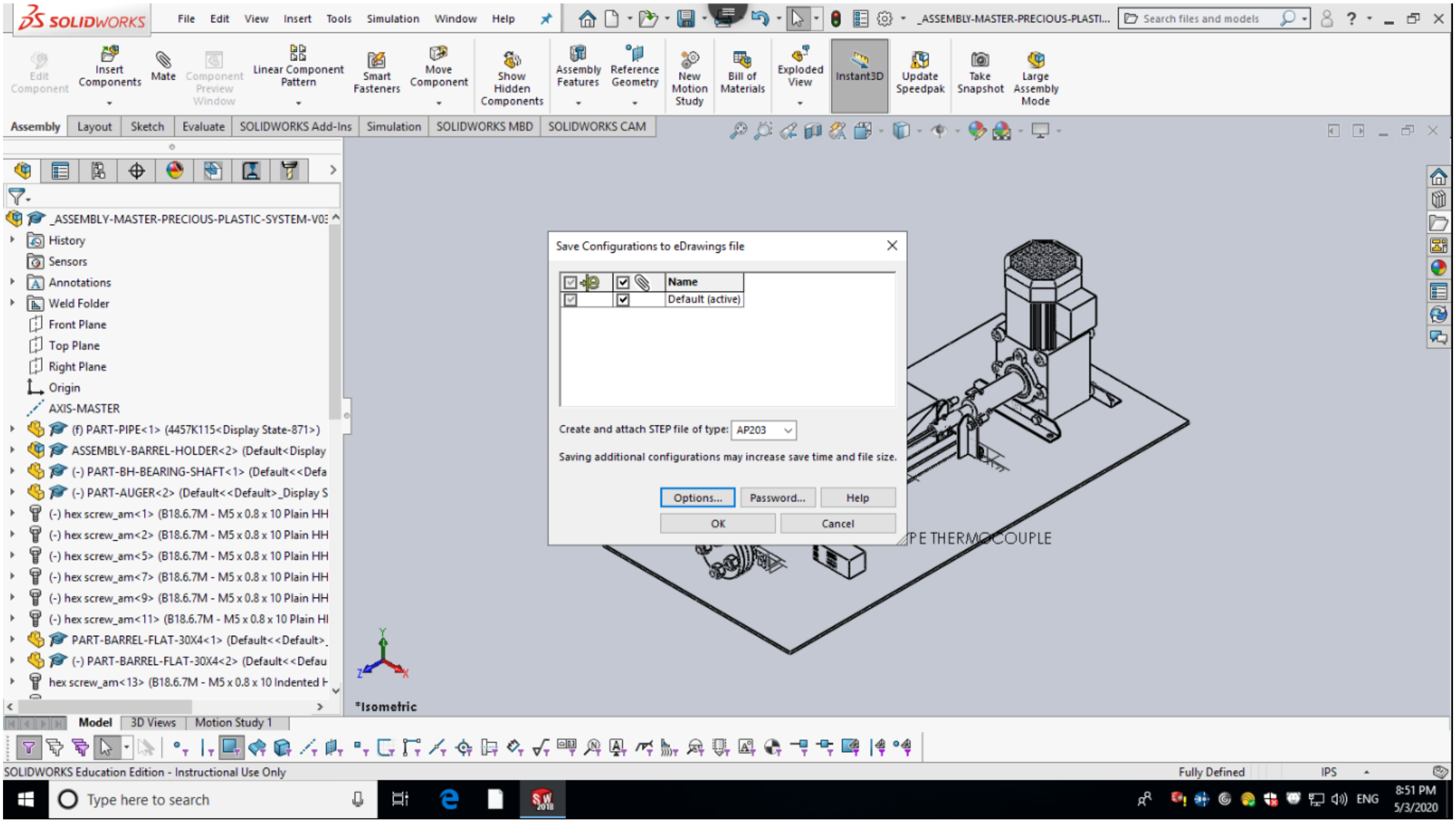
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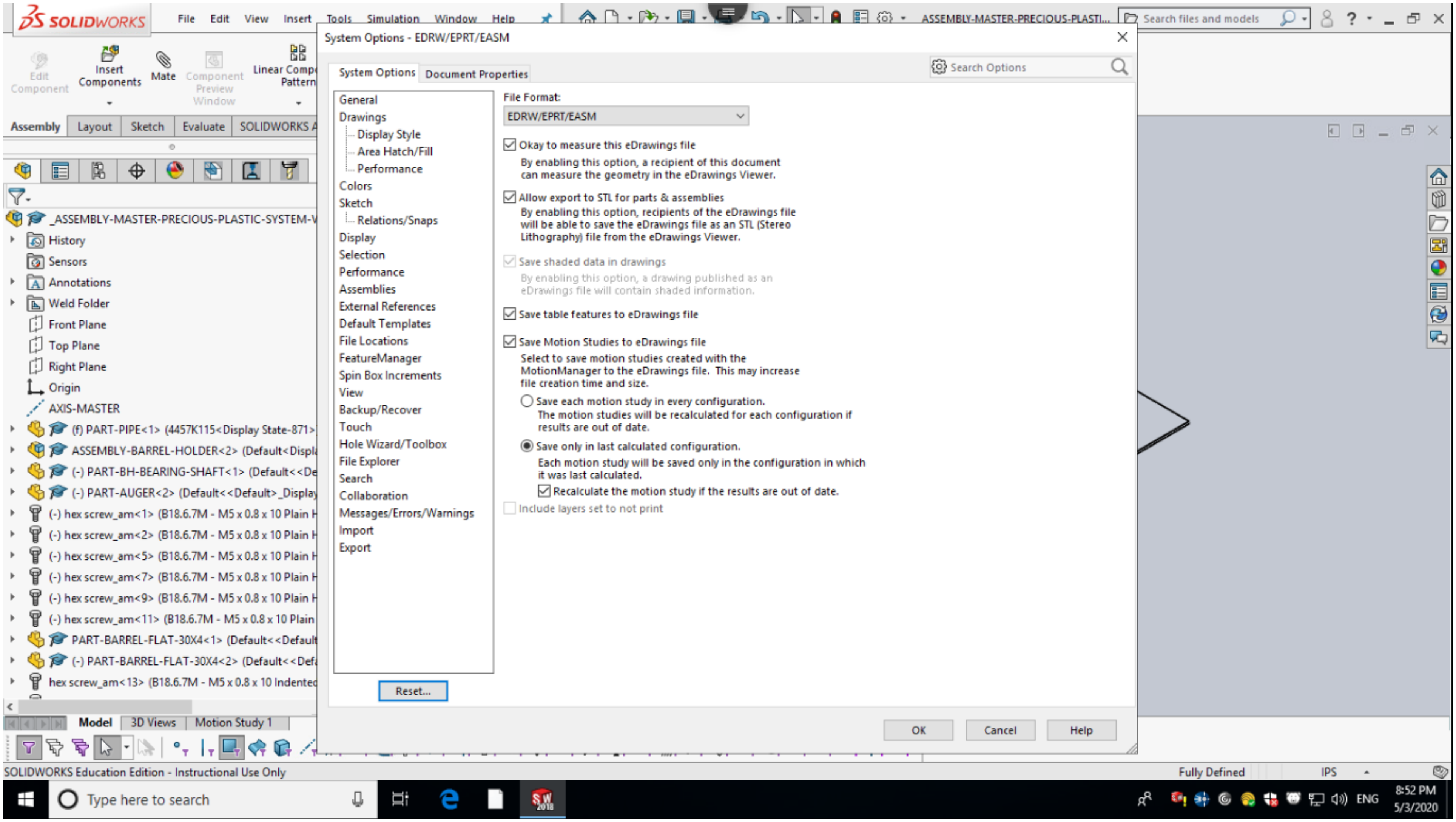
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Okay to measure this eDrawings file
By enabling this option, a recipient of this document can measure the geometry in the eDrawings Viewer.
Allow export to STL for parts & assemblies
By enabling this option, recipients of the eDrawings file will be able to save the eDrawings file as an STL (Stereo Lithography) file from the eDrawings Viewer.
Save shaded data in drawings
By enabling this option, a drawing published as an eDrawings file will contain shaded information.
Save table features to eDrawings file
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Select to save motion studies created with the MotionManager to the eDrawings file. This may increase file creation time and size.
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The motion studies will be recalculated for each configuration if results are out of date.
Save only in last calculated configuration.
Each motion study will be saved only in the configuration in which it was last calculated.
Recalculate the motion study if the results are out of date.
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Fully Defined
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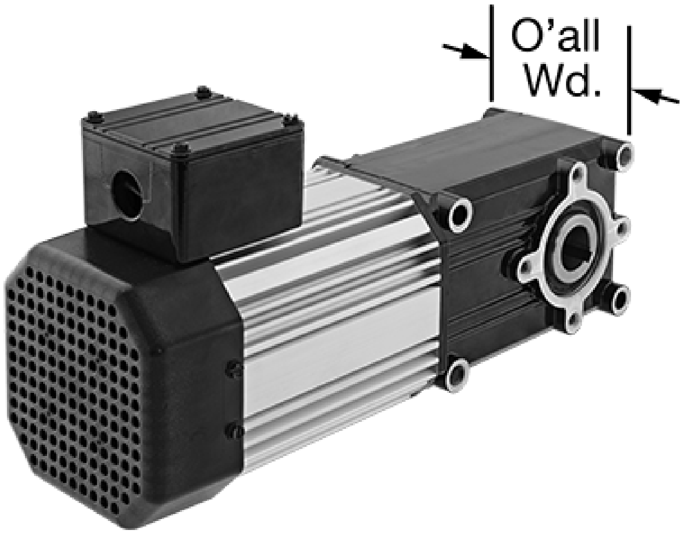
5/3/2020

McMASTER-CARR®

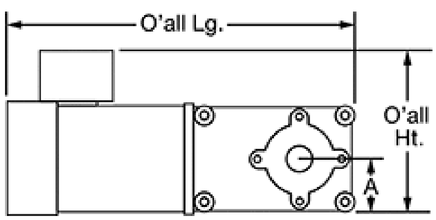
AC Gearmotor

Fits 1-1/4" Diameter Shaft, 230V AC, 1/2 hp, 80 rpm

$913.83 Each
6660N57



Gearmotor



Power Source	Electric
Mounting Style	Face, Flange
Voltage	230 Volts AC
Electrical Phase	Three
Power	1/2 hp
Speed @ Continuous Operating Torque	80 rpm @ 327 in.-lbs.
Starting Torque	894 in.-lbs.
Motor Enclosure Type	Totally Enclosed Fan Cooled (TEFC)
Full Load Current	1.9 A
Frequency	60 Hz
Electrical Connection Type	Hardwire
Wire Connection Type	Wire Leads
Inverter Rated	Yes
Duty Cycle	Continuous
Service Factor	1
Overall	
Length	13 3/4"
Width	6"
Height	7 3/4"
Mounting Orientation	Any Angle, Horizontal, Vertical
Enclosure Material	Anodized Aluminum
Gear	
Type	Hypoid
Material	Steel
Bearing Type	Ball and Roller
Output	
For Shaft Diameter	1 1/4"
Shaft Center to Base (A)	2.28"
Shaft Orientation	Right Angle
Direction of Operation	Clockwise or Counterclockwise
Insulation	
Class	F
Maximum Temperature	311° F
Specifications Met	IP54, UL Recognized Components
Country of Origin	United States
Related Product	Optional Keyed Shafts with Key Stock

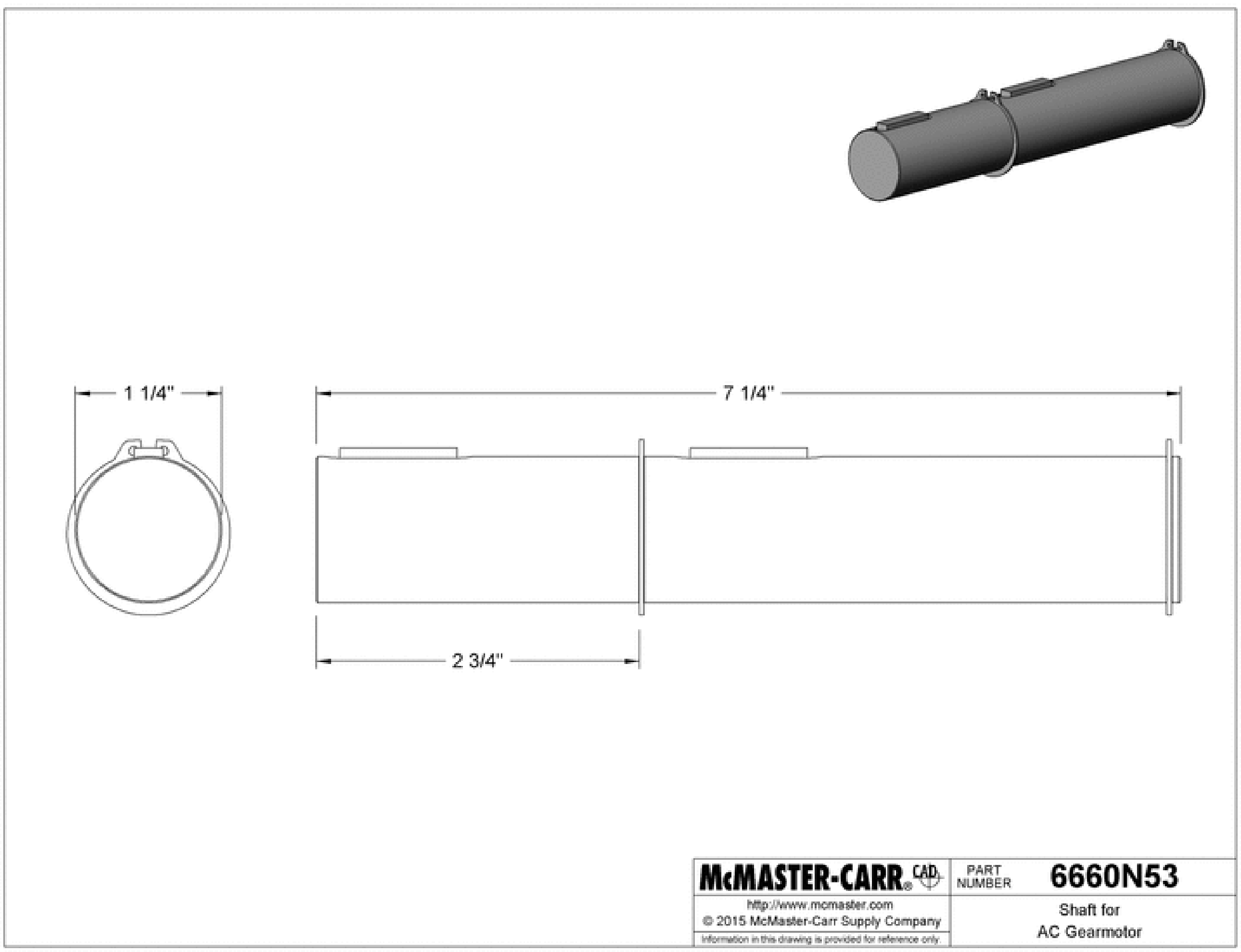
A motor and speed reducer in one, these gearmotors have hypoid gears for energy-efficient operation. You can use them to turn a shaft on your equipment or add a keyed shaft (sold separately). Wire for clockwise or counterclockwise rotation; instructions are included. Gearmotors meet IP54 for protection from dust and splashed water. They're inverter rated so you can use them with a motor speed control (not included) to adjust the motor speed.

Keyed Shaft, 1-1/4" Diameter, with Key Stock, for AC Gearmotor

$49.82 Each
6660N53

Country of Origin	United States

A motor and speed reducer in one, these gearmotors have hypoid gears for energy-efficient operation. You can use them to turn a shaft on your equipment or add a keyed shaft (sold separately). Wire for clockwise or counterclockwise rotation; instructions are included. Gearmotors meet IP54 for protection from dust and splashed water. They're inverter rated so you can use them with a motor speed control (not included) to adjust the motor speed.



The information in this 3-D model is provided for reference only.

McMASTER-CARR®

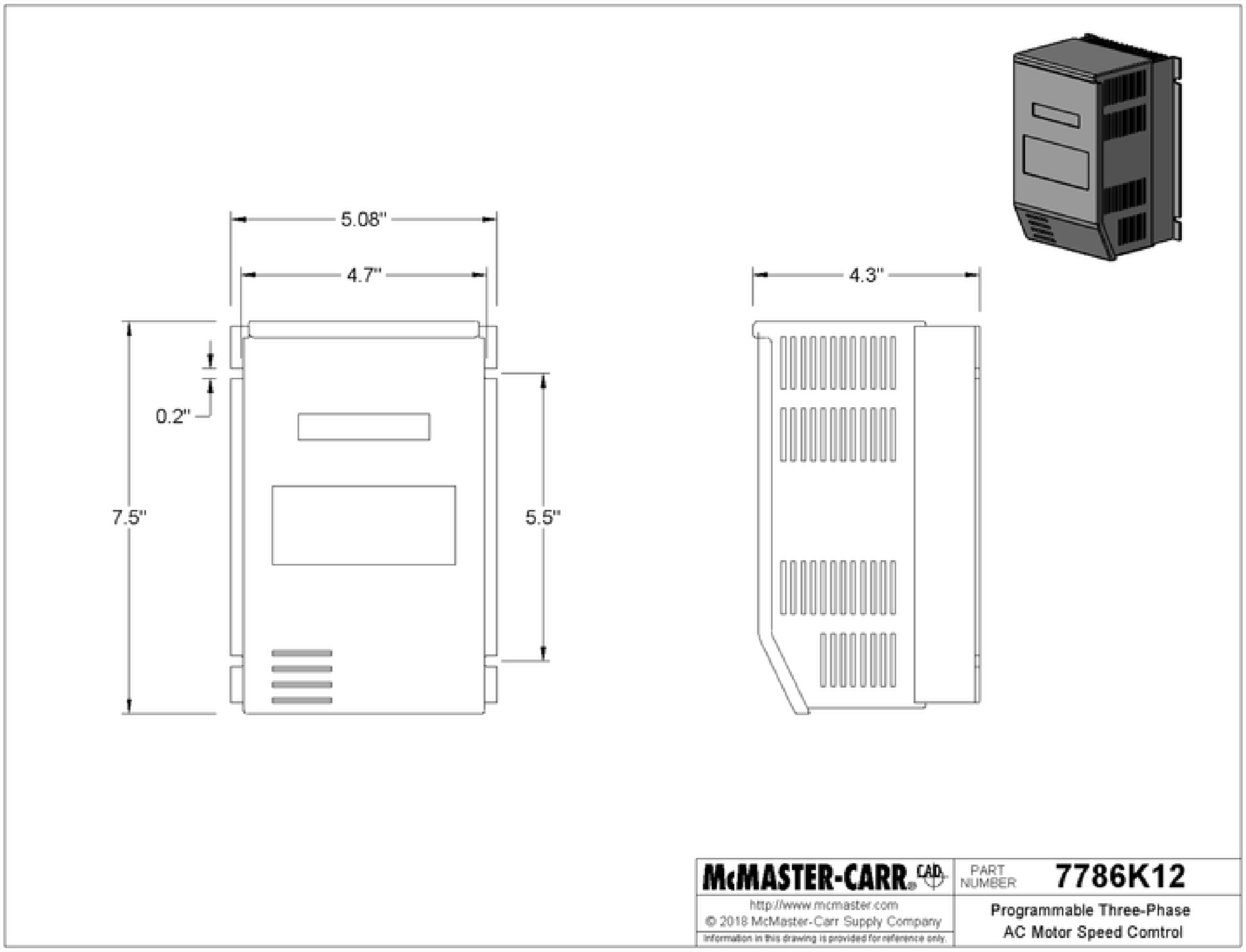
Programmable 3-Phase AC Motor Speed Control

with 200V-240V AC Three-Phase Input for 1 hp

$600.97 Each
7786K12

Input Electrical Phase	Three
For Motor Electrical Phase	Three
Horsepower	1 hp
Input Voltage	200-240V AC
Current	4 A
Output	
Voltage	200-240V AC
Frequency	0-120 Hz
Input Signal	
Voltage	0-10V DC
Current	4-20 mA
Height	7.5"
Width	5.08"
Depth	4.3"
Reversing Capability	Reversing
Housing	
Material	Steel
Color	Gray
Number of Mounting Holes	4
Mounting Hole Diameter	0.2"
Mounting Fasteners Included	Yes
Environment	Indoor
Environmental Rating	NEMA 1
Features	Thermal Overload Protection
Specifications Met	UL Listed C-UL Listed CE Marked
Additional Specifications	Current Ratings for Single-Phase and Three-Phase Motors
Country of Origin	Mexico

Set these controls to automatically adjust motor speed. Wire a potentiometer (not included) for remote manual control.



The information in this 3-D model is provided for reference only.

Lukas DiBeneditto
MET 314 Precious Plastic Project Notes

Plan:

Build a Precious Plastic Type device that uses 3 elements which is approved by Professor Sisk. As a team we have selected the heated plastic extruder.

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https://purdue.brightspace.com/d2l/le/content/8234/Home

Work with your group to design and build one of the machines developed by 'Precious Plastics'. You must design at least 3 machine elements using the methods learned in class. Some ideas are: bearings, bolts, welds, shafts, brakes, tolerances, gears, keys, springs, etc.

In addition to your machine, you must design a plastic part, and any molds/forming tools needed to create the part. Your mold must be compatible with one of the machines built by the class; it does not have to be compatible with your own machine.

Your grade for the project will be based on:

Design computation work for the 3 elements 50%
Functionality of prototype 40%
Plastic part mold functionality 10%

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DIY Extruder Screw - Dave Hakkens
https://davehakkens.nl/community/forums/topic/diy-extruder-screw/

discussion thread on ideas behind the auger

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Improvements to a wood auger based plastics extruder - Pragmatism in code
https://deeemm.com/index.php/entry/general/improvements-to-a-wood-auger-based-plastics-extruder

the original idea on how to make the precious plastic extruder

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DIY Extruder screw making machine Part 2 - Mounting the grinder - Pragmatism in code
https://deeemm.com/index.php/entry/general/diy-extruder-screw-making-machine-part-2-the-grinder

jig for grinder to custom make the auger bit

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IRWIN WeldTec 1-in Woodboring Auger Drill Bit at Lowes.com
https://www.lowes.com/pd/IRWIN-WeldTec-1-in-Woodboring-Auger-Drill-Bit/1000235579

Item # 331842 Model # 3043013
IRWIN WeldTec 1-in Woodboring Auger Drill Bit

$33.98
Aggressive screw pitch
Patent pending welded cutting edge
Wide flutes

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IRWIN 3/4-in Woodboring Ship Auger Drill Bit at Lowes.com
https://www.lowes.com/pd/IRWIN-3-4-in-Woodboring-Ship-Auger-Drill-Bit/1000791686

Item # 749989 Model # 1779341
IRWIN 3/4-in Woodboring Ship Auger Drill Bit

$19.48
Hollow center flute clears chips quickly out of the hole
Short length allows bit to be used in tight areas
Wide lands keep the bit straight as it bores through the hole

Power drill short ship auger bits single cutter and side lip is designed to bore holes in wood where nails may be encountered. Cuts through nails without damaging the bit.

Hollow center flute clears chips quickly out of the hole
Short length allows bit to be used in tight areas
Wide lands keep the bit straight as it bores through the hole
All bits have a 5-in twist length and 7-1/2-in overall length

Series Name	N/A
Sub-Brand	N/A
Bit Type	Ship auger bit
Bit Diameter	3/4-in
Bit Length	7-1/2-in
Shank Size	7/16-in
Shank Type	Hex
Material	High-speed steel
Case Type	N/A (no case)
Quick Change	No
For Use With	Power tool
For Use on Metal	No

For Use on Wood Yes
Warranty None
Set/Individual Individual
Package Quantity 1
CA Residents: Prop 65 Warning(s) Yes
Brand/Model Compatibility All

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UA Local 67 Welds Carbon Steel Schedule 40 Pipe - YouTube
https://www.youtube.com/watch?v=4Hlwuyieu1E

welding sch 40 steel pipe

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What is Black Iron Piping? - Introduction to Black Iron Pipe and Fittings
https://www.pvcfittingsonline.com/resource-center/what-is-black-iron-piping/

Black iron pipe used to be found in water lines, but has been much more popular for gas since the advent of copper, CPVC, and PEX. ... Despite its name, black iron pipe is actually made of a low-grade "mild steel" compound. This gives it much better corrosion resistance than traditional cast iron piping. Dec 19, 2017

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black iron pipe is milde steel

it has a coating on it

Welding Black Pipe - The Home Machinist!
http://www.chaski.org/homemachinist/viewtopic.php?t=88036

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Can You Weld Black Iron Pipe? And Is It Safe? • WelditU
https://welditu.com/welding/tips-mig/weld-black-iron-pipe/

Can You Weld Black Iron Pipe? And Is It Safe?

With threaded connections and a choice of sizes, it’s easy to create projects from the black pipe and fittings found at home improvement stores or in scrap piles.

But can you weld black iron pipe?

Its unique feel and appearance adds a great vintage/industrial look to any plans—but do you have any idea what the black coating is?

Let’s find out what black iron pipe is all about.

Black iron pipe fittings.

Welding black iron pipe

You can weld black “iron” pipe because it’s made of mild steel, not iron. Black steel pipe can be welded using any welding method used for steel. This includes MIG, flux core, TIG, and stick arc welding.

But black-pipe fittings are made of malleable black iron. Black-iron fittings are difficult to weld without causing damage to the fitting.

What is black metal pipe?

Often mistaken for cast iron because of its heft and dark appearance, they make black steel pipe of mild steel. It’s usually a low-grade and not galvanized.

With good corrosion resistance and strength, they commonly use black pipe for natural gas and propane lines, steam lines, and fire sprinkler systems.

Short section of black iron pipe.

The phrase “black steel pipe” is a generic term rather than a specification. It’s used in the trades when referring to regular steel pipe rather than a galvanized steel pipe.

The ASTM (American Society for Testing and Materials) published the A53 standard that covers carbon steel pipe specifications.

What is the coating on black steel pipe?
The manufacturing process results in a dark iron oxide coating on black steel pipe. This coating improves corrosion resistance over bare metal.

To further inhibit rust, manufacturers may use a variety of coatings such as coal tar enamel, lacquer, and oil.

Is it safe to weld black pipe?

Yes, because black pipe isn’t galvanized with zinc, there’s no risk of creating poisonous zinc-oxide fumes while welding. Normal safety precautions are sufficient.

Removing mill-scale and other manufacturing coatings (inside as well as outside) is a good practice to reduce fumes and ensure a quality weld. It’s always a good idea to provide adequate ventilation and use a respirator.

Person stick welding black pipe.

Is black malleable iron weldable?

The heating of white cast iron for days creates malleable iron with beneficial properties. Black pipe fittings made of malleable iron are tough with good resistance to wear and shock.

“If malleable cast iron is heated above its critical temperature, approximately 1700℉ (925℃), the carbon will recombine with the iron, transforming back into white cast iron."

L. Jeffus "Welding Principles and Applications" (8th Edition, p.668)
So, black iron fittings are not good to weld because the heat of welding will change its characteristics. The fittings become brittle and prone to cracking.

Brazing, or braze welding at a temperature under 1700℉ is a good way to join iron fittings with black steel pipe.

Another alternative is to use weldable forged iron pipe fittings like these socket weld fittings.

Can you weld black pipe to steel?
Yes, black pipe is mild carbon steel. You can weld it to other carbon steel using routine steel-to-steel welding methods.

This guy makes pipe welding look easy:

Upshot

Because it's plain old mild steel, you can weld black iron pipe, also known as black steel pipe, using whatever welding method you prefer for steel.

And, with proper cleaning and preparation, there is no additional risk when welding black pipe.

However, malleable iron fittings are difficult to weld, so brazing is a better way to go. Otherwise, you can use socket weld fittings.

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Mig Pipe Welding For Beginners - YouTube
https://www.youtube.com/watch?v=ZoBG9yrCnmw&feature=emb_logo

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Beginners Pipe Welding Rules to Live By - YouTube
https://www.youtube.com/watch?v=4V3f5Ixf3Aw

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Start an Extrusion Workspace to Recycle Plastic
https://preciousplastic.com/starterkits/showcase/extrusion.html

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This is a Plastic Extrusion Workspace - YouTube
https://www.youtube.com/watch?v=MR-CNopHNlU

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Precious Plastic - Build the extrusion - YouTube https://www.youtube.com/watch?v=p4NoY33-Tfo

IMPORTANT

needs screw for adjusting flow control

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Making Plastic Rod Stock - Melting HDPE Milk Jugs - YouTube
https://www.youtube.com/watch?v=erlZ-FdBB2I

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How to build a pro plastic extrusion machine - YouTube
https://www.youtube.com/watch?v=3-JFVo6BDA4

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Precious Plastic Community
https://community.preciousplastic.com/academy/download

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Casting a Metal Object with a Clay Mold (Low Budget) - YouTube
https://www.youtube.com/watch?v=wnElouMy4_w

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Use a Glue Gun to extrude parts? How To Recycle HDPE Plastic To Make Parts! Part 4? - YouTube
https://www.youtube.com/watch?v=JX9C4uwlAAc

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(Operation Manual) Plastic Melter / Densifier (Waste Plastic Recycling into bricks etc) - YouTube
https://www.youtube.com/watch?v=594HFX_Oh40

10% styrofoam
40% shredded plastic
50% used cooking oil

1. load cooking oil
2. turn on gas stove
3. wait until oil is above 100 C = 212 F
4. turn on the stirrer
5. load shredded plastic and styrofoam
6. cook for 1 hour
7. drain oil until plastic flows
8. mold the melted plastic (bricks)
9. let dry for 3 hours

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Portable Plastic Shredder / Crusher / Pulverizer / Grinder (Trailer Type: 10HP-12.5HP) rev01 - YouTube https://www.youtube.com/watch?v=ULA6_rEqzwE

basically a leaf shredder for all different types of plastic

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Forming Useful Pieces Of Recycled HDPE - YouTube
https://www.youtube.com/watch?v=dQPnlnRaWyI

heating hdpe plastic in sandwich toaster using cooking/baking paper then putting it into a wooden mold

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Precious Plastic Community
https://community.preciousplastic.com/academy/build/compression

compression type precious plastic sheets

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Precious Plastic Community
https://community.preciousplastic.com/how-to/glue-with-a-heat-gun-hdpe--pp

heating hdpe and glueing it with hot glue gun except it doesnt work all that well

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Precious Plastic Basic Machines
https://preciousplastic.com/solutions/machines/basic.html

Type Single screw
Cost (NL) 1.200 €
Weight 90 KG
Dimensions 1000x500x1100 MM
Power (W) 4 KW
Voltage (V) 400 V
Amperage (AMP) 16 A

Precious Plastic Community
https://community.preciousplastic.com/academy/build/extrusion

6 sub assemblies or components

hopper

barrel
nozzle
barrel holder
framework
electronics

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15 U.S. Code § 206 - Standard gauge for sheet and plate iron and steel | U.S. Code | US Law | LII / Legal Information Institute
https://www.law.cornell.edu/uscode/text/15/206

[metal gage] [metal gauge]

Number of gauge 3

Approximate thickness in fractions of an inch 1/4

Approximate thickness in decimal parts of an inch .25

The effect of melt viscosity on thermal efficiency for single screw extrusion of HDPE - ScienceDirect
https://www.sciencedirect.com/science/article/pii/S0263876213005431

The Dynisco Extrusion Processors Handbook 2nd edition Written by: John Goff and Tony Whelan Edited by: Don DeLaney
https://www.dynisco.com/userfiles/files/27429_Legacy_Txt.pdf

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precious-plastic-kit/3. Build/4. Extrusion at master · ONEARMY/precious-plastic-kit · GitHub
https://github.com/ONEARMY/precious-plastic-kit/tree/master/3.%20Build/4.%20Extrusion

cad files

drawings

MET 314
LUKAS DIBENEDITTO
CAD FILE SOURCES

Standard-Wall Steel Pipe, Threaded on Both Ends, 3/4 NPT, 18" Long | McMaster-Carr
https://www.mcmaster.com/4457k115

Medium-Pressure Iron Pipe Fitting, Cap, 3/4 NPT Female | McMaster-Carr
https://www.mcmaster.com/4627k174

Medium-Pressure Iron Pipe Fitting, Plug with External Square Drive, 3/4 NPT | McMaster-Carr
https://www.mcmaster.com/4627k334

Medium-Pressure Iron Pipe Fitting, Straight Connector, 3/4 NPT Female | McMaster-Carr
https://www.mcmaster.com/4627K154

Iron | McMaster-Carr
https://www.mcmaster.com/black-iron-pipe-fittings/medium-pressure-iron-and-steel-threaded-pipe-and-pipe-fittings-7/

Medium-Pressure Steel Flange, 300 Class, 3/4 NPT | McMaster-Carr
https://www.mcmaster.com/6806K121
6806K121_MEDIUM-PRESSURE BLACK STEEL FLANGE.SLDPRT

Professor Sisk,

The following pages are my notes and previous attempts.

They should be included to document my effort, not be graded for problem submission of machine elements.

Thank you,

Lukas DeBenedetto

transistance equation

thrust bearing boundary lubricated bearing chp 16 560
plain

→ weld all around

BS
P or product
low
high

plastic viscosity estimate

small nozzle high viscous
fluid going to push back

dont require wires every nut and bolt

bead size required

need holes for bolts

1/8 bead due diligence

no drawings

→ bolts in tension
pressure in mold cavity
cross section of mold
more area
Injection molding

1000psi
fittings backing out

→ hydraulic lift
viscosity varies a lot with temperature

Cross Section below oxygen oxidizing

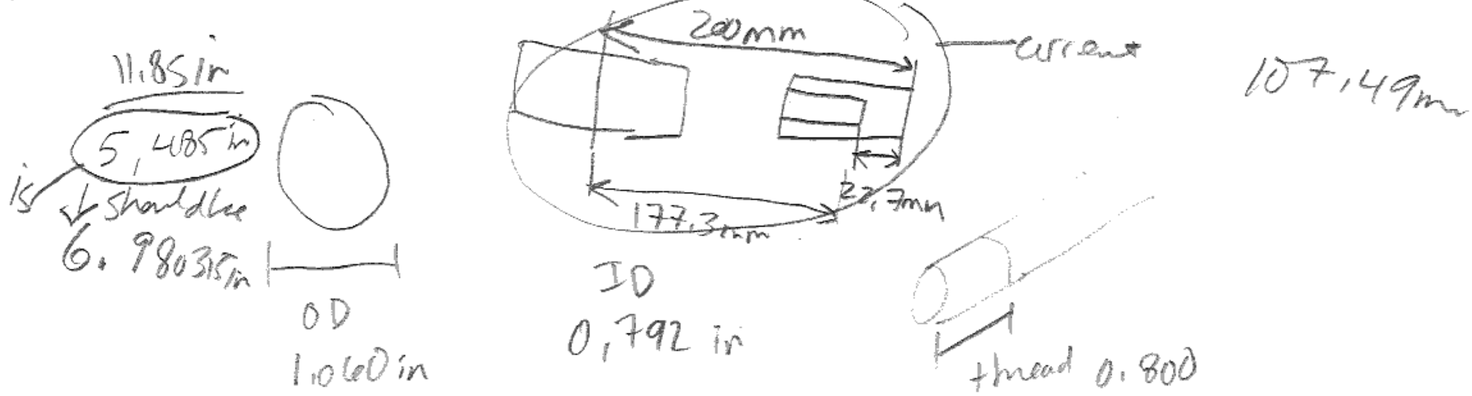
assume low viscosity

backup machine element
4th element

~~120 mm~~ 200 mm currently 7.8740157 in

m5 thread 0.18 mm

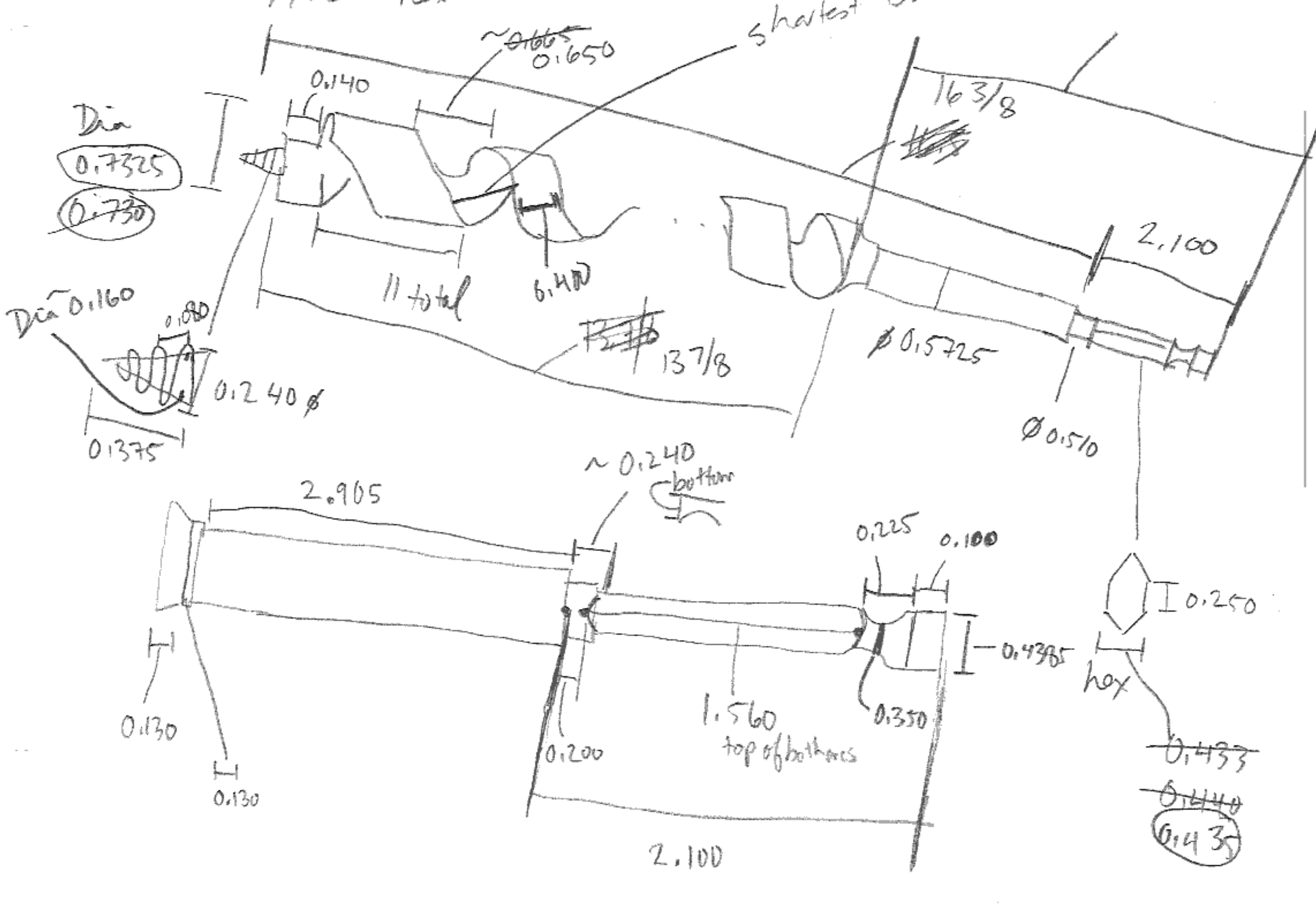
Southland 3/4" X 30" Black ~~Pipe~~ 584-300L W/ STEEL PIPE



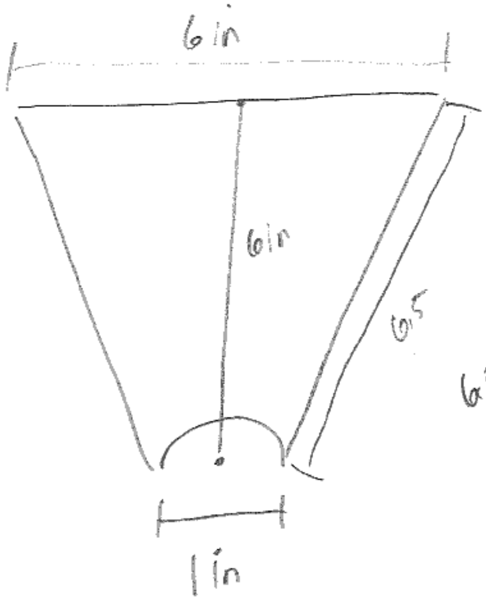
metal sheet thickness 0.0275 22GA 12"x24"

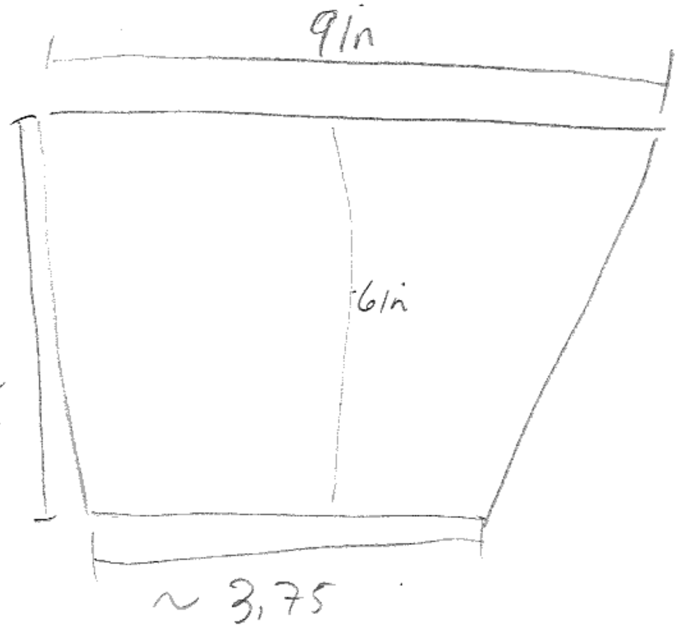
Southwire 3/4 in Ship Auger bit 3/4" x 18"

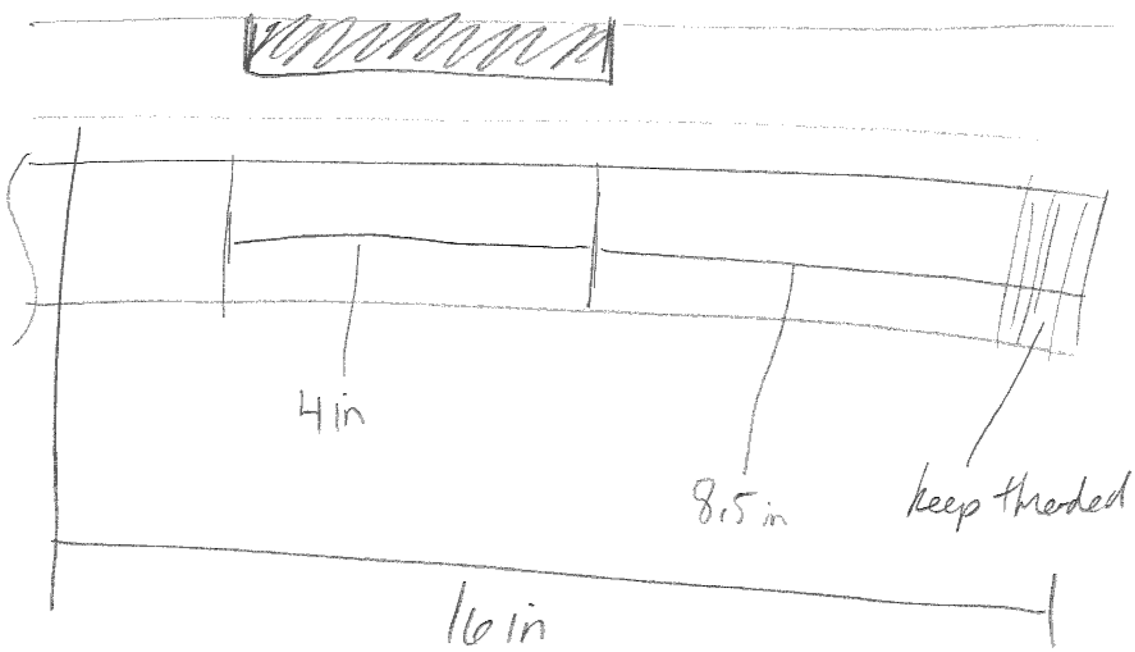
7/16" hex shank



metal sheet thickness 0,0275
22GA







See Chp 16 pg 560

PV product for #3?

MET 314
2020-04-23
Lukas DiBenedetto
Meeting Webex with Professor Sisk

Suggested

3 + 1 Elements

backup?

1. Weld all around, bead size required

2. Bolts in tension

3. Boundary lubricated thrust bearing plain

Not required

Wires

Every nut and bolt

No drawings

Include

Holes for bolts

Type of plastic → melting point range, choose just below burning to decrease viscosity → viscosity → approximate hydraulic fluid → cross sectional area → pressure → force → counteracting force

flow rate?

Change to 80 rpm

Assuming motor $\overset{1.02362}{26} \times \overset{23.622\,in}{600\,mm}$ rotating around 70 rpm [pp 3 of]
Assuming Viscosity as a function of temperature, and non newtonian fluid,
Assuming pressure range 0.34 to 2.07 mPa, and optimal melt temperature → HDPE 240°C [dynisco.com], Similar to screw pumps

$$P_{Avg.} = \frac{P_1 + P_2}{2} = \frac{(0.34 + 2.07)\ mPa}{2} = \frac{2.41\ mPa}{2} = 1.205\ mPa = \boxed{1.205 \times 10^6 Pa}$$

$$P = \frac{F}{A} \rightarrow F = P \cdot A = P \cdot (\pi D^2/4)$$

$$D = ID \rightarrow ID = 20.1168\ mm = 0.0201168\ m$$

$$F = 1.205 \times 10^6 Pa \cdot \frac{\pi (0.0201168 m)^2}{4} \cong 382.9964\ Pa \cdot m^2$$

$$382.9964\ \cancel{Pa} \cdot \cancel{m^2} \cdot \frac{N/\cancel{m^2}}{1\cancel{Pa}} = 382.9964\ N$$

Force to Thrust load on auger to Barrel holder

pg 509 bearing shaft to Two bolt, flange mount, mounted bearing units, cast iron housing, metric shaft sized UCFL204, ast bearings.com than to bolts, than to barrel holder

astbearings.com / catalog.html ? page = product & id = UCFL204

basic dynamic radial load rating (C_r) = 12,843 N

basic dynamic axial load rating (C_a)

static load rating (C_{or}) = 6,668 N

cast iron housing chrome steel bearing

DC motor

460V three phase AC   filled field of 300V

0 to 500V armature

base speed of 1750rpm

motor speed of 1500rpm

~~500~~ screw 90 rpm

motor speed 500rpm

screw speed 30rpm

AC motor

PWM

gear box   16.67:1

reduction ratio

pdf 104

pg

4 inch diameter extruder will have a back thrust of 28 tons

if the pressure at the end of the screw is 4000 psi

use

roller bearing for high thrust loads

motor in ~~rule of thump~~

$$~~Hp = \frac{24}{1}~~ \quad L/D = \frac{24}{1} \frac{13+7/8 \text{ in}}{0.7325 \text{ dia}} = \frac{24}{1} \frac{13.875 \text{ in}}{0.7325 \text{ in}} = \frac{24}{1} \cdot 18.941979$$

Hp needed = 454.6 hp

1.5 in Dia → 12 kW   16 HP motor needed

$$\dot{\gamma}_w = \left[\frac{(3n'+1)}{4n'}\right] \dot{\gamma}_{w,a}$$

$$n' = \frac{[d \log (R \Delta P / 2L)]}{[d \log (4 Q / (\pi R^3))]}$$

Sheer stress on wall of die

$$\tau_w = \frac{PR}{2L}$$

P = pressure measured
R = die radius and
L = length of die

P8
32

$$\tau_{w,a} = R \Delta P / 2L$$

sheer stress wall actual

$$\dot{\gamma}_{w,a} = \frac{4Q}{\pi R^3}$$

L = Screw length
D = Screw diameter
Compression ratio = $\frac{\text{Channel Depth start}}{\text{Channel depth final}}$

think operate at 2 X 10,000 psi
Barrel pressure 10,000 psi or 70 MPa
withstand

$$Q = \pi S D^3/4$$

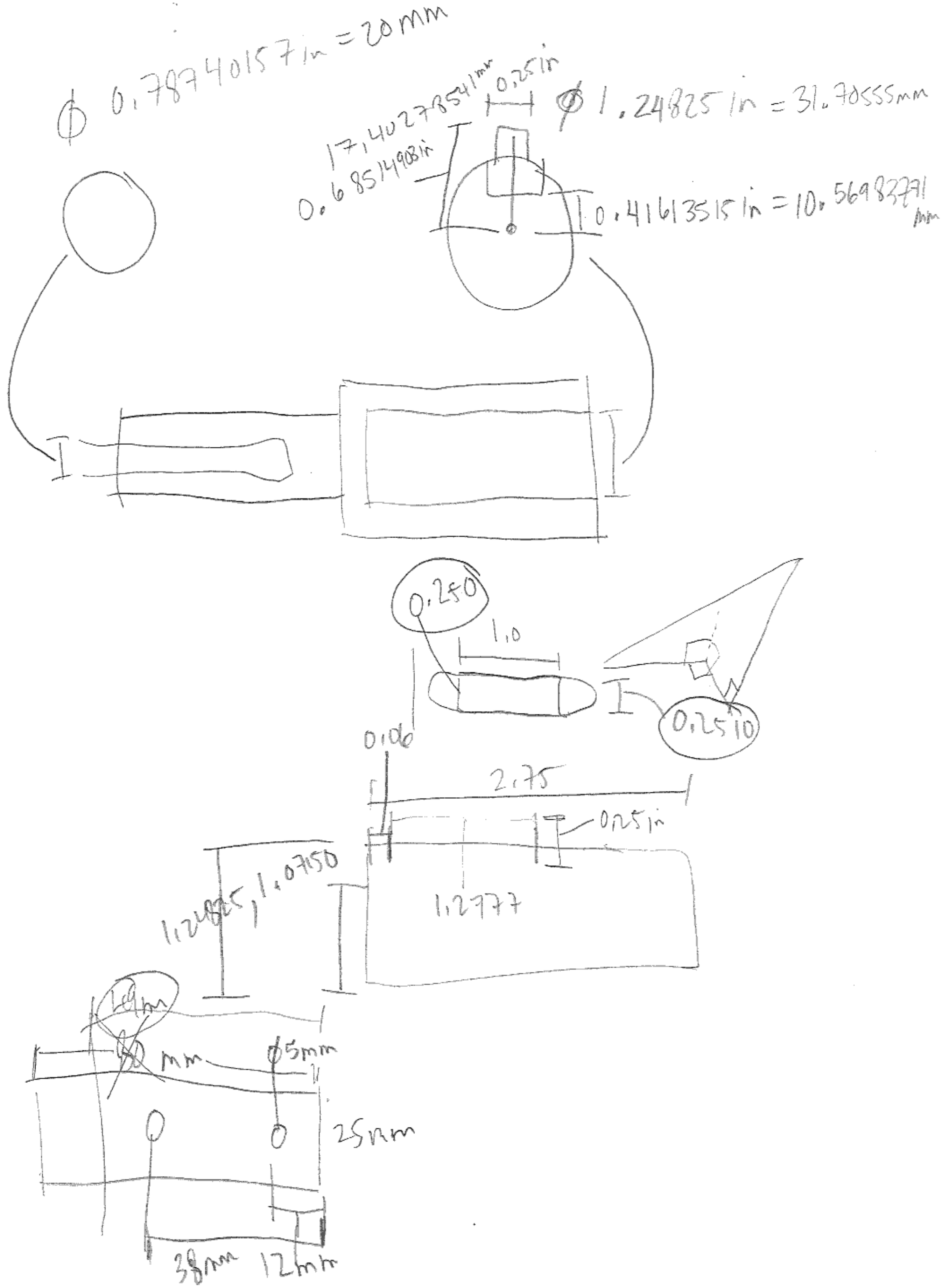
$$\dot{\gamma}_{w,a} = SD^3/R^3 \ s^{-1} \qquad \text{eq 6}$$

Ex] If barrel diameter is 9.550 mm standard size

$$\dot{\gamma}_{w,a} = 91.203 \ S/R^3 \ s^{-1}$$

capillary radius in mm
ram speed in mm/s

Since shear stress at wall given by $\tau_w = PR/2L$
then for 20:1 die $\tau_w = P/80$



ϕ 0.78740157 in = 20 mm
17.4027854 mm
0.25 in
ϕ 1.24825 in = 31.70555 mm
0.685149081 in
0.41613515 in = 10.5698371 mm
0.250
1.0
0.2510
0.106
2.75
0.25 in
1.12485, 1.0750
1.2777
19 mm
mm
ϕ5mm
25mm
38mm
12mm

dynisco.com

257469_legacy1-Txt.qxd

pg 69

Shear stress

greek letter τ units $\frac{\text{force}}{\text{area}}$

$1 \text{ dyn cm}^2 = 0.002088 \text{ lbf/ft}^2 = 0.0000145 \text{ lbf/in}^2$ or psi

Shear rate $\dot{\gamma}$ 1/time in seconds = sec^{-1}

apparent Viscosity η_a at a particular shear rate is obtained by dividing τ shear stress by the corresponding $\dot{\gamma}$ shear rate units of $\frac{\text{force}}{\text{unit area time in seconds}}$

normally obmitted

$\text{One poise} = 1P = 10^{-1} Pa-s = 10^{-1} Ns/m^2 = 0.000\,0145 \text{ lbf/sin}^2$

$\text{One poise} = 1P = 0.1 Pa\text{-}s = 0.1 N\,s/m^2 = 0.102 \text{ kgf s/m}^2$

$= 10 P = 0.02088 \text{ lbf s ft}^2$

$= 0.000145 \text{ lbf s/in}^2$

HDPE 240°C ~~...~~ 464°F Range 205-280°C 401-536°F

non newtonian polymer melt

shear rate at the wall of the die $\dot{\gamma}_{w,a} \neq$ true shear rate $\dot{\gamma}_w$

pg 31

$$\dot{\gamma}_w = \frac{(3n'+1)}{4n'} \frac{(4Q)}{\pi R^3}$$

where

$$n' = \frac{[d\log(PR/2L)]}{[d\log(4Q/(\pi R^3)]}$$

$\dot{\gamma}_w$ = shear rate at the wall of the die

τ_w = shear stress at the wall of the die = $PR/2L$

shear stress (Pa or Nm^{-2})

shear rate s^{-1}

Q = volumetric output rate

P = measured pressure

R = die Radius

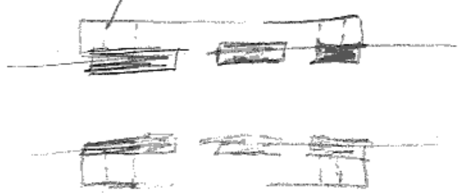
L = die length

d log = discrete logarithm

d log (x)

→

3 guage =
1/4 in thick Steel



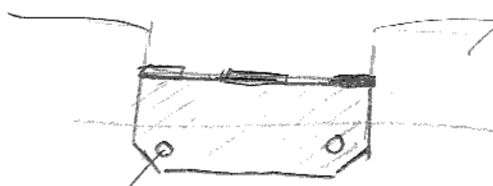
HDPE

Density kg/m^3

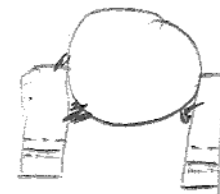
~958 kg/m^3

~ 131.967 °C
melt peak

barrel



hole

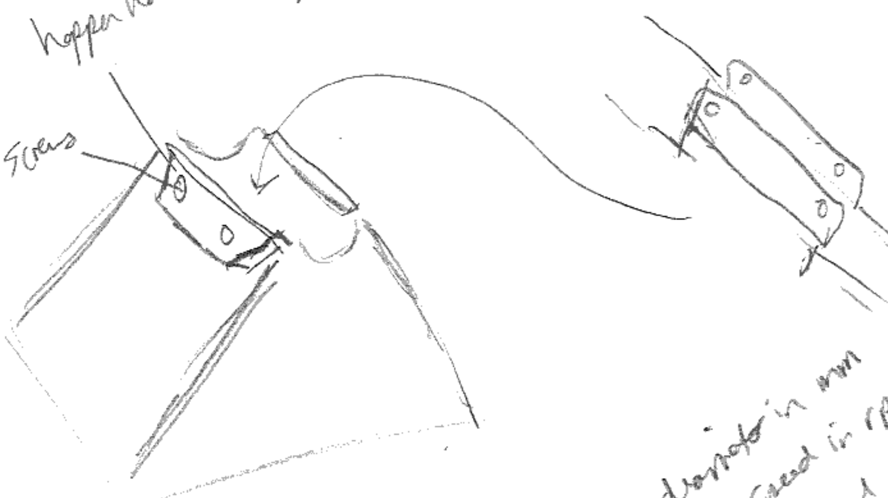


melt viscosity
tapped at 200°C
10 rpm
h = 3.46 mm

hopper holder

screws

mounted upside down to wear



$\dot{\gamma}$ / s^{-1}
9.54 s^{-1}

Mesh °C
231.00

η (Ti)
0.479

D = screw diameter in mm
N screw speed in rpm
h is channel depth in mm

η (Pa s)

9.7.01

Gils Bulk Viscosity $\dot{\gamma} = \frac{\pi D N}{60 \times h}$ (s^{-1})

At 180°C nonlinear behavior

HDPE linear MS (in/in) or (mm/mm)
0.015 – 0.040
% MS
1.5 – 4.0

MFR

Cp Specific Heat
3640 $\frac{J}{kg \cdot K}$

Ex] pg 20

An Electric motor is rotating at 1750 revolutions per minute (rpm), Express the Speed in radians per second (rad/s)

$$\text{Rotational speed} = 1750\,rpm = 1750\frac{rev}{min} = 1750\frac{\cancel{rev}}{\cancel{min}}\;\frac{2\pi\,rad}{\cancel{rev}}\;\frac{1\cancel{min}}{60s} \cong 183.2596\frac{rad}{s}$$

Pg 35 elongation

tensile stress $\sigma = \frac{F}{A}$ $\frac{\text{Force}}{\text{Area}}$

modulus of elasticity $= E$

$\delta = \frac{FL}{EA}$

Pg 738

Polyurethane

100 ksi

690 MPa

$\delta = \epsilon L$

$\epsilon = \frac{\delta}{L}$

modulus of Elasticity

E_{app}

pg 36

Coefficient of thermal expansion

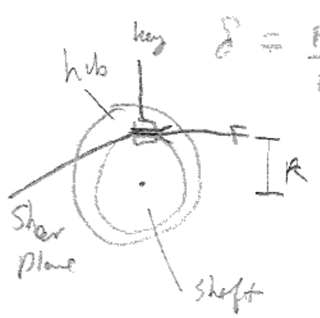
$$\alpha = \frac{\text{change of length}}{L_0(\Delta T)} = \frac{\text{strain}}{(\Delta T)} = \frac{\epsilon}{(\Delta T)}$$

Where L_0 = original length

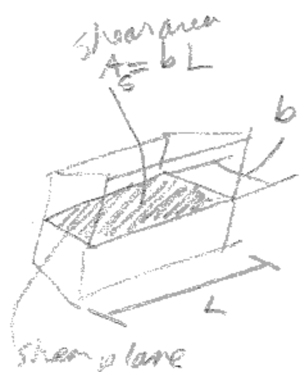
ΔT = change in temperature

pg 91

computes the stretch due to the direct axial tensile load or the shortening due to a direct axial compressive load



$\delta = \frac{FL}{EA}$



δ = total deformation of the member carrying the axial load

F = direct axial load

E = modulus of elasticity of the material

A = cross sectional area

pg 15

tensile stress area for threads

English

$$A_t = 0.7854\left(D - \frac{0.9743}{n}\right)^2$$

<u>Metric</u>

$$A_t = 0.7854(D - 0.9382\ P)^2$$

$P = \text{Pitch}$

$P = \frac{1}{n}$

<u>Ex. 1</u> $\underbrace{m}_{\text{metric}}\ \underbrace{10}_{\text{major diameter } D = 10\,mm} \times \underbrace{1.5}_{\text{pitch } P = 1.5\,mm \text{ between adjacent threads}}$

$$A_t = 0.7854(10\,mm - 0.9382 \cdot 1.5\,mm)^2$$

$$A_t \cong 57.9896\ mm^2 \cong 58.0\ mm^2$$

pg 15

pitch of a screw thread ?

the distance between corresponding points on two adjacent threads

it is the distance the screw would move axially when the screw is turned one complete revolution

pitch $P = \frac{1}{n} = \frac{1}{\text{number of threads per inch}}$

Example

$1/2 - \underbrace{13}_{}$ UNC

13 number of threads per inch

pitch $P = \frac{1}{n} = \frac{1}{13} \cong 0.0769 \text{ in}$

For metric

it is the axial distance between adjacent threads in mm milli meters

M 10 x 1.5

1.5: pitch of 1.5 mm between adjacent threads

10: basic major diameter D in mm → 10 mm

M: stands for metric

pg 89

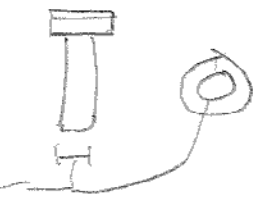
Direct Tensile or Compressive Stress

$$\sigma = \frac{\text{force}}{\text{area}} = \frac{F}{A}$$

pg 15

American standard unified thread

Nominal major diameter D



Smaller than 1/4 in are given in numbers from 0 to 12 while fractional inch sizes are specified for 1/4 in and larger sizes

UNC American Standard Unified Coarse Threads

UNF American Standard Unified Fine Threads

Examples

6-32 UNC → number size 6 → less than 1/4 in

→ 32 threads per inch

→ coarse thread

12-28 UNF → number size 12 → less than 1/4 in

→ 28 threads per inch

→ fine thread

$\frac{1}{2}$ -13 UNC

coarse thread

13 threads per inch

fractional size ½ in

$1\frac{1}{2}$ - 12 UNF

fine thread

12 threads per inch

fractional size $1\frac{1}{2}$ in

σ pg 89

A_t pg 15

A, I, S, r, J, Z_p pg 16

Rotational speed pg 20

plastic properties pg 738

thermal expansion pg 36

plastics pg 59

shear area pg 91

torque T
power P
speed n pg 92

n_s pg 665

1 hp = 746 W pg 663

Fasteners

metric Grades of Steel bolts Grade 4.8 pg 632

pg 632 M10 Tensile strength 420 MPa

Yield Strength ~340 MPa

Proof Strength 310 MPa

MD x Pitch

pg 634 M10 x 1.5

·Basic major diameter $D = 10mm$

Tensile area $58.0\ mm^2$

Tensile stress area

eq 19-2 $A_t = (0.7854)[D - (0.9382)p]^2$

$A_t = (0.7854)[10mm - (0.9382)1.5]^2$

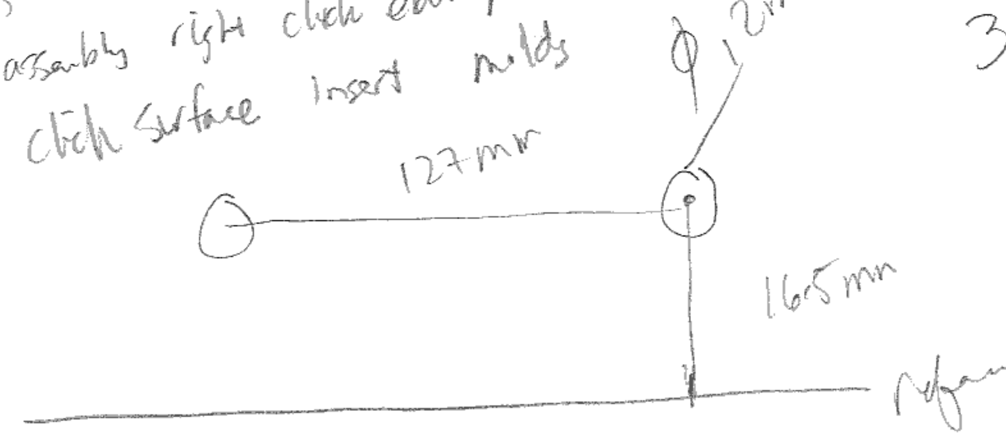
$A_t \cong 57.9896\ mm^2$

see pg 635

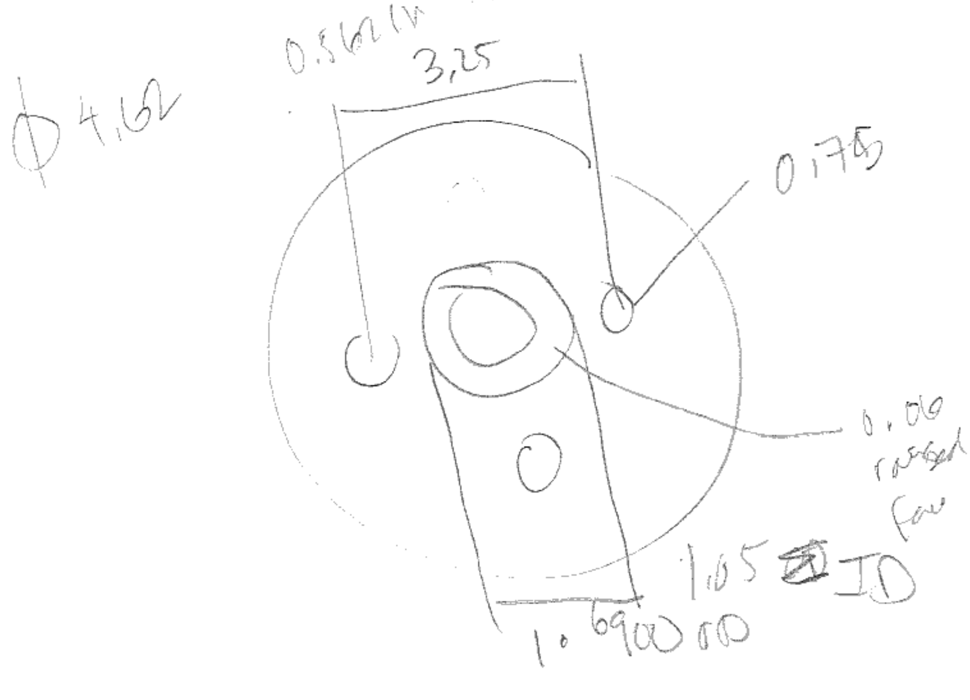
.375 in

toolbars turn on mold
in assembly right click edit part, not open part
click surface insert molds

30 x 30 x 3



30mm
3mm



pg 92 eq 3-5

Power Torque Speed Relationships

$T = \frac{P}{n}$ $\boxed{\text{Torque}} = \frac{\text{Power}}{\text{Speed}}$ $\frac{\text{watts}}{\text{radians per second } \frac{rad}{s}}$

Newton meters per second $\frac{N \cdot m}{s}$

pg 665 chp 21

AC motor zero load near its synchronous speed

$n_s = \frac{120 f}{p}$ p = number of electric poles

$\to \frac{rev}{min}$

$$\boxed{1\,hp = 746\,W}$$

pg 663

pg 664

f = frequency 60 Hz   homes single phase 2 conductors + ground

p = number of poles   industrial 3 phase

Moters

Motor type: DC, AC, single-phase three phase etc

Power rating and speed

Operating frequency and voltage

Type of enclosure

Frame size

Mounting details

power = torque x speed

$P = T \times n$

$P = Tn$

$1\,hp = 0.746\,kW = 746\,W$

$550\, lb_f \frac{ft}{s} = 1\,hp$

pg 664

Fractional horsepower

$\frac{1}{2}$ hp to 1 hp

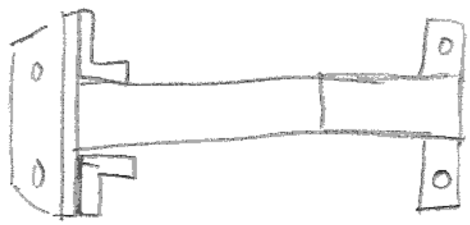
37 to 746 W

Speed = 80 rpm

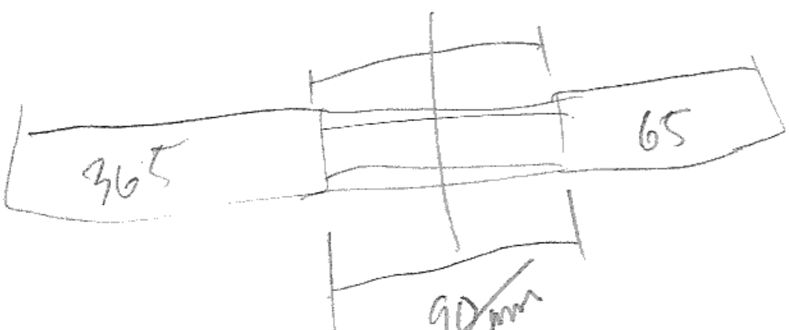
at 327 in-lbs $\frac{1}{2}$ hp

video preview plate — build the extension

8:36



75 mm ~~#~~365 mm +



~~90 mm~~

~~94 mm~~

90 mm

Nominal torque
109 Nm

Output speed
40–140 r/min

380 V
5,8A

26 X 600 mm
wood auger

1,02362 in X 23,622 in
wood auger

Bearing
UCFL 204

0.125 in

0.64741 in

1.25

precios plastic

Direct Drive Torque motor

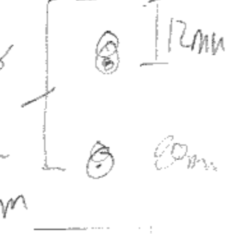
motor around 70 rpm — chng to 80

3 phase AC motor

0.762 in

20 mm ∅

5 m hole ∅



.1150

20mm

SSR 2-24V

Solid state Relay

Power Switch 220V

Power 230V

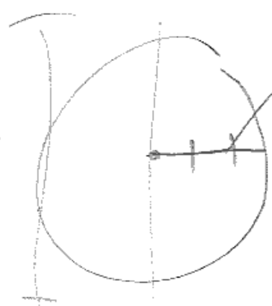
Input 3-32V

SSR Relay

output 24-380V

25mm thickness

$0.381/3 = 0.127$



heating element

4x 220V 190W

type k temperature measure

Band heater

motor with fixed speed

mcmaster carr 6660N57

→ AC Gearmotor Fits 1-1/4" Diameter Shaft 230V AC 60 Hz 1.9A

1/2 hp 80 rpm @ 327 in-lbs, 894 in-lbs starting torque

6660N530 Keyed Shaft 1-1/4" Diameter with key stock for AC Gearmotor

Lukas DiBenedetto

Given:

1/2 hp AC motor 230V AC 60 Hz 1.9 A

80 rpm @ 327 in·lbf

Starting torque 894 in·lbf

→ mount controller

→ controller req

ssr req

temperature

heating collers

no box for electron

plate

$\boxed{\text{12pm - 1pm}}$

3pm - 4pm

→ MET 314

e clear 1p this for precision fit

coefficient of thermal expansion

thermal gradient have short propagation

insulate motor

1 7/8 + 1 7/8, 4 3/16

Mel

ϕ 1.163in

ϕ 1.05in

relief cut not necessary

weakness | strength

detail

11 th

tuesday 9 am

rules of

5 to 10 threads

1/2 to 1/4 wide

516 - 517 thrust

neglect inertia

close to center line

operates at steady state

→ mod flow

liquid flow

thermal trap

operating angle

no radial force

neglect

→ specify from book

2 in

47

both

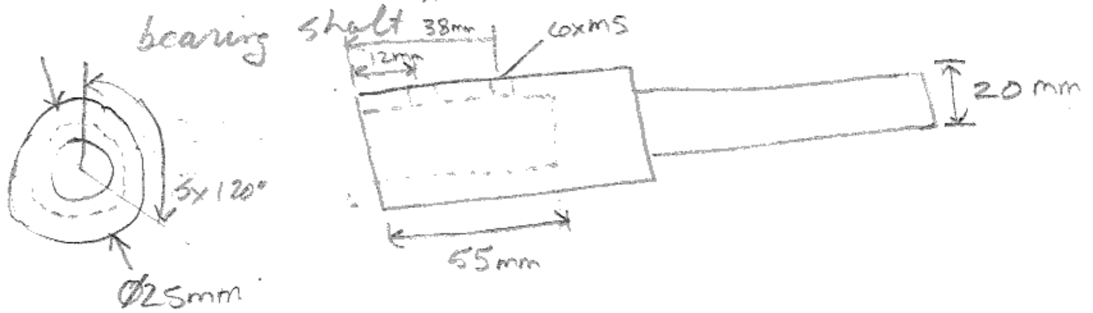
1.5 single row ball line

—) Thrust Bearing Selection pg 517 procedure

Assuming any mass is not generating inertia of signifigance, which is close to center line, and the system is operating at steady state, with constant rotational velocity. We can assume 0 N of radial load and 100% of 382.9965 N to be thrust load. Assume 80 rpm.

Given

Thrust bearing must fit shaft "Barrel holder bearing shaft"



$F = 382.9965\ N$ $\qquad n = 80\ rpm$

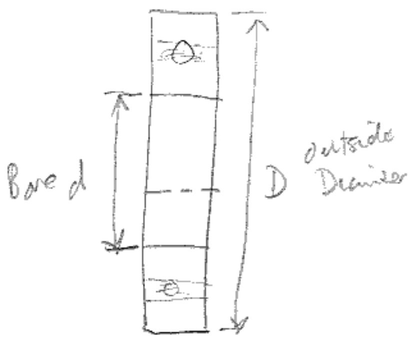
1.) pg 516 eq 14-5

Equivalent Load with Radial and Thrust loads

$$P = VXR + YT$$

where P = equivalent load
V = rotation factor as defined
R = applied radial load
T = applied thrust load
X = radial factor
Y = thrust factor

→



For Reference only
Not to scale

4.) Selected to test

Bearing 6000 with Dynamic 20mm.

5.)

$$\boxed{\begin{aligned} C &= 4.62\ kN \\ C_0 &= 1.96\ kN \end{aligned}}$$

Can stop here
Any bearing in
Chart would work.

6.) $\dfrac{T}{C_0} = \dfrac{382.9965\ N}{1.96\ kN} = \dfrac{0.382.9965 \times 10^3 N}{1.96\ kN}$

Test

$\dfrac{T}{C_0} \cong 0.1954$ ND , $Y = 1.50$, Assuming $X = 0.56$

7.) Interpolation

e	T/c0	Y
0.19	0.014	2.30
e	0.1954	Y
0.22	0.028	1.99

$\rightarrow e \cong$

8.) $\dfrac{T}{R}$ → However only thrust Load is

Assume $R = 1 \rightarrow \dfrac{382.9965N}{1} = 382.9965N$

If $\dfrac{T}{R} > e \Rightarrow 382.9965N > 0.1791$ true →

pg 517

Assume liveshaft

$V = 1.0$

Assume 0 N Radial Load

$R = 0\,N$

$F = T = 382.9965\,N$

Assume Per Prof. Sish

$X = 0.56$

Assume Reasonable pg 517

$Y = 1.50$

2.) $P = VXR + YT$

$P = \cancel{(1.0)(0.56)(0\,N)}^{0N} + (1.50)(382.9965\,N)$

$\boxed{P_d = P = 382.9965\,N}$

3.) Basic Dynamic Load Rating eq 14-3 pg 515

$C = P_d\,(L_d/10^6)^{1/k}$

$P_d = P = 382.9965\,N$ $n = 80\,rpm$

$L_d = (h)(rpm)(60\,min/h)$

Assume $L_{10,h}$ for general industrial machine pg 515

$h \cong 25000$ hours

Assume k pg 515

$k = 3.00$

$L_d = (25000\,h)\cdot(80\,rpm)\cdot(60\,min/h)$

$\boxed{L_d = 1.2 \times 10^8\ rev}$

$C = 382.9965\,N\,[(1.2 \times 10^8 rev)/10^6]^{(1/3.00)}$

$\boxed{C \cong 1889.1012\,N} = \boxed{1.8891012\,kN}$

new Y

$P = VXR + YT$

$P = (1.0)(0.56)(0N) + (2.4127)(382.9965\ N)$

$P \cong 924.0557N$

$C \cong 924.0557N\left(1.2\times10^{8}\ rev/10^{6}\right)^{1/3}$

$C \cong 4557.8345N = 4.5578345\ kN$

Selected Bearing 6000

$C = 4.62\ kN$
$C_o = 1.96\ kN$
} confirmed

Selected Bearing material Rolling Element SAE 52100 steel

pg 509

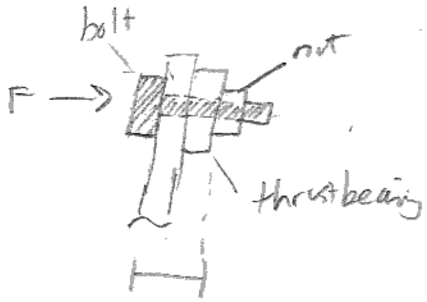
Note per prof Sish calculated selected and SOLIDWORKS selected do not have to match as long as SOLIDWORKS will support load.

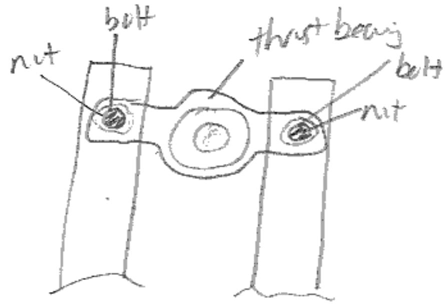
Now the load

assume bearing
check to see wok

II.) Fastener Selection   Approach assume the Size then find material

Assume 100% of Force from auger to plastic to thrust bearing is divided exactly equally between 2 hex bolts and 2 hex nuts. Specify suitable bolts





Assume $F = 382.9965\,N$ Loaded in tension

Assume each bolt stressed to 75% proof strength

Assume UCFL 204 thrust bearing mount holes ID = ϕ10mm

$F_G = F_{Given} = F = 382.9965\,N$

$F_{PB} = F_{per\ Bolt} = \frac{F}{2} = \frac{382.9965\,N}{2} \cong 191.4983\,N$

pg 634 eq 19-2

Tensile Stress area for metric Threads

$A_t = (0.7854)(D - (0.9382)p)^2$

D = major diameter

p = pitch

M10 x 1.5

$A_t = (0.7854)(10mm - (0.9382)(1.5mm))^2$

$A_t = 57.9896\,mm^2 \rightarrow \boxed{A_t = 58.0\,mm^2}$ ✓   Table 19-5 ✓ pg 634

Assume SAE Grade 5 Proof Strength   pg 635

85000 psi $\rightarrow$ 586.1×10^8 Pa $\rightarrow$

Use table 19-3 pg 632

Assume 4.6, M5-M36 steel proof strength

to calculate factor of safety $\frac{400}{200} = 2$ = Factor of Safety

$\sigma_a = 0.75(F_{PB}) = 0.75(225\ MPa)$

$\sigma_a \cong 4.3958 \times 10^{10}\ Pa = 4.3958 \times 10^{10} \frac{N}{m^2}$

$A_t = \frac{load_{max}}{\sigma_a} \longrightarrow load_{max} = A_t \cdot \sigma_a$

tensile strength 400 MPa

testing

$load_{max} = 5.8 \times 10^{-9}\ m^2 \times 4.3958 \times 10^{10} \frac{N}{m^2}$

$load_{max} \cong 2.5496 \times 10^6\ N$

pg635 eq 19-3 — pg635 = 0.15 average condition Assume

$T_{max} = KDP_{max}$

testing

$= (0.15)(\overset{10mm}{0.01m})(4.3958 \times 10^{10}\ Pa)$

$T_{max} \cong 6.5937 \times 10^7\ Pa \cdot m$

where $F = P$ — given from plastic

$At_{min} = \frac{load}{\sigma_a} = \frac{F}{\sigma_a} = \frac{\quad N}{4.3958 \times 10^{10} \frac{N}{m^2}}$

$At_{min} = 8.7128 \times 10^{-9}\ m^2$

Any size bolt and nut of the same size in table 19-5 pg 634 would meet the requirements

Because of selection of UCFL 204 thrust bearing ID ϕ10mm which is slightly larger than an actual M10 X1.5 than

$\boxed{\text{2 Bolts and 2 nuts M10 X1.5 Grade 4.6 steel will work}}$

A307 Grade A

In an attempt to find d_p went back to chp 8 to use gear and tooth features pg 280 table 8-1

$$p = \frac{\pi D}{N} \qquad m = \frac{D}{N}$$

$$N = \frac{\pi D}{p} \qquad N = \frac{D}{m}$$

$$\frac{D}{m} = \frac{\pi D}{p}$$

$$\frac{D}{D} = \frac{\pi m}{p}$$

$$1 = \frac{\pi m}{p}$$

$$p = \pi m$$

$$m = \frac{p}{\pi}$$

$$m = \frac{0.125\,mm}{\pi}$$

$$m = 0.0796\,mm$$

pg 282 where $m = \frac{1}{P_d}$ where P_d is also pitch diameter

$$P_d = \frac{1}{m}$$

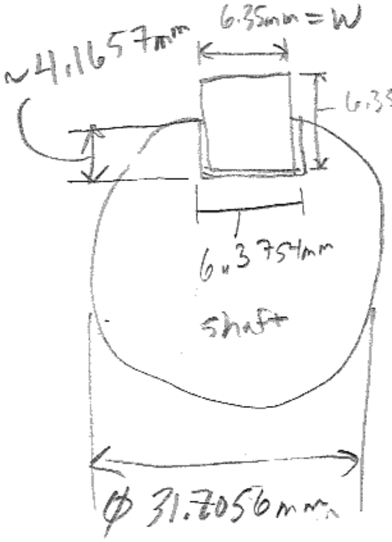
$$P_d = \frac{1}{0.0796\,mm} = 12.5628\,in^{-1}$$

Since $P_d =$

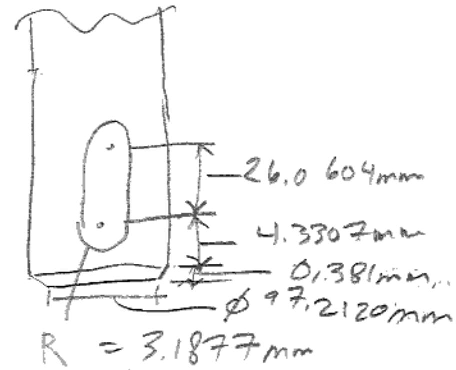
English

III. Rectangular Parallel key Selection
For motor and shaft Interface

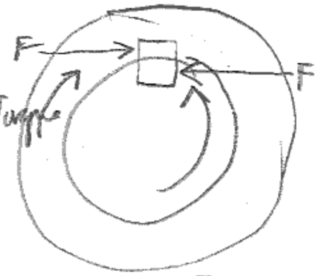
Motor Just Shaft
6660N530
mcmaster.com/6660n53



Shear plane = WL

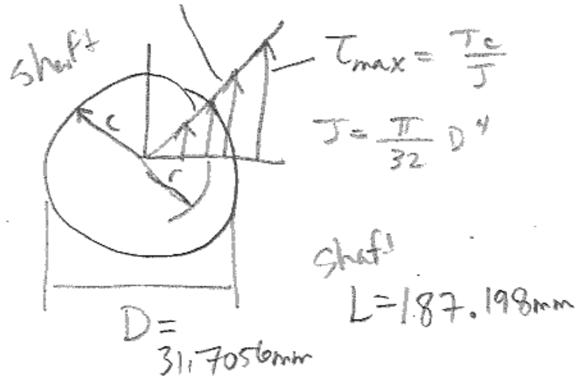


Hub is driving the shaft

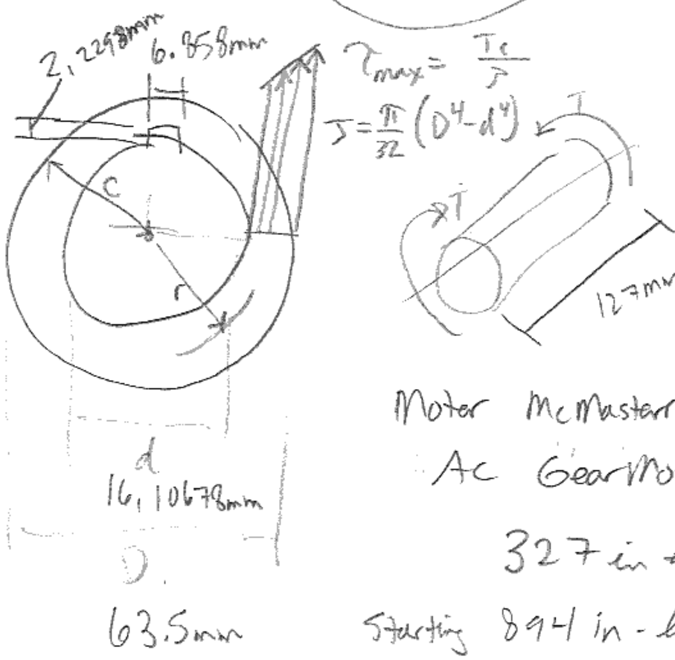


pg 93

$\tau = \frac{Tr}{J}$



pg 94



Motor McMaster Carr #6660N57

Ac GearMotor ~ 230V 1.9A 1/2 hp

327 in-lbf → 36.95 Nm @ 80rpm

Starting 894 in-lbf → 101 Nm

1/2 hp → 373 W → 373 Nm/s

pg 20
n = Rotational speed = $80 \frac{rev}{min} \cdot \frac{2\pi \, rad}{rev} \cdot \frac{1 min}{60 s} \cong 8.3776 \frac{rad}{s}$

pg 92 Torque(T) = $\frac{Power(P)}{Speed(n)} \rightarrow T = \frac{373 \, Nm/s}{8.3776 \, rad/s} \cong \boxed{44.5235 \, N \cdot m}$

pg 75 eq 3-11
Torsional Deformation

$$J = \frac{\pi D^4}{32} = \frac{\pi (31.7056mm)^4}{32}$$

$J = 99207.3386 mm^4$

Shaft $\theta = \frac{TL}{GJ}$

T = Torque
Assuming G = 80 GPa Steel Shear modulus
Shaft L = 187.198mm

$$\theta = \frac{(44.5235\times10^3 N\cdot mm)(187.198mm)}{(80\times10^3 \frac{N}{mm^2})(99207.3386mm^4)}$$

$\theta = 0.00105$ rad

$\theta = 0.00105 \text{ rad} \cdot \left(\frac{180°}{\pi \text{ rad}}\right) = 0.060017°$

Over the length of 187.198mm the shaft twists 0.060170°.

pg 428
Shearing stress

$$\tau = \frac{F}{A_s} = \frac{T}{(D/2)(WL)} = \frac{2T}{DWL}$$

$D_{shaft} = 31.7056$ mm
W = 6.35 mm
L = 25.4 mm

Solve for length
use eq 11-5
assume material
then calculate

Shaft $\tau = \frac{2(44.5235\times10^3 N\cdot mm)}{(31.7056mm)(6.35mm)(25.4mm)}$

$\tau = 17.4131 \frac{N}{mm^2}$

$\tau = 17.4131$ MPa $= 1.7413\times10^7$ Pa

Set $\tau_d = \tau$

$\tau_d = \frac{(0.5)S_y}{N} \rightarrow S_{y\,needed} = \frac{\tau_d N}{0.5}$

Safety factor
Assuming N = 3 pg 429

$$S_{y\,needed} = \frac{1.7413\times10^7 Pa \cdot 3}{0.5}$$

✓ $S_{y\,needed} = 104.478\times10^6$ Pa = 104.478 MPa ✓ SAE 1020 min S_y = 207 MPa

Any of the Steels pg 725, 726 Appendix 3 would work $\boxed{\text{SAE 1018}}$ key minimum Required Length for Shear when $\tau = \tau_d$

$$L_{min} = \frac{2T}{\tau_d DW} = \frac{2(44.5235 \times 10^3 N \cdot mm)}{(1.7413 \times 10^7 Pa)(31.7056 mm)(6.35 mm)}$$

$$\boxed{L_{min} = 25.4001 \times 10^{-6} m}$$

Basically the auger is going to spin in the Barrel no matter what when power is supplied to the motor.

where

SAE 1020

$\boxed{S_y = 207\ MPa} = \boxed{207 \times 10^6 Pa}$

$$\boxed{\tau_d = 0.5 \frac{S_y}{N}} \longrightarrow \frac{0.5(207 \times 10^6 Pa)}{3}$$

$$\boxed{\tau_d = 34.5 \times 10^6 Pa}$$

and

$$L_{min} = \frac{2T}{\tau_d DW} = \frac{2(44.5235 \times 10^3 N \cdot mm)}{(34.5 \times 10^6 Pa)(31.7056 mm)(6.35 mm)}$$

$$L_{min} = 12.8201 \times 10^{-6} m$$

Again the auger is going to spin no problem.

Min Req. key Length if key Material is weakest

$$L_{min} = \frac{4TN}{DWS_y} = \frac{4(44.5235 \times 10^3 N \cdot mm)(3)}{(31.7056 mm)(6.35 mm)(207 \times 10^6 Pa)}$$

$\hookrightarrow N/m^2$

$$\boxed{L_{min} = 12.8201 \times 10^{-6} mm}$$

$\boxed{\text{Key } 6.35 \times 6.35 \times 25.4\ mm \text{ SAE 1018 more than sufficient}}$