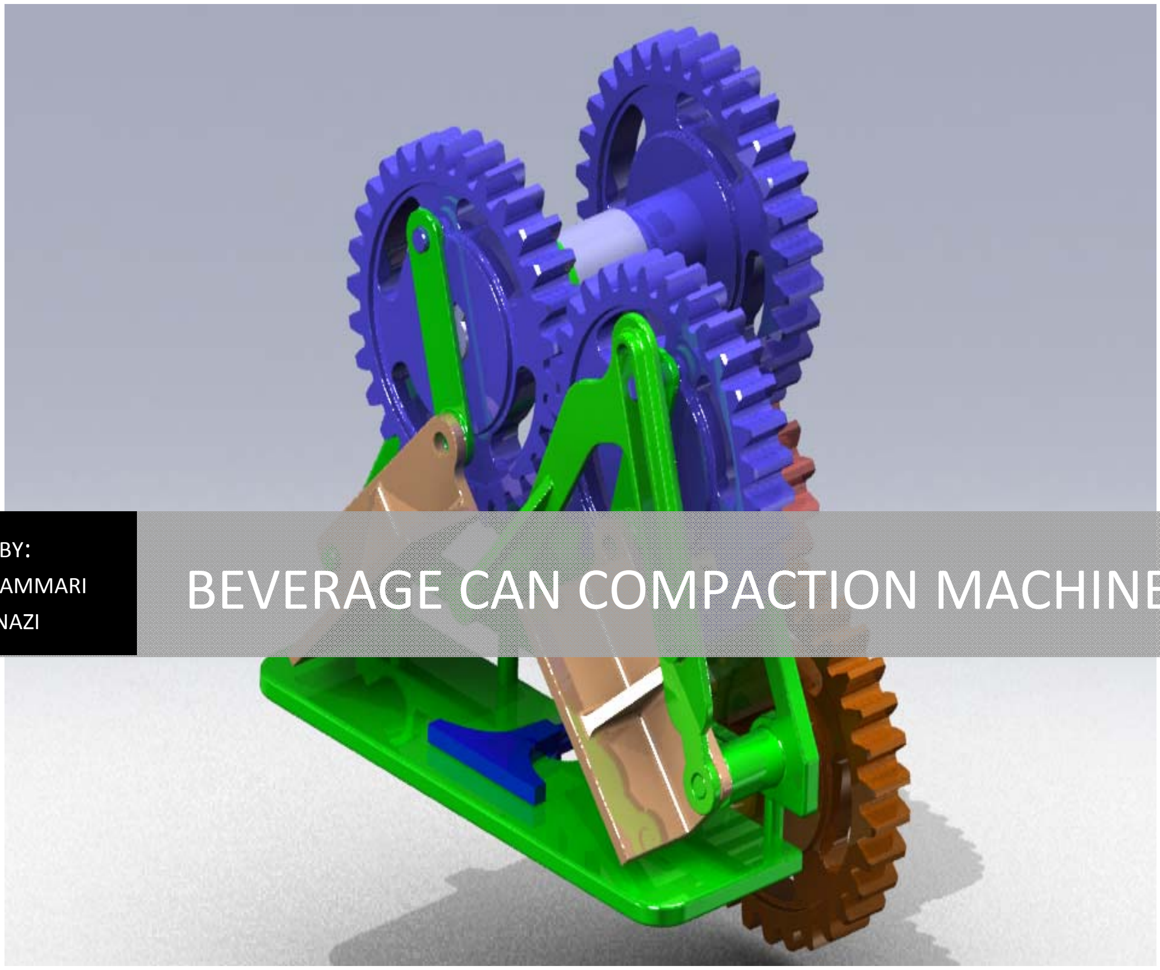
Mechanical Engineering Department



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BEVERAGE CAN COMPACTION MACHINE

Learning outcome assessment
ASSE2111
Dr- Emad Tanbour

Summary

This report presents the design of beverage cans crasher machine and it is components based on the rotation and linkage mechanism. The beverage cans crusher machine concept and objective to recycling the beverage can. Calculations to determine the size of the gears which are the mean devices in the machine and the force require making a compacting in the beverage can. A famous computer-aided design (CAD) program is used to model our design and confirm that all part fit together. Beverage can crusher is designed with the possibility that it can be make it in Saudi Arabia.

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list of contents **page**

List of Tables **page**

List of figures **page**

Introduction

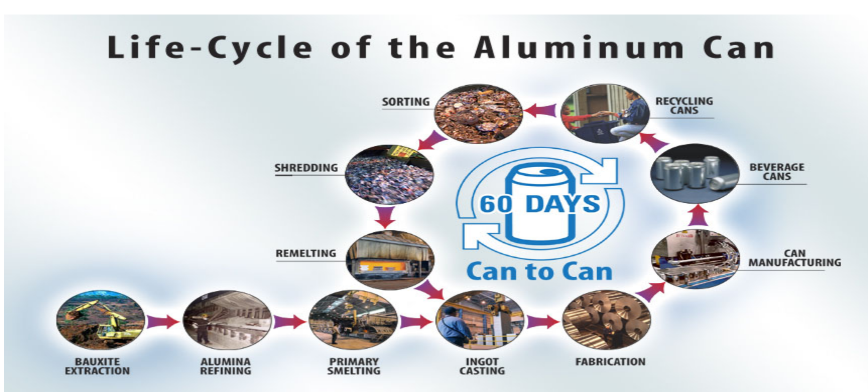
The most frequent use of aluminum is in beverage cans. Since we use aluminum so frequently it is important to get as many uses out of it as we can. Recycling aluminum not only helps to keep the landfills clear but it also saves energy.

Nearly three-quarters of all aluminum ever made remains in use today, representing a growing energy and resource bank. Recycling 40 aluminum beverage cans saves the energy equivalent of one gallon of gasoline. Using recycled material for new aluminum beverage cans uses 95%less energy and produces 95% less greenhouse gas emissions than making a can from new materials. An aluminum beverage can, once recycled, can be back on the store shelf in as little as 60 days. Americans earn about $1 billion a year recycling aluminum cans. Aluminum produced from scrap uses only 5% of the energy that producing aluminum from ore does. The aluminum can today is the most recycled of any beverage container. Aluminum is durable, flexible, lightweight, strong and recyclable. 75% of aluminum ever produced is still in use. Aluminum building components can be repeatedly recycled back into similar products with no loss of quality. 95% of aluminum in buildings is recycled.

Aluminum recycling is the process by which scrap aluminum can be reused in products after its initial production. The process involves simply re-melting the metal, which is far less expensive and energy intensive than creating new aluminum through the electrolysis of aluminum oxide, which must first be mined from bauxite ore and then refined using the Bayer process. Recycling scrap aluminum requires only 5% of the energy used to make new aluminum. For this reason, approximately 31% of all aluminum produced in the United States comes from recycled scrap.

Recycling is an important means of preserving our environment, and a good way of getting started is by recycling aluminum cans. In most cases (depending on where you live and what the laws are) the cans are collected in drop-off programs or at your curbside, and then cans are sorted, consolidated, and crushed. The crushed cans are then baled for transportation to a recycling facility which melts them down and converts the old aluminum into new products.

Figure # 1 life- cycle of the aluminum can



A- Recycling fun fact:

1. Recycling aluminum cans saves 95 percent of the energy used to make aluminum cans from virgin ore.
2. In 1972, 53 million pounds of aluminum cans were recycled. Today, that amount is exceeded by 1,612 million pounds.
3. Aluminum cans distinguish them as the most recycled and most recyclable beverage container in the world. An awesome 105,784 cans are recycled every minute nationwide.
4. Used aluminum cans are recycled and returned to a store shelf as a new can in as few as 60 days. That means a consumer could purchase basically the same recycled aluminum can from a retailer's shelf nearly every 9 weeks or 6 times a year.
5. The weight of 1,665 million pounds of aluminum cans recycled in 2001 was equal to the weight of 14 aircraft carriers.
6. Americans earn about $1 billion a year recycling aluminum cans. A used aluminum can returned to a recycling center is worth about a penny to consumer recyclers.
7. For each pound of aluminum recovered, Americans save the energy resources needed to generate about 7.5 kilowatt-hours of electricity. That's enough energy saved each year by recycling aluminum to meet the lighting needs of a city the size of Pittsburgh, PA for six years.
8. Beverage containers represent less than 20 percent of the materials collected in curbside recycling programs and they generate up to 70 percent of total scrap value. Aluminum cans are the most valuable commodity to curbside programs helping to pay for the collection of other containers.
9. Aluminum can recycling rate is better than 1 out of 2 cans.
10. Recycling diverted 1.7 billion pounds from landfills.
11. Using recycled aluminum beverage cans to produce new cans allows the aluminum can industry to make up to 20 times more cans for the same amount of energy.
12. It's estimated that since 1972 some 18.7 million tons of aluminum have been recycled. These 1,099 billion aluminum cans placed end-to-end could stretch to the moon and back some 174 times.
13. Aluminum cans have amazing strength. Four six-packs (24 cans) can hold a 4,000-pound aluminum-bodied sedan.
14. In 2003, Americans recycled 62.6 billion aluminum cans. Those cans, placed end-to-end, could make 171 circles around the earth.
15. America recycled enough aluminum cans last year to stretch to the moon and back 8 times.
16. Since 1972 Americans have recycled 37 billion lbs. or 1,099 trillion aluminum cans and earned over $25 billion by recycling aluminum beverage cans.
17. Every minute of everyday, an average of 105,800 aluminum cans are recycled.
18. When you think it is hot, consider the following: Did you know that aluminum begins to melt at a whopping 1220 degrees Fahrenheit
19. Over the past 10 years, the number of aluminum cans recycled has doubled

20. The average employee consumes 2.5 cans of soda each day at work.
21. Recycling one aluminum can saves enough energy to run a television for three hours.
22. Enough aluminum cans were recycled in 2002 to fill a hollow Empire State Building 24 times.

23. Each year Americans receive enough money from recycling aluminum cans that every kid in the U.S. could buy two movie tickets.
24. The number of cans recycled every 30 seconds equals the number of people who could fill an entire pro football stadium.
25. Every 3 seconds a baby is born. In that time, 140 cans were born.
26. If the 2003 Corvette convertible was on a seesaw, it would take 107,214 used aluminum cans on the other side to balance the car.
27. In 2001, beverage cans delivered 9,409 billion gallons of pure refreshing beverage—enough to fill 37,634 Olympic pools.
28. 10,433 empty aluminum beverage cans weigh as much as Shaw O'Neal.
29. In 2001, Americans bought 351 aluminum beverage cans per person, twice as many as in 1980.
30. The average American family recycles 150 six packs of aluminum can a year.
31. Used aluminum cans are melted down into ingots that can weigh as much as 30,000 tons. That's enough aluminum to make 1.6 million cans.
32. Aluminum never wears out, it can be recycled forever.
33. Americans drink an average of 380 beverages in aluminum cans each year.

b- Problem definition:

Design a beverage can crusher to handle aluminum cans only to reduce the volume of shipping recycled cans.

c- Scope of project:

This project is limited to designing the crusher components that are critical. The crusher will be designed to handle beverage cans only. The components will be designed such that the material is available locally and it can be manufactured it in Saudi Arabia.

Concept design:

The design project for compacting of empty beverage cans for compacting the can thought interaction of three arm device. The first arm contacting a mid portion of the can and compressing that mid portion and the second and third arms acting on end regions on either side of the mid portion to compress the remaining portions of the can.

The arms mechanism working by the rotation of the driven and drive gears creating that type of motion and compacting. The drive gear is connecting by the shaft with another transition gear that takes the rotation from the mean gear which is the pinion gear. The pinion gear takes the duty from the mean motor and connecting together by the shaft.

For the ejection cam device is connecting with the shaft that take the duty from the second transition gear. The second transition gear is rotated by the pinion gear.

The first input for our design was the speed of the pinion gear which is 120 RPM and the requirement force to crushing the empty beverage can which will discuss in the coming section in the report. The most important and objective of our design to provide a device for compacting empty beverage cans of aluminum requiring minimum of power and yielding a noise level.

The main component in the project is the gears. For that we concentrate in the design calculation in this device. Spur gears are simply toothed wheels used for transmitting power and motion from one shaft to another. The design of gears is highly standardised by the AGMA (American Gear Manufacturers' Association). Like bearings, gears represent a product of excellence in engineering design.

The advantages of m are: (1) transmit large power, (2) high efficiency, (3) stable speed ratio, (4) long life, and (5) reliable. The disadvantages are: (1) high requirements in manufacturing and assembling, (2) expensive, and (3) unsuitable for long distance transmission.

The design of spur gears requires the study and objective understanding of the following subjects:

- -- Kinematics and geometrical shapes
- -- Analysis of forces produced in gears and in gear trains
- -- Design of gears against breakage
- -- Design of gears against deterioration and wear

Figure # 2 machine front views

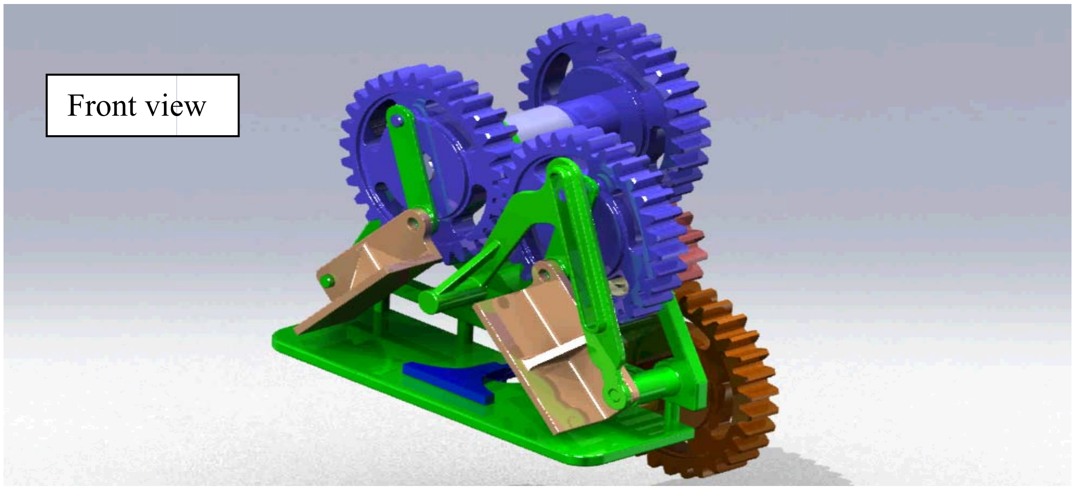
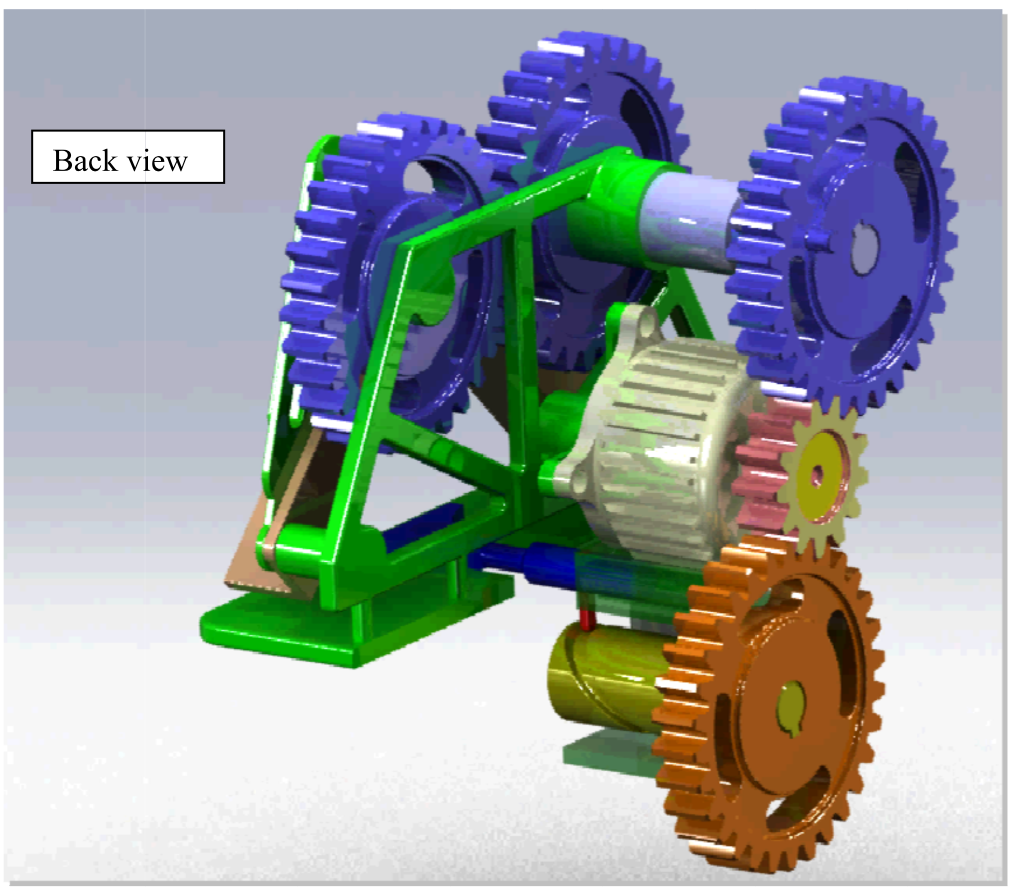


Figure # 3 machine back view



Power :

It should be noted again that power is equal to torque multiplied by rotation speed.

$$P = T\omega$$

And this must be constant from the input gear to the output gear. Therefore, if torque *T* rises, then speed must be reduced. The power is constant; we cannot put five watts in and get fifteen watts out! Notice also, in SI units:

$$1\ watt = 1\ N \cdot m \times 1\ rad / sec$$

Dynamic Forces between Gear Teeth

Noise which is generated at high speeds by a pair of gears is caused by the impact forces between contacting tooth surface. The greatest cause of these dynamic forces is error in teeth profile due to improper manufacturing. Various approaches have been taken to determine the dynamic force.

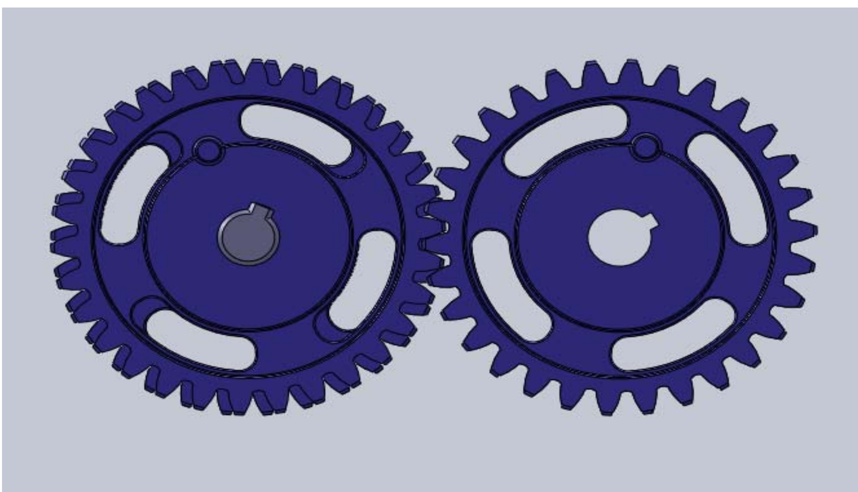


Figure # 4 Two transfer gear driver

Bending Stresses

The allowable bending stress on a tooth could limit the power transfer for thinner teeth at low contact ratios. The simple graph deals with the bending stress at the root of a gear tooth. The additional tables here give more detailed information.

Usually gears fail because the tooth surface is deformed and wear takes place due to the small sliding action of the contact point. Thus the contact stress may also be the critical design stress.

Contact Stresses

If contact stresses are too high the surfaces of the gear teeth will be gouged. Lubrication films break down and metal-to-metal contact takes place. The teeth grind away the profile due to sliding. If the gear is surface hardened, surface fatigue may occur, resulting in surface flaking. These flakes can then become a grinding powder that rapidly destroys the machine.

Gears calculation

Pitch Diameter (D): The diameter of the Pitch Circle from which the gear is designed.

An imaginary circle, which will contact the pitch circle of another gear when in mesh.

PD = N/P = 30/4.1 = 7.3 cm

Diametric Pitch (P): A ratio of the number of teeth per cm of pitch diameter.

P = N/ D = 30/7.3 = 4.1

Addendum (A): The radial distance from the pitch circle to the top of the gear tooth.

A = 1/ P= 1/4.1 = 0.243 cm

dendum (B): The radial distance from the pitch circle to the bottom of the tooth.

B = 1.157/P=1.157/4.1=0.282 cm

Outside Diameter (OD): The overall diameter of the gear

OD= N + 2/P = 30+2/4.1 = 7.8 cm

Root Diameter (RD): The diameter at the Bottom of the tooth.

RD =N − 2/P = 30-2/4.1= 6.82 cm

Base Circle (BC): The circle used to form the involutes section of the gear tooth

BC = D * Cos PA = 7.3*cos4.1*0.243 = 1.77 cm

Circular Pitch (CP): The measured distance along the circumference of the Pitch Diameter from the point of one tooth to the corresponding point on an adjacent tooth.

CP = 3.1416D/P = 3.1416D/P = 3.1416*7.3/4.1 = 5.59 cm

Circular Thickness (T): Thickness of a tooth measure along the circumference of the Pitch Circle.

T= 3.1416D/2N = 1.57/1.36 = 1.154cm

Torque:

T= F * D = 90 * 2.1=189N/cm

P= T * w = 189 * 1.047 = 197 watt

Forces on spur gear teeth:

Ft: transmitted forces

FN: normal forces

Fr: resultant force

Ft = 2*189/1.1 = 343.5N

FN = Ft cos 20 = 125 N

Fr = Ft/cos 20 = 343.5/cos20 = 365.5 N

Materials used for gears:

The most important in the design select the proper material. There are more than twenty material types in the market. In our design project we selected the Alloy steel because of treatable to provide highest strength and durability.

Material	Notes	applications
Ferrous metals		
Cast Iron	Low Cost easy to machine with high damping	Large moderate power, commercial gears
Cast Steels	Low cost, reasonable strength	Power gears with medium rating to commercial quality
Plain-Carbon Steels	Good machining, can be heat treated	Power gears with medium rating to commercial/medium quality
Alloy Steels	Heat Treatable to provide highest strength and durability	Highest power requirement. For precision and high precision
Stainless Steels (Aust)	Good corrosion resistance. Non-magnetic	Corrosion resistance with low power ratings. Up to precision quality
Stainless Steels (Mart)	Harden able, Reasonable corrosion resistance, magnetic	Low to medium power ratings Up to high precision levels of quality
Non-Ferrous metals		
Aluminum alloys	Light weight, non-corrosive and good	Light duty

	machinability	instrument gears up to high precision quality
Brass alloys	Low cost, non-corrosive, excellent machinability	Low cost commercial quality gears. Quality up to medium precision
Bronze alloys	Excellent machinability, low friction and good compatibility with steel	For use with steel power gears. Quality up to high precision
Magnesium alloys	Light weight with poor corrosion resistance	Light weight low load gears. Quality up to medium precision
Nickel alloys	Low coefficient of thermal expansion. Poor machinability	Special gears for thermal applications to commercial quality
Titanium alloys	High strength, for low weight, good corrosion resistance	Special light weight high strength gears to medium precision
Di-cast alloys	Low cost with low precision and strength	High production, low quality gears to commercial quality
Sintered powder alloys	Low cost, low quality, moderate strength	High production, low quality to moderate commercial quality
Non metals		
Acetal (Delrin	Wear resistant, low water absorbtion	Long life , low load bearings to commercial quality
Phenolic laminates	Low cost, low quality, moderate strength	High production, low quality to moderate commercial quality
Nylons	No lubrication, no lubricant, absorbs water	Long life at low loads to commercial quality
PTFE	Low friction and no lubrication	Special low friction gears to commercial quality

Our design assumption and input data are:

1- The input pinion is made of 15 teeth.
2- 2.5 mm module.
3- 20 full depth teeth of hardness 330Bhn.
4- The pinion speed = 120 RPM.
5- The driven gear hardness = 280Bhn.
6- The ultimate tensile strength of pinion = 420 Mpa , gear = 385 Mpa.

The bending fatigue stress is found from AGMA equation as:

Stress = (Ft/bmj) Kv Ko Km

We know that,

Z2 = Z1 * (N1/N2)

Z2 = 15 * (120/60) = 30

Table # 1 Data given for gear and pinion

	N	Z	M	D= MZ	B
Pinion	120 RPM	15	2.6 mm	39mm	12mm
Gear	60 RPM	30	2.6 mm	78 mm	12mm

Using the values from table #1

V= 3.14dn/60000 = 0.245 m/s

We know that:

Kv = 50+ $(78V)^{0.5}$/50 = 1.14

Table #2 J values for pinion and gear

	Z	J(sharing)	Kv	Ko	Km
Pinion	15	0.338	1.14	1.25	1.6
Gear	30	0.385	1.14	1.25	1.6

The J is obtained from Fig # 5 for sharing teeth as in practice. Ko and Km values are obtained from table # 3 and # 4 for the given condition.

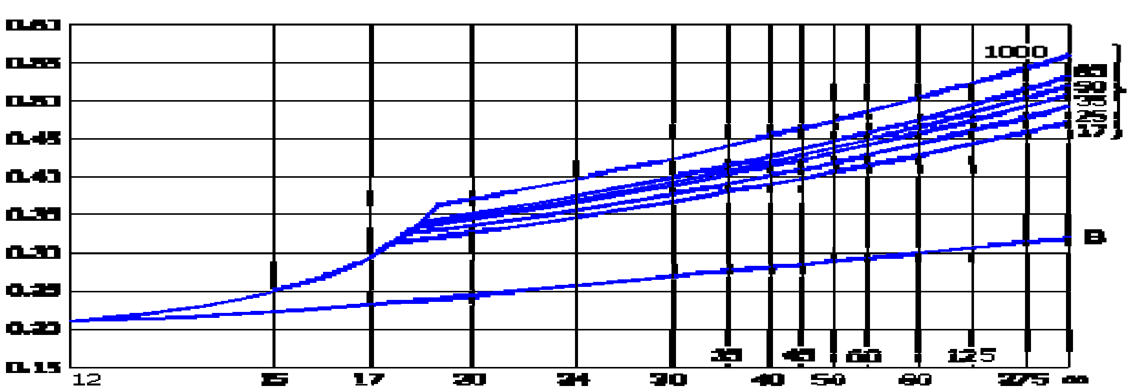


Figure # 5 geometric factor J

From fig # 5. We can know the value of J. it is based in the number of teeth and hardness of the material. The number of teeth is (30) and hardness we assumed it as 280 Bhn.

Spur gear – tooth bending stress (AGMA).

Table # 3 overload factor Ko

		Driven machinery	
Source of power	Uniform	moderate	Heavy shock
Uniform	1.00	1.25	1.75
Light shock	1.25	1.50	2.00
Medium shock	1.50	1.75	2.25

Table # 4 - load distribution factor Km

	Face width (mm)			
Characteristics of support	0-50	150	225	400 up
A ccurate mounting, small bearing clearances, minimum deflection, precision gears	1.3	1.4	1.5	1.8
Less rigid mountings, less accurate gears, Contact across the full face.	1.6	1.7	1.8	2.2
Accuracy and mounting such that less than Full- face contact exists	Over 2.2	Over 2.2	Over 2.2	Over 2.2

For pinion:

Stress = Ft/bmj (Kv Ko Km)

= 343.5N/12*2.6*0.25 (1.14*1.25*1.6)

= 100.3 N/mm2

For gear:

Stress = Ft/bmj (Kv Ko Km)

= 343.5N/12*2.6*0.338 (1.14*1.25*1.6)

= 74.2 N/mm2

Fatigue strength of the material is:

Stress = stressKl KvKs KrKtKm

Tale #5 properties of pinion and gear

prop	Ult, Mpa	Stress =0.5(ult)Mpa	Kl	Kv	Ks
Pinion	420	210	1	1	0.8
Gear	385	187.5	1	1	0.8

Endurance limit of the material is given by:

Stress = stress; KvKs KrKtKm

Where (stress) is the endurance limit of rotation beam.

From table #5:

Kl = load factor = 1.0 bending loads

Kv = size factor = 1.0 for < 5mm

Ks = surface factor, is take it from Fig # 6 based on the ultimate tensile strength of the material.

Kr = reliability factor given in table # 6

Kt = temperature factor = 1 T < 350 C

= 0.5 for 350<T<500C

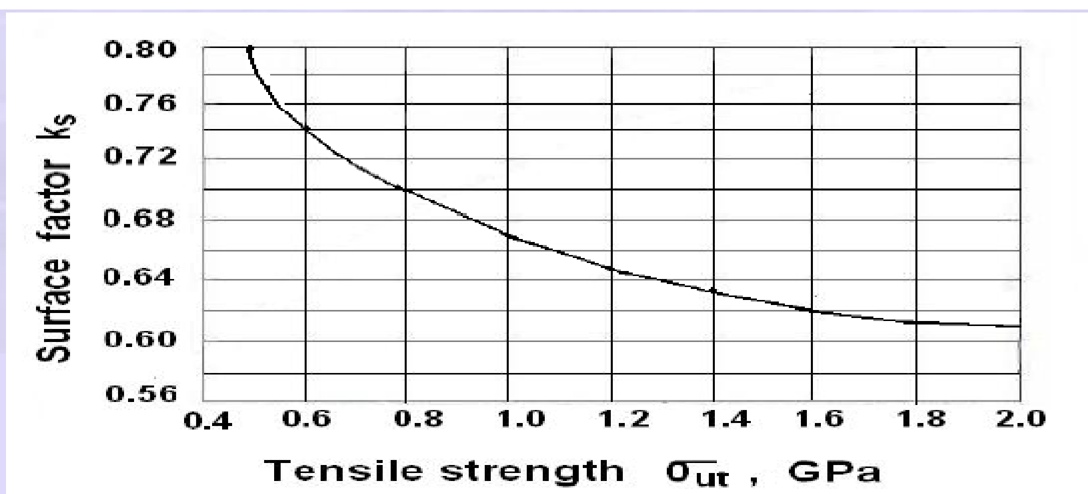


Fig #6 surface factor Ks

Reliability of 90%, working temperature < 150 C and reversible is assumed.

Kf = 1.0

Km = 1.0 for reverse bending assume.

Table #6 K term pinion and gear

prop	Kr	Kt	Kf	Km
pinion	0.897	1.0	1.0	1.0
gear	0.897	1.0	1.0	1.0

Table # 7 reliability factor R

reliability factor R	0.50	0.90	0.95	0.999	0.9999
Factor Kr	1.0	0.897	0.868	0.814	0.712

The design equation from bending consideration is:

Stress < {stress}

Factor of safety required = 1.3

Table # 8 strength value of pinion and gear

Prop	Stress e	{stress}=stress e/S	stress
Pinion	146.9	113	100.3
Gear	131.1	100.8	74.2

Table #8 show that the pinion is weaker than gear. And the maximum tangential force that can be transmitted is; Ft = 343.5 N

So, the maximum power that can be transmitted is:

W = Ft v /1000

= 343.5(0.450)/1000

= 0.154 KW. Approx. 1/3 hp

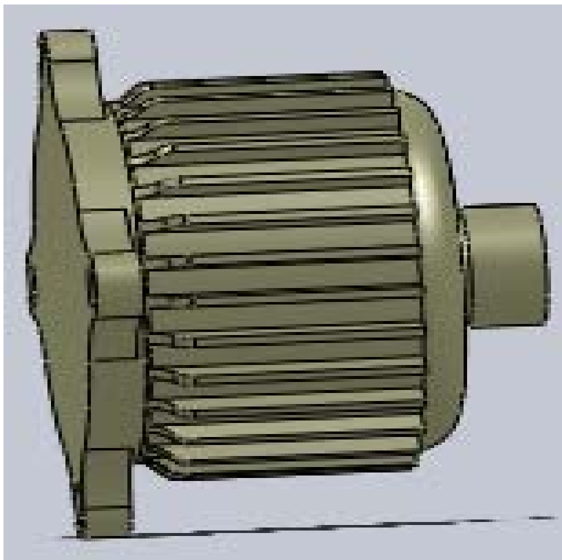
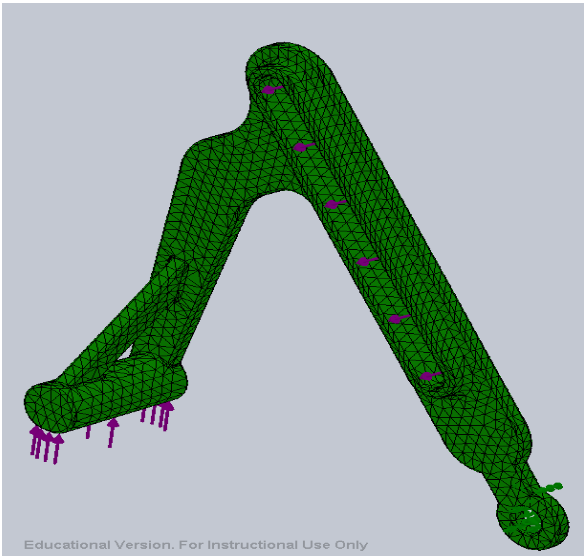
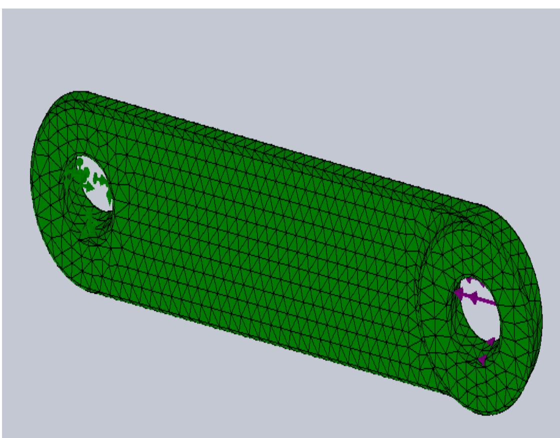


Figure # 7electrical motor



Mesh type	***Solid Mesh***
Element size	***0.195899*** cm
Tolerance	***0.00979494*** cm
Mesh quality	***High***
Total nodes	***20655***
Total elements	***11598***
Time to complete mesh(hh:mm:ss)	***00:00:05***

Figure # 8 Can holding link (mesh)

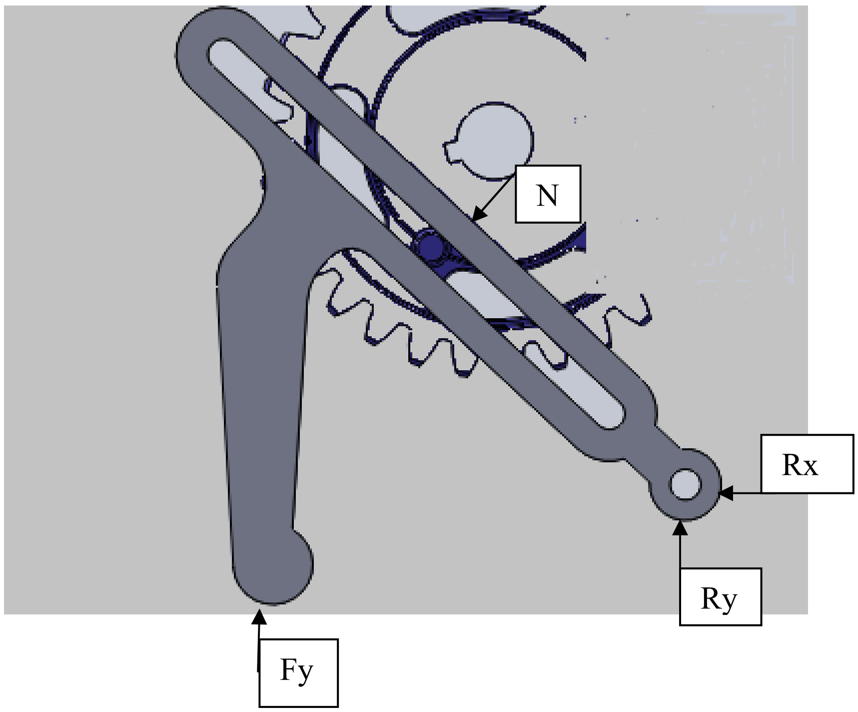


Mesh type	***Solid Mesh***
Element size	***0.106315 cm***
Tolerance	***0.00531574 cm***
Mesh quality	***High***
Total nodes	***14623***
Total elements	***8453***
Time to complete mesh (hh:mm:ss)	***00:00:02***

Figure # 9link (mesh)

Force analysis:

Figure #10 Can holding link (force analyzes)



$\sum Fx=0$

$\rightarrow$ N cos46 =F -Rx

$\sum Fy=0$

N sin□ = Ry+Fy

M=0$\sum$

N(5.91)=Fy(7.13)   experimentally Fy = 40 N

N = 48 N

<u>Stress analysis:</u>

A) - Can holding link (stress):

After doing stress analysis for the can holding link using solidwork,we found that the maximum yield strength for the part is 77.8 MPa which is far away from the yield strength for the material used to manufacture the part. That indicate high safety factor.

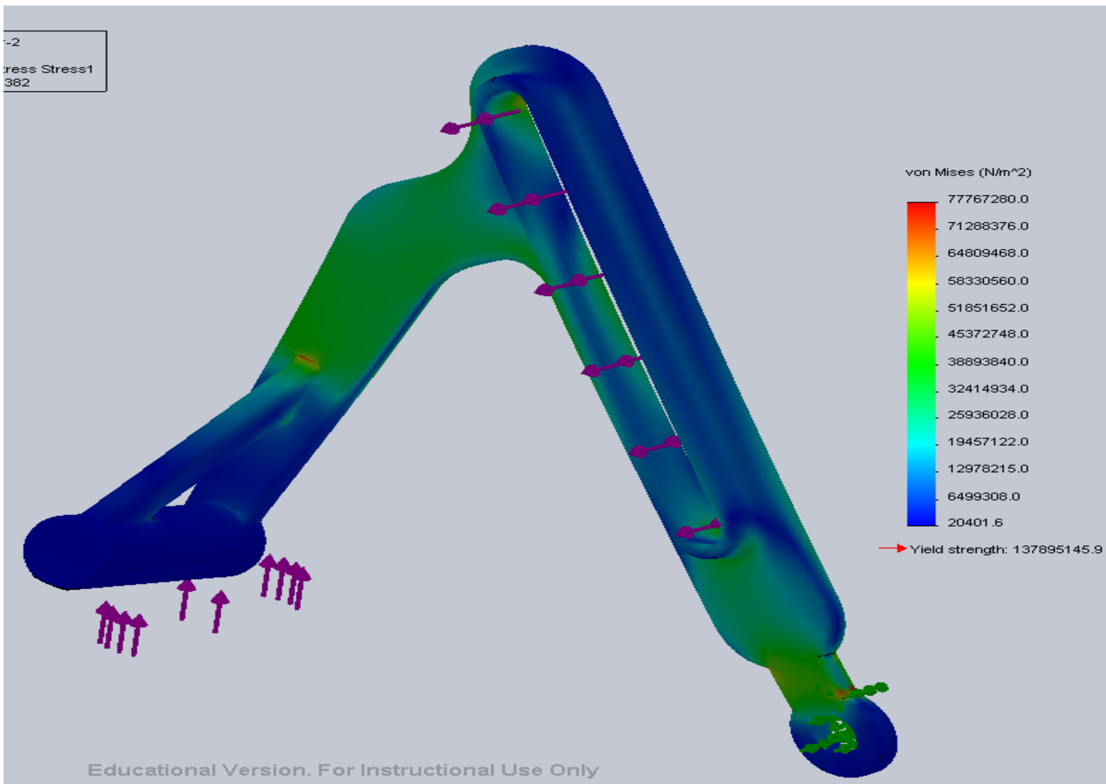


Figure # 9 Can holding link (stress)

Figure # 10 Can holding link (stress)

b) - link (stress):

After doing stress analysis for the link using solidwork, we found that the maximum yield strength for the link is 137.8 Mpa which is far a way from the highest stress in the link as you see it in the Fig # 10 which is show you 17.3 Mpa. That indicate high safety factor.

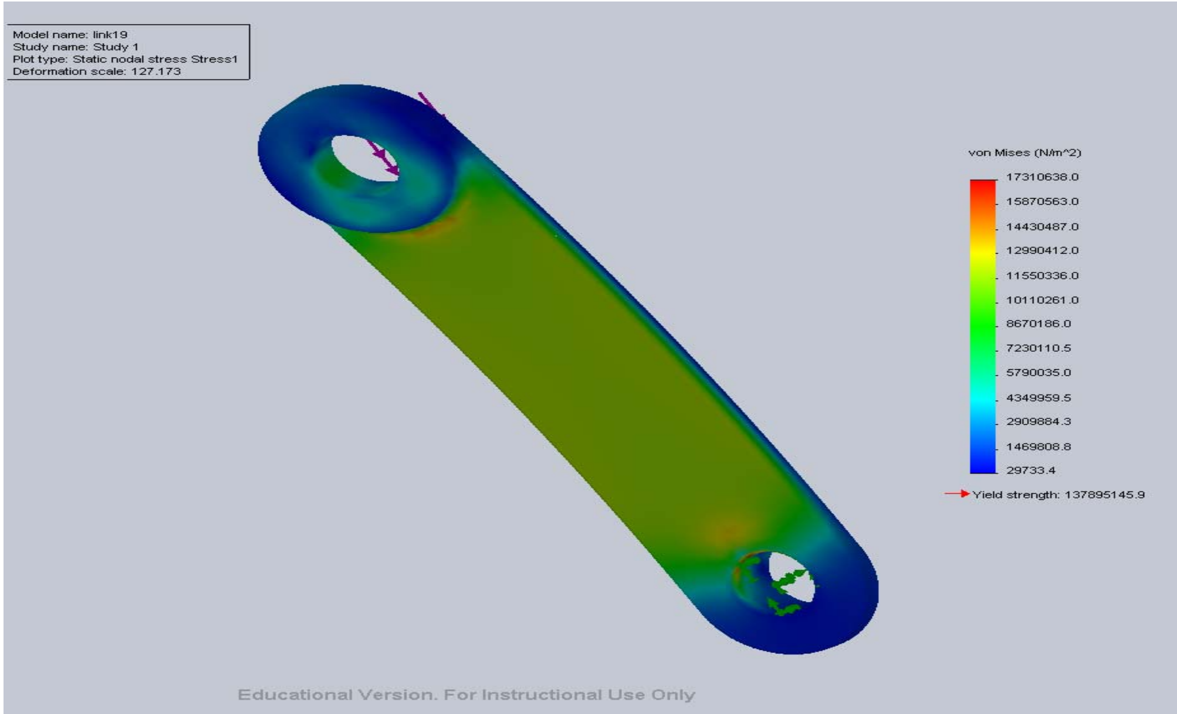


Figure #11link (stress)

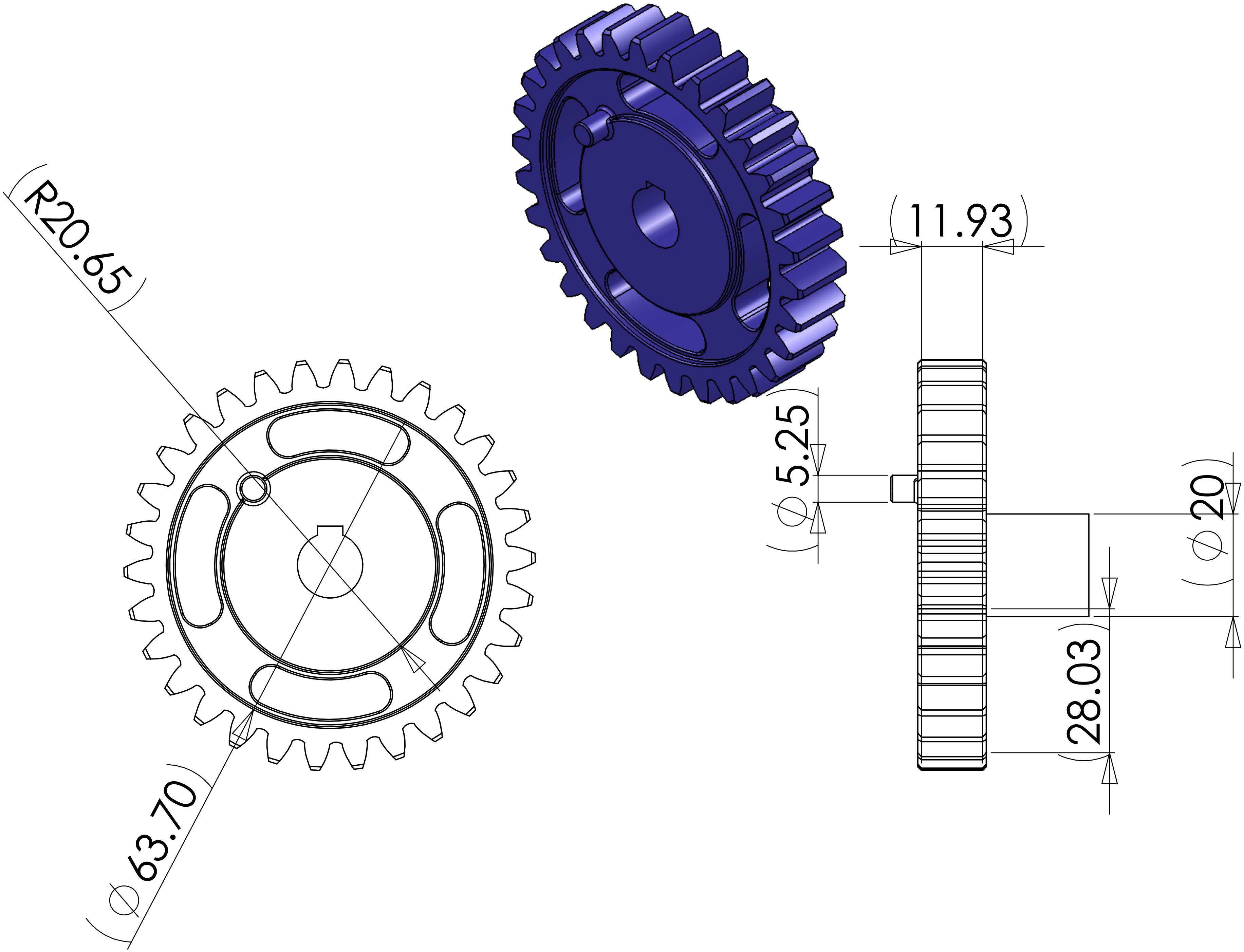
Conclusion

We learned from this project that designing is not easy job. Many factors have to be considered also the calculations to be repeated many times. This needs a team effort and more experience since we are students for that our project is limited.

We spent in this project more time in each activity from organizing the time table then the project selection. After we selected the project we progressed to model it and calculate many component by helping of computer aided design. In this project we learned a lot but we still need to learn more and more before us becoming more professional designer.

The design activities were so enjoyable and interesting because our project objective will help our country to recycle the cans and gain the benefit in the economy side and environmental side. In three months which the time for our project we focused to model the project design in the computer aided design (CAD) and make calculations for some components. In our project the main component was the gears design.

In this project, we learned very useful knowledge in designing machines especially the computer aided design. We learned how properly created schedule and take the responsibility of time keeping and activity control.



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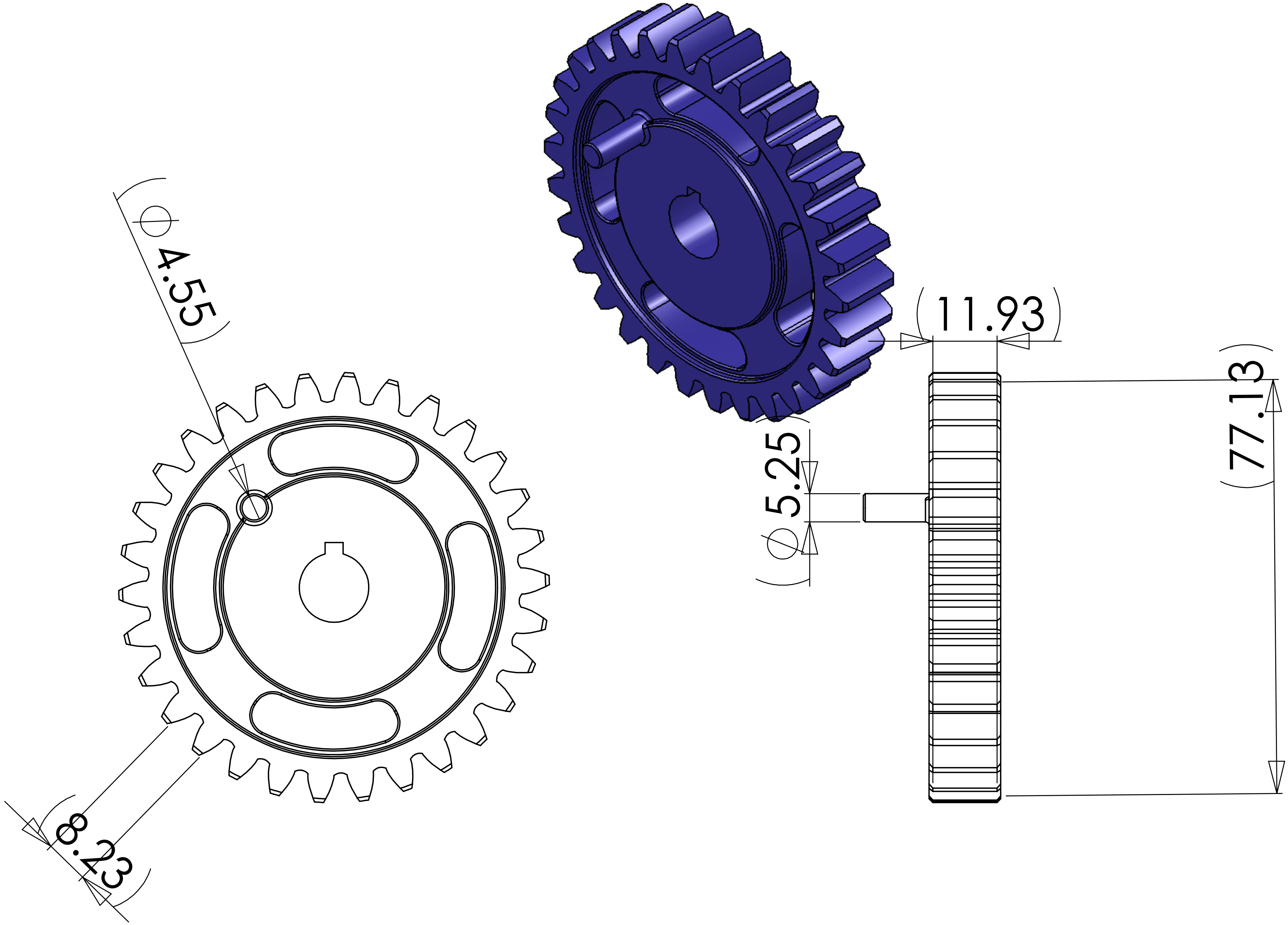
Adel Alshammari	spur gear-left	08-01-2011



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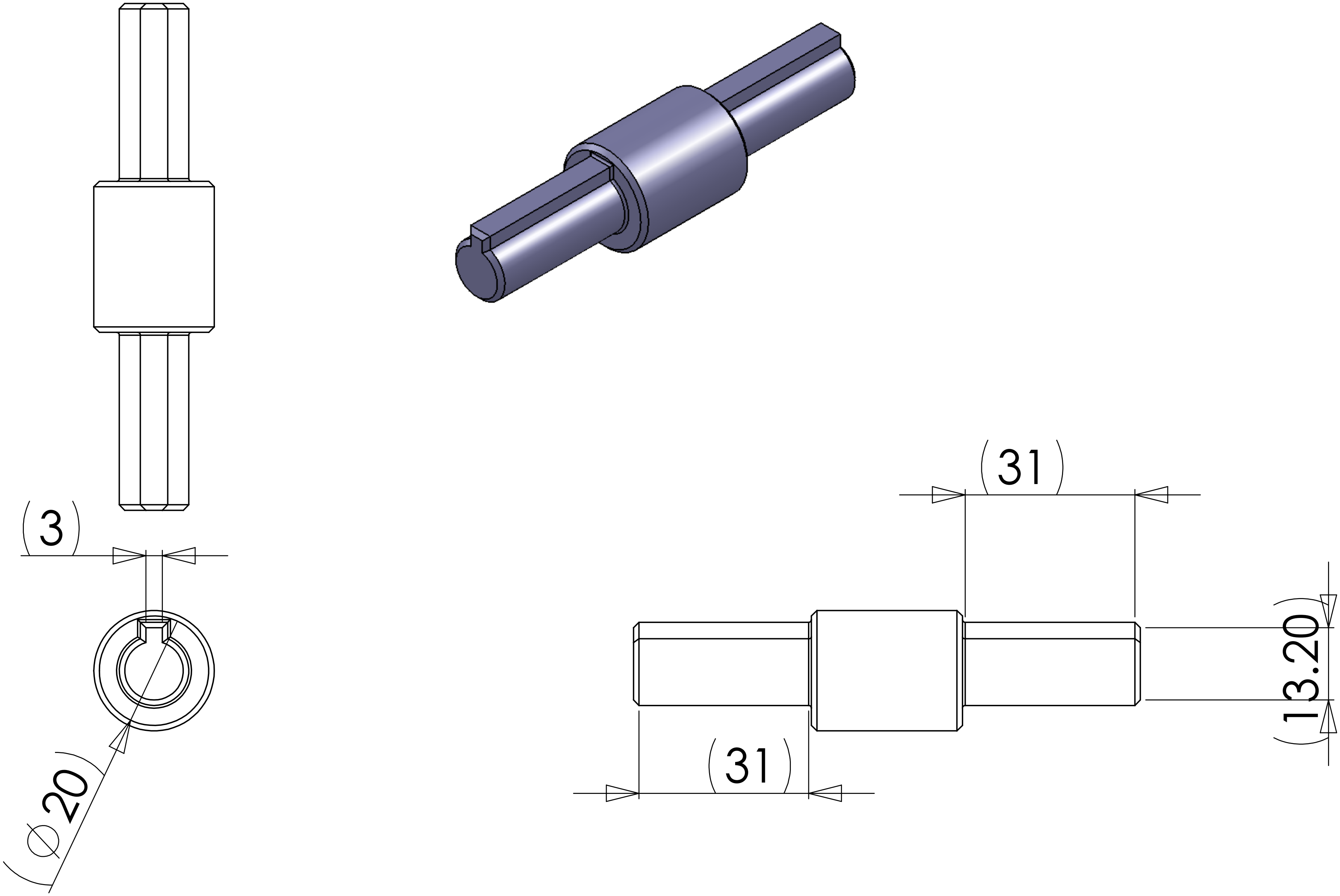

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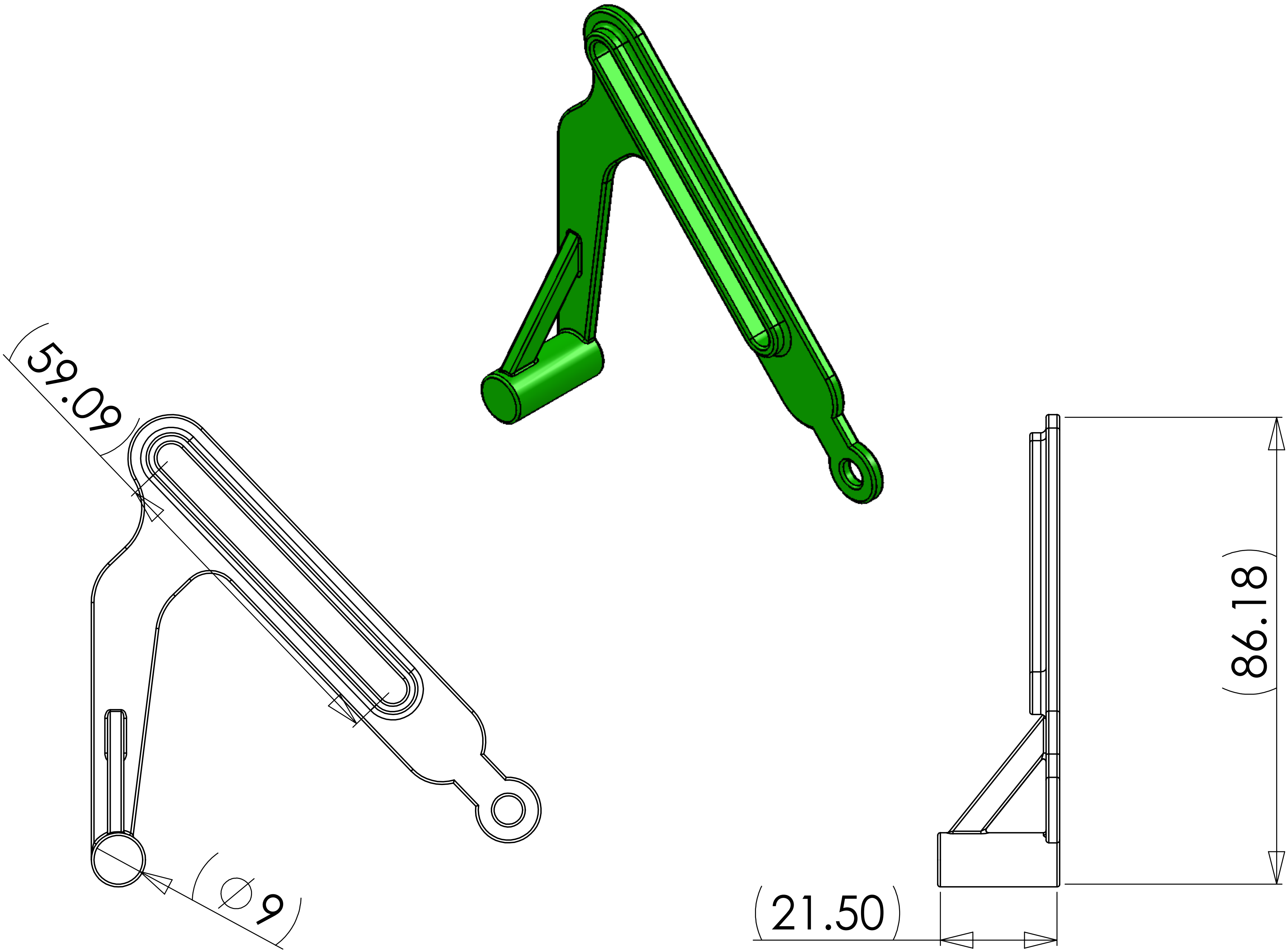

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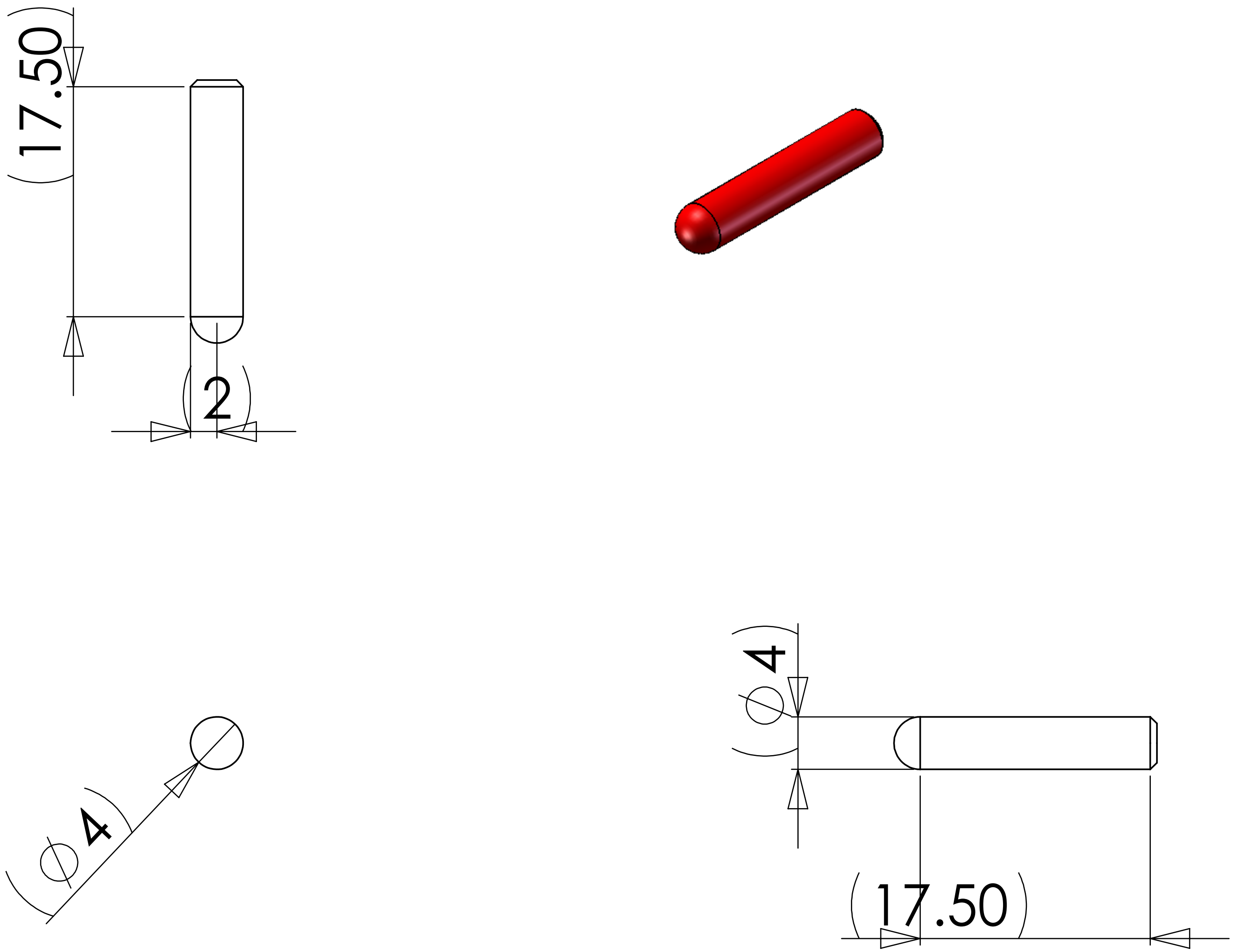

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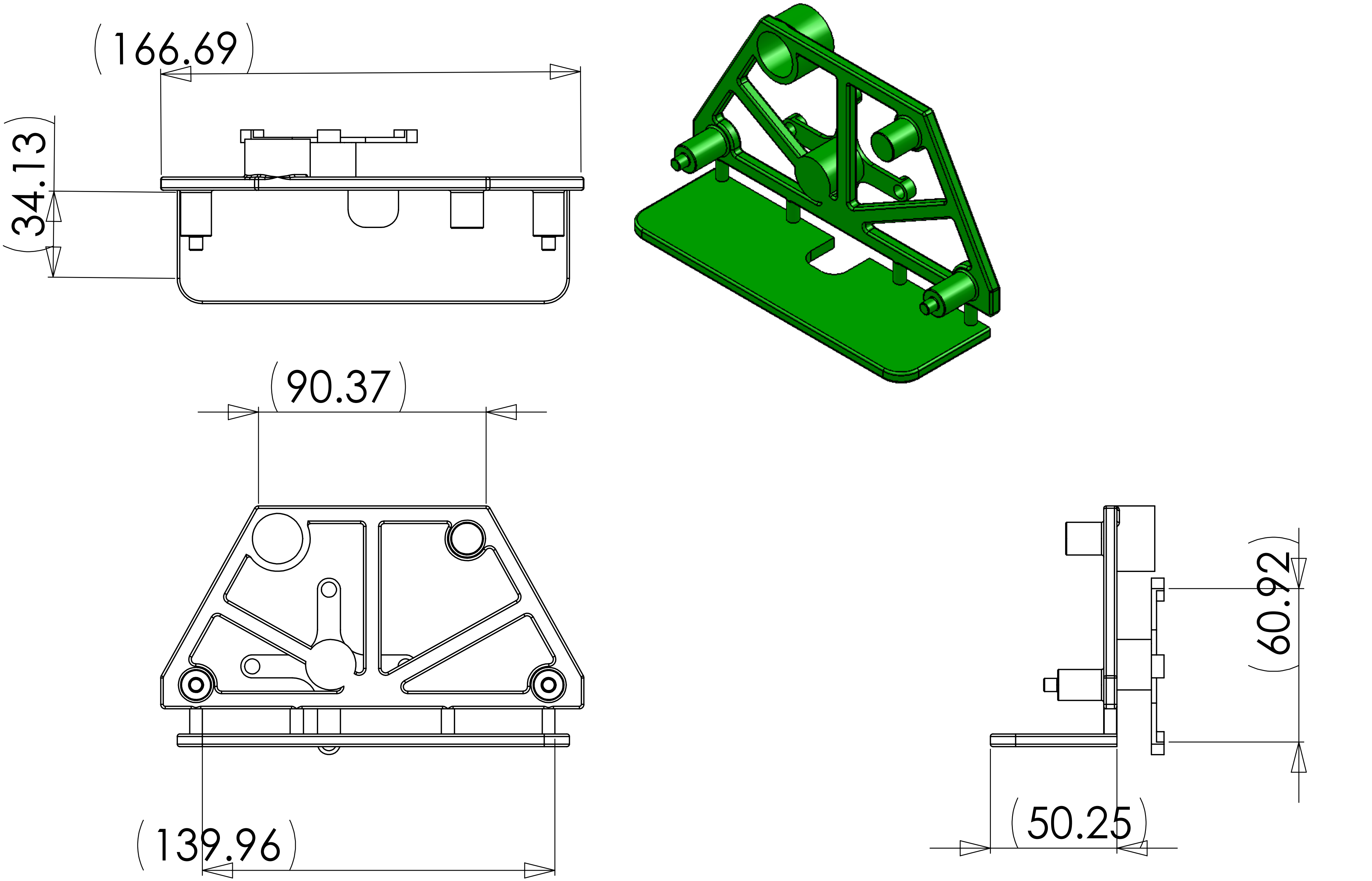

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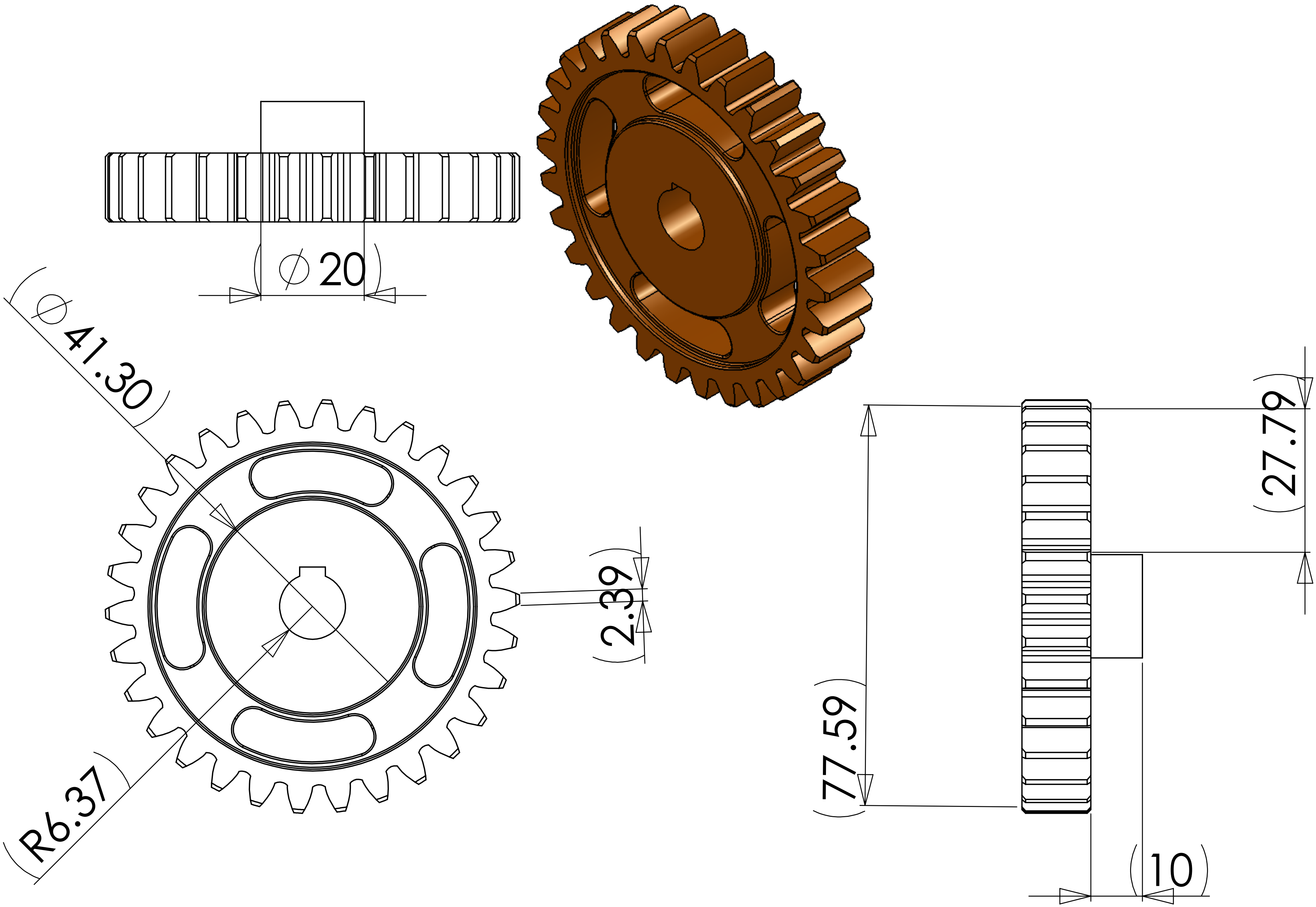
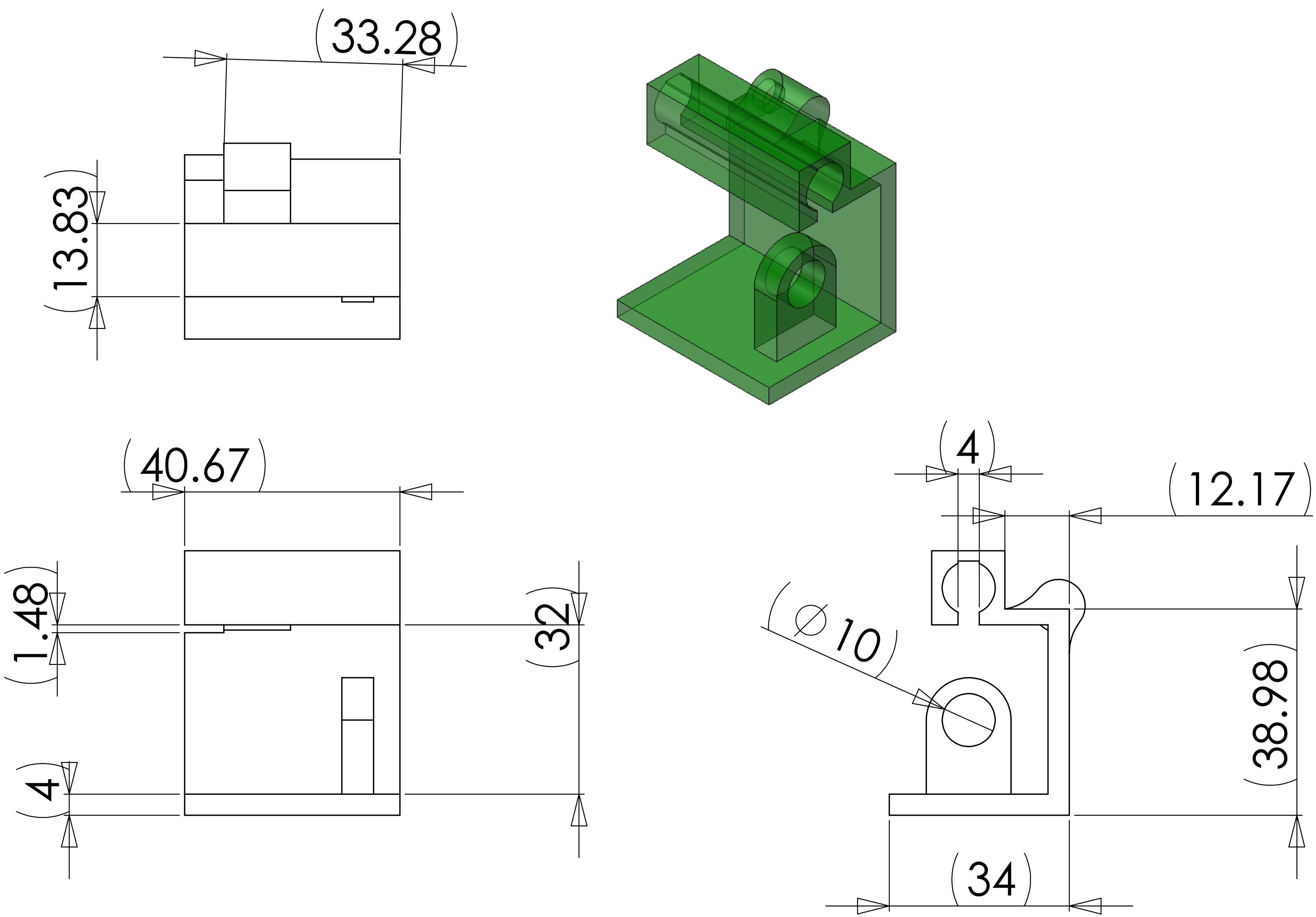
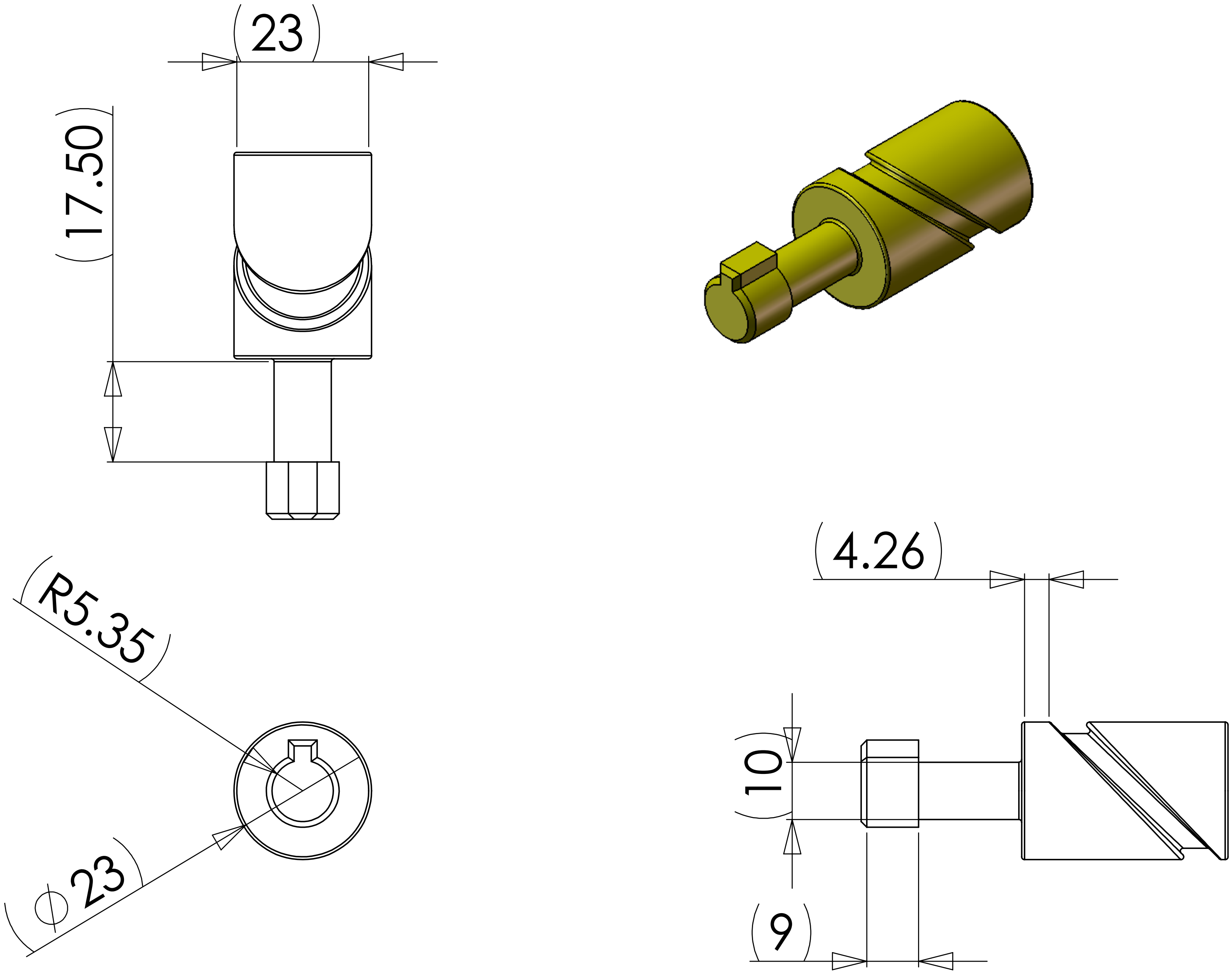


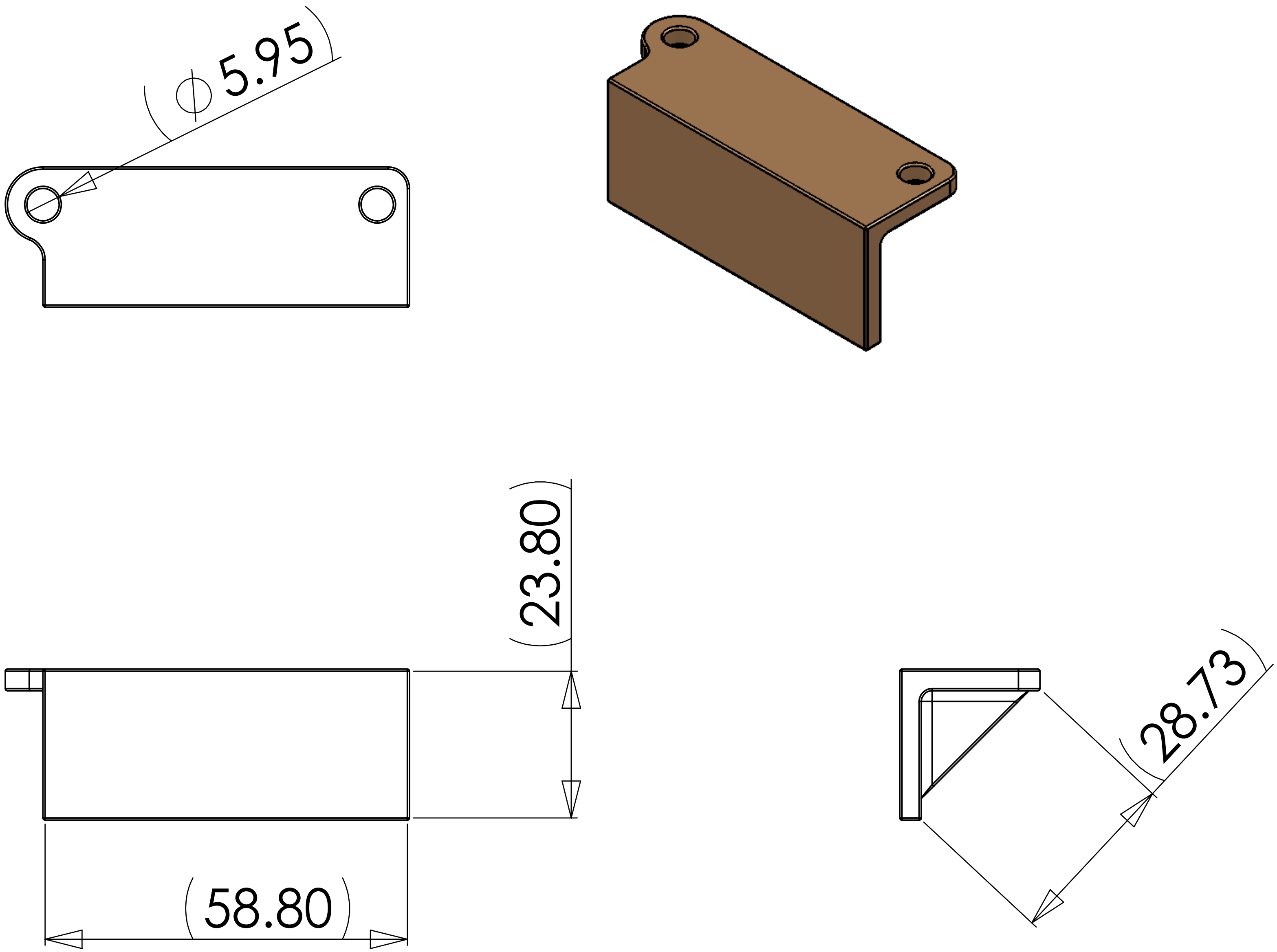
drawen by	part name	date
fayez alanzi	gear for ejector	08-01-2011



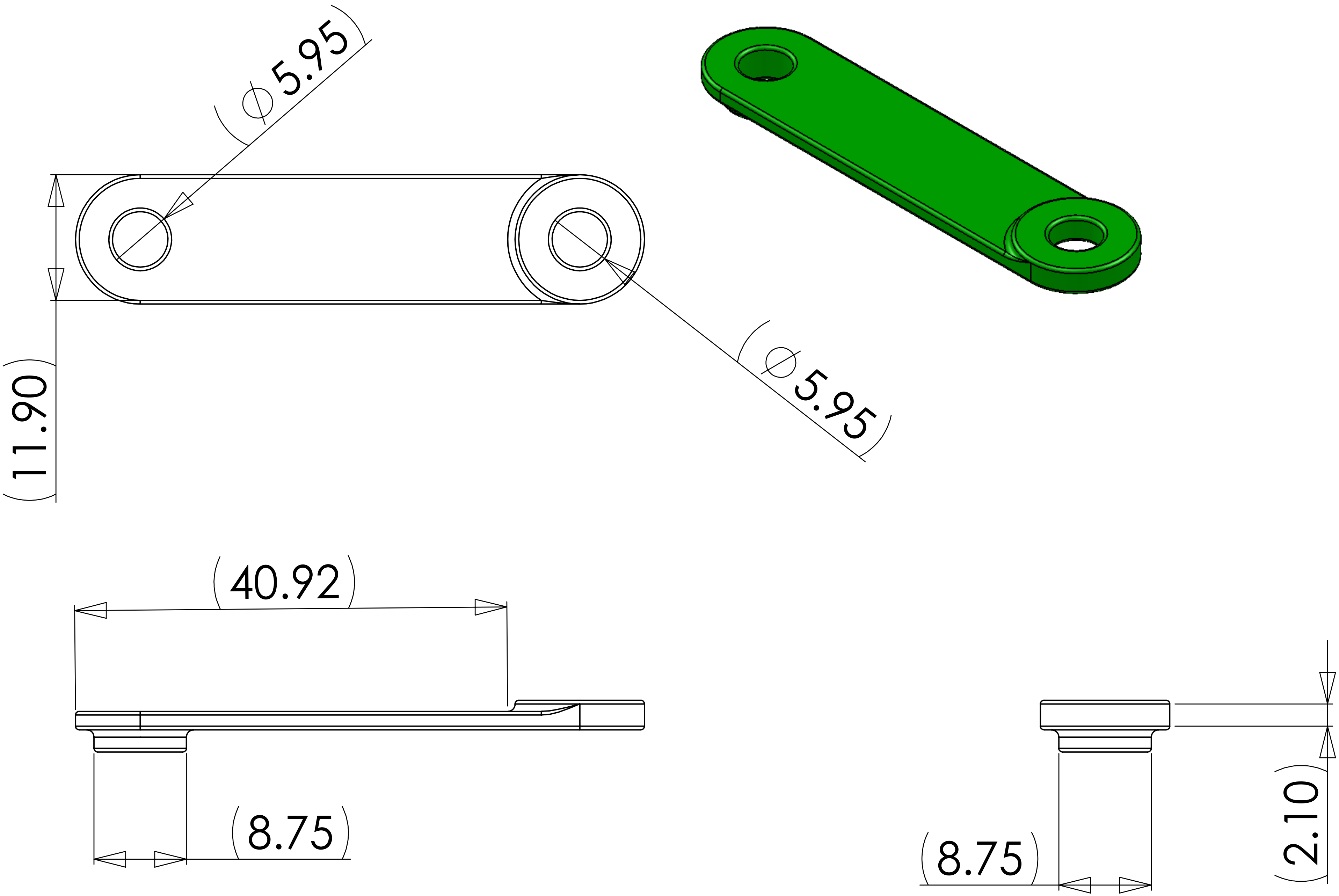
drawen by	part name	date
adel alshammari	ground groved cam	08-01-2011



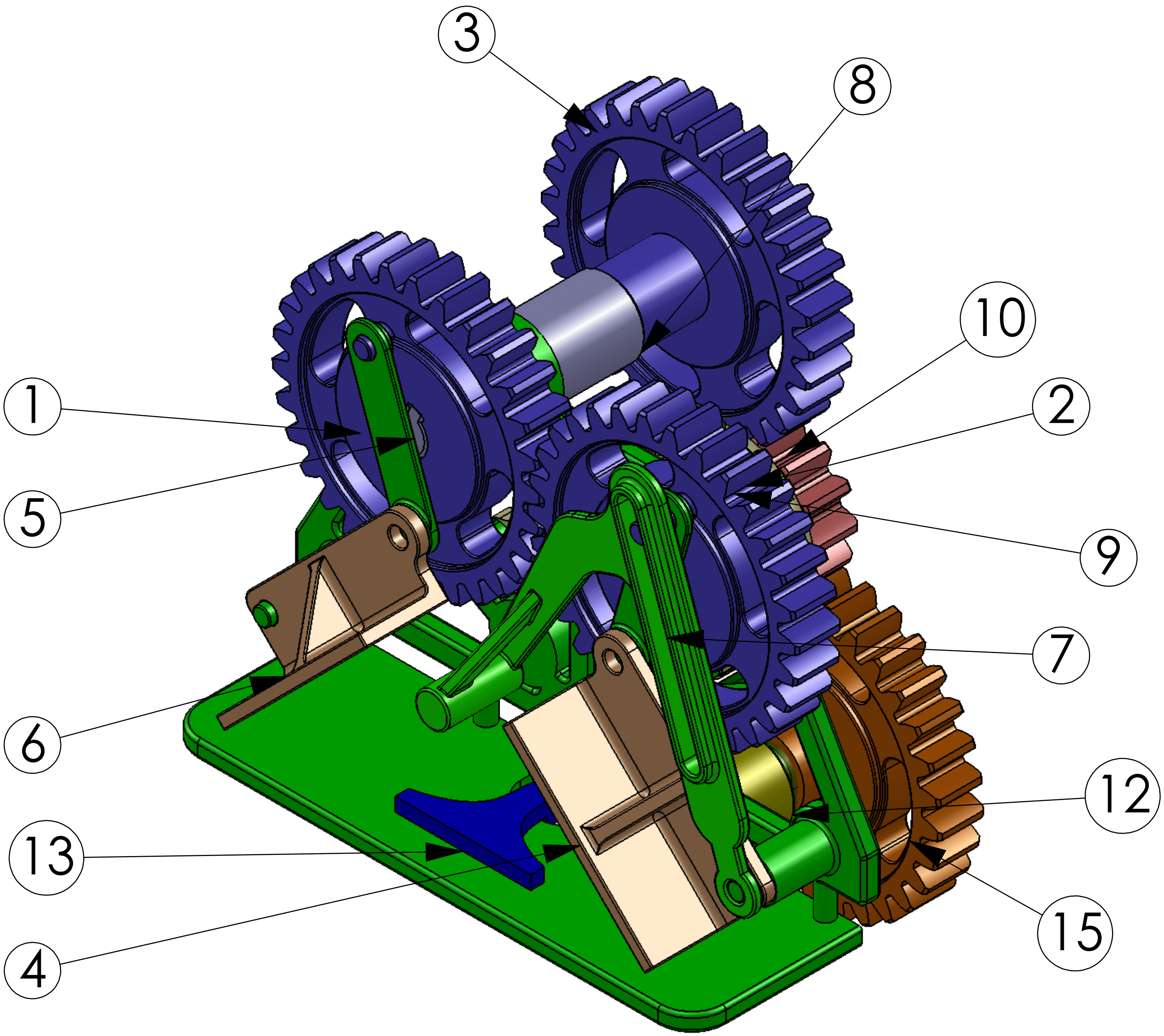
drawen by	part name	date
fayez alanzi	groved cam	09-01-2011



drawen by	part name	date
fayez alanzi	crusher	10-01-2011



drawen by	part name	date
fayez alanzi	link 19	09-01-2011



ITEM NO.	PART NUMBER	QTY.
1	frame1	1
2	20cm sppurr gear-right	1
3	20cm sppurr gear-left	2
4	link 14	1
5	link19	2
6	link 14left	1
7	can-holder-2	1
8	back shaft	1
9	motor	1
10	pinion1	1
11	ground-for-groved-cam	1
12	groved cam	1
13	piston	1
14	follower	1
15	gear for ejector	1