



University of Wales Trinity Saint David

GD&T AND DRAFTING

Data Collection

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1. Introduction

Nowadays at engineering world is very common reducing costings and save time, increasing the way to get more profit at the manufacturer process. In addition, GD & T (Geometric Dimension and Tolerance) is the best way to manufacture high quality products.

This method uses a symbolic language in engineering drawings, that drawings describes the geometry of the product and the allowable variation.

The following assignment will produce a GD&T assembly of a triple clamps off an Honda CRF 450. An engineering drawing will be done via CAD using the software Solidworks. The principal aim of this assignment will be modify the clamps after having calculated the tolerances of the components and having drawn and estimate the engineering drawings required. For that, different techniques of engineering drawing will be explained and how the tolerances have been calculated. A list of the material used (BOM) will be done including an explication of the chosen material for each part of the clamp.

Finally, a conclusion of the importance of using GD&T will be discussing according with the obtained results.

2. Research

The first manifestation of technical drawing comes from an sculpture called 'The architect', from 2122 b.C. Nowadays is exposed at the Louvre Museum at Paris. (*History of the Technical Drawing, 1995*).

Along the years and diverse famous mathematicians discovered the 2D geometry around the space, arithmetic's and mechanic. Nowadays and due to the technologies advantages engineers and architects have changed the paper and pencil for a computer. The first CAD (Computer Advanced Design) software was launched in 1965 by ITEK Control Data Corp; priced at 500.00 USD. It was not very popular to design via computer until Autodesk launched AutoCAD in 1992; being one of the most important design software nowadays.

2.1 Geometric Dimensioning and Tolerances

Nowadays the use of geometric and dimensioning tolerances is very important to design and manufacturing articles of every dimensions.

The tolerances are focused to describe and create a capable margin of error for manufacturing, increasing the productivity and quality of the final product; also is capable to reduce costs and lost.

GD & T is an international language that used in engineering drawings to accurately describe the size, shape, orientation, and location of part features. It is also a sizing design that encourages designers to define a part based on how it works in the final product or assembly.

GD & T is an exact language that allows design engineers to "say what they want to say" in a drawing, thereby improving product designs and reducing costs. Process and manufacturing engineers must use the language to interpret the design intent and to determine the best manufacturing method. Quality control and inspection must use the language of GD & T to determine the proper follow-up and verification of parts.

By providing the company with uniformity of width in drawing specifications and interpretation, GD & T reduces the controversy, conjecture and assumptions of the entire design, manufacturing and inspection process.

GD & T was created to ensure the correct assembly of coupling parts, to improve quality and reduce costs. GD & T is a design tool.

2.2 Calculating tolerances

In all mechanical manufacturing processes, it is essential to use drawings and graphic representations of the parts and components that you wish to manufacture. In these cases, most of the pieces that are represented in plans are not totally defined with their drawing and dimension, because there will always be a discrepancy between the theoretical or exact measurements that appear in the drawings and the actual measurements of the parts.

These discrepancies may be due to a large number of factors, among which are:

- The existence of games and clearances in tools or machine tools.
- Errors of measuring instruments or of the operators that measure.
- The expansion or deformation of the pieces because of the temperatures they acquire during the machining and manufacturing processes.
- Deformations produced by internal stresses that originate in the pieces.

In practice, two types of tolerances are distinguished:

- **Dimensional tolerances:** they affect the measurements of a dimension of the piece.
- **Geometric tolerances:** affect the shape and position of the geometry of the piece.

2.2.1 Concepts

Nominal Size: The size used for general description.

Basic Size: The size used when the nominal size is converted to the decimal and from which deviation are made to produce limit dimension.

Limit Dimension: The Lower and Upper permitted sizes for a single feature.

Tolerance: Is the allowable variation for any given size in order to achieve a proper function. Tolerance equals the difference between lower and upper limit dimensions.

Bilateral tolerance: It is a way to express tolerance by using both minus and plus variations from a given size.

$$34.00 \pm 0.04$$

Unilateral tolerance: Exist when a target dimension is given along with tolerance that allows occurring just in one direction.

$$34.00^{+0.04}_{-0.00}$$

General tolerances: If tolerances are not specified, general tolerances may be applied:

- Angles ± 0.5 degrees
- X.X = ± 0.020
- X.XX = ± 0.010
- X.XXX = 0.005
-

2.2.1 Standard tolerance Values

The international standard ISO 286 defines 20 different tolerance grades, the bigger the tolerance grade, the bigger the tolerance is. (Figure 1)

Figure 1: https://www.engineersedge.com/international_tol.htm

Basic size mm		International tolerance (IT) grades																	
		IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10	IT11	IT12	IT13	IT14	IT15	IT16	IT17	IT18
Above	Up to and in- cluding	Tolerances																	
		micrometers											millimeters						
-	3	0.8	1.2	2	3	4	6	10	14	25	40	60	0.1	0.14	0.25	0.4	0.6	1	1.4
3	6	1	1.5	2.5	4	5	8	12	18	30	48	75	0.12	0.18	0.3	0.48	0.75	1.2	1.8
6	10	1	1.5	2.5	4	6	9	15	22	36	58	90	0.15	0.22	0.36	0.58	0.9	1.5	2.2
10	18	1.2	2	3	5	8	11	18	27	43	70	110	0.18	0.27	0.43	0.7	1.1	1.8	2.7
18	30	1.5	2.5	4	6	9	13	21	33	52	84	130	0.21	0.33	0.52	0.84	1.3	2.1	3.3
30	50	1.5	2.5	4	7	11	16	25	39	62	100	160	0.25	0.39	0.62	1	1.6	2.5	3.9
50	80	2	3	5	8	13	19	30	46	74	120	190	0.3	0.46	0.74	1.2	1.9	3	4.6
80	120	2.5	4	6	10	15	22	35	54	87	140	220	0.35	0.54	0.87	1.4	2.2	3.5	5.4
120	180	3.5	5	8	12	18	25	40	63	100	160	250	0.4	0.63	1	1.6	2.5	4	6.3
180	250	4.5	7	10	14	20	29	46	72	115	185	290	0.46	0.72	1.15	1.85	2.9	4.6	7.2
250	315	6	8	12	16	23	32	52	81	130	210	320	0.52	0.81	1.3	2.1	3.2	5.2	8.1
315	400	7	9	13	18	25	36	57	89	140	230	360	0.57	0.89	1.4	2.3	3.6	5.7	8.9
400	500	8	10	15	20	27	40	63	97	155	250	400	0.63	0.97	1.55	2.5	4	6.3	9.7
500	630	9	11	16	22	32	44	70	110	175	280	440	0.7	1.1	1.75	2.8	4.4	7	11
630	800	10	13	18	25	36	50	80	125	200	320	500	0.8	1.25	2	3.2	5	8	12.5
800	1000	11	15	21	28	40	56	90	140	230	360	560	0.9	1.4	2.3	3.6	5.6	9	14
1000	1250	13	18	24	33	47	66	105	165	260	420	660	1.05	1.65	2.6	4.2	6.6	10.5	16.5
1250	1600	15	21	29	39	55	78	125	195	310	500	780	1.25	1.95	3.1	5	7.8	12.5	19.5
1600	2000	18	25	35	46	65	92	150	230	370	600	920	1.5	2.3	3.7	6	9.2	15	23
2000	2500	22	30	41	55	78	110	175	280	440	700	1100	1.75	2.8	4.4	7	11	17.5	28
2500	3150	26	36	50	68	96	135	210	330	540	860	1350	2.1	3.3	5.4	8.6	13.5	21	33

The IT grade number obtained is related to the manufacturing process used for making the part of the piece.

Figure 2: <http://www2.mae.ufl.edu/designlab/Lab%20Assignments/EML2322L-Tolerances.pdf>

Manufacturing Process	IT Grade														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Lapping															
Honing															
Superfinishing															
Cylindrical grinding															
Diamond turning															
Plan grinding															
Broaching															
Reaming															
Boring, Turning															
Sawing															
Milling															
Planing, Shaping															
Extruding															
Cold Rolling, Drawing															
Drilling															
Die Casting															
Forging															
Sand Casting															
Hot rolling, Flame cutting															

The ISO tolerances are represented as the following way:

30 **H** 6 30 **h** 7

Where 30 is the nominal cote; the letter represents where the tolerance is located, capital letter for holes and normal for shafts; the last number represents the IT of the tolerance. The following tables will show the relation between the letter and the position of the tolerance.

Figure 3: <https://ingemecanica.com/tutorialsemanal/tutorialn19.html>

Posición	a	b	c	cd	d	e	ef	f	fg	g	h	j			k	
Calidad												5 y 6	7	8	>4 y ≤ 7	<4 y >7
Diferencia fundamental	Diferencia superior $tsup$											Diferencia inferior $tinj$				
$m \leq 3$	-270	-140	-60	-34	-20	-14	-10	-6	-4	-2	0	-2	-4	-6	0	0
$3 < m \leq 6$	-270	-140	-70	-46	-30	-20	-14	-10	-6	-4	0	-2	-4	-	+1	0
$6 < m \leq 10$	-280	-150	-80	-56	-40	-25	-18	-13	-8	-5	0	-2	-5	-	+1	0
$10 < m \leq 14$	-290	-150	-95	-	-50	-32	-	-16	-	-6	0	-3	-6	-	+1	0
$14 < m \leq 18$																
$18 < m \leq 24$	-300	-160	-110	-	-65	-40	-	-20	-	-7	0	-4	-8	-	+2	0
$24 < m \leq 30$																
$30 < m \leq 40$	-310	-170	-120	-	-80	-50	-	-25	-	9	0	-5	-10	-	+2	0
$40 < m \leq 50$	-320	-180	-130													
$50 < m \leq 65$	-340	-190	-140	-	-100	-60	-	-30	-	-10	0	-7	-12	-	+2	0
$65 < m \leq 80$	-360	-200	-150													
$80 < m \leq 100$	-380	-220	-170	-	-120	-72	-	-36	-	-12	0	-9	-15	-	+3	0
$100 < m \leq 120$	-410	-240	-180													
$120 < m \leq 140$	-460	-260	-200													
$140 < m \leq 160$	-520	-280	-210	-	-145	-85	-	-43	-	-14	0	-11	-18	-	+3	0
$160 < m \leq 180$	-580	-310	-230													
$180 < m \leq 200$	-660	-340	-240													
$200 < m \leq 225$	-740	-380	-260	-	-170	-100	-	-50	-	-15	0	-13	-21	-	+4	0
$225 < m \leq 250$	-820	-420	-280													
$250 < m \leq 280$	-920	-460	-300	-	-190	-110	-	-56	-	-17	0	-16	-26	-	+4	0
$280 < m \leq 315$	-1050	-540	-330													
$315 < m \leq 355$	-1200	-600	-360	-	-210	-125	-	-62	-	-18	0	-18	-28	-	+4	0
$355 < m \leq 400$	-1350	-680	-400													
$400 < m \leq 450$	-1500	-760	-440	-	-230	-135	-	-68	-	-20	0	-20	-32	-	+5	0
$450 < m \leq 500$	-1650	-840	-480													

Figure 4: <https://ingemecanica.com/tutorialsemanal/tutorialn19.html>

Posición	m	n	p	r	s	t	u	v	x	y	z	za	zb	zc
Calidad	Todas las calidades													
Diferencia fundamental	Diferencia inferior tinf													
$m \leq 3$	+2	+4	+6	+10	+14	-	+18	-	+20	-	+26	+32	+40	+60
$3 < m \leq 6$	+4	+8	+12	+15	+19	-	+23	-	+28	-	+35	+42	+50	+80
$6 < m \leq 10$	+6	+10	+15	+19	+23	-	+28	-	+34	-	+42	+52	+67	+97
$10 < m \leq 14$	+7	+12	+18	+23	+28	-	+33	-	+40	-	+50	+64	+90	+130
$14 < m \leq 18$								+39	+45	-	+60	+77	+108	+150
$18 < m \leq 24$	+8	+15	+22	+28	+35	-	+41	+47	+54	+63	+73	+98	+136	+188
$24 < m \leq 30$						+41	+48	+55	+64	+75	+88	+118	+160	+218
$30 < m \leq 40$	+9	+17	+26	+34	+43	+48	+60	+68	+80	+94	+112	+148	+200	+274
$40 < m \leq 50$						+54	+70	+81	+97	+114	+136	+180	+242	+325
$50 < m \leq 65$	+11	+20	+32	+41	+53	+66	+87	+102	+122	+144	+172	+226	+300	+405
$65 < m \leq 80$				+43	+59	+75	+102	+120	+146	+174	+210	+274	+360	+480
$80 < m \leq 100$	+13	+23	+37	+51	+71	+91	+124	+146	+178	+214	+258	+335	+445	+585
$100 < m \leq 120$				+54	+79	+104	+144	+172	+210	+254	+310	+400	+525	+690
$120 < m \leq 140$				+63	+92	+122	+170	+202	+248	+300	+365	+470	+620	+800
$140 < m \leq 160$	+15	+27	+43	+65	+100	+134	+190	+228	+280	+340	+415	+535	+700	+900
$160 < m \leq 180$				+68	+108	+146	+210	+252	+310	+380	+465	+600	+780	+1000
$180 < m \leq 200$				+77	+122	+166	+236	+284	+350	+425	+520	+670	+880	+1150
$200 < m \leq 225$	+17	+31	+50	+80	+130	+180	+258	+310	+385	+470	+575	+740	+960	+1250
$225 < m \leq 250$				+84	+140	+196	+284	+340	+425	+520	+640	+820	+1050	+1350
$250 < m \leq 280$	+20	+34	+56	+94	+158	+218	+315	+385	+475	+580	+710	+920	+1200	+1550
$280 < m \leq 315$				+98	+170	+240	+350	+425	+525	+650	+790	+1000	+1300	+1700
$315 < m \leq 355$	+21	+37	+62	+108	+190	+268	+390	+475	+590	+730	+900	+1150	+1500	+1900
$355 < m \leq 400$				+114	+208	+294	+435	+530	+660	+820	+1000	+1300	+1650	+2100
$400 < m \leq 450$	+23	+40	+68	+126	+232	+330	+490	+595	+740	+920	+1100	+1450	+1850	+2400
$450 < m \leq 500$				+132	+252	+360	+540	+660	+820	+1000	+1250	+1600	+2100	+2600

Figure 5: <https://ingemecanica.com/tutorialsemanal/tutorialn19.html>

Posición	A	B	C	CD	D	E	EF	F	FG	G	H
Calidad	Todas las calidades										
Medida Nominal	Diferencia inferior Tinf										
$m \leq 3$	+270	+140	+60	+34	+20	+14	+10	+6	+4	+2	0
$3 < m \leq 6$	+270	+140	+70	+46	+30	+20	+14	+10	+6	+4	0
$6 < m \leq 10$	+280	+150	+80	+56	+40	+25	+18	+13	+8	+5	0
$10 < m \leq 18$	+290	+150	+95	-	+50	+32	-	+16	-	+6	0
$18 < m \leq 30$	+300	+160	+110	-	+65	+40	-	+20	-	+7	0
$30 < m \leq 40$	+310	+170	+120	-	+80	+50	-	+25	-	+9	0
$40 < m \leq 50$	+320	+180	+130								
$50 < m \leq 65$	+340	+190	+140	-	+100	+60	-	+30	-	+10	0
$65 < m \leq 80$	+360	+200	+150								
$80 < m \leq 100$	+380	+220	+170	-	+120	+72	-	+36	-	+12	0
$100 < m \leq 120$	+410	+240	+180								
$120 < m \leq 140$	+460	+260	+200								
$140 < m \leq 160$	+520	+280	+210	-	+145	+85					
$160 < m \leq 180$	+580	+310	+230								
$180 < m \leq 200$	+660	+340	+240								
$200 < m \leq 225$	+740	+380	+260	-	+170	+100	-	+50	-	+15	0
$225 < m \leq 250$	+820	+420	+280								
$250 < m \leq 280$	+920	+480	+300	-	+190	+110	-	+56	-	+17	0
$280 < m \leq 315$	+1050	+540	+330								
$315 < m \leq 335$	+1200	+600	+360	-	+210	+125	-	+62	-	+18	0
$335 < m \leq 400$	+1350	+680	+400								
$400 < m \leq 450$	+1500	+760	+440	-	+230	+135	-	+68	-	+20	0
$450 < m \leq 500$	+1650	+840	+480								

Tablas de posiciones de tolerancia para

Figure 6: <https://ingemecanica.com/tutorialsemanal/tutorialn19.html>

Posición	J			K				M					N					P			
Calidad	6	7	8	5	6	7	8	5	6	7	8	≥9	5	6	7	8	≥9	5	6	7	≥8
Medida Nominal	Diferencia superior Tsup																				
$m \leq 3$	+2	+4	+6	0	0	0	0	-2	-2	-2	-2	-2	-4	-4	-4	-4	-4	-6	-6	-6	-6
$3 < m \leq 6$	+5	+6	+10	0	+2	+3	+5	-3	-1	0	+2	-4	-7	-5	-4	-2	0	-11	-9	-8	-12
$6 < m \leq 10$	+5	+8	+12	+1	+2	+5	+6	-4	-3	0	+1	-6	-8	-7	-4	-3	0	-13	-12	-9	-15
$10 < m \leq 18$	+6	+10	+15	+2	+2	+6	+8	-4	-4	0	+2	-7	-9	-9	-5	-3	0	-15	-15	-11	-18
$18 < m \leq 30$	+8	+12	+20	+1	+2	+6	+10	-5	-4	0	+4	-8	-12	-11	-7	-3	0	-19	-18	-14	-22
$30 < m \leq 40$	+10	+14	+24	+2	+3	+7	+12	-5	-4	0	+5	-9	-13	-12	-8	-3	0	-22	-21	-17	-26
$40 < m \leq 50$																					
$50 < m \leq 65$	+13	+18	+28	+3	+4	+9	+14	-6	-5	0	+5	-11	-15	-14	-9	-4	0	-27	-26	-21	-32
$65 < m \leq 80$								Tablas de posiciones de tolerancia para agujeros													
$80 < m \leq 100$	+16	+22	+34	+2	+4	+10	+16	-8	-6	0	+6	-13	-18	-16	-10	-4	0	-32	-30	-24	-37
$100 < m \leq 120$																					
$120 < m \leq 140$																					
$140 < m \leq 160$	+18	+26	+41	+3	+4	+12	+20	-9	-8	0	+8	-15	-21	-20	-12	-4	0	-37	-36	-28	-43
$160 < m \leq 180$																					
$180 < m \leq 200$																					
$200 < m \leq 225$	+22	+30	+47	+2	+5	+13	+22	-11	-8	0	+9	-17	-25	-22	-14	-5	0	-44	-41	-33	-50
$225 < m \leq 250$																					
$250 < m \leq 280$	+25	+36	+55	+3	+5	+16	+25	-13	-9	0	+9	-20	-27	-25	-14	-5	0	-49	-47	-36	-56
$280 < m \leq 315$																					
$315 < m \leq 335$	+29	+39	+60	+3	+7	+17	+28	-14	-10	0	+11	-21	-30	-26	-16	-5	0	-55	-51	-41	-62
$335 < m \leq 400$																					
$400 < m \leq 450$	+33	+43	+66	+2	+8	+18	+29	-16	-10	0	+11	-23	-33	-27	-17	-6	0	-61	-55	-45	-68
$450 < m \leq 500$																					

2.2.2 Limits and fits

Fit: The general term of fit to describe the range of tightness designed into parts, which assemble one into another. The fit can be explained under two categories.

- **Clearance Fit:** The shaft is always smaller than the hole.
- **Interference Fit:** the shaft is always bigger than the hole.

Limits and fits are standardized according to the standard ISO 285, where there are two different systems that can be used for obtaining any type of fit:

- Hole Basis system: The hole size is kept constant and the size of the shaft changes.
- Shaft Basis system: Shaft is kept constant and the size of the hole varies.

The table above shows preferred fits for hole and shaft basis systems:

Figure 7: Preferred fits.

	ISO SYMBOL		DESCRIPTION	
	Hole Basis	Shaft Basis		
Clearance Fits	H11/c11	C11/h11	<u>Loose running fit</u> for wide commercial tolerances or allowances on external members.	More Clearance 
	H9/d9	D9/h9	<u>Free running fit</u> not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.	
	H8/f7	F8/h7	<u>Close running fit</u> for running on accurate machines and for accurate location at moderate speeds and journal pressures.	
	H7/g6	G7/h6	<u>Sliding fit</u> not intended to run freely, but to move and turn freely and locate accurately.	
	H7/h6	H7/h6	<u>Locational clearance fit</u> provides snug fit for locating stationary parts; but can be freely assembled and disassembled.	
Transition Fits	H7/k6	K7/h6	<u>Locational transition fit</u> for accurate location, a compromise between clearance and interference.	
	H7/n6	N7/h6	<u>Locational transition fit</u> for more accurate location where greater interference is permissible.	
	H7/p6 ¹	P7/h6	<u>Locational interference fit</u> for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.	
Interference Fits	H7/s6	S7/h6	<u>Medium drive fit</u> for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.	More Interference
	H7/u6	U7/h6	<u>Force fit</u> suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.	

2.2 Geometrical Tolerances

Defined by the standard **ASME Y14.5**, used to state the max allowable variations in the form of a feature or its position for perfect geometry.

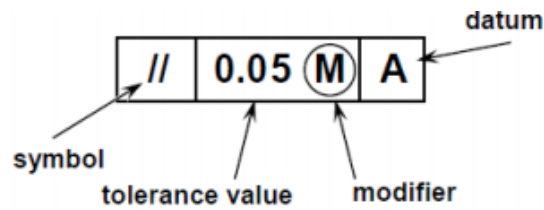
The different types of geometric tolerances are defined using standard symbols showed at the following table.

Figure 8: Symbols GD&T tolerances

Form Controls		Orientation Controls	
• Flatness		• Parallelism	
• Straightness		• Perpendicularity	
• Circularity		• Angularity	
• Cylindricity		Location Controls	
Profile Controls		• Position	
• Profile of a line		• Concentricity	
• Profile of a surface		• Symmetry	
Runout Controls			
• Circular Runout			
• Total Runout			

Geometric tolerances are indicated on drawings using a feature control frame as shown in the figure:

Figure 9: Geometric Tolerance diagram



The Datum is to use multiples reference at the same time.

The modifiers are used to specify the condition to which the tolerances are applied. There are three modifiers:

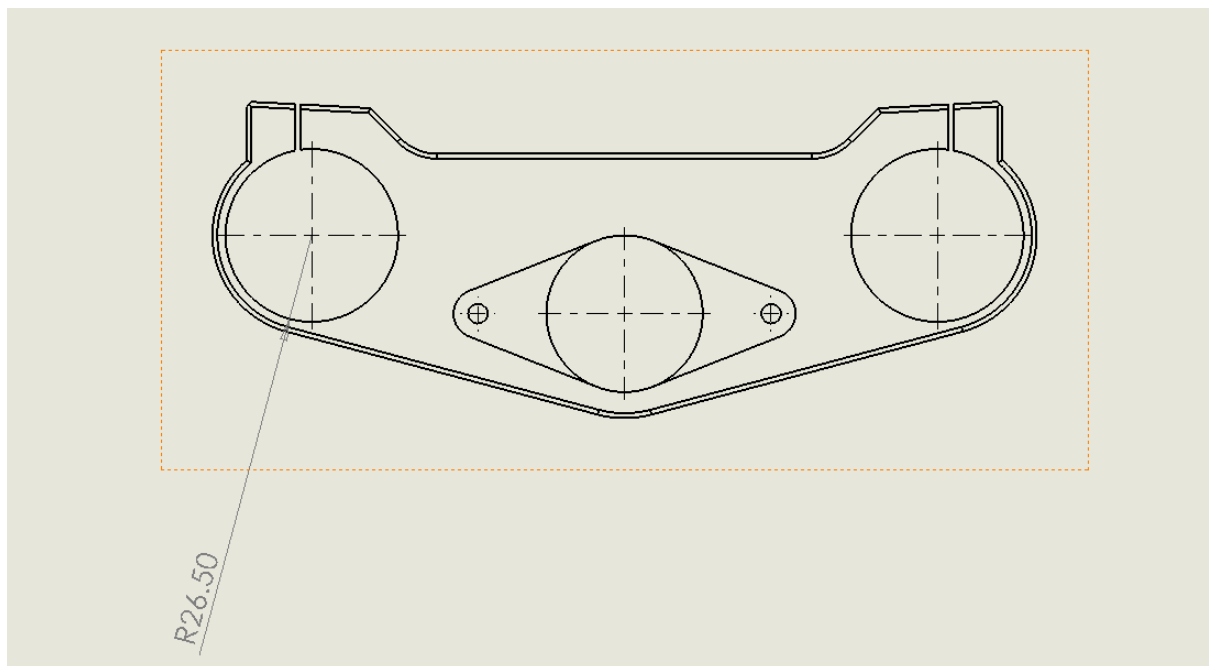
- Maximum Material Control (**MMC**)
- Regardless of Feature Size (**RFS**)
- Least Material Condition (**LMC**)

3. Methodology

The main objective of this assignment was to modify the whole measurements of some given parts to rebuild it accordingly with the ISO standard. To do this, the parts were first measured, and the relevant holes in which the two axes were driven.

3.1 Top Yoke

Figure 10: Top Yoke

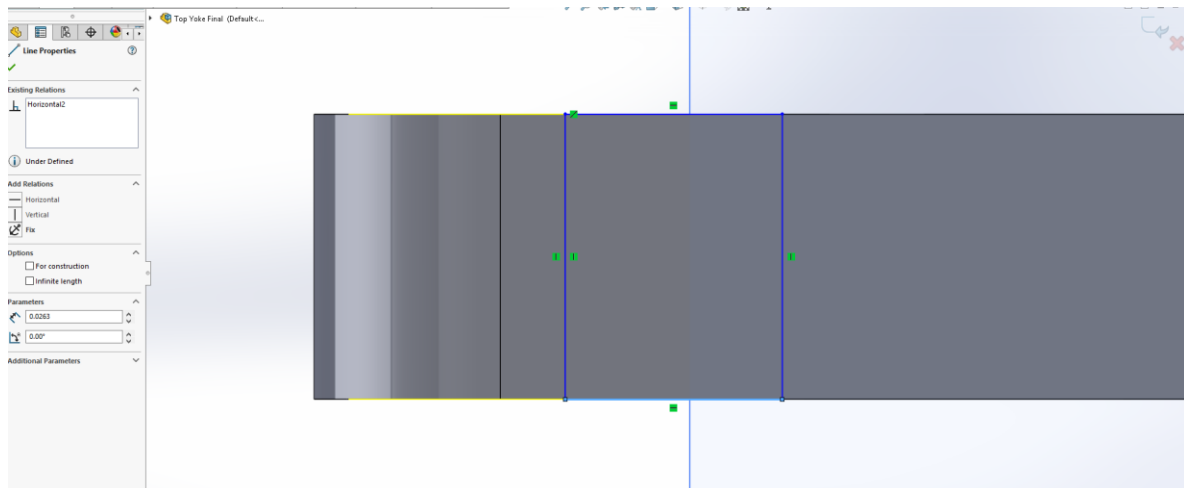


For the figure above, the two symmetric holes were measured. The diameter was 53mm. However, the shaft was 52.60mm, it means a difference of 40mm what is very huge for this part and the material that will choose for that part.

The material chosen was **Aluminium 2024**, and alloy with copper combination with parts, which need high strength and weight ratio and good with fatigue resistance. Both, the material chosen and the use that will be given to that specific area of the part are essential elements to choose the correct choice of IT and where the tolerance will be applied.

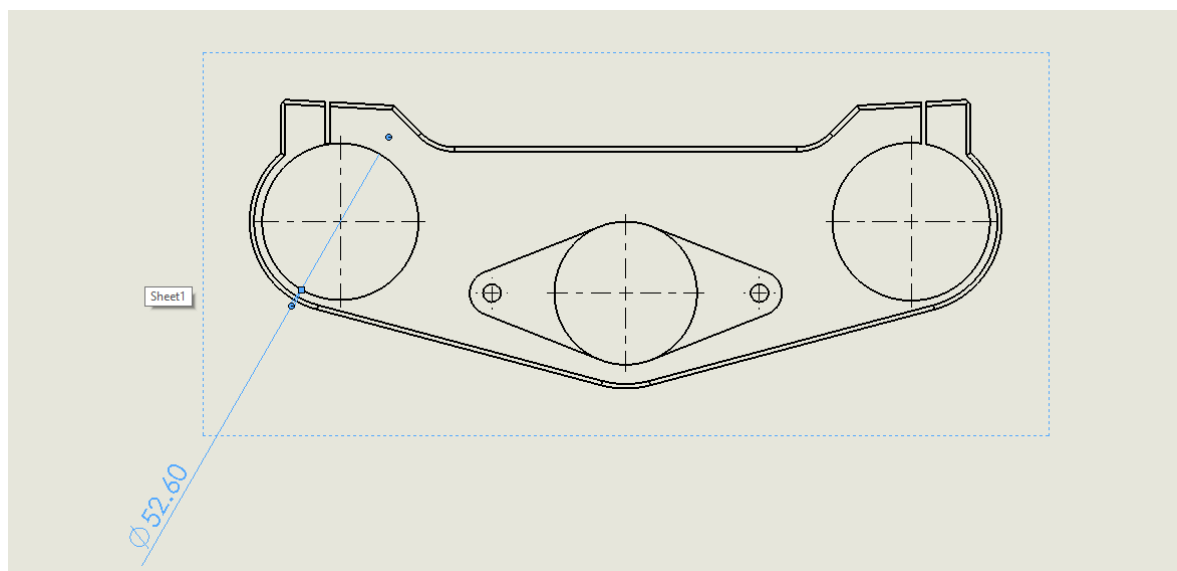
The first step was to modify the whole measurement according with the shaft (52.60mm).

Figure 11: Shaft modified top view



The length of the square was changed from 0.0265 to 0.0263 (Zoom the image) to achieve a diameter of the whole of 52.6mm.

Figure 12: Top Yoke modified



The rule applied to calculate the tolerance of the whole was *the hole basis system*, mentioned before.

The fit before the modification was clearance and after will be clearance as well.

The fit chosen was **52.6 H8** for the hole and **52.6 f7** for the shaft, the grade 8 for the hole has been chosen due that the hole not need to be accurate, the bolts can be fit the hole and the shaft; also holes should have just H limit to prevent an interface. Grade and location of the tolerance has been selected via the ISO tables, see *figure 7* and *figure 1*.

Calculating tolerances

- 52.6 H8 (+0.046 0) *ISO tables*
Max hole size: 52.646 mm
Min hole size: 52.600 mm
- 52.6 f7 (-0.03 -0.06) *ISO tables*
Max shaft size: 52.570 mm
Min shaft size: 52.54 mm

$J_{\max}$ = Difference between the max hole measurement and min shaft measurement.

$$J_{\max} = 52.646 - 52.540 = 0.106 \text{ mm}$$

$J_{\min}$ = Difference between the min hole and the max shaft measured

$$J_{\min} = 52.600 - 52.570 = 0.03 \text{ mm}$$

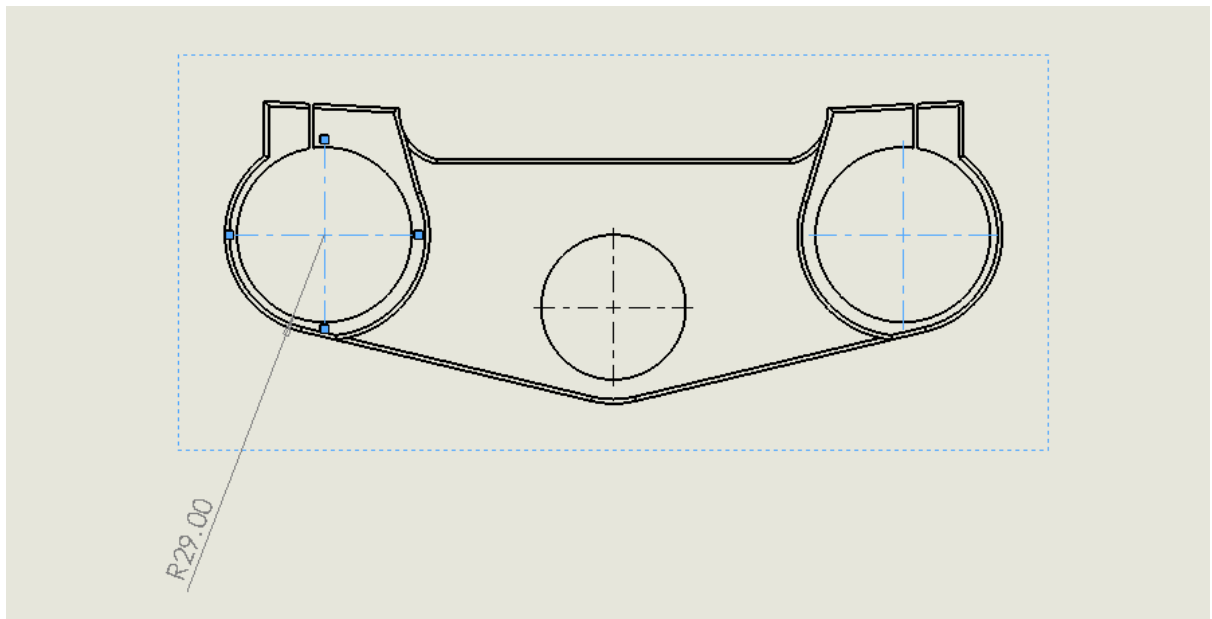
$$\text{Tolerance} = J_{\max} - J_{\min} = 0.106 - 0.03 = \mathbf{0.076 \text{ mm}}$$

Having in account the calculations above, it could be possible to apply an **H8 d9** fit to save cost, depends of the manufactured process of the part, also the manufacture procedure will be chose depending if the part will be used for road motorbike or motorsport for example.

3.2 Bottom yoke

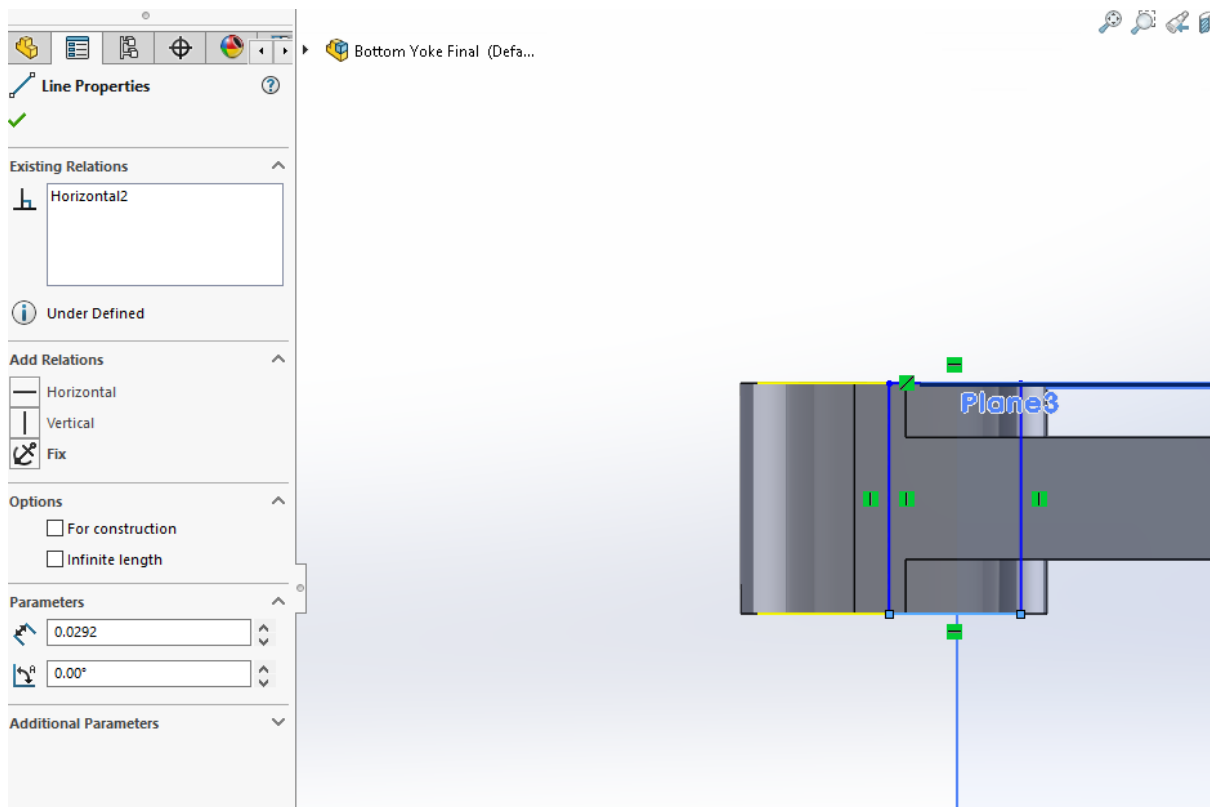
Same process has been applied for the bottom yoke.

Figure 13: Bottom yoke



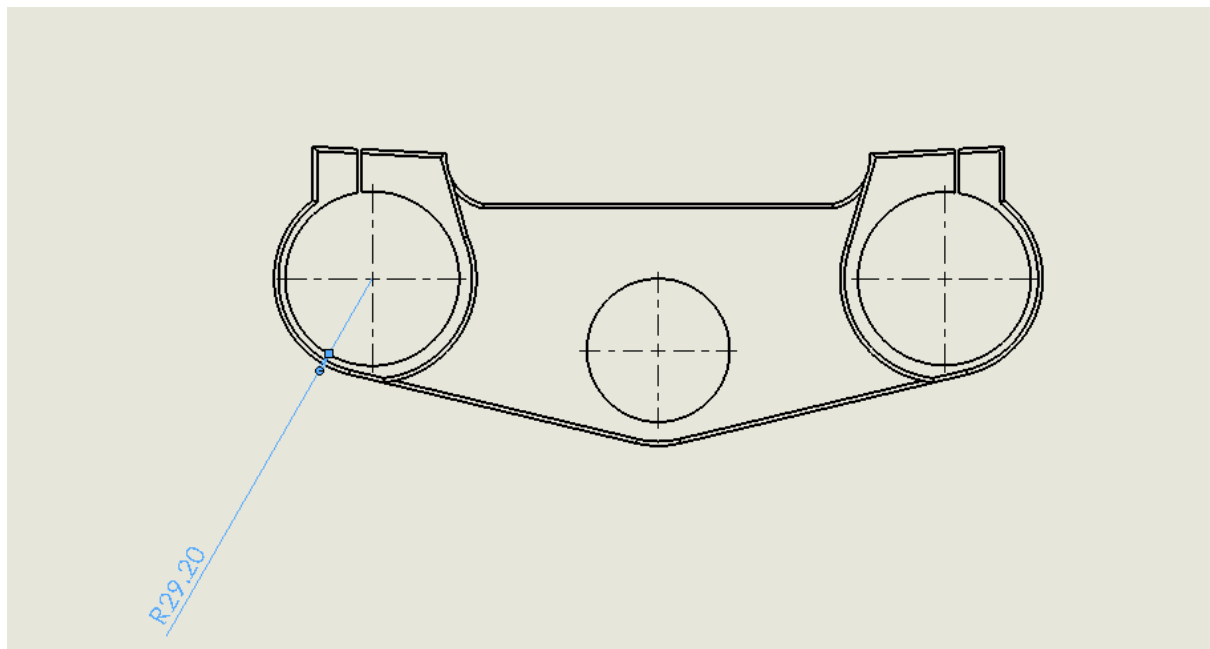
The initial diameter for the bottom yoke was 58.000 mm. However, the shaft has a diameter of 58.400mm, the diameter of the hole was changed to 58.400mm. The following figure will show the procedure to change the diameter, the same as the tope yoke.

Figure 14: Hole modification



The length of the square was changed from 0.029 to 0.0292 to get a diameter of 58.4mm to calculate the proper tolerance as the top yoke.

Figure 15: Bottom yoke modified



To calculate the tolerance will also apply the *hole basis system*. The fit **was interference** and will need a **clearance fit**.

The fit choose was **H8** for the hole and **f7** for the shaft. The same as the other yoke. The tolerance are the same as the top yoke. The following step will show in the next section, as are result of calculating drawings and therefore the rest of the tolerance will be calculated.

4. Drawings

Figure 16: Steam steel drawing with tolerances

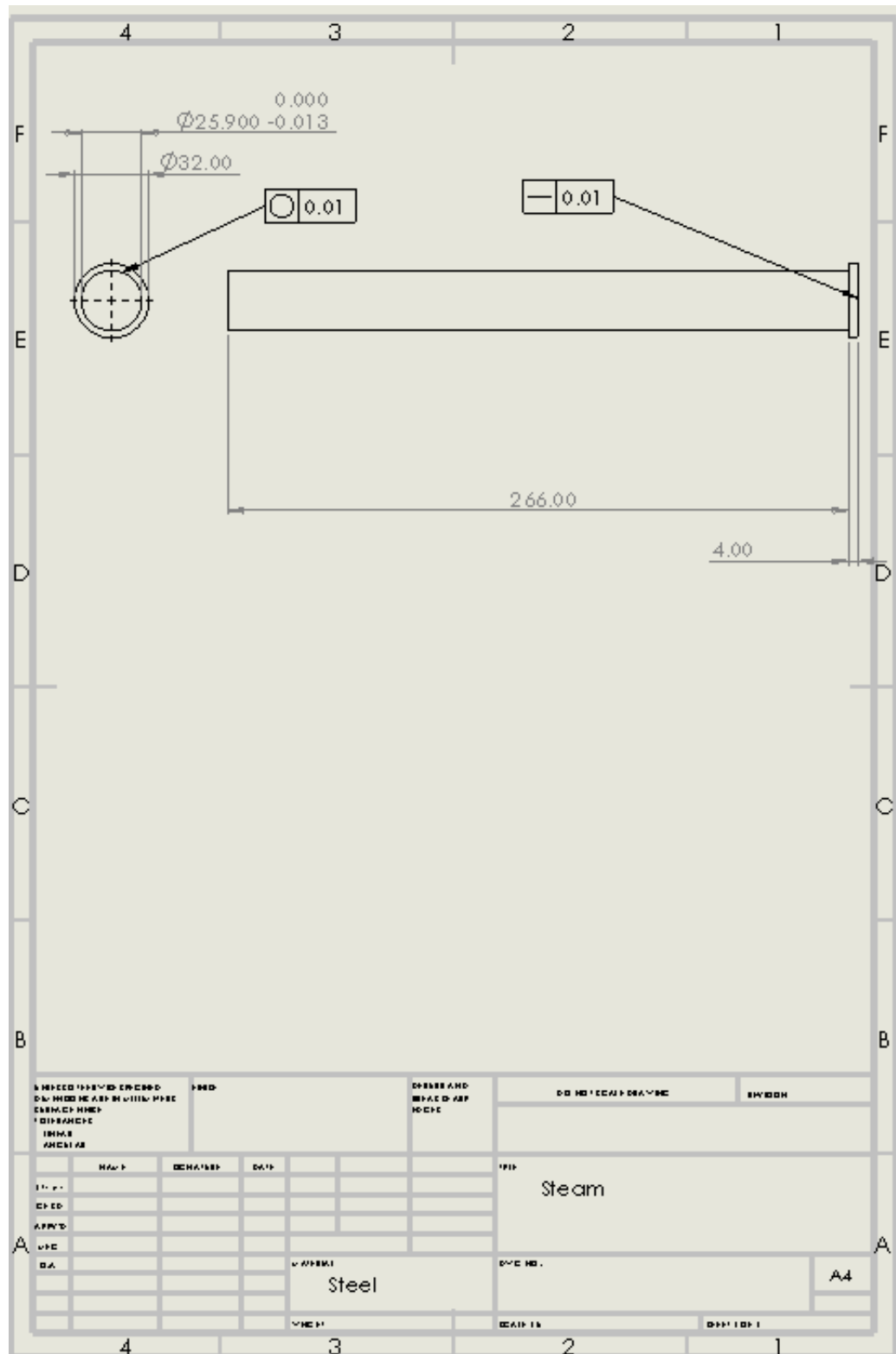


Figure 17: Insert Bottom

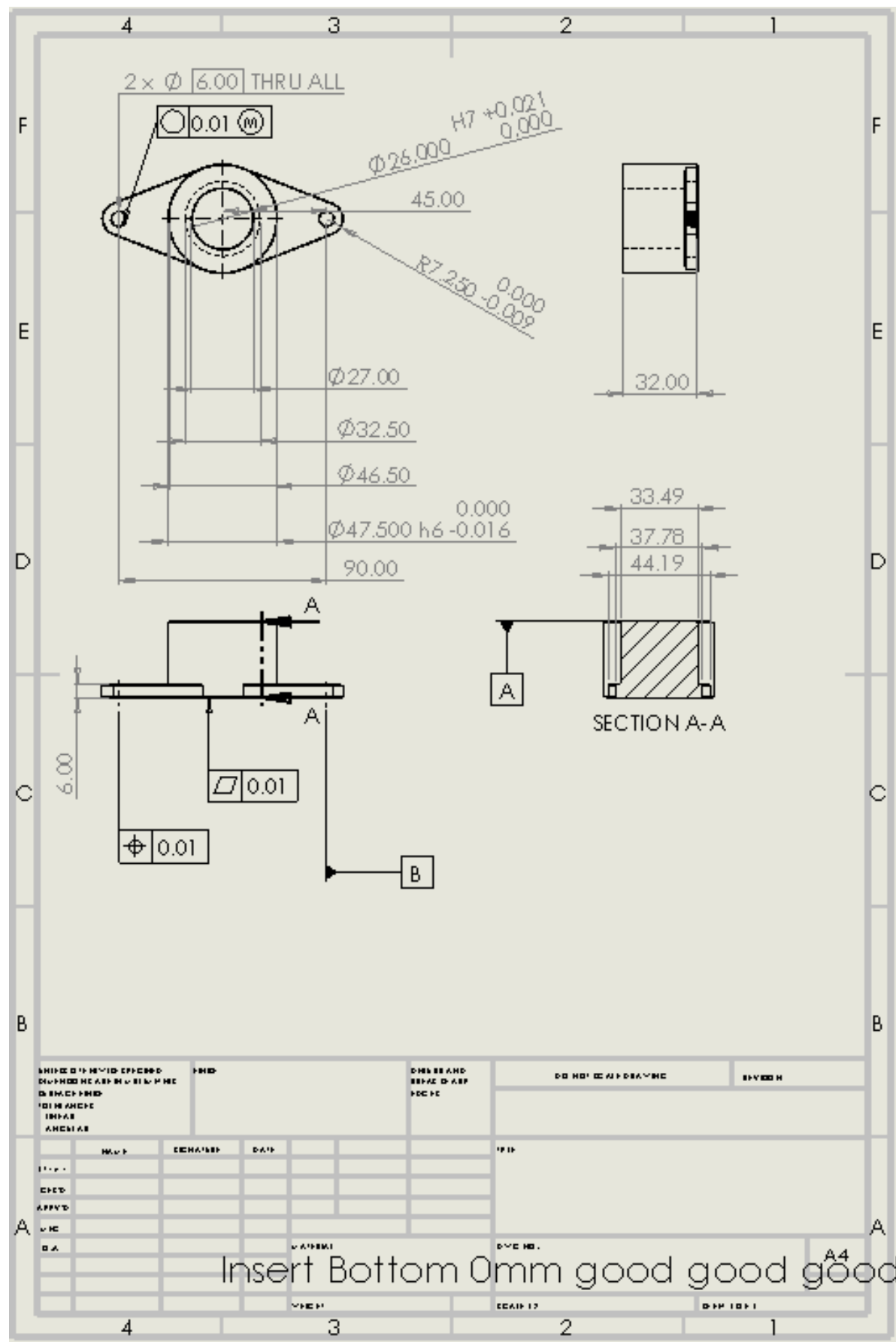


Figure 18: Upper insert

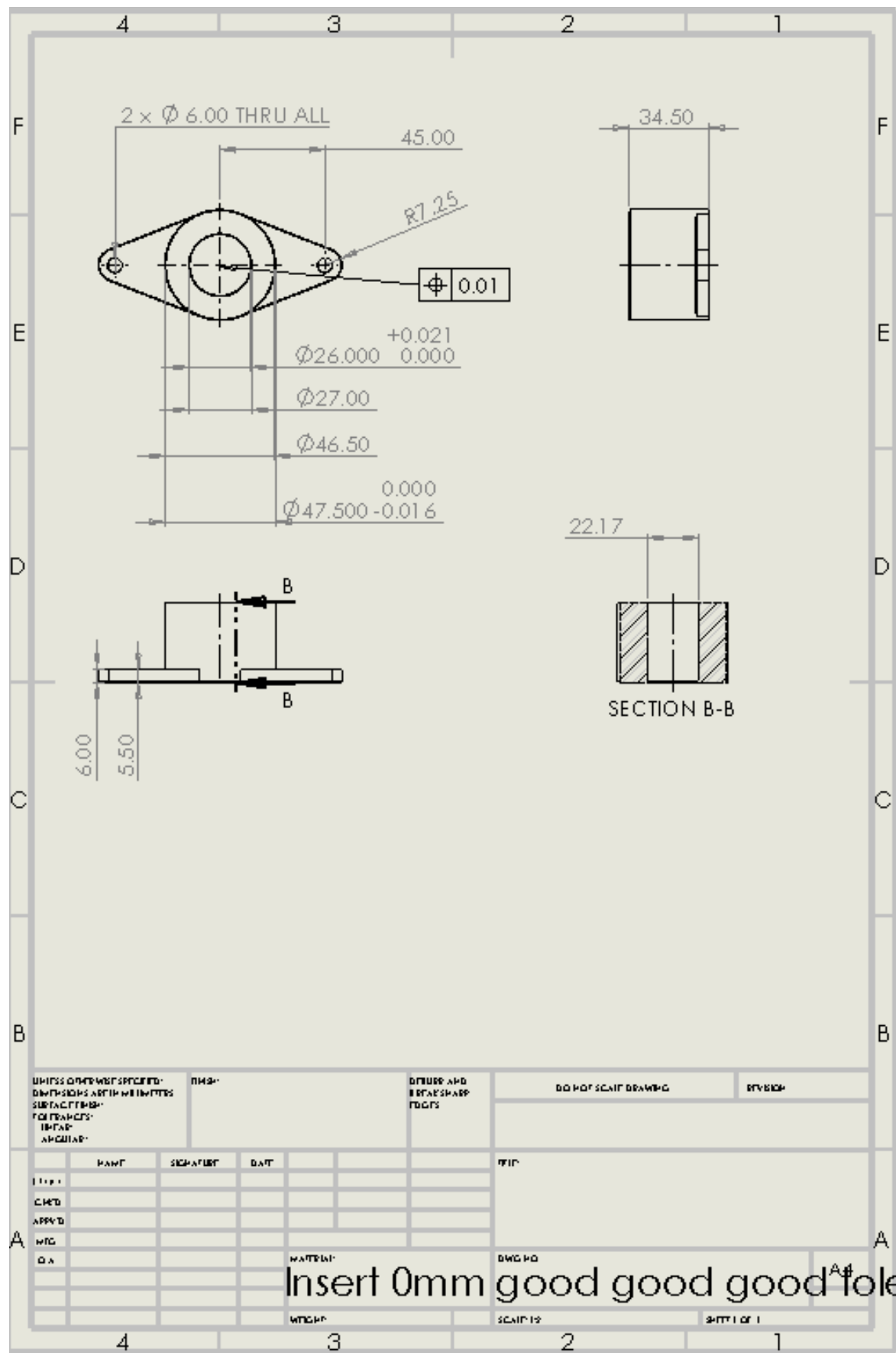


Figure 19: Bottom Yoke final

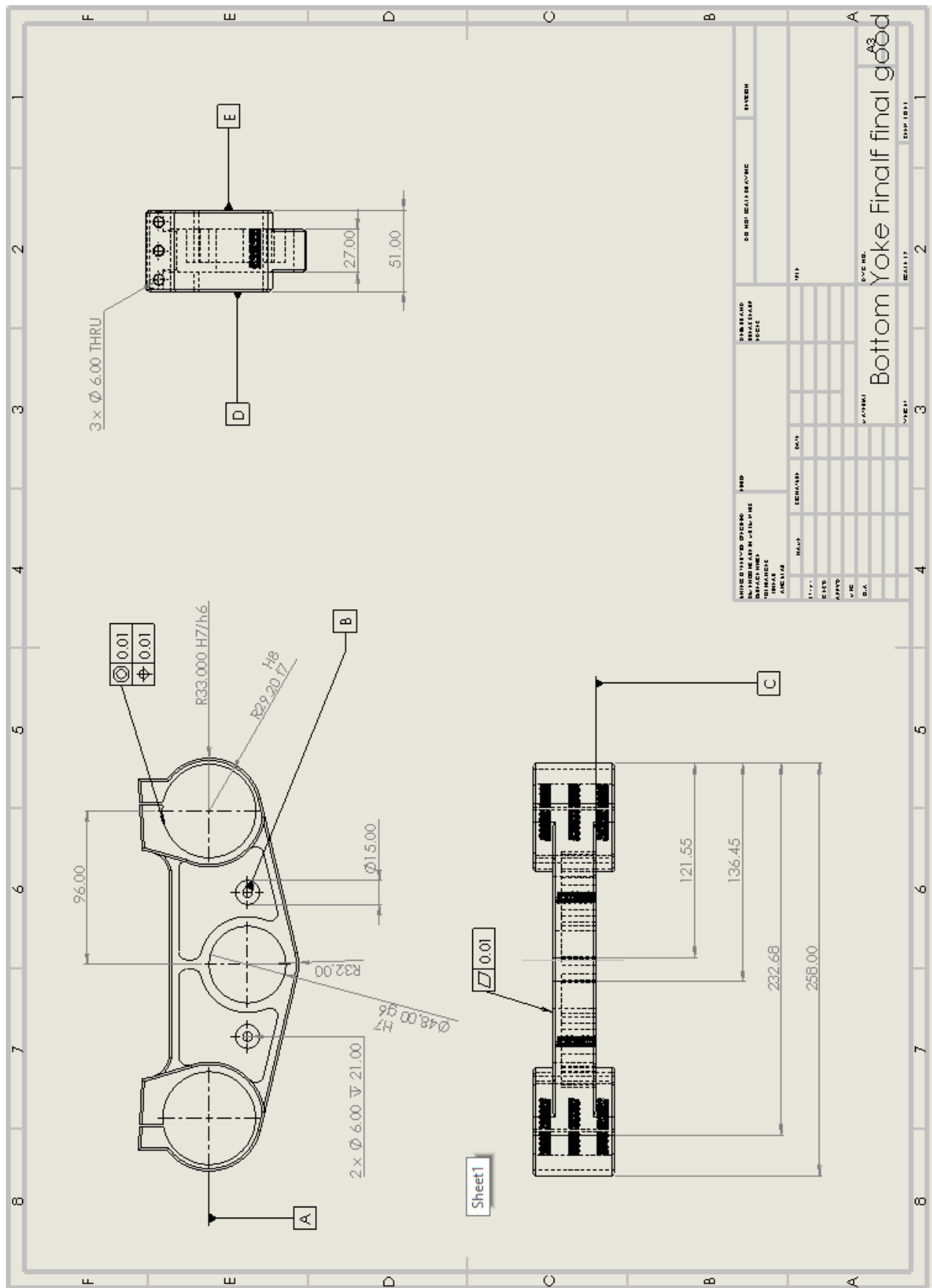


Figure 20: Top yoke final

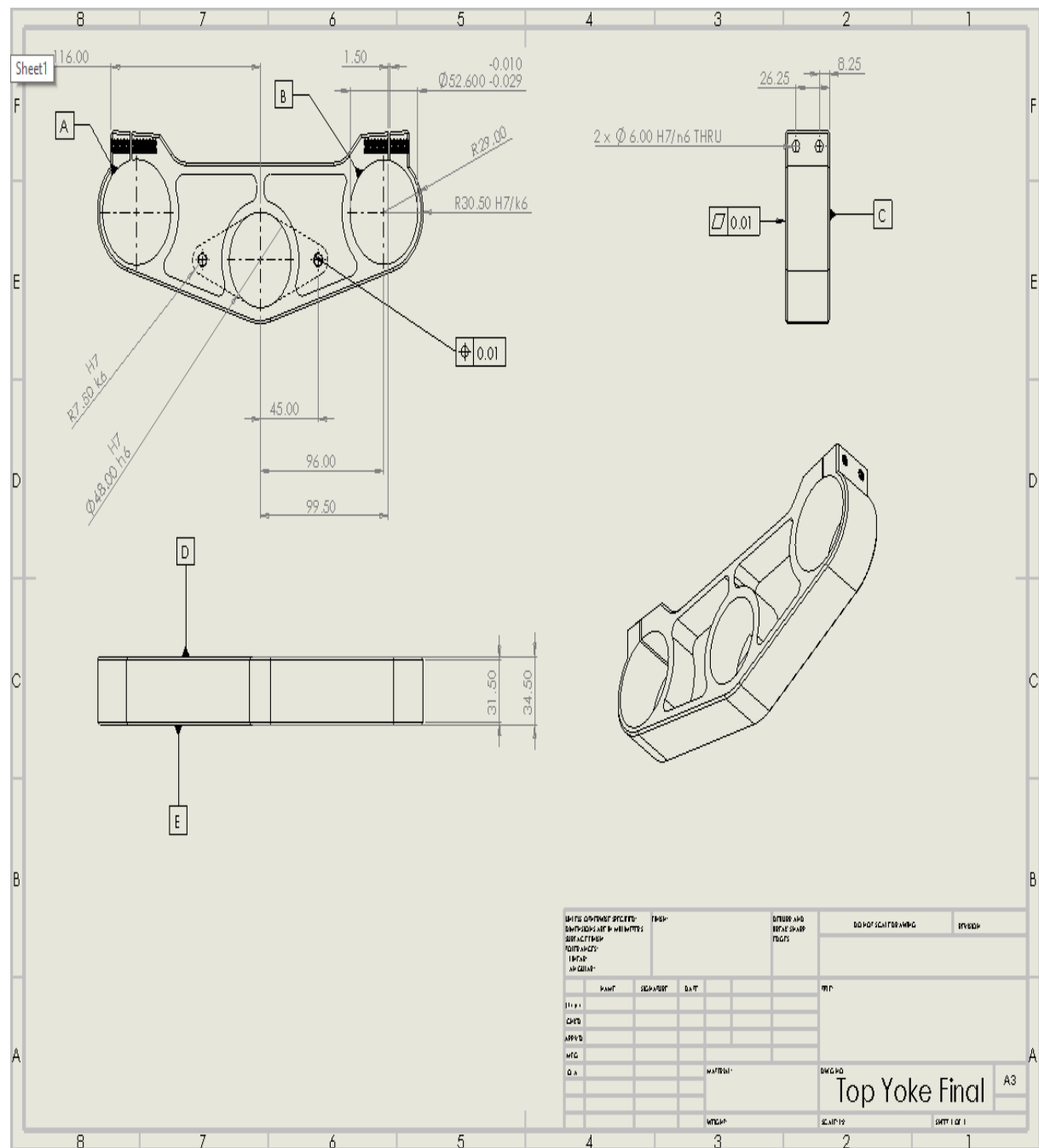


Figure 21: M16 socket

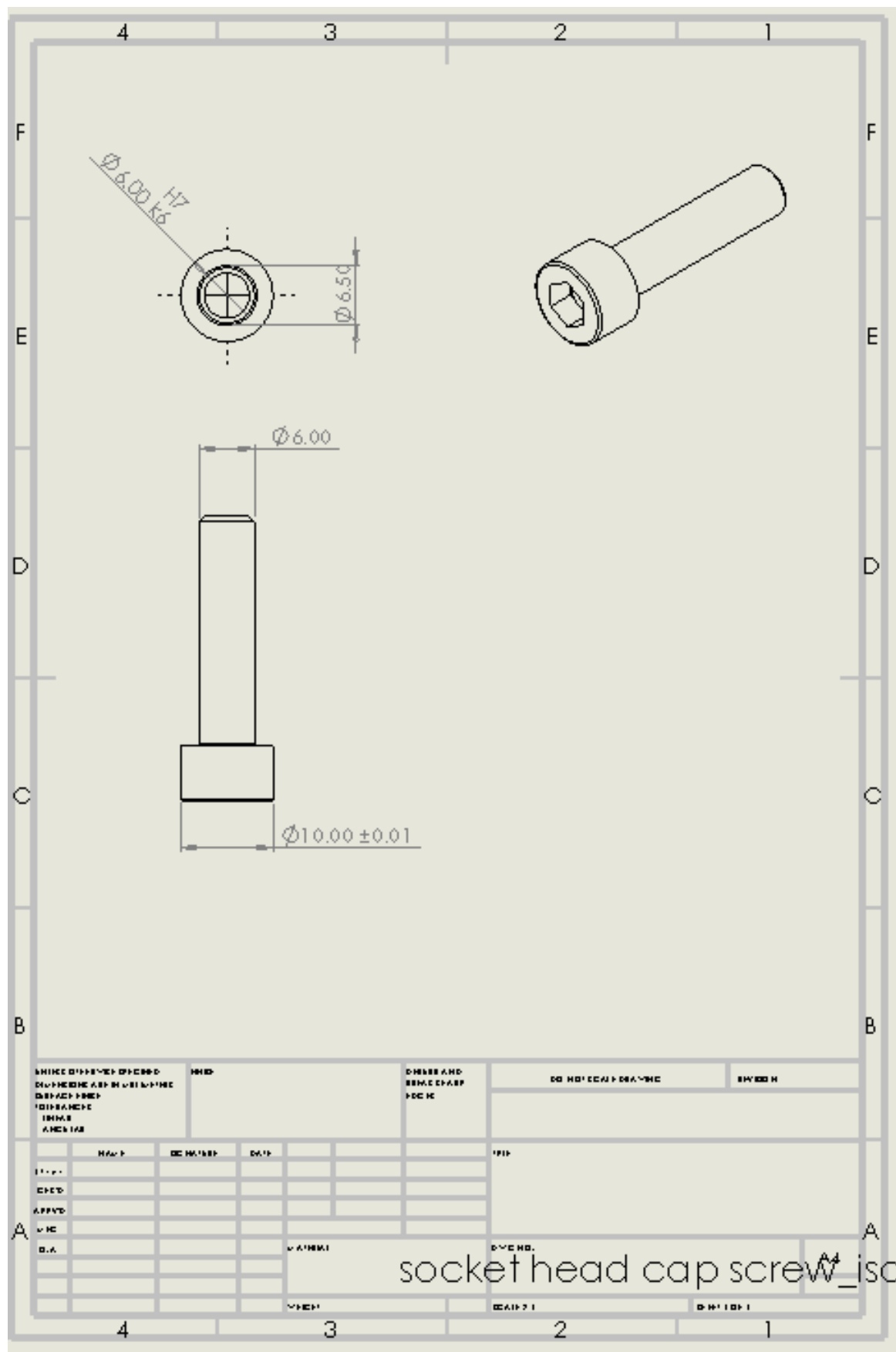


Figure 22: Hexagonal bolt

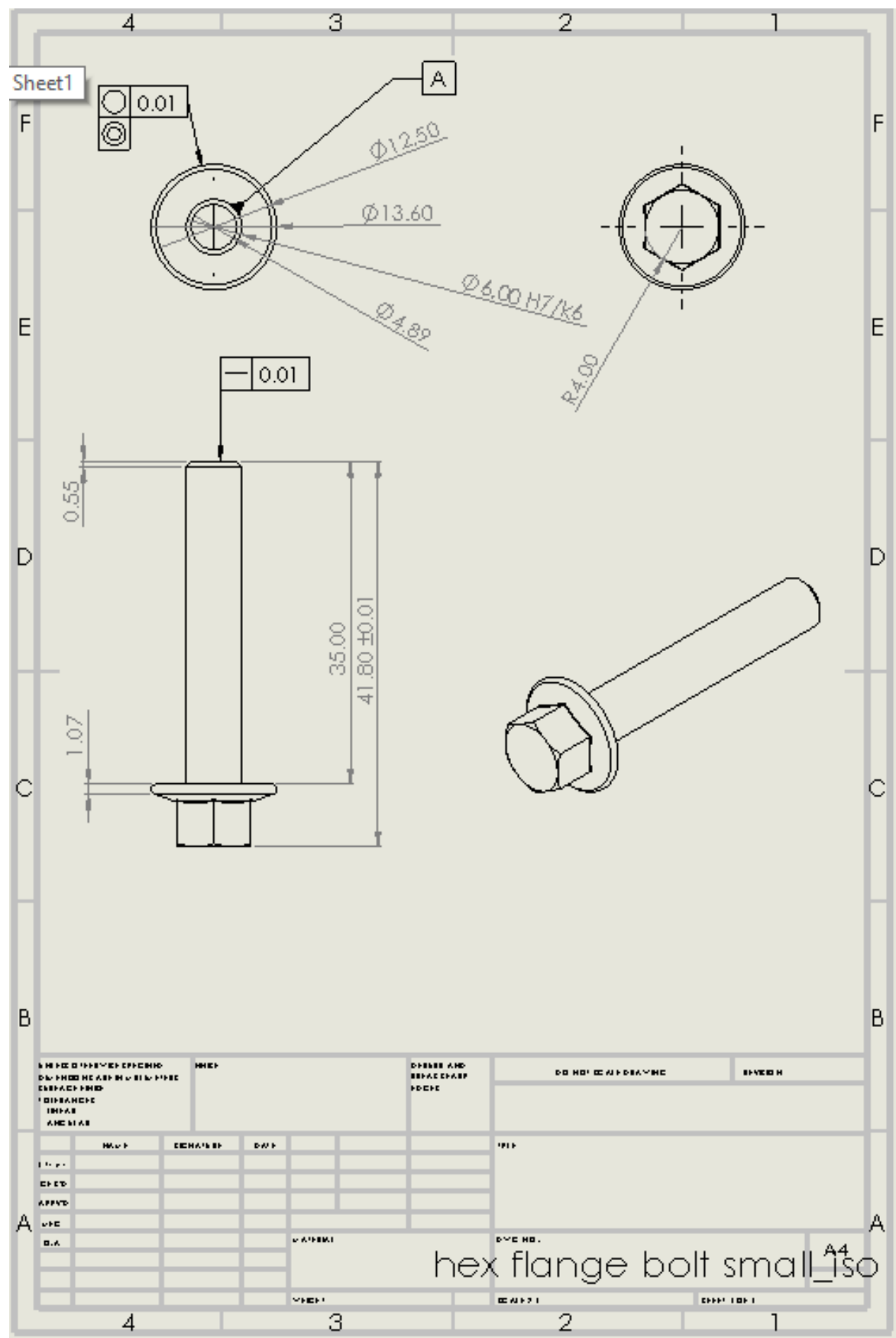
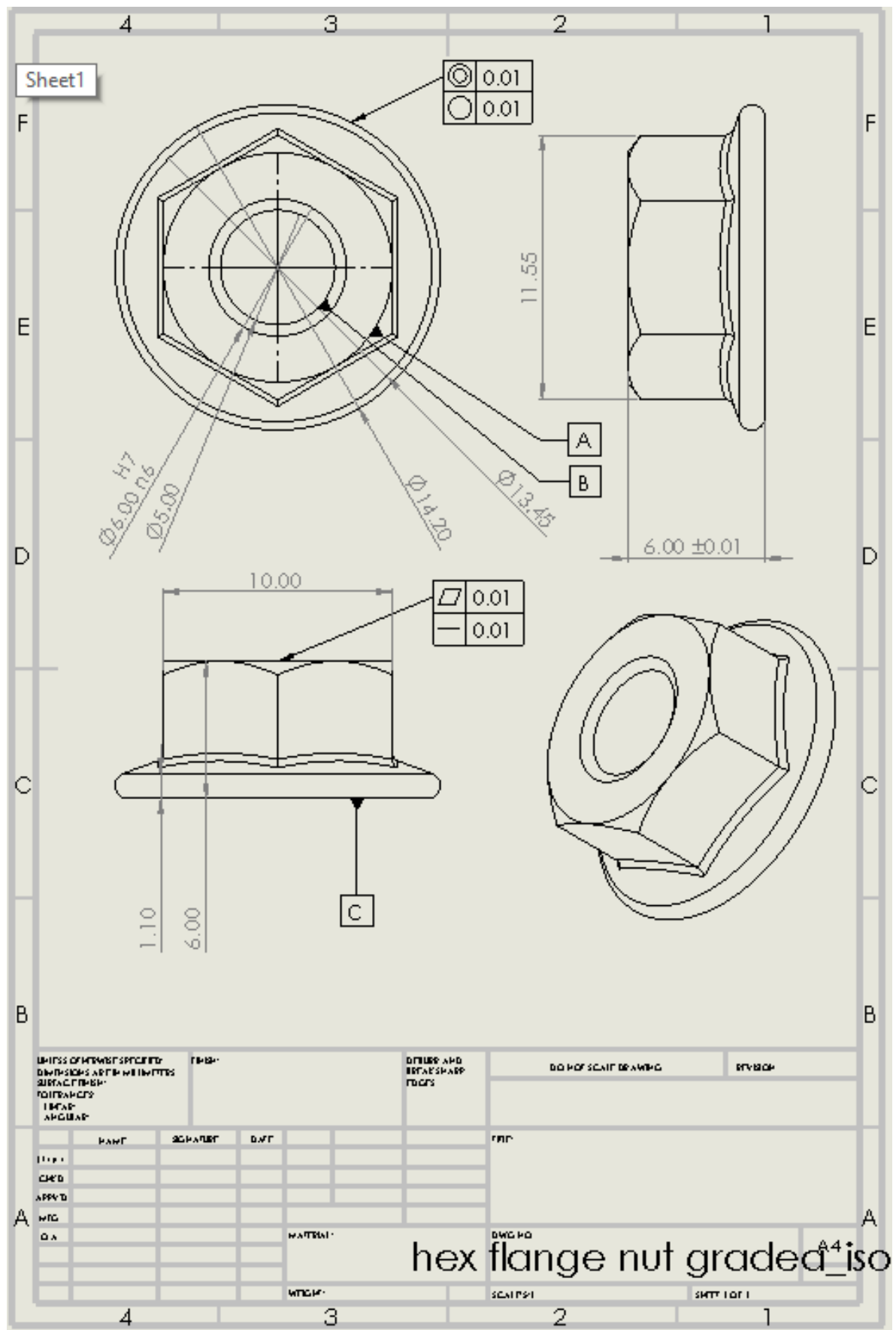


Figure 23: M16 nut



5. Tolerances calculations

- 48 H7 h6 (*Medium big hole at bottom and upper yoke*)

Locational clearance: The direction shaft, which must not move too much, just for assembly and disassembly, is not fixed by any, just a bearing below and above.

Max hole size: 48.025 mm

Min hole size: 48.000 mm

Max shaft size: 48.000 mm

Min shaft size: 47.984 mm

$$J_{\max} = 48.025 - 47.984 = 0.041 \text{ mm}$$

$$J_{\min} = 48.000 - 48.000 = 0 \text{ mm}$$

$$\text{Tolerance} = \mathbf{0.041 \text{ mm}}$$

- 26 H7 g6 (*Insert hole and shaft*)

Sliding fit: location accurately to insert the steam on in. not bolt required doing the fit.

Max hole size: 26.021 mm

Min hole size: 26.000 mm

Max shaft size: 25.980 mm

Min shaft size: 25.993 mm

$$J_{\max} = 26.021 - 25.980 = 0.041 \text{ mm}$$

$$J_{\min} = 26.00 - 25.993 \text{ mm} = 0.007 \text{ mm}$$

$$\text{Tolerance} = \mathbf{0.034 \text{ mm}}$$

- 7.5 H7 k6 (*Corner of the Insert hole, fitted at top and bottom yoke*)

Locational transition: Has to fit to the yoke, is also fixed by bolts, the result will be discuss at conclusions.

Max hole size: 7.515 mm

Min hole size: 7.500 mm

Max shaft size: 7.510 mm

Min shaft size: 7.501 mm

$$J_{\max} = 0.014 \text{ mm}$$

$A_{\max}$ = Difference between max shaft and min hole.

$$A_{\max} = 7.510 - 7.50 = 0.010$$

$$\text{Tolerance} = \mathbf{J_{\max} + A_{\max}}$$

$$\text{Tolerance} = \mathbf{0.024 \text{ mm}}$$

- 6 H7 k6 (*Bolts*)
Transition fit: This type of fit has been chosen as it could be probably the best for bolts, once the results will show, a discussion will be made at the last point of this assignment.
Max hole size: 6.012 mm
Min hole size: 6.000 mm

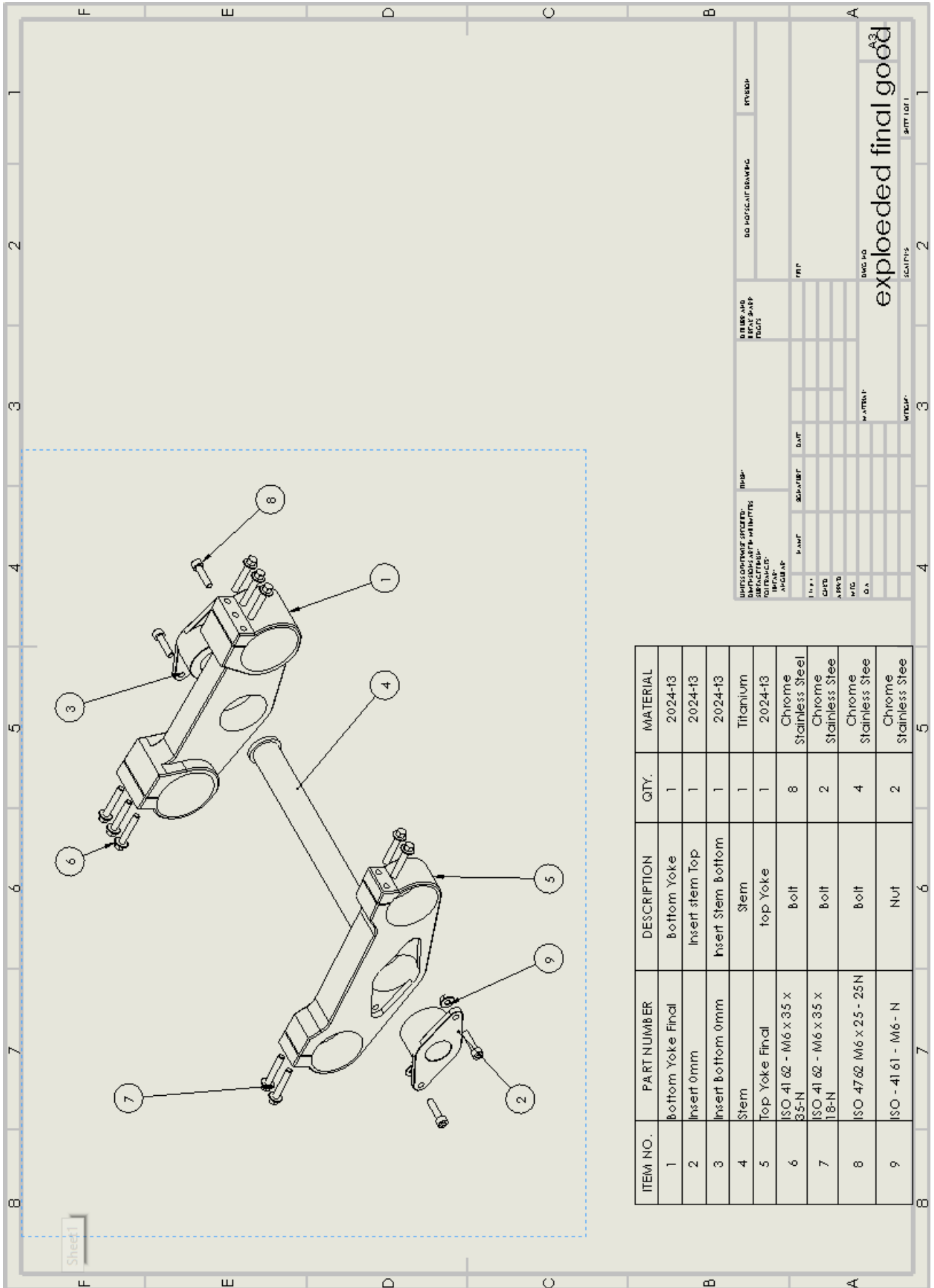
Max shaft size: 6.016 mm
Min shaft size: 6.008 mm

 $J_{\max} = 0.004 \text{ mm}$

 $A_{\max} = 0.016 \text{ mm}$

Tolerance = 0.016 mm

6. Exploded view and BOM



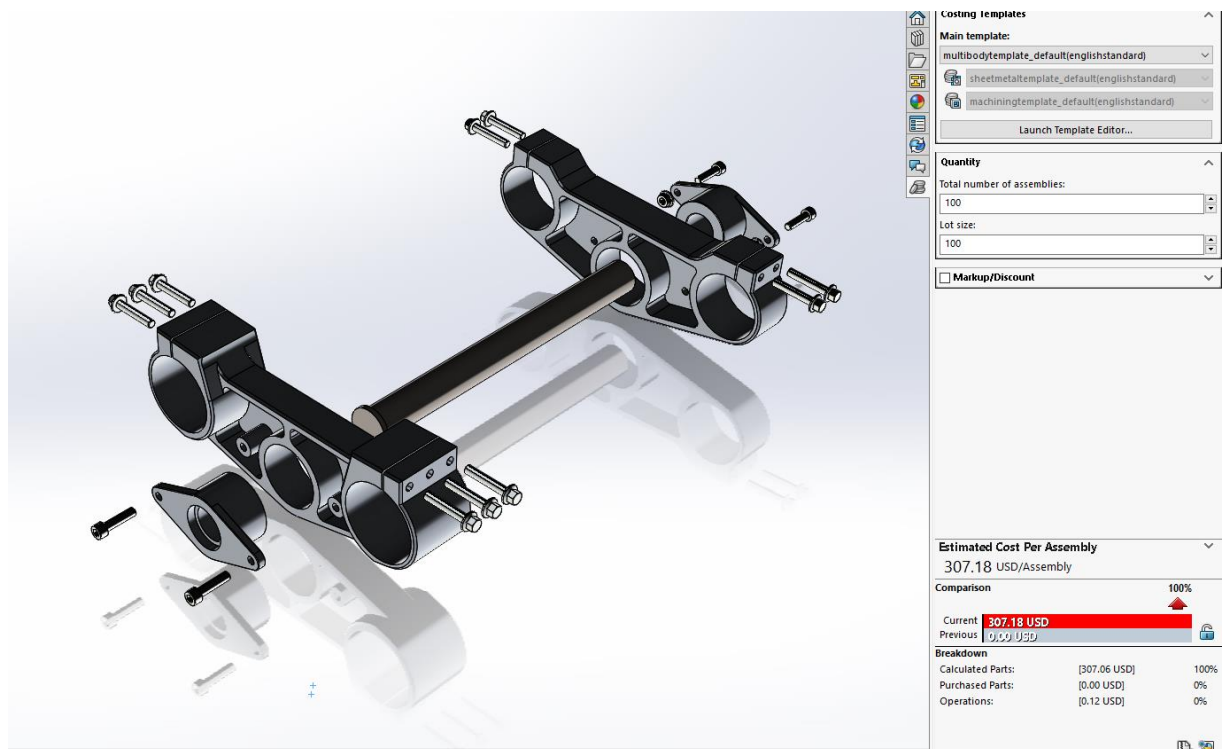
7. Materials and costing

7.1 Materials used

- **2024 – T3:** Aluminium alloy with copper as the primary element. Chosen for Upper and bottom yokes and upper and bottom inserts due to the strength and fatigue resistance. Has a tensile strength of 400–430 MPa, yield strength of at least 270–280 MPa and the young's modulus of 73GPa. Those proprieties in compared with other 2024 series of aluminium otorgue a good quality – cost ratio with the others 2024 series of alloy. This material has been chosen at these parts just for use at motorsport, due to the costs implied and the quality of elements, this material is used in aircrafts and motorsport due the proprieties; for urban use it would be better choose a poor aluminium quality.
- **Titanium:** as is stronger and lighter compared with stainless steel, has less chemical reactions which benefits the motorbike when is running different surfaces, lower modulus of elasticity so is less rigid and better for any vibrations caused by the bumps and difficult surfaces, greater strength under stressed so is better for impact instead of alloy. However the cost is higher than aluminium and steel. This material will be applied to the steam and folks of the motorbike and used just for motorsport purposes.
- **Chrome stainless steel:** Due to the high corrosion resistant will use at the bolts and nuts of the assembly. Is also stronger than the regular steel and will not lose the resistance when are scratched during the use or installation. The grade of the bolts and nuts will be Grade 8/G, they are stronger than other grades and they are used in automotive suspension as they are has to hold high bearing load and high stresses and pressures.

7.2 Costing

Figure 24: Screenshot costing.



The costing was calculated via Solidworks/evaluate/costings, this calculation includes top and bottom yokes and the stem. It must to be added bolts and nuts. The price of the bolt is 0.18 USD and the nut 0.07 USD (<https://www.nutsandbolts.com/>), so the total cost is:

- $307.18 + ((0.18 \times 12) + (0.07 \times 2)) = 309.48 \text{ USD.}$

8. Conclusions

Throughout this work, tolerances have been, as it has been needed according to the non-mobile parts of the assembly. Thus, after modifying the holes in both yokes, the best allowed tolerance has been calculated according to the needs of each fit, always taking into account the cost at all times given that the greater the degree of tolerance, the greater the cost.

After having calculated tolerances and taking into account the aforementioned cost, some tolerances could be modified to lower the cost since such high precision is not needed. In the case of the external holes of both yoke, the tolerance could be seen to be up to **H9 d9** being free running instead of close running since they are screwed by ISO 4162 - M6 x 35 x 35-N according to the standard. Besides being the screws of a grade 8 and the yoke of an aluminium alloy, we can assure that there would be no problems of in any case given that both the parts and the folk are not exposed to a source that supposes an increase in temperature and therefore the tolerance will not be affected by an expasino thermal.

The same case for the hole in the middle of each yoke, we can increase the tolerance to **H8 f7** given the quality of the folks that are made of titanium and that quality will affect the future tolerances of the geometry of the piece.

Throughout the assignment have been applied the ISO standards and the standards of tolerance qualities **ISO 235** for linear tolerances and **ASME Y14.5** for geometrical tolerances. Throughout the assignment the important tolerances have been calculated, which referred to holes and shafts. Likewise, the most important geometrical tolerances have been calculated so that the technician who used the CNC would take into account when the part would be manufactured (position, flatness and staginess). To each of the geometric tolerances it has been given a value of 0.01 as stipulated by the tort law according to the number of decimals of the nominal measure, as well as a tolerance of 0.01 for the other linear tolerances in each of the drawings, also stipulated by the law explained in previous paragraphs.

Finally and to conclude, this work has served to calculate tolerances in function of the use of the piece, material and manufacturing process, once calculated the tolerances have been modified to lower the cost of each one and that the final result is the same. Adjusted for both, the final customer and the company that makes the piece.

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