AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Pitch Control Mechanism

MDP 211

Machine Element Design

Team BM2

ID	Student Name
19P7372	Ahmed Adel Saleh
19P7696	Ahmed Amr Abdelbaki
19P1197	Eaman Mohamed Afan
19P9349	Mazen Ahmed Ellaboudy
19P6927	Mohab Tamer Hamed
19P5760	Mohamed Ahmed Badr
19P6291	Mohamed Yehia Metwally
19P1060	Omar Mahrous Eltoutongy

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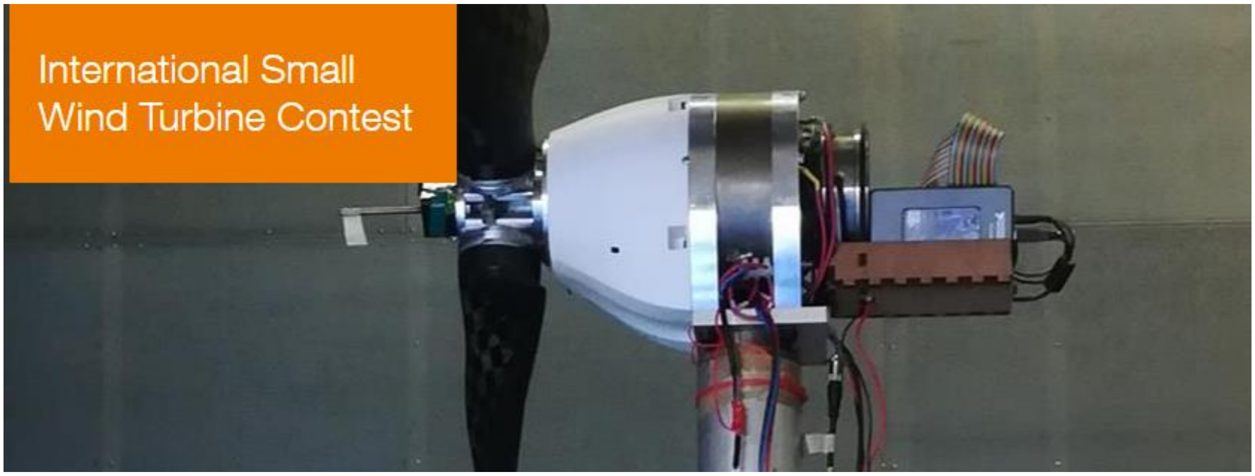
Abstract

Recently, the renewable energy, especially wind energy, has been paid much attention due to the energy shortage and environmental concern. As the penetration of the wind energy into the electrical power grid is extensively increased, the influence of the wind turbine systems on the frequency and voltage stability becomes more and more significant. Wind turbine rotor bears different types of loads; aerodynamic loads, gravitational loads and centrifugal loads. These loads cause fatigue and vibration in blades, which cause degradation to the rotor blades. These loads can be overcome and the amount of collected power can be controlled using a good pitch controller (PC) which will tune the attack angle of a wind turbine rotor blade into or out of the wind. Each blade is exposed to different loads due to the variation of the wind speed across the rotor blades. For this reason, individual electric drives can be used in future to control the pitch of the blades in a process called Individual Pitch Control. The pitch control monitors and adjusts the angle of the wind turbine's rotor blades, which can measure up to 65 meters long, and thus controls the rotational speed of the turbine. Although pitch controls play a vital role, they account for less than 3% of a wind turbine's capital expense.

But "research shows that pitch subsystem failures account for 23% of all downtime in wind turbines … more than any other turbine component or subsystem. … and pitch subsystems tallied the highest percentage of all component failures in wind turbines at more than 21%," according to Prasad Padman in a 2016 article in *North American Clean Energy* magazine. And when a wind turbine goes offline due to unplanned maintenance, the owner/ operator can lose, on average, several thousand dollars per day. Pitch controls are in the hub of the wind turbine where each blade requires a pitch actuator. To repair or service a pitch controller, technicians must usually travel to a remote site, climb 260 to 525 ft (80 to 160 m), unless the turbine comes equipped with a lift or small elevator. The expense of getting to the device requires that engineers develop low-maintenance, compact mechanism. When pitch controls do break, the ideal replacement is something a maintenance technician can carry, along with a satchel or kit of tools.

Besides the challenges of getting to the turbine's nacelle, equipment there must survive ambient temperatures ranging from −40° to 130° F (−40° to +55°C) and prolonged vibrations that put great stress on components. Whether it's scheduled or unscheduled, reducing the frequency and length of downtime is crucial for wind turbine operators. This means the pitch controls should be simple to maintain, relatively compact, lightweight, and reliable.

1. Introduction



The aim of this project is to design and manufacture a prototype for a pitch control mechanism to be fitted to small horizontal axis wind turbine competing in the International Small Wind Turbine Contest (ISWTC) held in the Netherlands in summer 2022.

The International Small Wind Turbine Contest (ISWTC) is a an annual contest in which University student teams from different countries can compete in designing and building the best performing Small Wind Turbine (SWT). The contest was first organized in 2013 by NHL University of Applied Sciences. Since 2018 the Hanze University of Applied Sciences (Hanze UAS) organizes the contest.

We had 2 options to operate the mechanism: using power screw, or using gears. After Considering Pros & Cons, we decided to go with the power screw. The power screw is coupled with a stepper motor to drive it. When the power screw rotates, it translates into linear motion via the guide nut. The guide nut is joined with a slider that is connected with 3 links. Those links are members of a slider-crank mechanism. Each mechanism is connected to a blade shaft that rotates from 0-90 degrees.

2. Project Specifications

The pitch control mechanism should be able to handle the following loads:

1. Force in the span-wise direction (pulling the blade in the direction of the centrifugal force) = 600 N

2. Wind force on the blade (assumed to be concentrated in the middle of the blade = 130 N

3. Required Pitching Torque = 2.5 Nm

The following Design Constraints should be considered:

1. Total length of the blade = 756 mm

2. Maximum Turbine rotor diameter = 1600 mm

3. Total swept area = 2 m^2

4. The mechanism is connected to the generator via 6 M8 Tap Bolts at PCD = 100 mm, with centering.

5. The blade should be rotated 0-90 Degrees.

6. The whole mechanism should be confined within the turbine nose.

7. The system should be operated by 12 Volt Battery. It can be tested using a power supply.

3.0 Design Steps

3.1 Initial Design

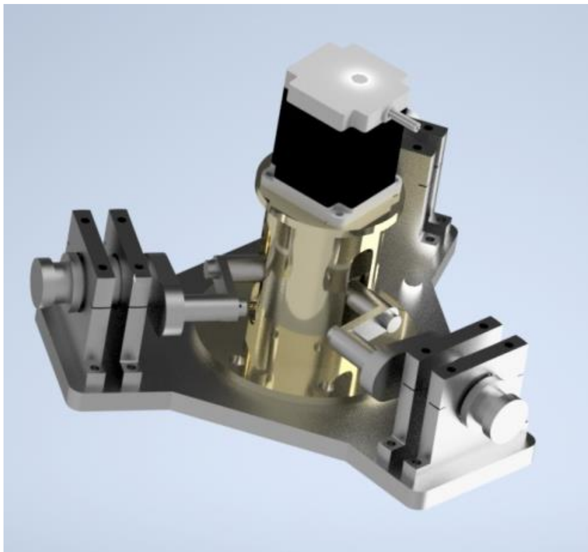


Figure 1: Initial Pitch Mechanism Design

Our initial design (Figure 1) contained a 3-armed plate, a cylindrical holder/slotter, a 2-part bearing bracket, and a slider-crank mechanism. The plate's arms were shaped 120 degrees apart. The bearing brackets were fixed at the end of the arms to accommodate the blade shafts. A sleeve was used to enlarge the shaft diameter to 25mm, because there are no standard bearings with inner diameter of 22.5mm. Spacers were used as method of fixation for bearings. The holder will be located at the center of the plate and fixated with 6xM8 bolts. It will have 3 slots for the link member pins. The slot's length will be 60mm so the mechanism can rotate from 0-90 degrees. Above the holder, the stepper motor will rest, and it will be coupled with the power screw inside the holder. The guide nut of the power screw will be fixated with a cover to join the pins and serve as the slider in the mechanism. The slider-crank mechanism will contain 2 links & 2 connecters. They will be joined together to transmit rotational motion to the blade shaft.

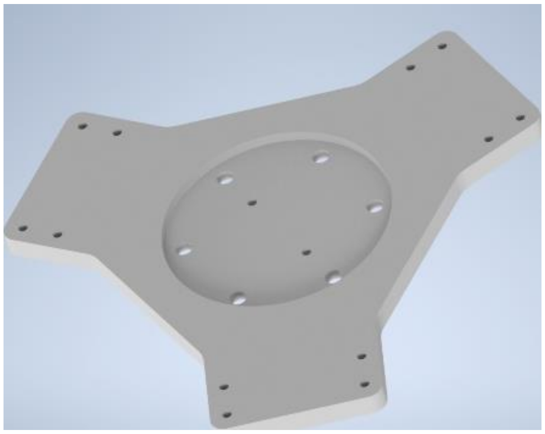


Figure 2: Holding Plate

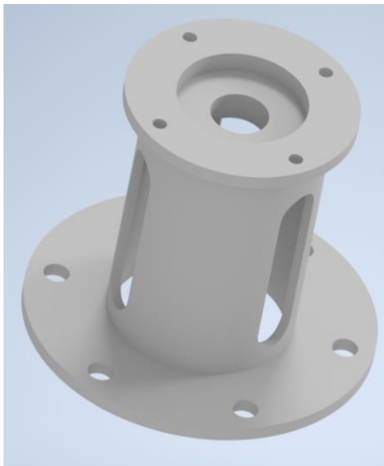


Figure 3: Holder

3.2 Final Design

When purchasing the material, we discovered that the material needed for the holder is too heavy, and a lot of it will be wasted. Therefore, we had to change the design to reduce the price and wasted material. We removed the holder & used a plate for the stepper & 3 columns for it. The plate was also altered as it required CNC or milling to be manufactured. Since CNC machining is very expensive and milling would consume a lot of time, we opted to go for a full circular plate to save time and money. The brackets were slightly changed. Instead of 2 shoulders in the fixed bearing bracket, we will use 1 shoulder & 1 external snap ring, so a small slot was made for the ring. The link was fitted with a slot to smooth the motion to avoid rigidness.

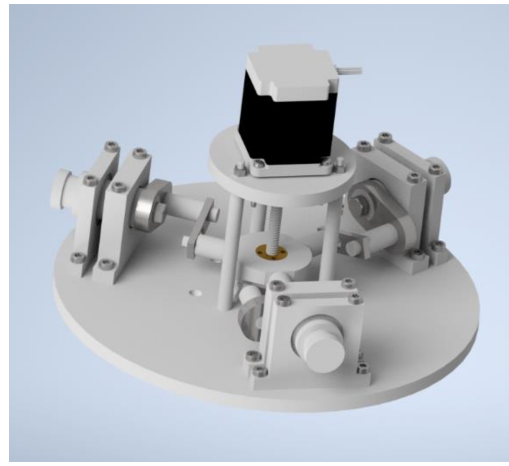


Figure 4: Final Design Assembly

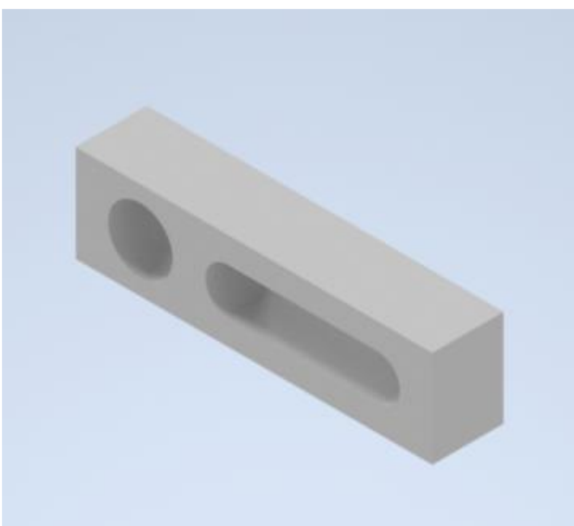


Figure 6: Link Member

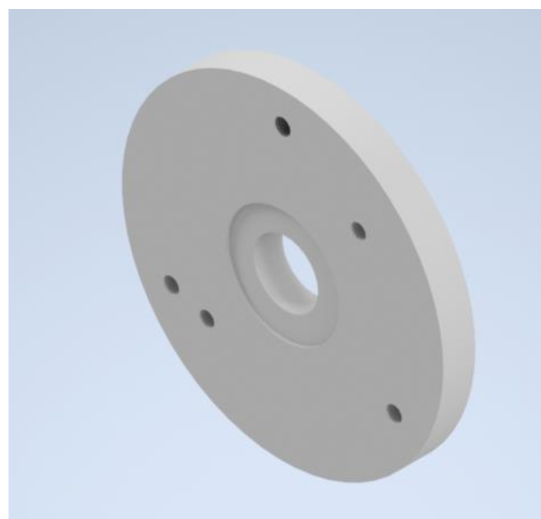


Figure 5: Stepper Plate

4.0 Calculations

4.1 Bolts Calculations

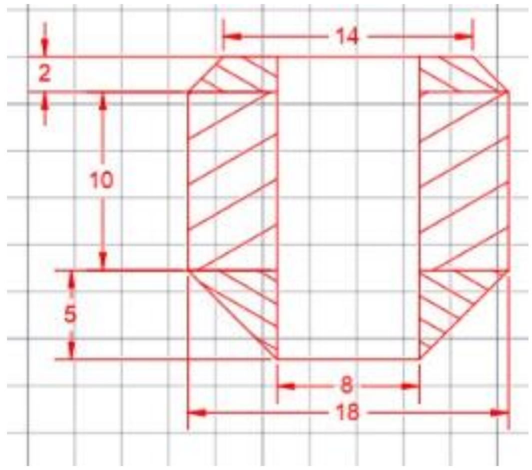


Figure 7: Shaft Bolt Influence cone

4.1.1 Shaft Tap Bolt

M8x22x18x10x1.25

$d_c = 7.06mm, A_c = \frac{\pi}{4}7.06^2 = 39.2mm^2, A_o = 113.1mm^2$

$C_{b1} = \frac{EA_0}{L} = \frac{210\times10^3\times113.1}{4} = 5937750\ N/mm$

$C_{b2} = \frac{EA_c}{L} = \frac{210\times10^3\times39.2}{13} = 633231\ N/mm$

$\frac{1}{C_b} = \frac{1}{C_{b1}} + \frac{1}{C_{b2}}$

$C_b = 572207\ N/mm$

$a = 9.5mm$

$A_1 = \frac{\pi}{4}(16^2 - 9.5^2) = 130.18mm^2 \quad d_m = \frac{14+18}{2} = 16mm$

$C_{j1} = \frac{EA_1}{L} = \frac{210\times10^3\times130.18}{2} = 13668873.3\ N/mm$

$A_2 = \frac{\pi}{4}(18^2 - 9.5^2) = 183.59mm^2 \quad d_m = \frac{18+18}{2} = 18mm$

$C_{j2} = \frac{EA_2}{L} = \frac{210\times10^3\times183.5}{10} = 3855323.2\ N/mm$

$A_3 = \frac{\pi}{4}(13 - 8^2) = 82.47mm^2 \quad d_m = \frac{18+8}{2} = 13mm$

$C_{j3} = \frac{EA_3}{L} = \frac{210\times10^3\times82.47}{5} = 3463605.9\ N/mm$

$\frac{1}{C_j} = \frac{1}{C_{j1}} + \frac{1}{C_{j2}} + \frac{1}{C_{j3}}$

$C_j = 1609640\ N/mm$

$F_{ex} = 600N$

$F_r = 0.3F_{ex} = 180N$

$F_j = \frac{C_j}{C_j + C_b} Fex = \frac{1609640}{572207 + 1609640} 600 = 442.6N$

$F_{max} = F_{ex} + F_r = 780N$

$F_i = F_j + F_r = 224.26N$

$T_1 = F_i \frac{d_m}{2} \frac{tan\alpha + \mu'}{1 - \mu' tan\alpha}$

$d_m = \frac{8 + 7.06}{2} = 7.13mm$

$tan\alpha = \frac{P}{\pi d} = \frac{1}{7.13\pi} = 0.0558$

$\mu' = \frac{\mu}{cos30} = 0.231$

$T_1 = 232.29\ N.mm$

$T_2 = F_i \mu \frac{d}{2} = 159.9\ N.mm$

$T_t = 232.29 + 159.9 = 392.8\ N.mm$

Assembly Stress Analysis

$\tau = \frac{16T_1}{\pi {d_c}^3} = 3.362\ MPa$ $\sigma = \frac{F_i}{\frac{\pi}{4}{d_c}^2} = 5.72\ MPa$

$\tau_{max} = \sqrt{3.362^2 + (\frac{5.72}{2})^2} = 4.414\ MPa$

Working Stress Analysis

$\sigma = \frac{F_{max}}{\frac{\pi}{4}{d_c}^2} = 19.9\ MPa$

$\tau_{max} = \frac{\sigma}{2} = 9.949\ MPa$

Working Stress is more critical

$9.949 \leq \frac{\sigma_y}{2n}$ $\quad \sigma_y = 39.796\ MPa$ $\quad$ Grade 8.8 is suitable

4.1.2 Lower Bracket Through Bolt

M6x30x12x1

$d_c = 4.67mm, A_c = \frac{\pi}{4}4.67^2 = 17.13mm^2, A_o = 28.27mm^2$

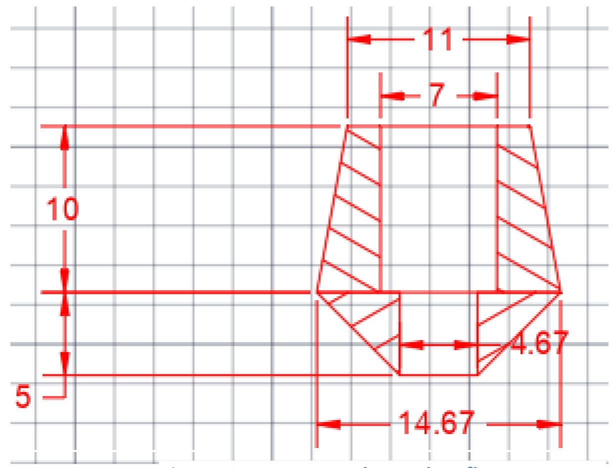


Figure 8: Lower Bracket Bolt Influence Cone

$$C_{b1} = \frac{EA_0}{L} = \frac{210\times10^3\times28.27}{30-12} = 329816.67\ N/mm$$

$$C_{b2} = \frac{EA_c}{L} = \frac{210\times10^3\times17.13}{12-7} = 719460\ N/mm$$

$$\frac{1}{C_b} = \frac{1}{C_{b1}} + \frac{1}{C_{b2}}$$

$$C_b = 226146.17\ N/mm$$

$$a = 7mm$$

$$A_1 = \frac{\pi}{4}(12.83^2 - 7^2) = 90.8mm^2 \quad d_m = \frac{11+14.67}{2} = 12.83mm$$

$$C_{j1} = \frac{EA_1}{L} = \frac{210\times10^3\times90.8}{10} = 1906800\ N/mm$$

$$A_2 = \frac{\pi}{4}(9.67^2 - 4.67^2) = 56.3mm^2 \quad d_m = \frac{4.67+14.67}{2} = 9.67mm$$

$$C_{j2} = \frac{EA_2}{L} = \frac{210\times10^3\times56.3}{5} = 2365148\ N/mm$$

$$\frac{1}{C_j} = \frac{1}{C_{j1}} + \frac{1}{C_{j2}}$$

$$C_j = 1055692.7\ N/mm$$

$F_{ex} = F_{sh} + F_m$

$F \times L = \frac{F_m}{L2}(n1 \times L1^2 + n2 \times L2^2)$

$130 \times 368 = \frac{F_m}{30}(2 \times 10^2 + 2 \times 30^2) \quad F_m = 717.6N$

$F_{sh} = \frac{600}{\mu \times n} = \frac{600}{0.2 \times 4} = 750N$

$F_{ex} = 750 + 717.6 = 1467.6N$

$F_r = 0.3F_{ex} = 440.3N$

$F_j = \frac{C_j}{C_j + C_b} Fex = 1208.7N$

$F_{max} = F_{ex} + F_r = 1907.9N$

$F_i = F_j + F_r = 1649N$

$T_1 = F_i \frac{d_m}{2} \frac{tan\alpha + \mu'}{1 - \mu' tan\alpha}$

$d_m = \frac{5 + 3.89}{2} = 4.445mm$

$tan\alpha = \frac{P}{\pi d} = \frac{1}{4.445\pi} = 0.0716$

$\mu' = \frac{\mu}{cos30} = 0.231$

$T_1 = 1127.65\ N.mm$

$T_2 = F_i \mu \frac{d}{2} = 733\ N.mm$

$T_t = 1127.65 + 733 = 1860.65\ N.mm$

Assembly Stress Analysis

$\tau = \frac{16T_1}{\pi {d_c}^3} = 56.4\ MPa \qquad \sigma = \frac{F_i}{\frac{\pi}{4}{d_c}^2} = 96.27\ MPa$

$\tau_{max} = \sqrt{56.4^2 + (\frac{96.27}{2})^2} = 74.15\ MPa$

Working Stress Analysis

$\sigma = \frac{F_{max}}{\frac{\pi}{4}{d_c}^2} = 122.95\ MPa$

$\tau_{max} = \frac{\sigma}{2} = 61.5\ MPa$

Assembly Stress is more critical

$74.15 \leq \frac{\sigma_y}{2n}$ $\sigma_y = 297\ MPa$ Grade 8.8 is suitable

4.1.3 Upper Bracket Through Bolt

M6x50x22x1

$d_c = 4.67mm, A_c = \frac{\pi}{4}4.67^2 = 17.13mm^2, A_o = 28.27mm^2$

$C_{b1} = \frac{EA_0}{L} = \frac{210\times10^3\times28.27}{50-22} = 212025\ N/mm$

$C_{b2} = \frac{EA_c}{L} = \frac{210\times10^3\times17.13}{22-7} = 239820\ N/mm$

$\frac{1}{C_b} = \frac{1}{C_{b1}} + \frac{1}{C_{b2}}$

$C_b = 112533.8\ N/mm$

$a = 7mm$

$A_1 = \frac{\pi}{4}(15.3^2 - 7^2) = 145.37mm^2$ $d_m = \frac{11+19.67}{2} = 15.3mm$

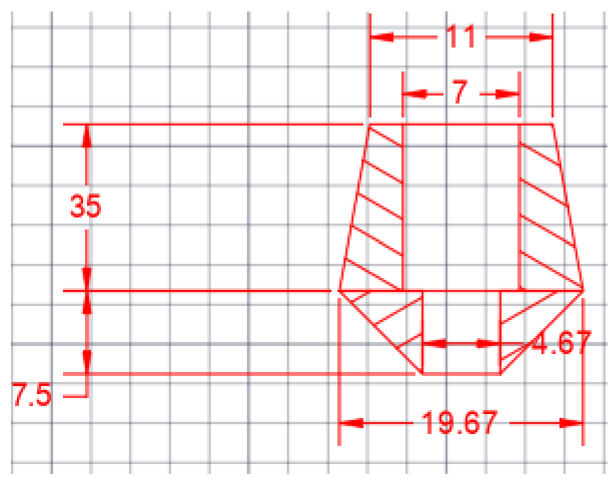


Figure 9: Upper Bracket Bolt Influence Cone

$C_{j1} = \frac{EA_1}{L} = \frac{210\times10^3\times145.37}{35} = 872220\ N/mm$

$A_2 = \frac{\pi}{4}(12.17^2 - 4.67^2) = 99.2mm^2$ $d_m = \frac{4.67+19.67}{2} = 12.17mm$

$C_{j2} = \frac{EA_2}{L} = \frac{210\times10^3\times99.2}{7.5} = 2777600\ N/mm$

$\frac{1}{C_j} = \frac{1}{C_{j1}} + \frac{1}{C_{j2}}$

$C_j = 663780.2\ N/mm$

$F_{ex} = F_{sh} + F_m$

$F \times L = \frac{F_m}{L2}(n1 \times L1^2 + n2 \times L2^2)$

$130 \times 368 = \frac{F_m}{30}(2 \times 10^2 + 2 \times 30^2) \quad F_m = 717.6N$

$F_{sh} = \frac{600}{\mu \times n} = \frac{600}{0.2 \times 4} = 750N$

$F_{ex} = 750 + 717.6 = 1467.6N$

$F_r = 0.3F_{ex} = 440.3N$

$F_j = \frac{C_j}{C_j + C_b} Fex = 1254.9N$

$F_{max} = F_{ex} + F_r = 1907.9N$

$F_i = F_j + F_r = 1695N$

$T_1 = F_i \frac{d_m}{2} \frac{tan\alpha + \mu'}{1 - \mu' tan\alpha}$

$d_m = \frac{5 + 3.89}{2} = 4.445mm$

$tan\alpha = \frac{P}{\pi d} = \frac{1}{4.445\pi} = 0.0716$

$\mu' = \frac{\mu}{cos30} = 0.231$

$T_1 = 1159.11\ N.mm$

$T_2 = F_i \mu \frac{d}{2} = 753\ N.mm$

$T_t = 1159.1 + 753 = 1912.1\ N.mm$

Assembly Stress Analysis

$\tau = \frac{16T_1}{\pi {d_c}^3} = 57.9\ MPa \qquad \sigma = \frac{F_i}{\frac{\pi}{4}{d_c}^2} = 98.96\ MPa$

$\tau_{max} = \sqrt{57.9^2 + (\frac{98.96}{2})^2} = 76.16\ MPa$

Working Stress Analysis

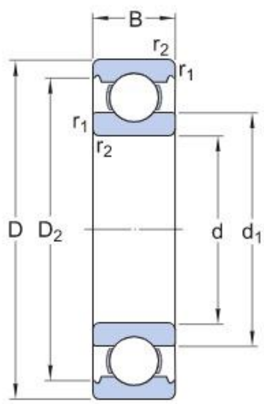
$$\sigma = \frac{F_{max}}{\frac{\pi}{4}{d_c}^2} = 122.95\ MPa$$

$$\tau_{max} = \frac{\sigma}{2} = 61.5\ MPa$$

Assembly Stress is more critical

$76.16 \leq \frac{\sigma_y}{2n}$ $\quad \sigma_y = 305\ MPa$ Grade 8.8 is suitable

4.2 Bearing Calculations: 61805



DIMENSIONS

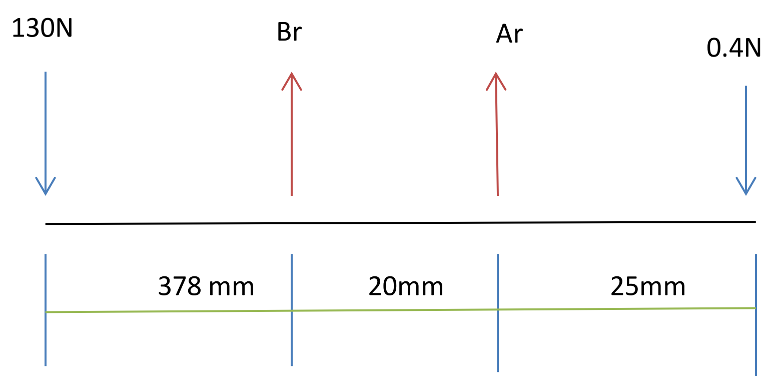
d	25 mm	Bore diameter
D	37 mm	Outside diameter
B	7 mm	Width
d_1	≈ 28.5 mm	Shoulder diameter
D_1	≈ 33.15 mm	Shoulder diameter
D_2	≈ 34.2 mm	Recess diameter
$r_{1,2}$	min. 0.3 mm	Chamfer dimension

Figure 10: Bearing 61805 Specs

CALCULATION DATA

Basic dynamic load rating	C	4.36 kN
Basic static load rating	C_0	2.6 kN
Fatigue load limit	P_u	0.125 kN
Reference speed		38 000 r/min
Limiting speed		24 000 r/min
Minimum load factor	k_r	0.015
Calculation factor	f_0	14.2

Figure 11: Bearing Calculation Data



$W_{Crank} = 0.4N$

$F_{Crank} = 14.5N$

$\sum M_A = 0$

$130(398) - (20) - 0.4(25) = 0$

$B_r = 2586.5\ N$

$\sum F_Y = 0$

$130 - 2586.5 + 0.4 - A_r = 0$

$A_r = 2456.1\ N$

$$F_{eq} = xvF_r + yF_a$$

Bearing A:

$F_{Ar} = 2456.1\ N\ , F_{Aa} = 614.5$

$v = 1$

$f_0 = 14.2, C_0 = 2600\ N, C = 4360\ N$

$\frac{f_0 F_a}{C_0} = 3.4$

$y = 1.15, x = 0.56$

$F_{Aeq} = 2082.1\ N$

Bearing B:

$F_{Br} = 2586.5\ N\ , F_{Ba} = 0$

$v = 1\ , x = 1, y = 0$

$F_{Beq} = 2586.5\ N$

Calculation factors for deep groove ball bearings

f_0F_a/C_0	Single row and double row bearings Normal clearance		
	e	X	Y
0,172	0,19	0,56	2,3
0,345	0,22	0,56	1,99
0,689	0,26	0,56	1,71
1,03	0,28	0,56	1,55
1,38	0,3	0,56	1,45
2,07	0,34	0,56	1,31
3,45	0,38	0,56	1,15
5,17	0,42	0,56	1,04
6,89	0,44	0,56	1

Figure 12: Bearing Calculations Factors

Assuming Bearing Life is 24 Hours

$$L = \frac{60 * L_H * N}{10^6} = \frac{60 * 24 * 1.5}{10^6} = 2.16 \times 10^{-3}, n = 3\ (Ball\ Bearing)$$

$$C = F_{eq} \sqrt[n]{L}$$

$C_A = 2082.1 * \sqrt[3]{2.16 \times 10^{-3}} = 269\ N\ < 4360\ N\ \ (Bearing\ A\ is\ suitable)$

$C_B = 2586.5 * \sqrt[3]{2.16 \times 10^{-3}} = 334\ N\ < 4360\ N\ \ (Bearing\ B\ is\ suitable)$

4.3 Slider-Crank Mechanism

$F_{moment} = \frac{T}{L} = \frac{2.5}{30 \times 10^{-3}} = 83.33$ N

T= 2.5 N.m , L= 30 mm

$F_{L2} = \frac{Fmoment}{\sin(2\emptyset 1)}$

$F_{L1} = FL2 \cos(2\emptyset 1)$

$F_{Nut} = FL2 \times Cos(90 - \emptyset)$

$Fa = F_{Nut} \times 3$

Max Fa = 720 N

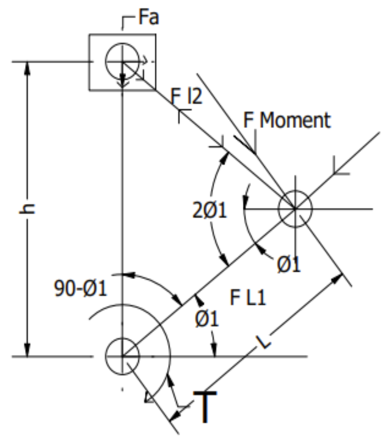


Figure 13: Slider Crank Mechanism

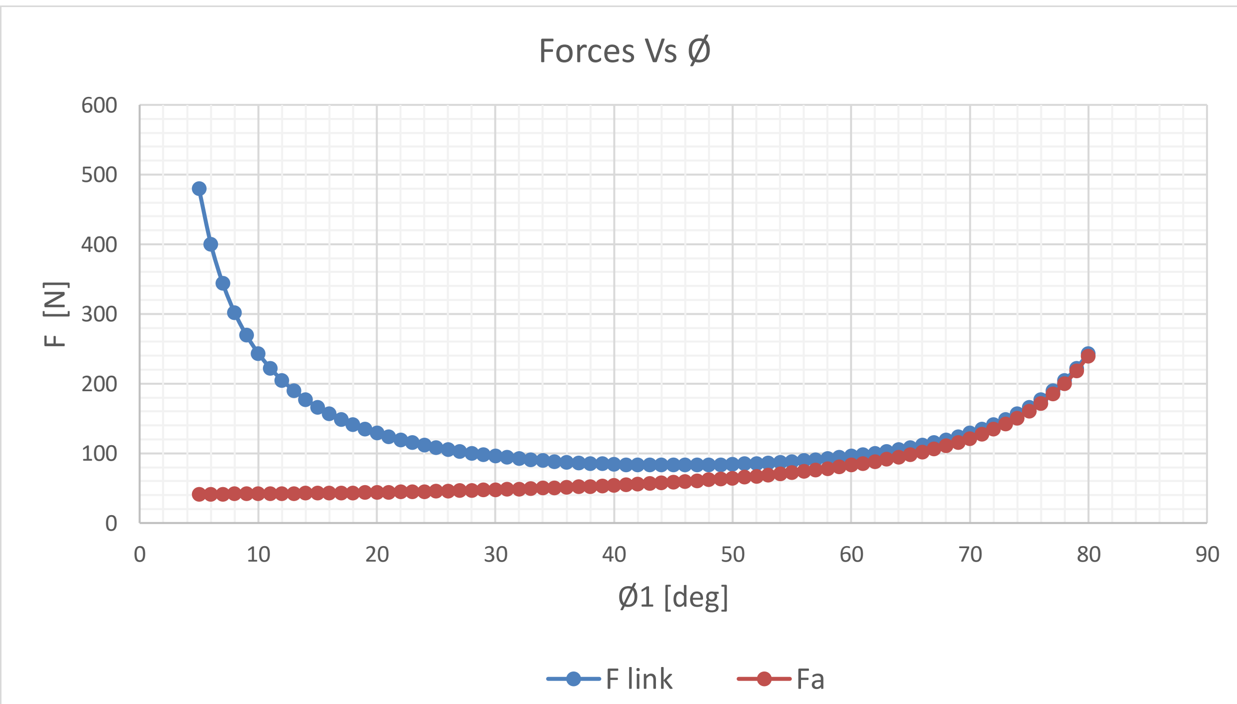


Figure 14: Slider Crank Graph

4.4 Power Screw Calculations:

Trapezoidal Power Screw 8x2mm

$$T = F_a \frac{d_m}{2} \frac{\mu' + tan\alpha}{1 - \mu' tan\alpha} + T_2$$

$$T_2 = 0, because\ there\ is\ no\ seat$$

$\mu' = \frac{\mu}{cos\beta} = \frac{0.2}{\cos(\frac{30}{2})} = 0.207$

$d_c = d_o - P - 0.5 = 8 - 2 - 0.5 = 5.5mm$

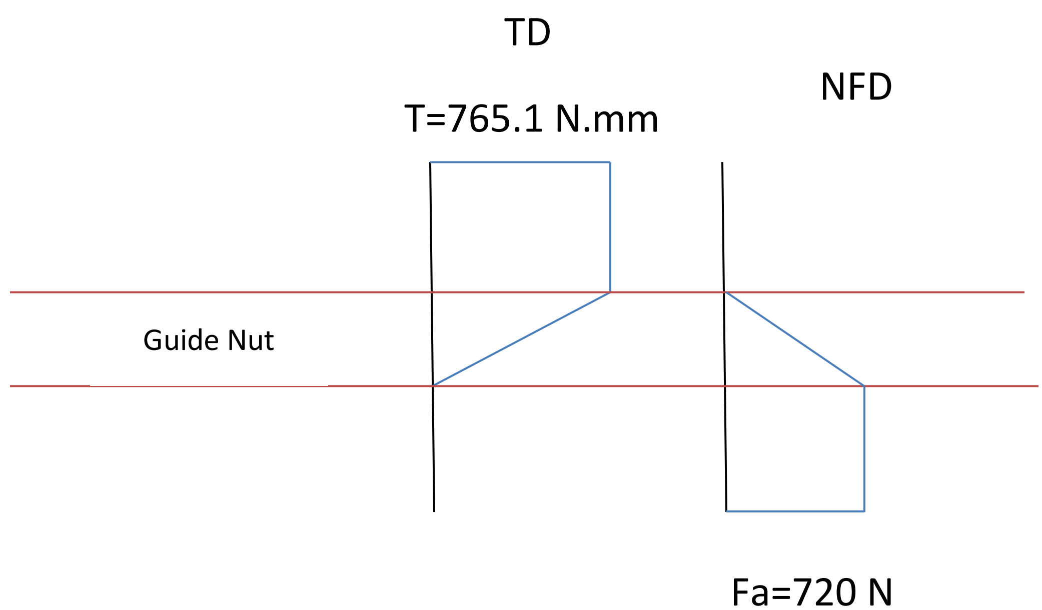
$d_m = \frac{d_o + d_c}{2} + 0.25 = \frac{8+5.5}{2} + 0.25 = 7mm$

$tan\alpha = \frac{P}{\pi d_m} = \frac{2}{7\pi} = 0.0909$

$F_a = 3F_{nut} = 3 * 240 = 720N$

$T = (720)\left(\frac{7}{2}\right)\left(\frac{0.207+0.0909}{1-0.207-0.0909}\right) = 765.1\ N.mm$

Diagrams



Stresses:

Above Guide Nut:

$$\tau = \frac{16T}{\pi d^3} = \frac{16*765.1}{\pi*5.5^3} = 23.42\ MPa$$

Below Guide Nut:

$$\sigma = \frac{F}{A} = \frac{720}{\frac{\pi}{4}d^2} = 30.31\ MPa$$

$$\tau = \frac{\sigma}{2} = 15.15\ MPa$$

Section above guide nut is more critical

$$\tau_{max} = \frac{\sigma_y}{2n} = 23.42\ MPa, \sigma_y = 170\ MPa\ (Stainless\ Steel)$$

$$n = \frac{170}{2*23.42} = 3.63\ (Safe)$$

Power screw Calculator

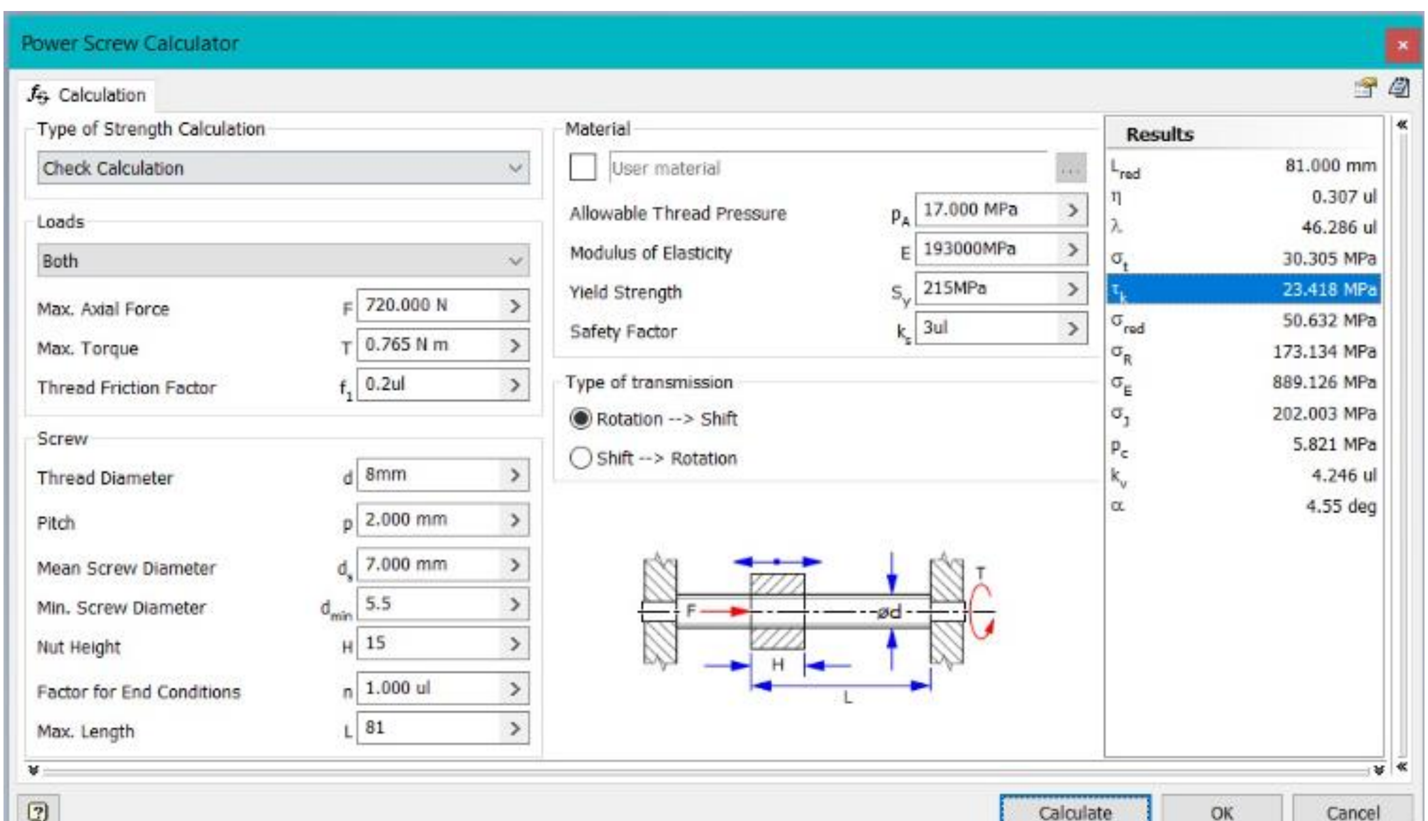


Figure 15: Power Screw Calculator

4.5 Guide Nut Calculations:

N due to Bearing Pressure:

$$\frac{F_a}{A} \leq B.P, \quad B.P = 17MPa$$

$$\frac{720}{\frac{\pi}{4}({d_o}^2 - {d_c}^2)*N} \leq 17$$

$$N = 1.6 \approx 2$$

N due to Bending Stress:

$$\frac{M_x}{I_x}y \leq \frac{\sigma_y}{n}, \quad \sigma_y = 125\ MPa\ (Bronze)$$

$$\frac{F*\frac{P}{4}*12}{N*\pi*d_o*(\frac{P}{2})^3}\frac{P}{4} \leq \frac{\sigma_y}{n}\ , assume\ n = 2$$

$$N = 1.38 \approx 2$$

N due to Shear Stress:

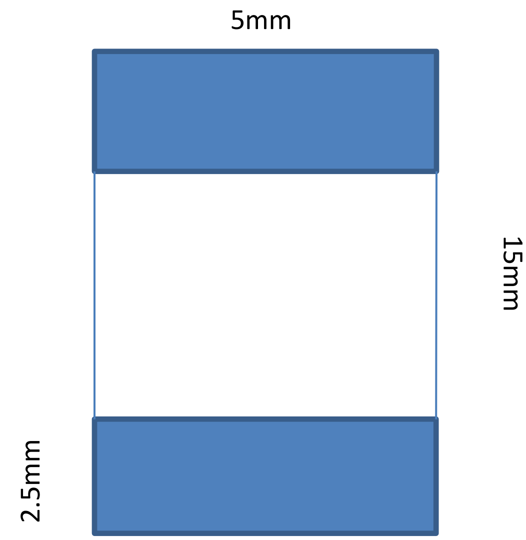
$$\frac{3V}{2A} \leq \frac{\sigma_y}{2n}$$

$$\frac{3F}{2\pi*d_m*\frac{P}{2}*N} \leq \frac{\sigma_y}{2n}$$

$$N = 1.57 \approx 2$$

$$Min.Nut\ Height\ H = N*P = 2*2 = 4mm$$

4.6 Stress on Slider-Crank Links:



$$\sigma = \frac{F}{A} = \frac{480}{2(2.5*5)} = 19.2\ MPa$$

$$\frac{\sigma}{2} = \frac{\sigma_y}{2n} \quad , assume\ n = 2$$

$$\sigma_y = 38.4\ MPa$$

5.0 Manufacturing Process

5.1 Plate

We started with turning machine to cut the plate to the desired shape then we used drilling machine to make the holes for the brackets, holders, flange bearings, and generator bolts.

Figure 16: Working Process (Plates)

5.2 Guide cover

We started with the turning machine. Then, we used the drilling to make 3 holes and tap them.

5.3 Brackets

We first shape the bracket with the milling machine. Then, we used turning to make the hole for the bearing.

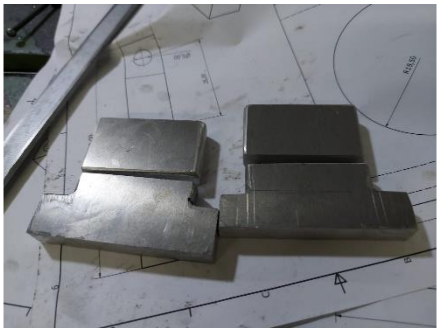


Figure 17: Working Process (Brackets)

5.4 Links

We used turning machine and drilling to make the crank to the desired shape. However, we used the CNC to make the mini link because it needs to be more accurate.

Figure 18: Working Process (Links , Connectors, Spacer and Sleeve)

5.5 Connectors

We used only the turning machine to manufacture the connectors.

5.6 Spacers & Sleeve

They were made only by using turning machine.

6.0 Stepper Motor Specs

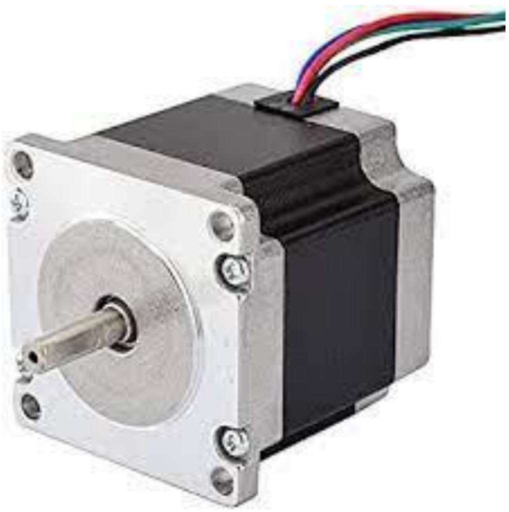


Figure 19: Stepper Motor Nema 23

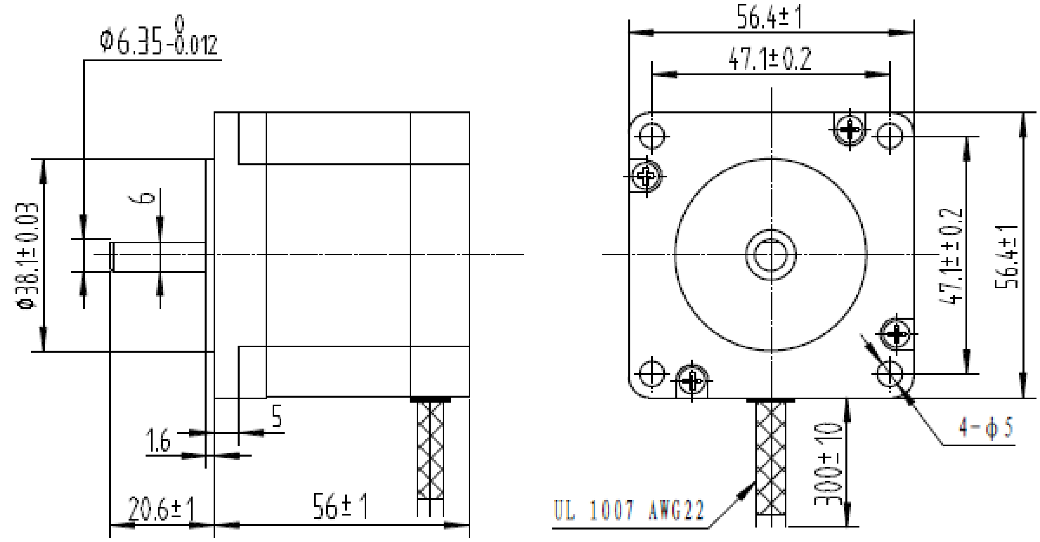
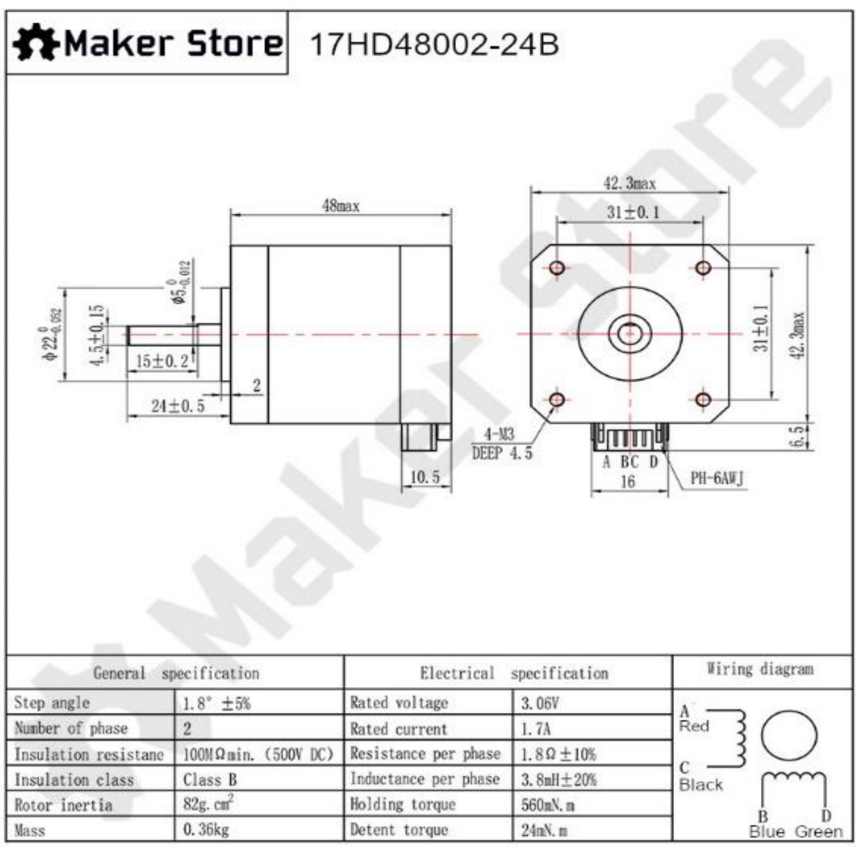


Figure 20: Stepper Dimensions



General specification		Electrical specification	
Step angle	1.8° ±5%	Rated voltage	3.06V
Number of phase	2	Rated current	1.7A
Insulation resistane	100MΩmin. (500V DC)	Resistance per phase	1.8Ω±10%
Insulation class	Class B	Inductance per phase	3.8mH±20%
Rotor inertia	82g. cm^2	Holding torque	560mN.m
Mass	0.36kg	Detent torque	24mN.m

7.0 Flowchart

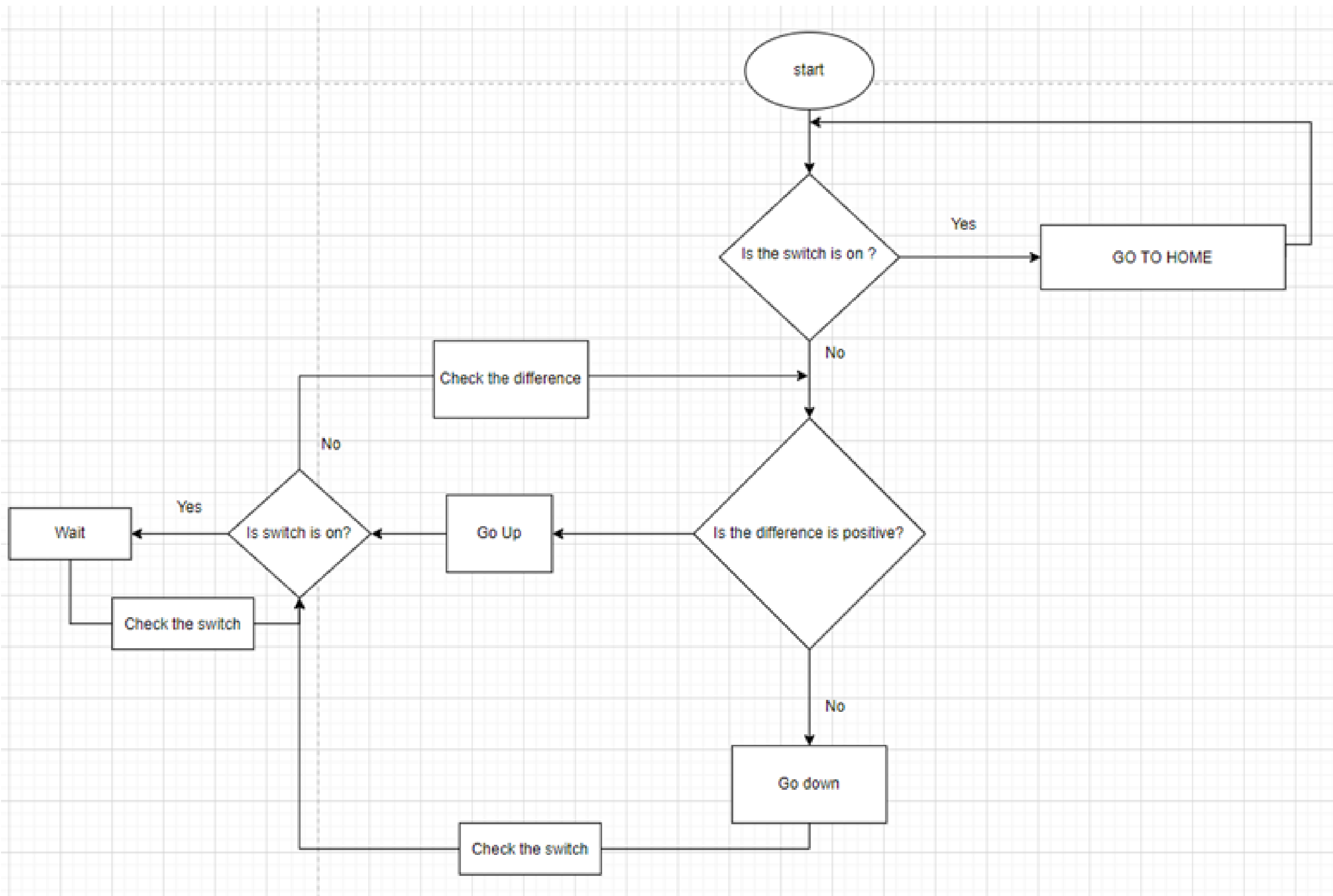


Figure 21: Process Flowchart

8.0 Electrical Components

8.1 Potentiometer

2 Potentiometers were used: 1 for the LCD and the other for input voltage. The second potentiometer is very critical. It reads from 0 to 1023 mV. This range is then converted from 0-2.5 volts and serve as input for the mechanism.

Figure 22: Potentiometer

8.2 LCD

An LCD is used to display the current voltage and angle the mechanism has turned. It is connected to a potentiometer to control brightness.

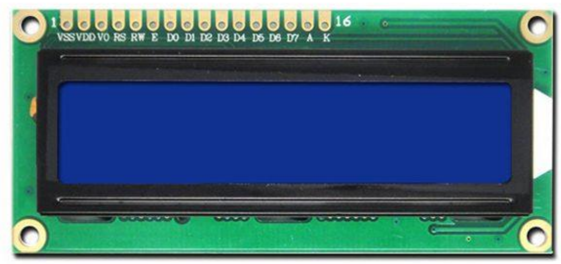


Figure 23: LCD

8.3 Stepper Drive

A stepper drive is used to control the stepper motor. It helps the motor deliver the required torque as input to our system.

Figure 24: Stepper Drive

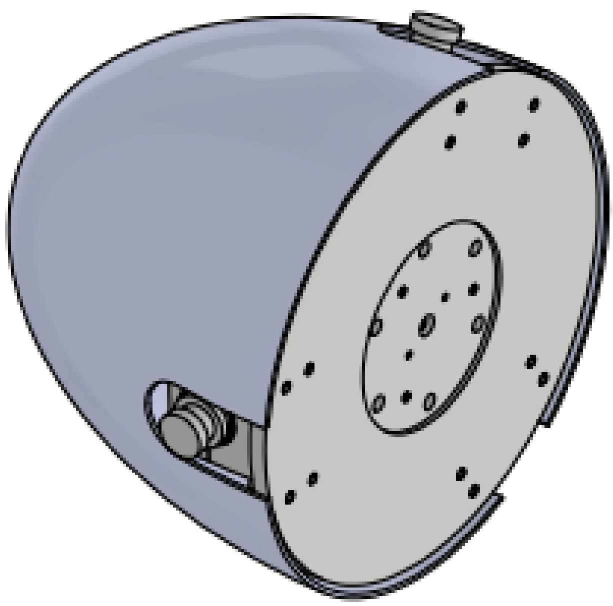
8.4 Arduino

The Arduino serves as the micro controller for our mechanism. It is given a program code and connected with sensors and motors to run the program smoothly and neatly.

Figure 25: Arduino

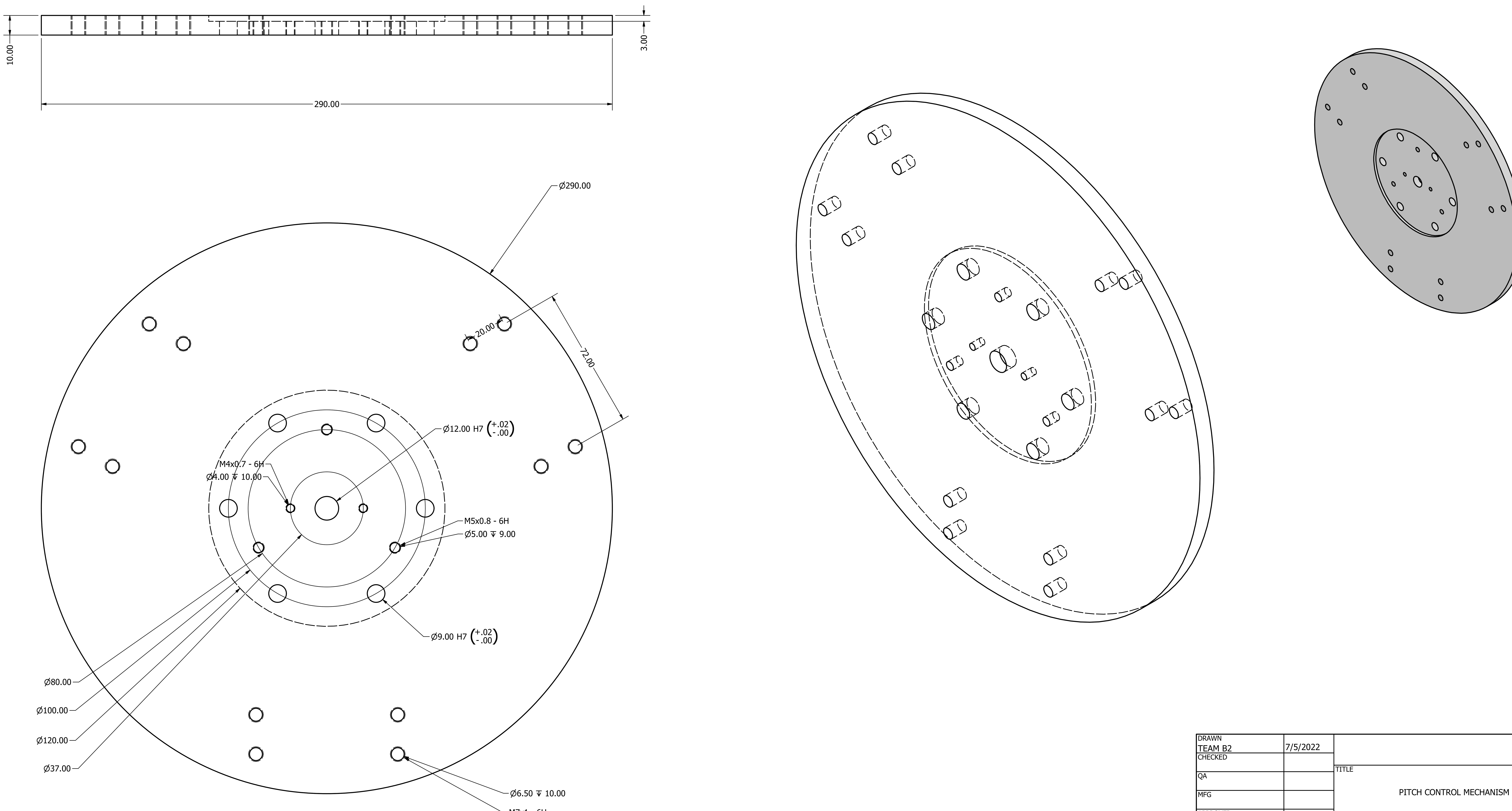
9.0 Working Drawings

9.1 Final Assembly with Nose



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	guid cover final
2	1	guide nut
3	3	connector_bet._2L_FINAL
4	2	link1
5	3	Assembly4
6	3	connector1_threaded_FINAL
7	3	shaft
8	3	Bat7a_Link_Final
9	1	minilink_FINAL
10	1	holding plate
11	1	Nose
12	1	flex coupler
13	1	Power_Screw_FINAL
14	1	stepper
15	1	Horizontal-Self-AligningFlangeBearing__ID=8mm
16	3	PlateShaft
17	1	StepperPlate
18	2	ANSI B18.6.4 - No. 6 - 32 - 3/8, CRFHTSTCTI(2)
19	12	Screw GB 6564 M6 x 40
20	12	Screw GB 6564 M6 x 20
21	3	ANSI B18.2.4.2M - M5x0.8
22	4	ANSI B18.6.4 - No. 8 - 32 - 1 1/4, CRFHTSTCTI(2)
23	4	AS 1237 - 4
24	4	ANSI B18.2.4.2M - M4x0.7
25	4	AS 1237 - 8
26	3	IFI 502 - M8x1.25 x 16, FUHHTSTDM

DRAWN omare 7/5/2022
CHECKED
QA
MFG
APPROVED
TITLE
SIZE A
DWG NO FINAL_ASSEMBLY 1
REV
SCALE 0.3 : 1
SHEET 2 OF 2



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MFG		
APPROVED		
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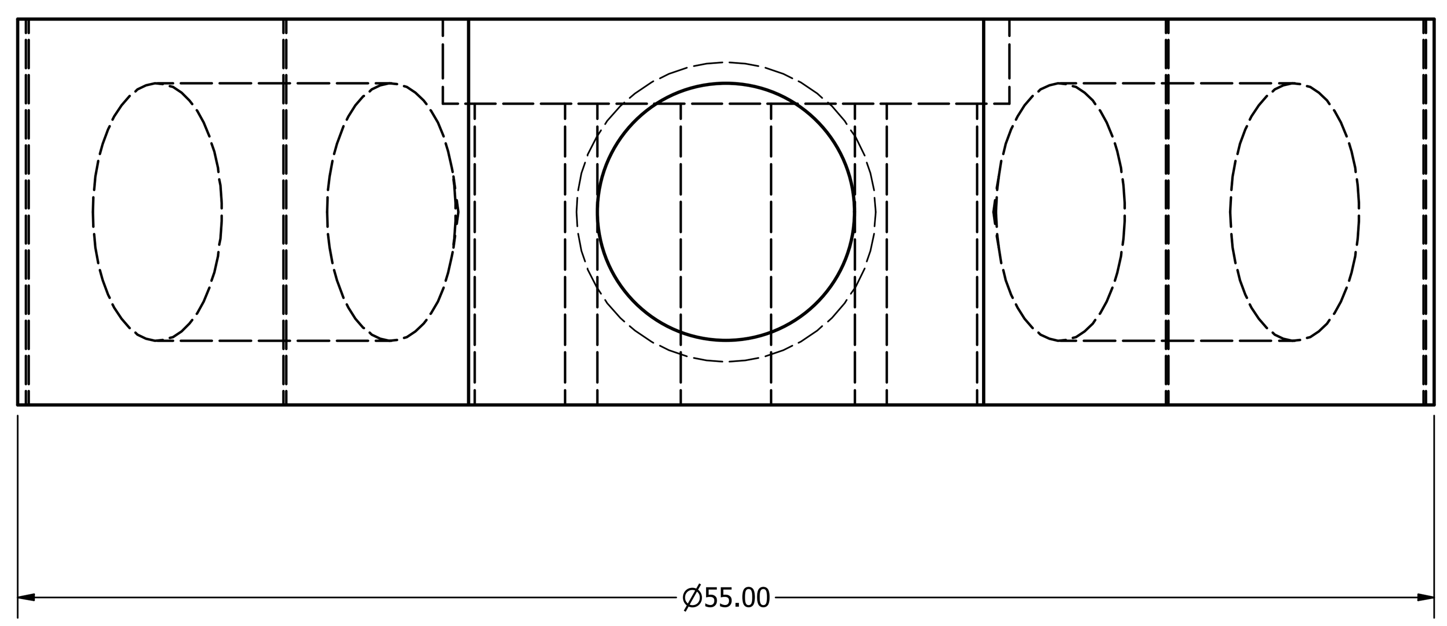
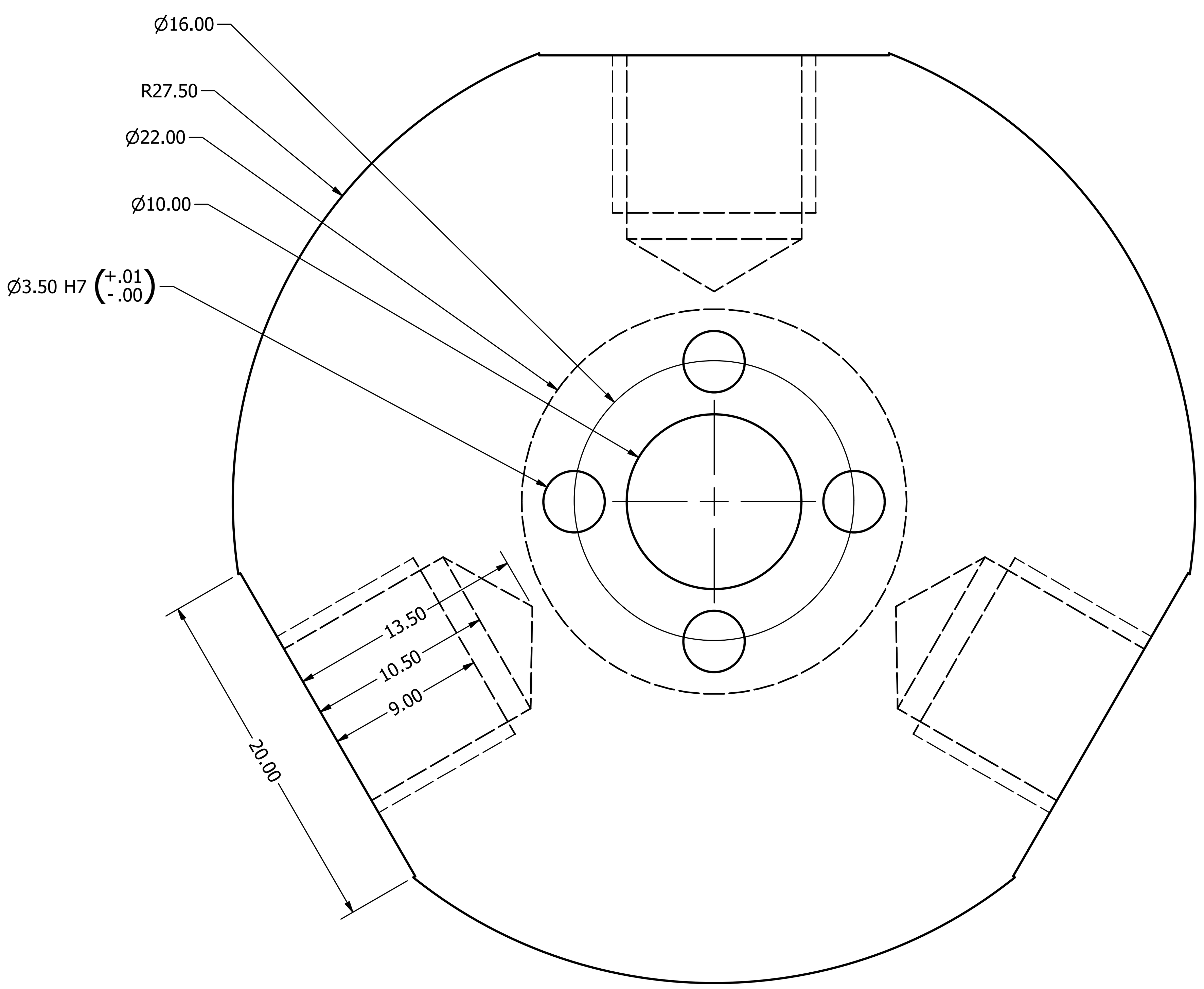
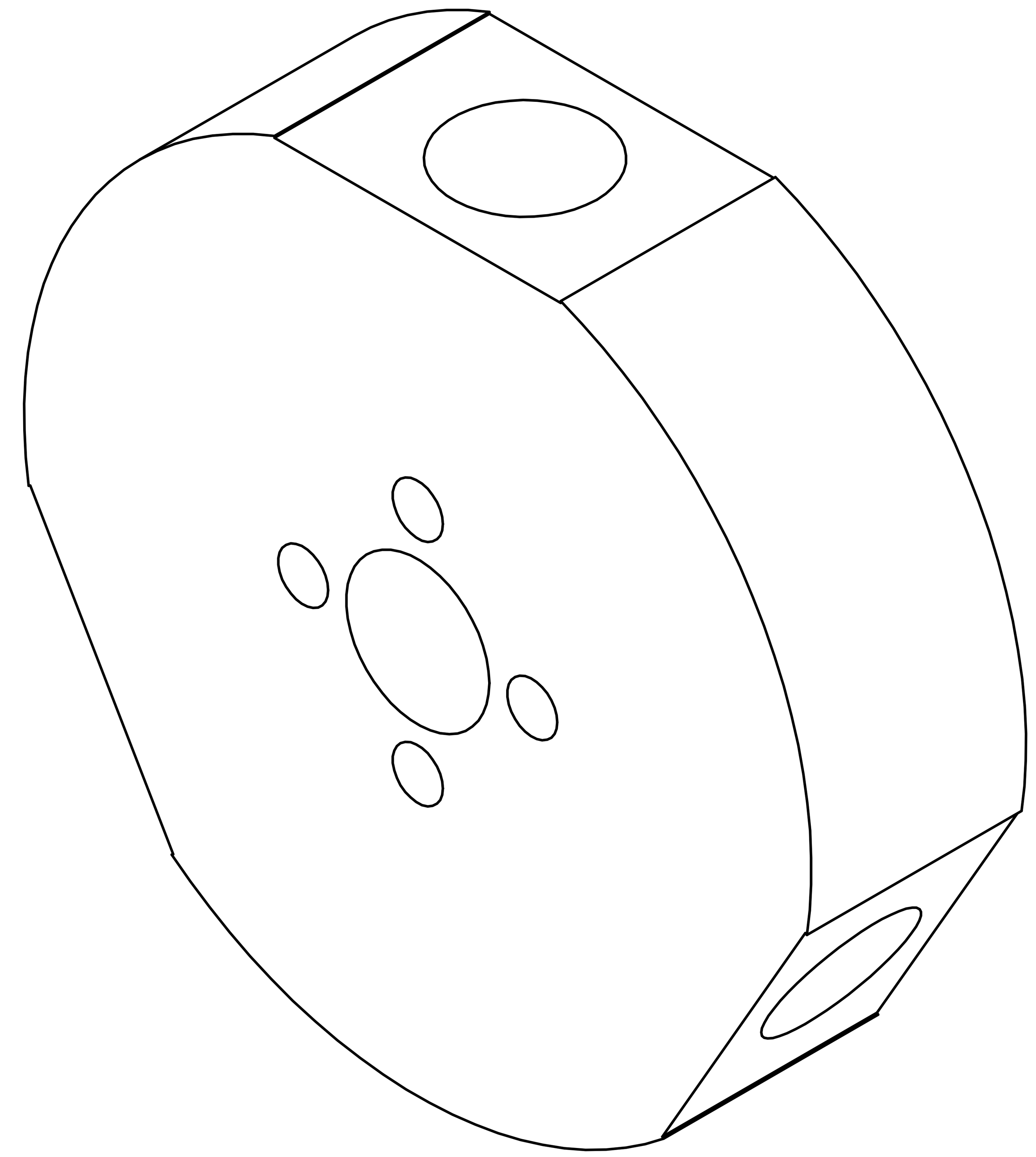
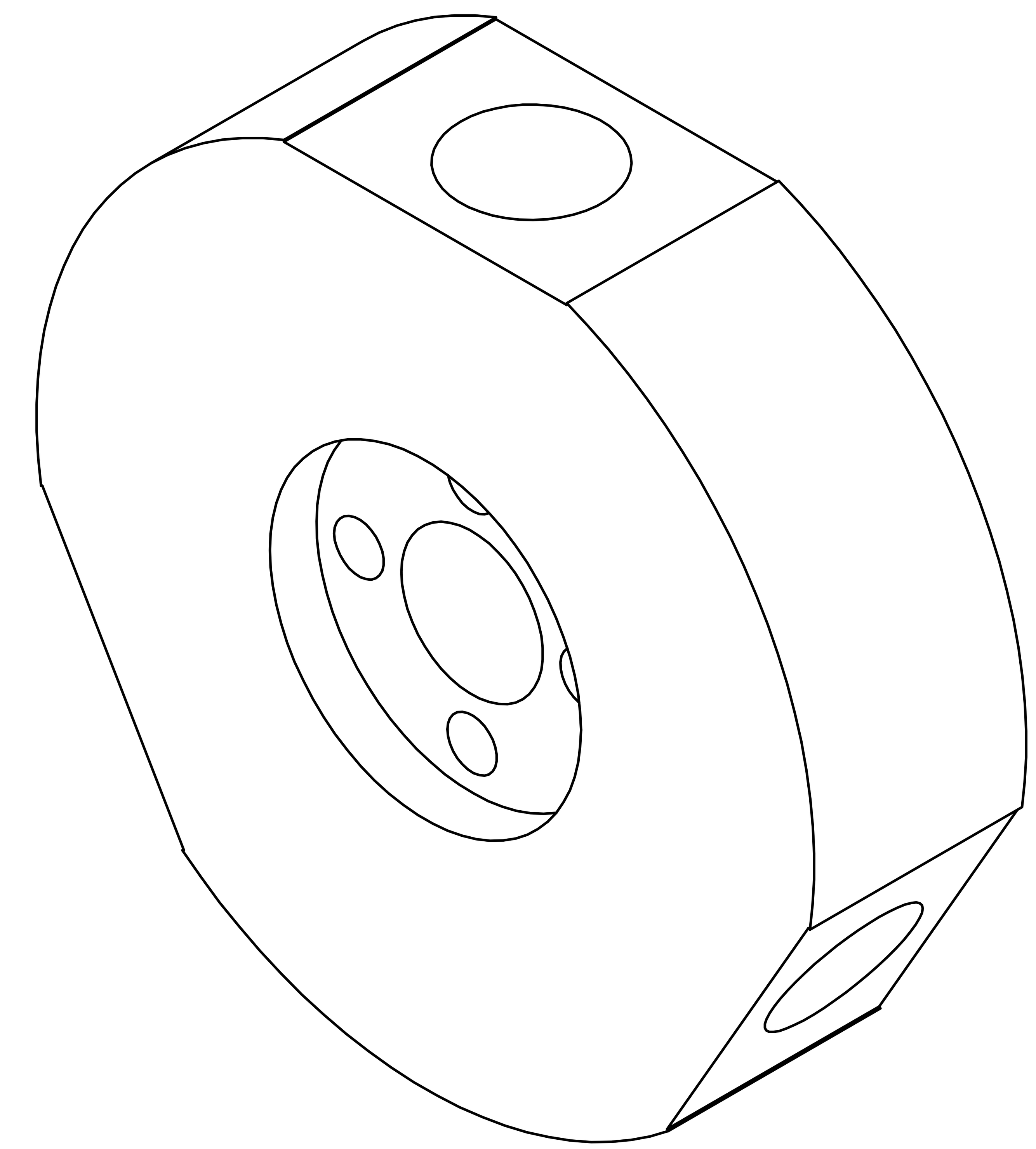
		SCALE 1 :1 / SHEET 1 OF 1









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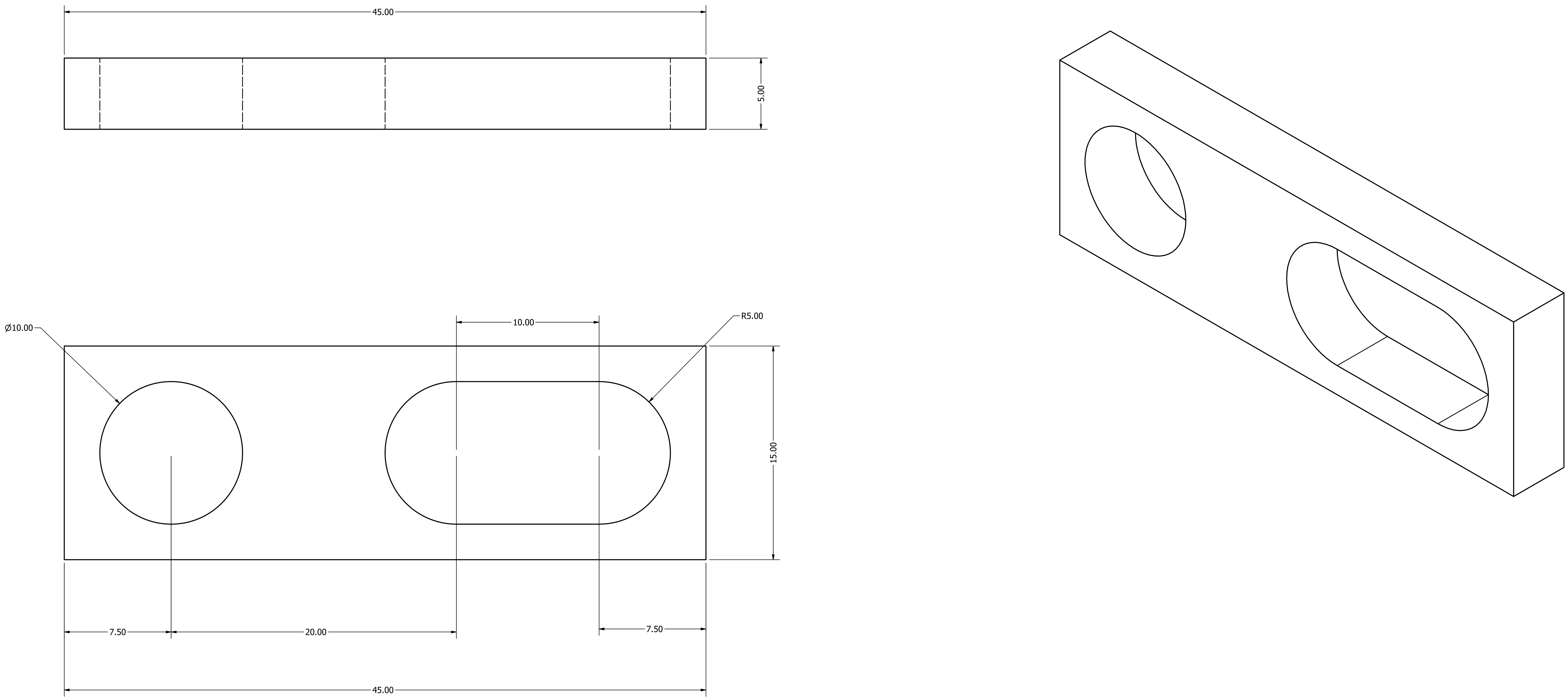
CHECKED		TITLE
QA		PITCH CONTROL MECHANISM
MFG		
APPROVED		
		SIZE D / DWG NO GUIDE COVER / REV
		SCALE 4 : 1 / SHEET 1 OF 1

DRAWN TEAM BM2	7/5/2022	
CHECKED		TITLE
QA		PITCH CONTROL MECHANISM
MFG		
APPROVED		
		SIZE D | DWG NO LINK | REV
		SCALE 7 : 1 | SHEET 1 OF 1



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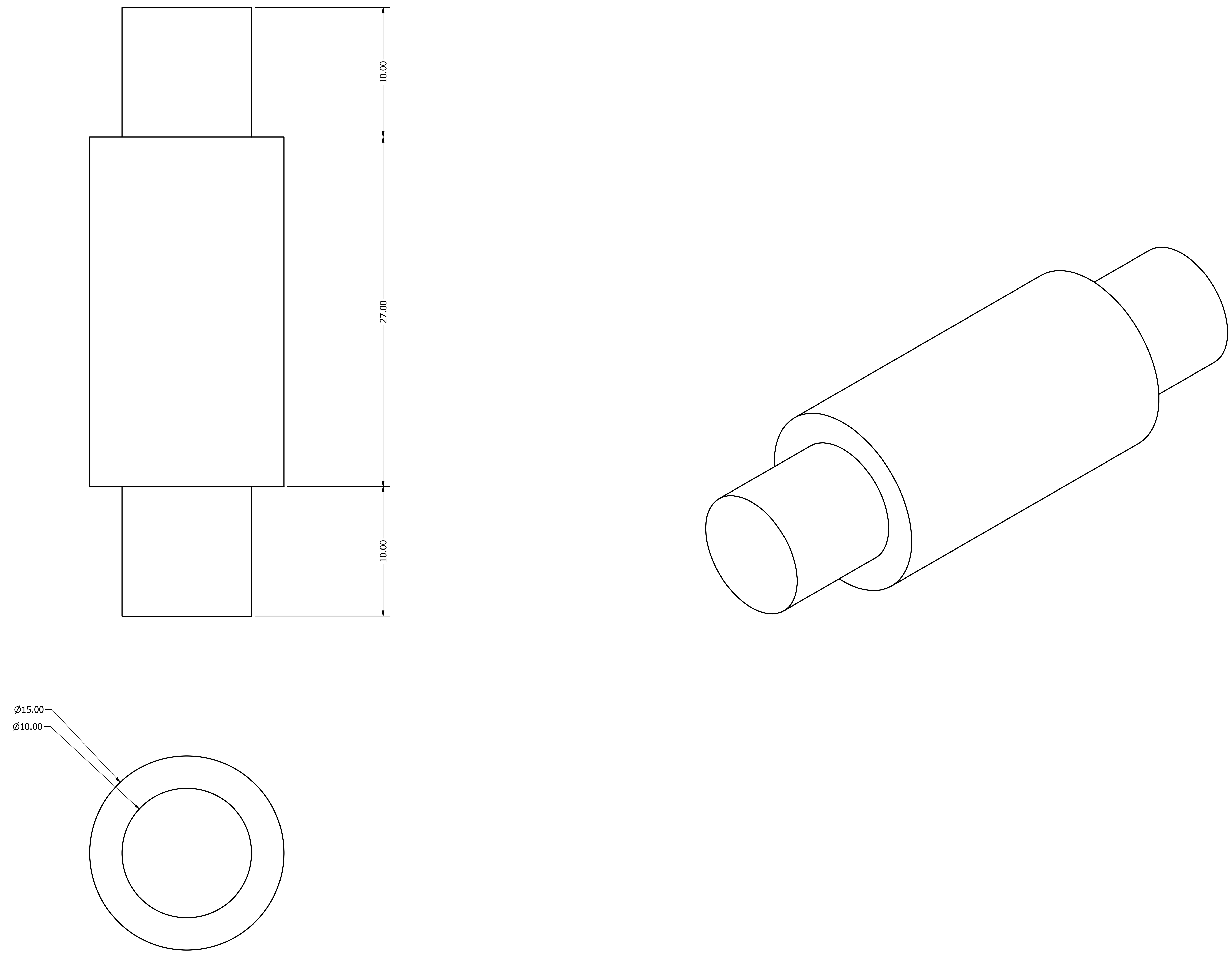
MFG		
APPROVED		SIZE D — DWG NO MINILINK — REV
		SCALE 7 : 1 — SHEET 1 OF 1



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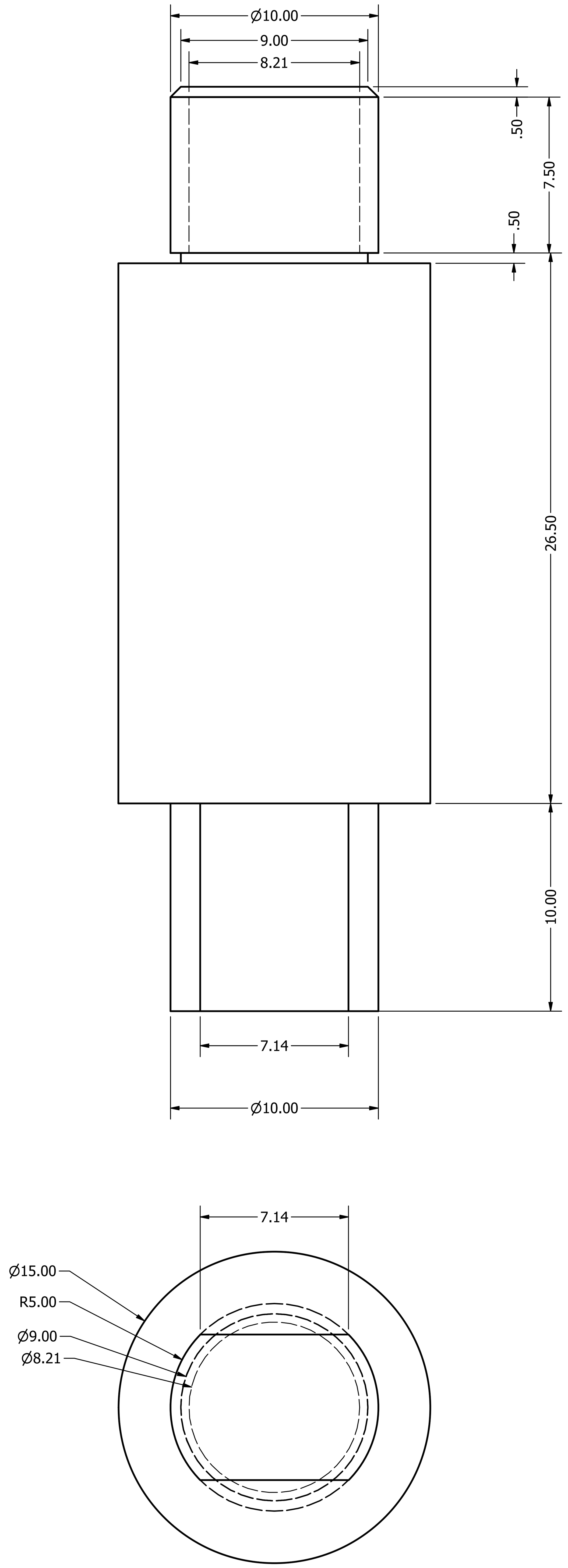
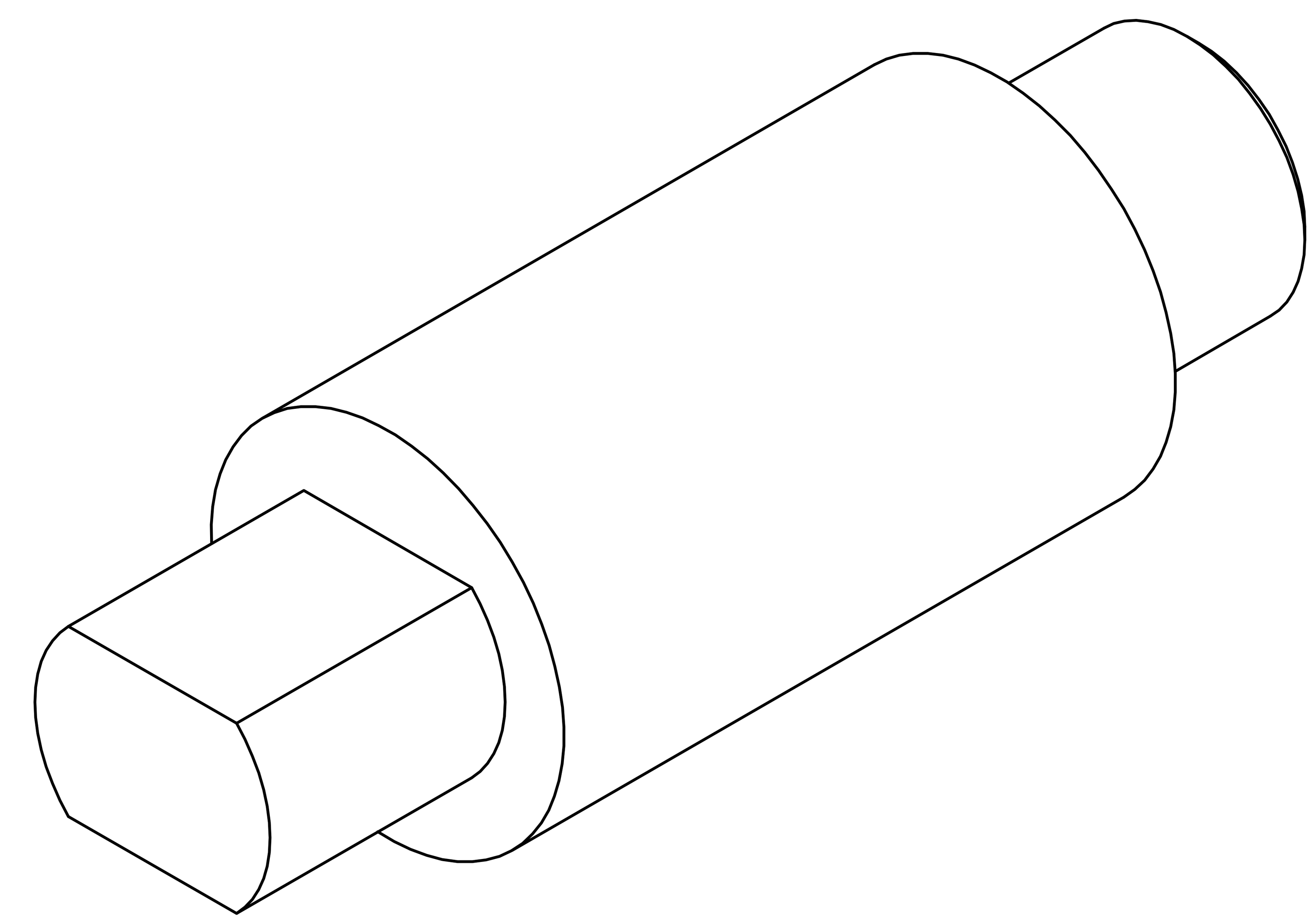
QA		PITCH CONTROL MECHANISM			
MFG					
APPROVED					
		SIZE D		DWG NO CONNECTOR BTW 2L	REV
		SCALE 6 : 1		SHEET 1 OF 1	





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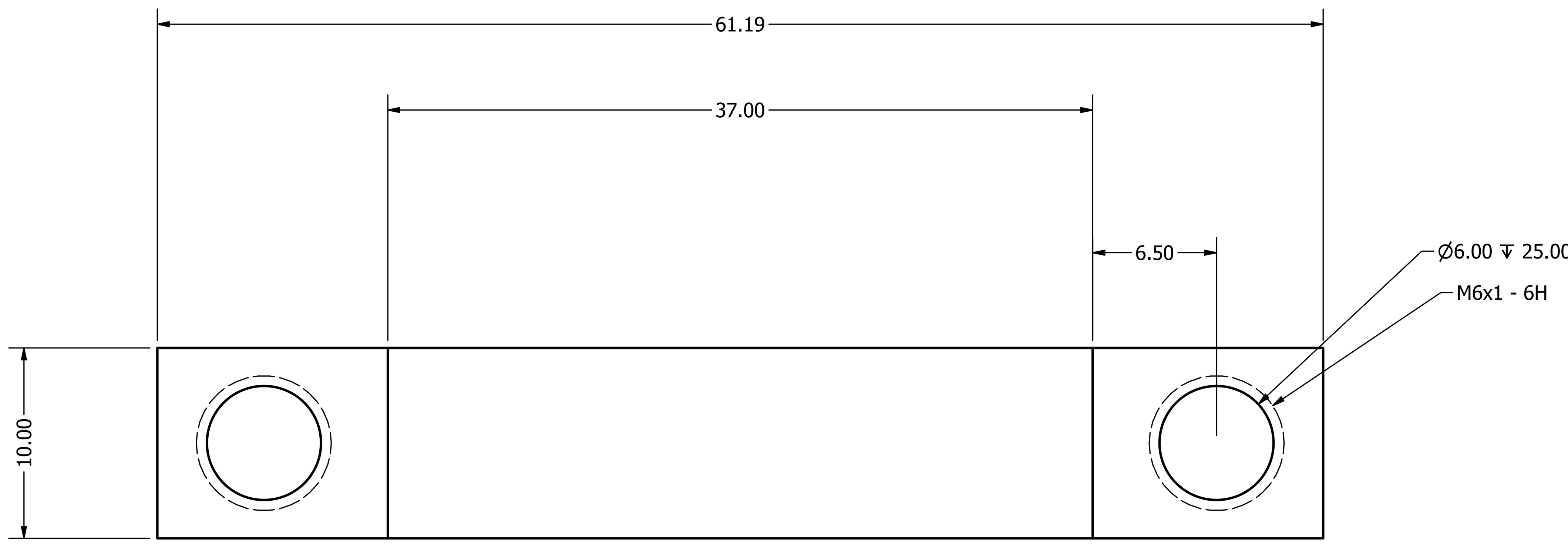
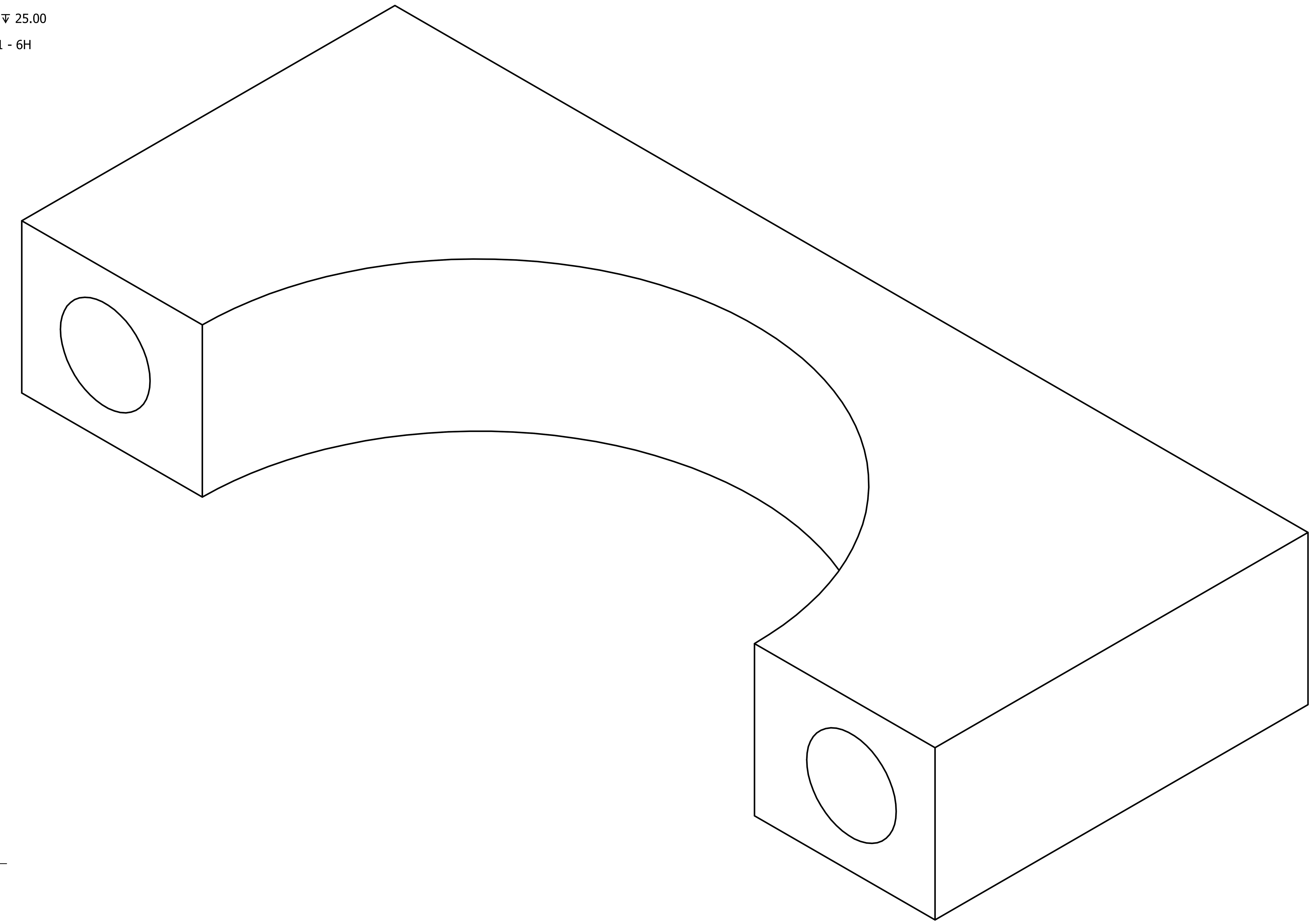
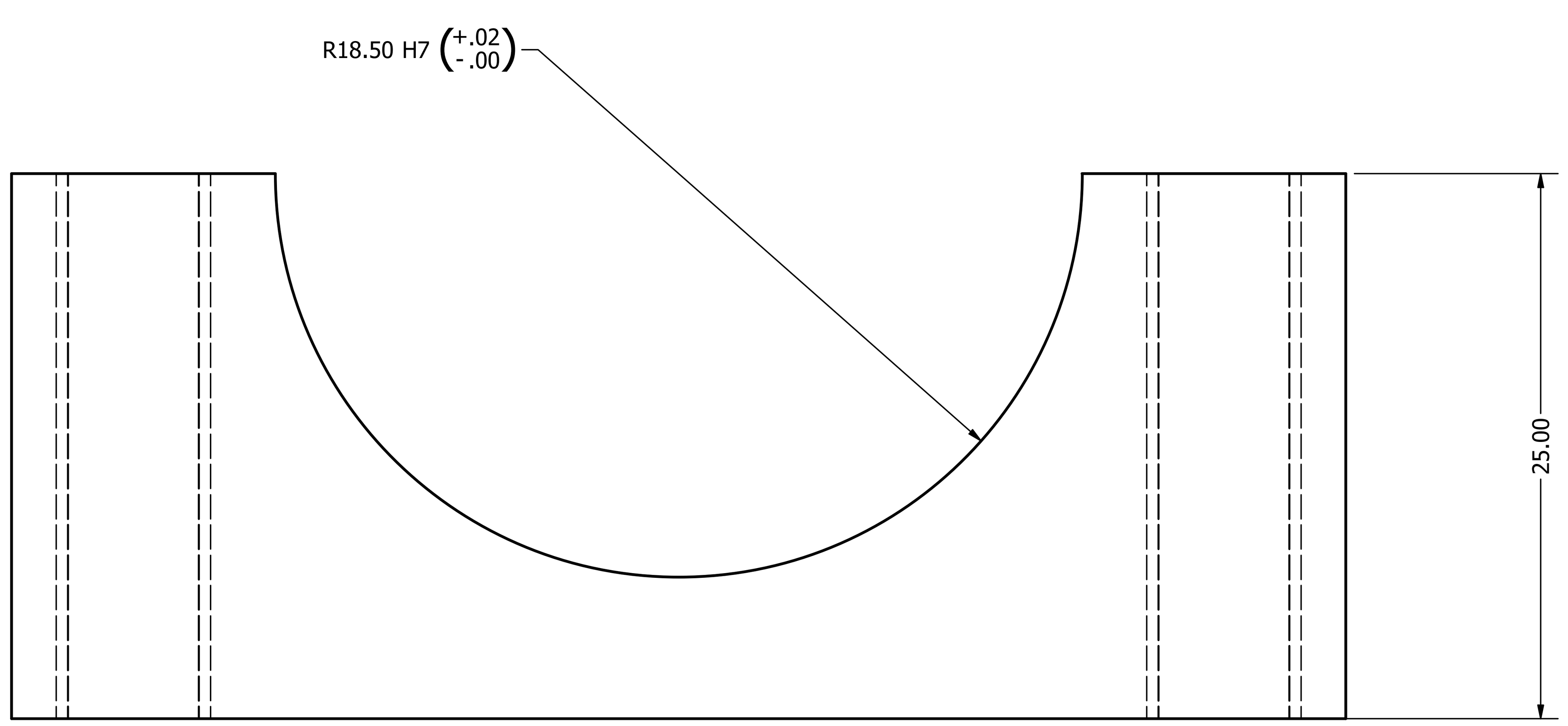
QA		PITCH CONTROL MECHANISM			
MFG					
APPROVED					
		SIZE D		DWG NO CONNECTOR THREAD	REV
		SCALE 6 : 1		SHEET 1 OF 1	







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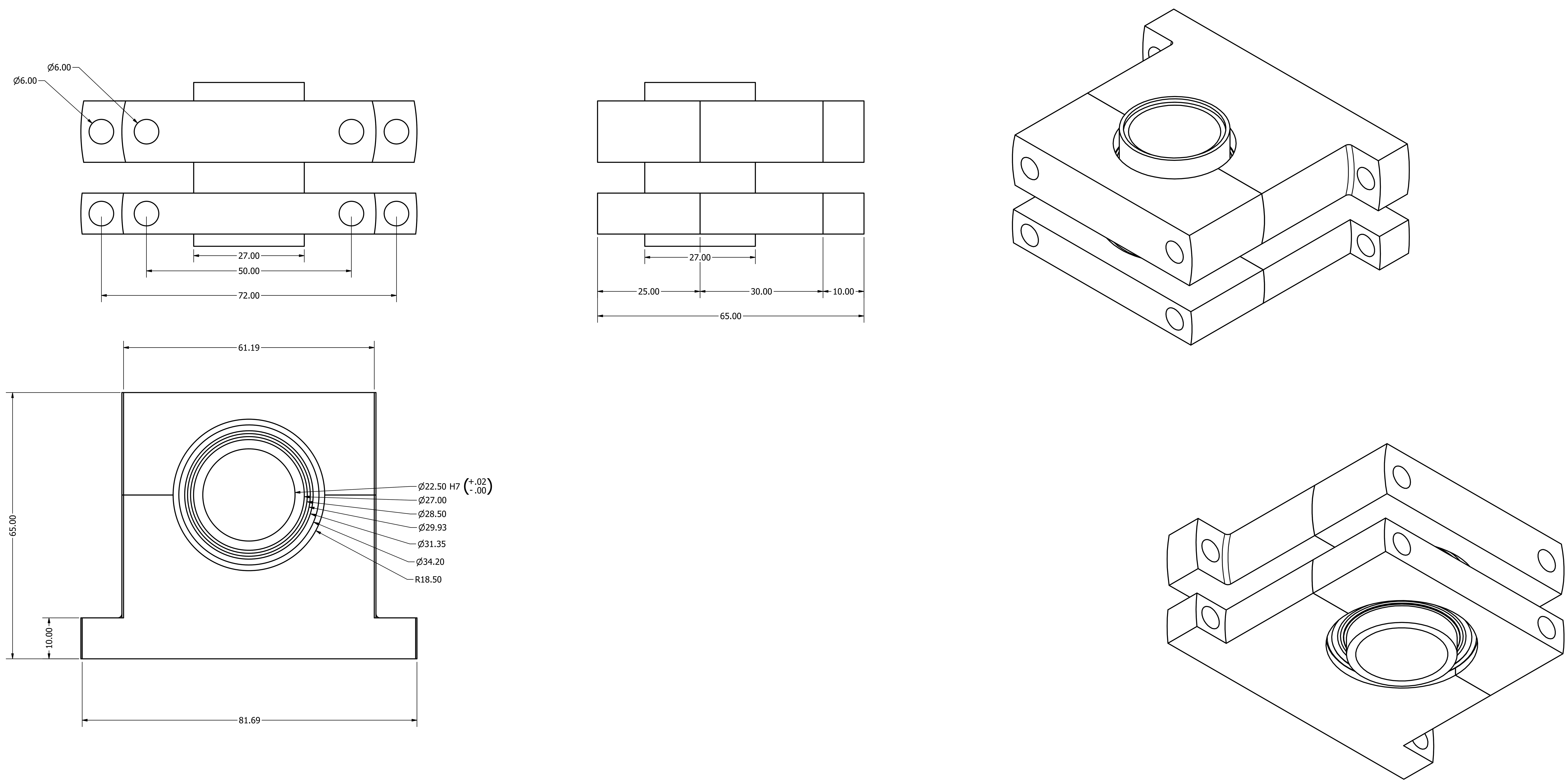
CHECKED		TITLE		
QA		PITCH CONTROL MECHANISM		
MFG				
APPROVED				
		SIZE D	DWG NO UPPER BRACKET 2	REV
		SCALE 7 : 1		SHEET 1 OF 1

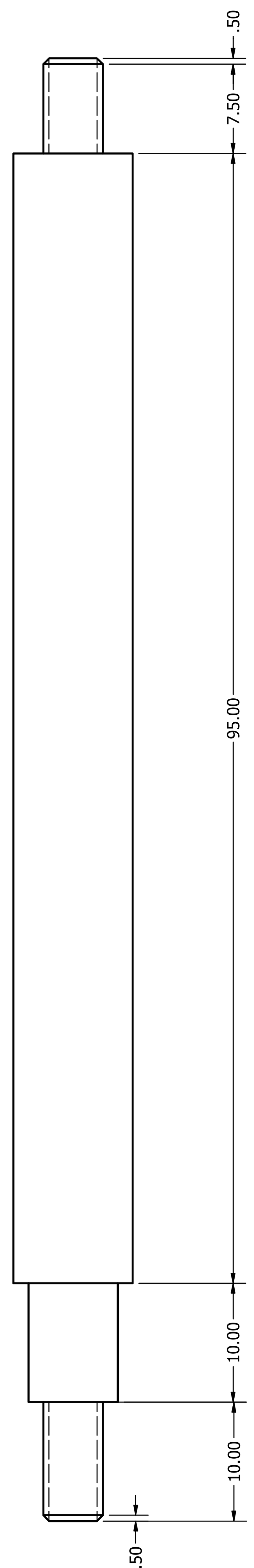
DRAWN TEAM B2	7/5/2022	
CHECKED		TITLE
QA		PITCH CONTROL MECHANISM
MFG		
APPROVED		SIZE D · DWG NO LOWER BRACKET 2 · REV
		SCALE 5: 1 · SHEET 1 OF 1

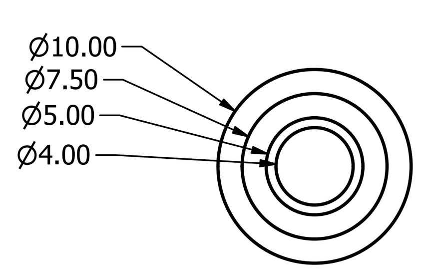
DRAWN TEAM B2	7/5/2022	
CHECKED		TITLE
QA		PITCH CONTROL MECHANISM
MFG		
APPROVED		SIZE D · DWG NO UPPER BRACKET 1 · REV
		SCALE 5: 1 · SHEET 1 OF 1

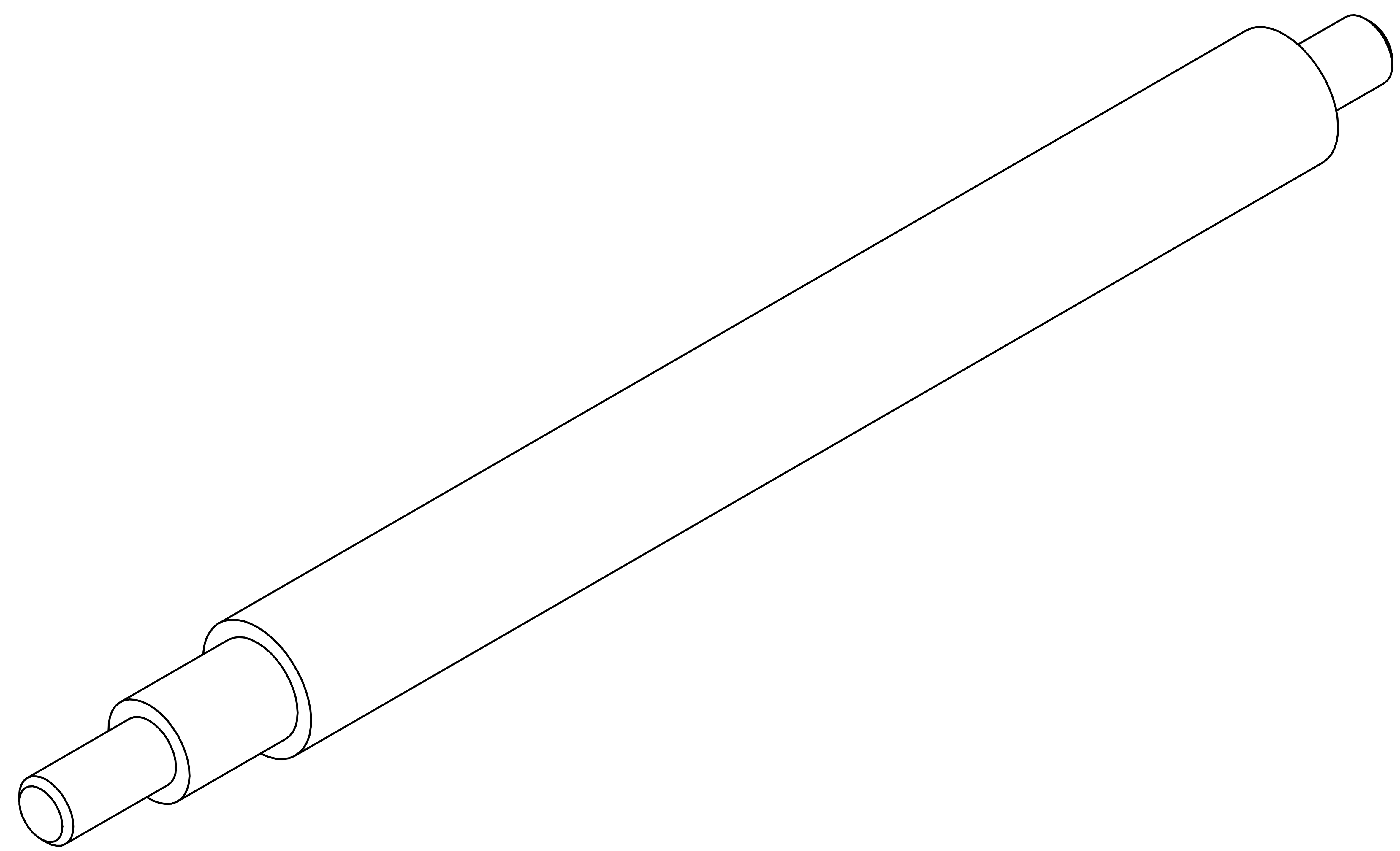
DRAWN TEAM BM2	7/5/2022	
CHECKED		TITLE
QA		PITCH CONTROL MECHANISM
MFG		
APPROVED		SIZE D · DWG NO LOWER BRACKET 1 · REV
		SCALE 4 : 1 · SHEET 1 OF 1



DRAWN TEAM B2	7/5/2022	
CHECKED		TITLE PITCH CONTROL MECHANISM
QA		
MFG		
APPROVED		
SIZE D	DWG NO BRACKET ASSEMBLY	REV
SCALE 2:1		SHEET 1 OF 1







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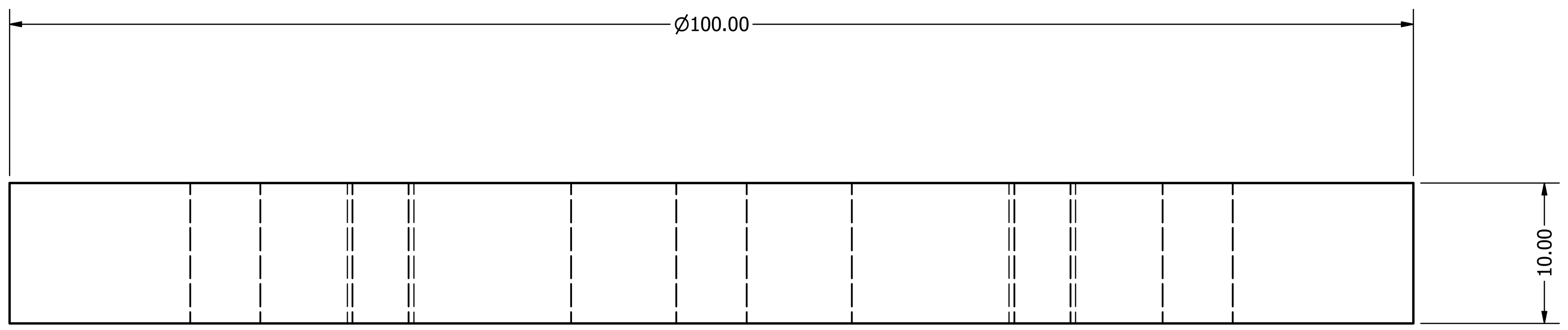
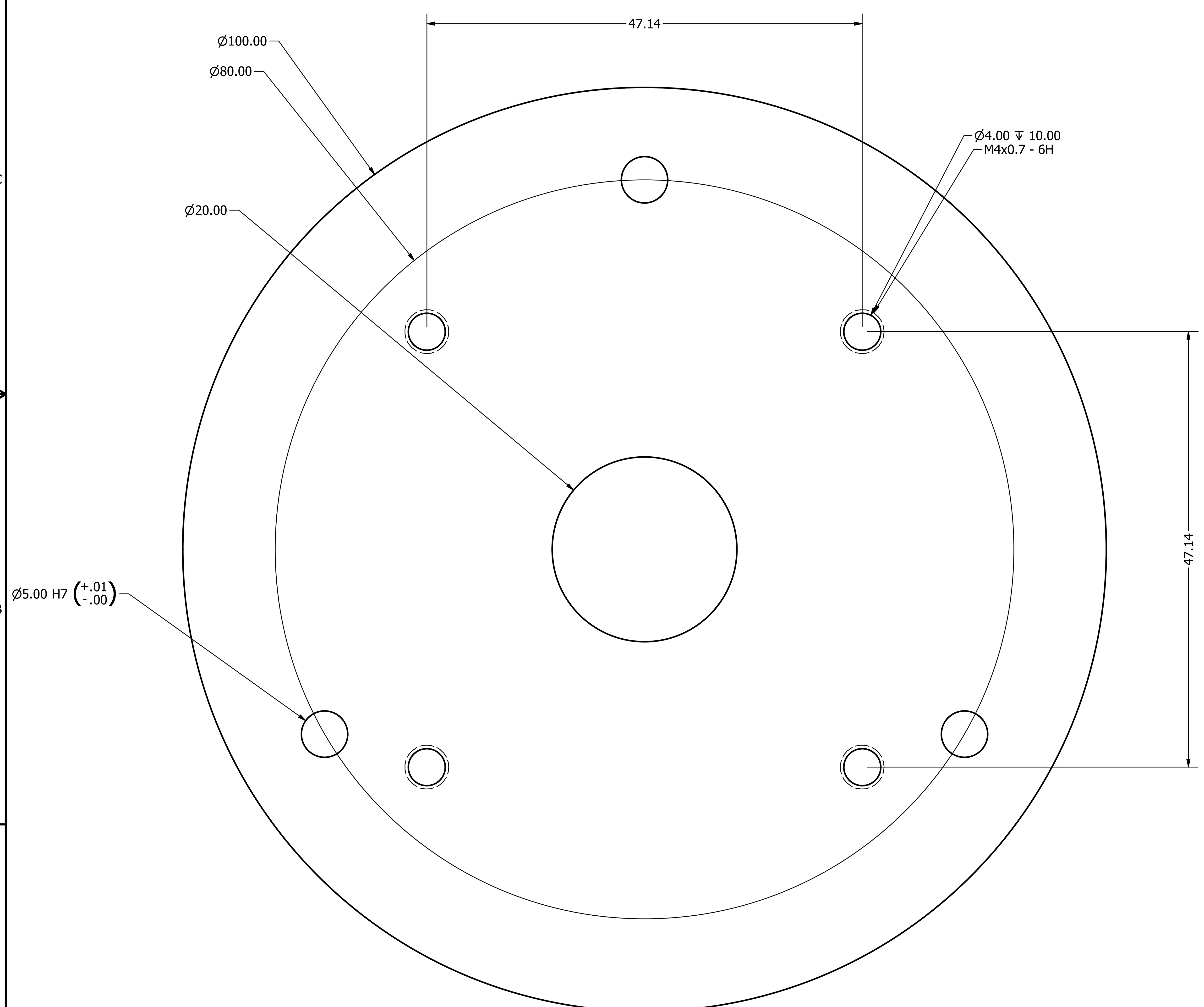
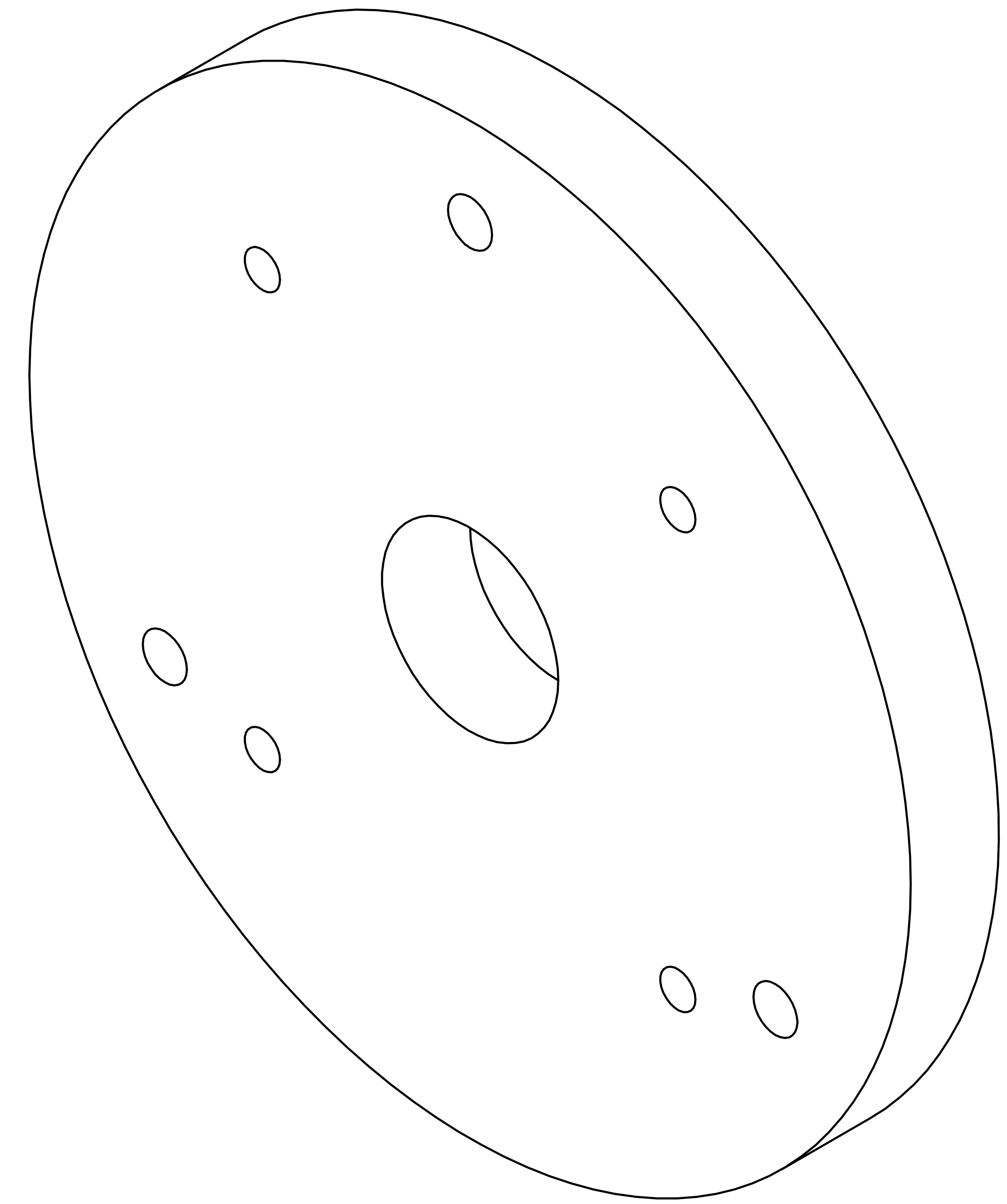
QA		PITCH CONTROL MECHANISM	
MFG			
APPROVED			
		SIZE D	DWG NO PLATE SHAFT	REV
		SCALE 3 : 1	SHEET 1 OF 1







DRAWN TEAM B2	7/5/2022			
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MFG				
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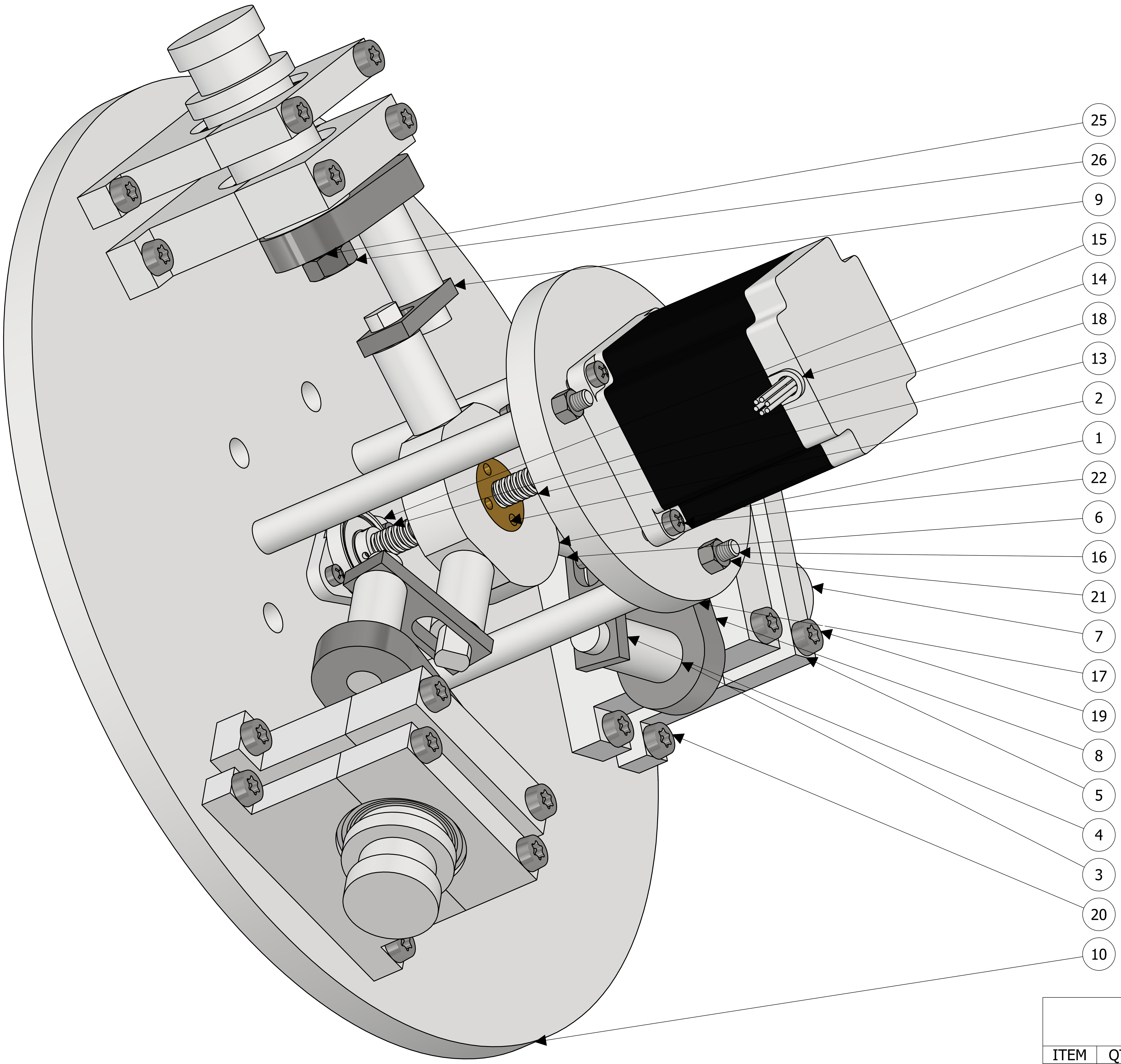
		SCALE 3 : 1		SHEET 1 OF 1



PARTS LIST

ITEM	QTY	PART NUMBER
1	1	guid cover final
2	1	guide nut
3	3	connector_bet._2L_FINAL
4	2	link1
5	3	Assembly4
6	3	connector1_threaded_FINAL
7	3	shaft
8	3	Bat7a_Link_Final
9	1	minilink_FINAL
10	1	holding plate
11	1	Nose
12	1	flex coupler
13	1	Power_Screw_FINAL
14	1	stepper
15	1	Horizontal-Self-AligningFlangeBearing__ID=8mm
16	3	PlateShaft
17	1	StepperPlate
18	2	ANSI B18.6.4 - No. 6 - 32 - 3/8, CRFHTSTCTI(2)
19	12	Screw GB 6564 M6 x 40
20	12	Screw GB 6564 M6 x 20
21	3	ANSI B18.2.4.2M - M5x0.8
22	4	ANSI B18.6.4 - No. 8 - 32 - 1 1/4, CRFHTSTCTI(2)
23	4	AS 1237 - 4
24	4	ANSI B18.2.4.2M - M4x0.7
25	4	AS 1237 - 8
26	3	IFI 502 - M8x1.25 x 16, FUHHTSTDM

DRAWN TEAM B2	7/5/2022		
CHECKED		TITLE	
QA		PITCH CONTROL MECHANISM	
MFG			
APPROVED		SIZE A0	DWG NO FINAL_ASSEMBLY 1	REV
		SCALE 2: 1	SHEET 2 OF 2

10. ANSYS

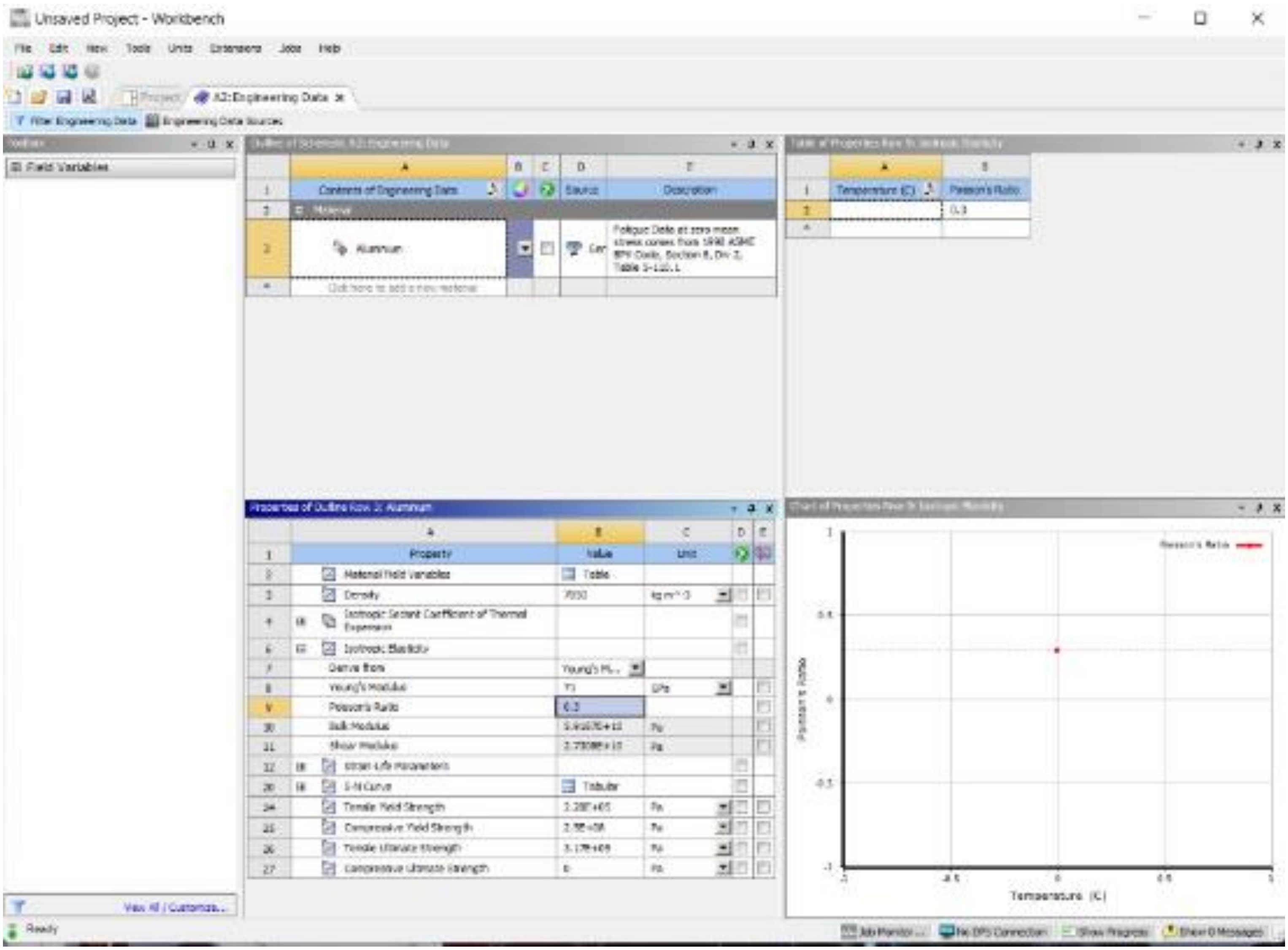


Figure 26: Engineering Data For Assembly Ansys

10.1 Assembly

Total Deformation

Max = 0.014432 mm

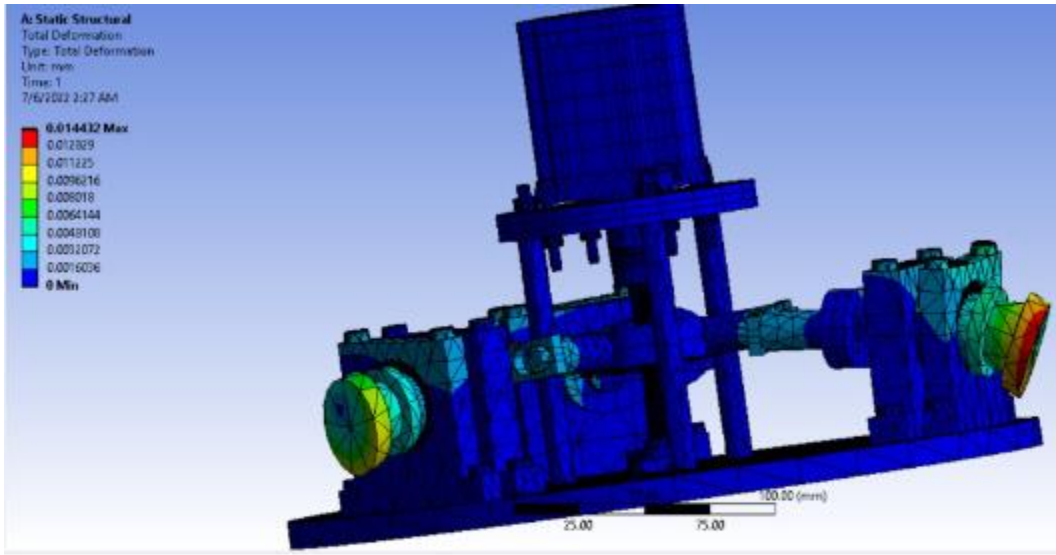


Figure 27: ANSYS Assembly Total Deformation

Stress

Max= 129.6 Mpa

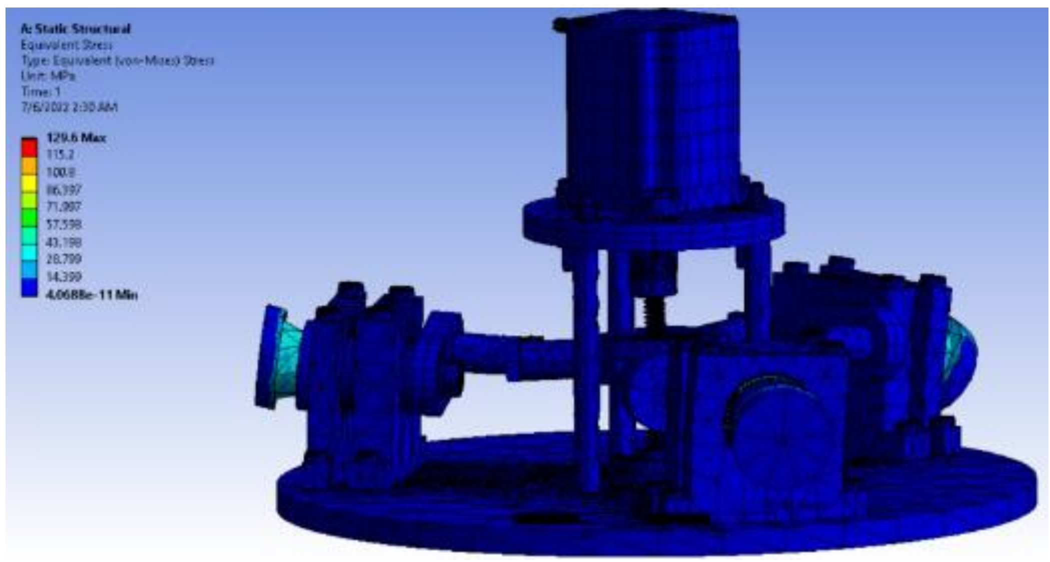


Figure 28: ANSYS Assembly Stress

Safety Factor

Min = 1.6731

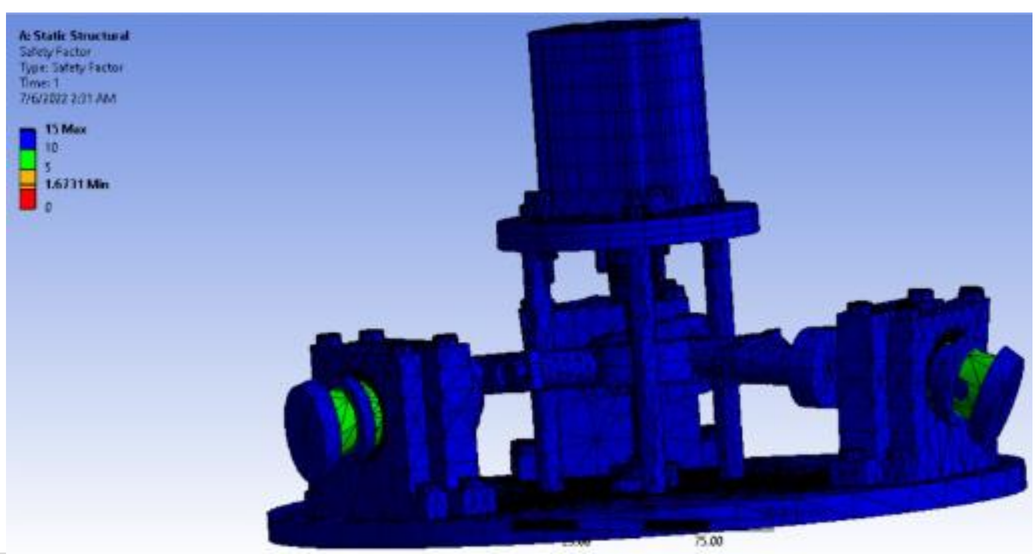


Figure 29: ANSYS Assembly Safety Factor

10.2 Bracket

Total Deformation

Max = 0.015099 mm

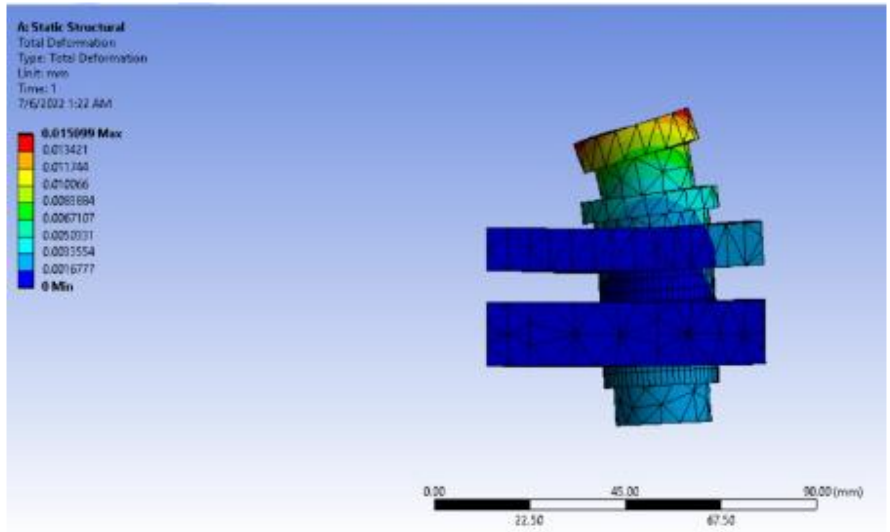


Figure 30: ANSYS Bracket Total Deformation

Stress

Max= 117.76 Mpa

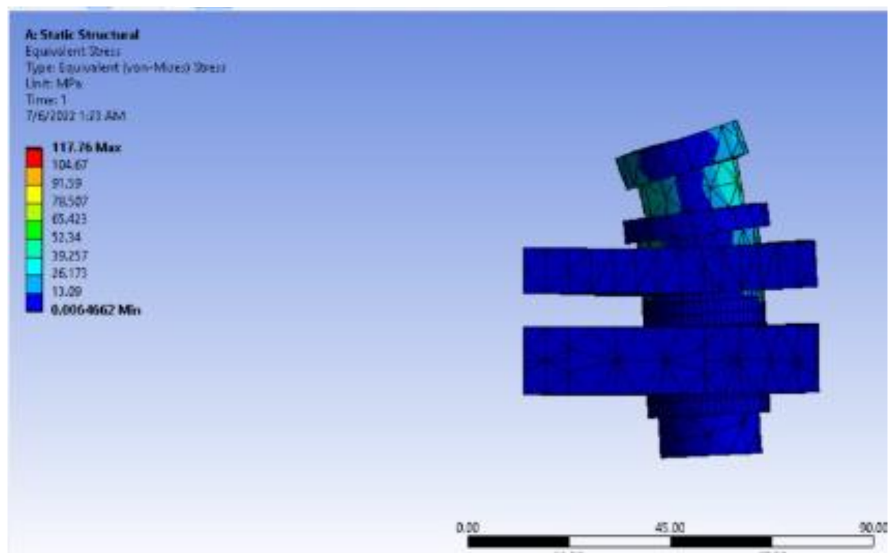


Figure 31:ANSYS Bracket Stress

Safety Factor

Min = 1.8872

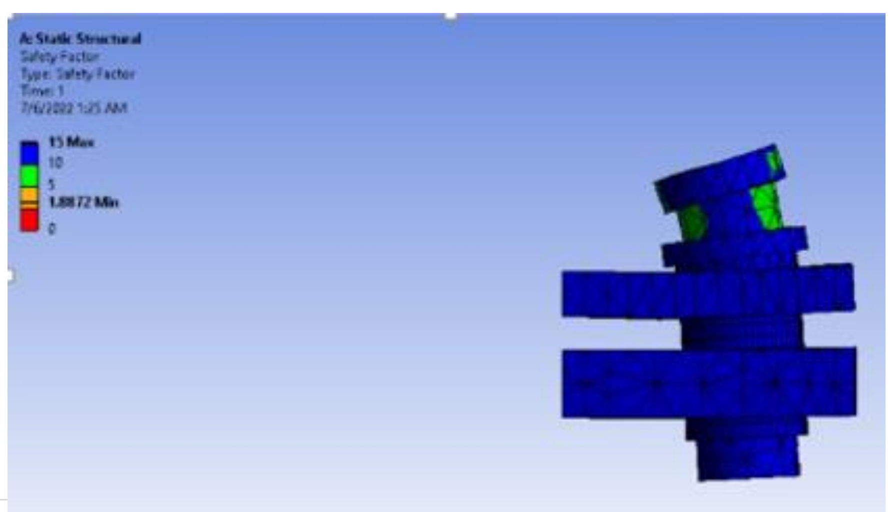


Figure 32: ANSYS Bracket Safety Factor

11. Brochure

Figure 33: BROCHURE

12. Bills of Material

Component	Bill/ Egp
Manufacturing	6500
Materials	1450
Equipments	330
Electronic components	287
Total	8567

13. Conclusion

It is seen that the thrust increases with increase in wind velocity, and decreases with increase in pitch angle. For a given wind velocity, there is an optimum pitch angle where the power generated by the turbine is maximum. In addition pitch control mechanism has many advantages such as it controls adjust the blades in wind turbines by rotating them so that they use the right fraction of the available wind energy to get the most power output, all the while ensuring the turbine does not exceed its maximum rotational speed.