Valve Lapping Machine for Internal Combustion Engines

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Abstract

Automobile maintenance is a major area in the industry of automobile and also a major income to the business. In present, Internal Combustion engine maintenance can be stated as a very important section in automobile maintenance and the valve lapping process that is subjected in this thesis is done during IC engine maintenance. The current methods used in most automobile maintenance businesses for valve lapping process are not effective and consume a lot of working hours. 'Valve lapping Machine for Internal Combustion Engines' is a machine designed to overcome these problems by minimizing the human involvement in the process. The thesis consist of the background in designing the machine, methodologies used, results obtained by data analysis in order to optimize the design and design of the valve lapping machine.

Keywords

Valve lapping; Engine valves; Cylinder head

1 INTRODUCTION

Valve lapping or the process of creating a good seat between engine valves and the corresponding valve seat area in the IC (internal combustion) engine head(cylinder head) is a task which have to be done very accurately. The importance of obtaining a good sea is that the air/fuel mixture(in petrol engines) or air(in diesel engines) is prevented from flowing in to the combustion chamber, same as the exhaust gas is prevented from flowing to the exhaust manifold from the combustion chamber until the right time. And also a good seat prevents compression leaks. The engine will lose its efficiency by huge percentages if any of the situations explained above happens. So as this is a very important task in IC engine maintenance, extra attention is given to this particular task by technicians. This process of valve lapping is typically done using a valve lapping stick or a power tool. As both of this tools are not very effective, these tools can be replaced by the ' Valve Lapping Machine for Internal Combustion Engines', specifically designed for the process of engine valve lapping. The machine employs a fully mechanical system which performs two different motions in two directions previously performed by hand when using valve lapping stick and power tool. Comparatively the valve lapping machine is very effective because the human involvement is very limited in the process.

1.1 Motivation

The idea of designing a machine for the valve lapping process came to me when i was working as a trainee automobile technician at Transmec Engineering PVT(LTD) of Micro Holdings Group from June to September 2014. I was assigned to the Engine room section where the maintenance of an IC engine is done. Engine overhauling was a daily maintenance process and i came through the valve lapping process during my 3rd week. The valves of a 3.0L 20 valve in-line engine. The process took about ten hours to finish including testing of the valve seat quality using petrol. As the process was done using a valve lapping stick, it was very hard and my efficiency of performing the process was very low after couple of hours. During my 11th week, I was introduced to valve lapping power tool which is comparatively more efficient than the valve lapping stick and took less time to complete the process. But still the hand holding the power tool and performing the hand motion was hard. This lead me to think how easy this process will be if there was a machine that has the performance of the power tool and the motion of the hand. 'Valve Lapping Machine for Internal Combustion Engines' was designed by the motivation of that idea.

1.2 Goals and objectives

The main goal of this project is to design a machine both efficient and effective than previously used methods for valve lapping and to reduce the labor cost by reducing the human involvement in the process. The objectives that had to be achieved in order to achieve the main goal were designing the basic model of the machine(structure), designing the valve lapping mechanism, assembly of the whole machine by designing the parts needed, calculating and designing the cam needed, analyzing data and categorizing them in order to design five valve holding pieces, analyzing data to obtain the specifications of the machine, obtaining two high torque dc motors that has specific RPM(revolutions per minute) values and deciding what materials must be used in order for the design to be durable and economical.

1.3 Literature review

Valve lapping and testing

In the process of valve lapping in an internal combustion engine cylinder head, the goal is to achieve a good seat between valve seating area of an engine valve(inlet valve or outlet valve) and the valve seat area of cylinder head in order to avoid the compression leaks through the seating from the combustion chamber and to avoid air/fuel-air mixture leaking in to the combustion chamber through the seating. The internal combustion engine operates by achieving a certain compression ratio which is differing from engine to engine and combusting a air-fuel mixture which is compressed to a certain volume decided by the compression ratio. And if the air-fuel mixture leaks through the seating, the volume of the air-fuel mixture will change and combustion process will not be accurate resulting a reduction in productivity of the engine. Therefore it is vital to have a fully sealed combustion chamber and the valve seating is very important in acquiring a fully sealed combustion chamber.

Figure 01: Valves positioned in the cylinder head [1]

While the valve lapping process, we have to observe the valve seat area time to time by the naked eye. It's the normal way to conclude whether the valve seat is good or further valve lapping is needed. Figure 02 shows a lapped valve and a non-lapped valve.

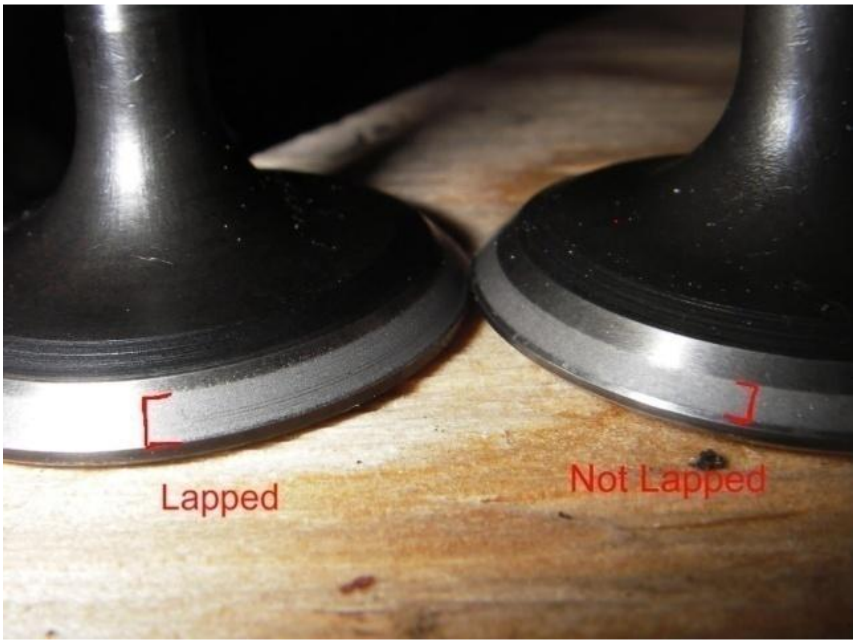


Figure 02: Lapped and non-lapped valves [2]

After the valve lapping process, the most common way to observe the seating of valves is a technique using petrol. After the valve job is done, the mechanic or technician place the precise valve in the precise spot in the cylinder head and pour petrol to the stem of the valve which he have to observe. This poured petrol then reaches the seating area of the valve. Then it is observed if petrol leaks through the seat.

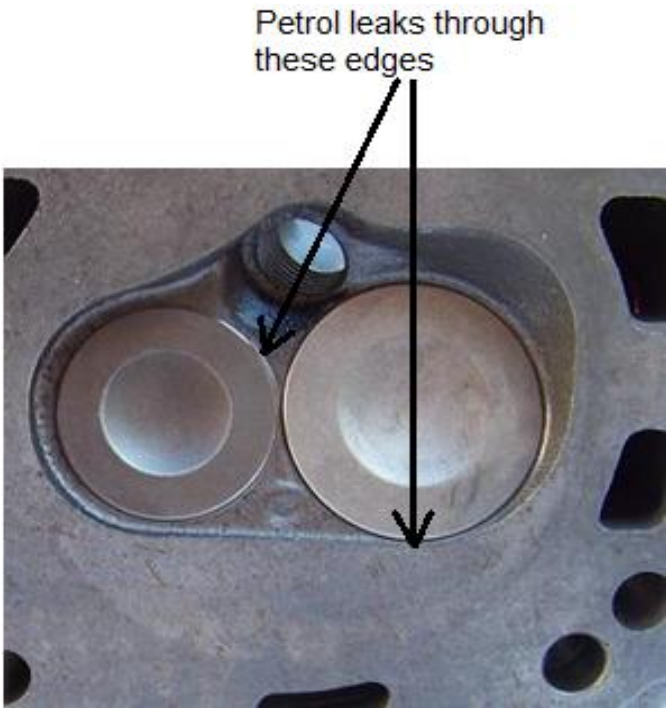


Figure 03: Observation of the seating surface [3]

If petrol leaks through the valve seat it concludes that the valve job is not successful and if petrol does not leaks through the valve seat it concludes that the valve has acquired a good seat, so recommending to assemble the engine using the valve.

Engine valves

There are two kinds of engine valves, intake/inlet valves and exhaust/outlet valves. These valves could be identified easily in a cylinder head. Inlet valves are usually bigger than exhaust valves. Although more than one inlet valve and exhaust valve can be present for a single cylinder. There are different designs for inlet valves and exhaust valves. The most commonly used valve design is **poppet valve** design. Then there are sodium valves used in some turbo-charges engines. And mask valves, mushroom valves, tulip valves could be observed in different situations. The following figure shows a detailed diagram of a valve.

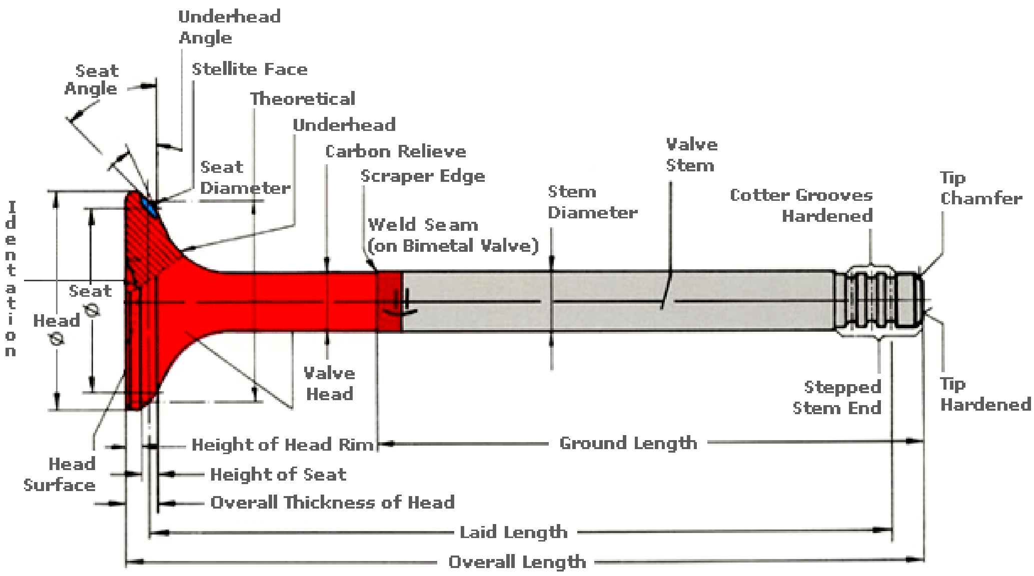


Figure 04: Detailed diagram of an engine valve [4]

As you can see in the figure 04 the seat angle is the most important thing in the valve lapping process. Seat angle is normally 45° and 30° in most of valves.

The other important factor of designing the valve lapping machine is the stem diameter of the valve. The valve is to be fixed to the valve lapping machine in order to start the lapping process by the stem of the valve. The dimensions from the collected data of valves are analyzed in order to acquire three categories of stem diameters. These analyzed data is used for the specifications of **valve holding pieces** of the machine to be built. Overall length of the valve is also a important factor to consider when adjusting the machines before starting the valve lapping process.

Valve lapping stick and hand motion

Valve lapping sticks are the tools that we use to lap valves by hand movement. The valve is attached to the sucker at the tip of the stick and lapping compound is applied before the process begins. This is a very hard process to undergo and it will take approximately half an hour to lap one valve of a 3.0 L engine. Following figures shows the valve lapping sticks and the hand movement used to lap valves.

Figure 05: Commonly used valve lapping sticks [5]

Figure 06: Hand movement while lapping valves [6]

While lapping valves as shown in figure 06, the technician have to decide whether to apply compound from observing the valve seat area time to time. This method is still used in basic garages.

Valve lapping power tool

Using the valve lapping power tool is much more efficient than the valve lapping by hand movement. It will take less than 15 minutes to lap a valve using the power tool. But still we have to hold the power tool in position for lapping process, which is somewhat hard labor to undergo. Power tools work using an electric motor or pneumatically using compressed air.

Figure 07: Valve lapping using a power tool [7]

Lapping compound

Lapping compound is applied to the valve seat before beginning of the process. Lapping compound wears surfaces of the valve and the valve seat of the cylinder block smoothing both surfaces and creating a good seat. A lapping compound tube usually has two types of compound available in the top end and bottom end separately. The two types named as fine and coarse. Technician decides which type of compound has to be used by observing the valve seat. If the valve seat has rough edges, coarse compound is used. Otherwise fine compound is used obtain a smooth surface.

Cylinder head

Cylinder head is the casting which seals the combustion end of the cylinder block and the inlet and exhaust valves and their ports are positioned in the cylinder head for air/fuel mixture intake and exhaust of the combustion products[8]. Cylinder head also facilitate overhead cam shafts if present and otherwise it facilitate rocker arms and valve springs.

Cam system

As a cam system is implemented in the machine, it is better to have a idea about cam systems. A cam , follower, follower system and a drive are the four basic parts of a cam system. *Clyde H. Moon, P.E.*[9] states that "*A cam is a mechanical part which imparts a prescribed motion to another part by direct contact. It may remain stationary, translate or* *rotate".* Follower is directly contacting the cam while the follower system receives a specific motion through the follower given by the cam. Drive is the element which transmits motion to the cam or to the follower system.

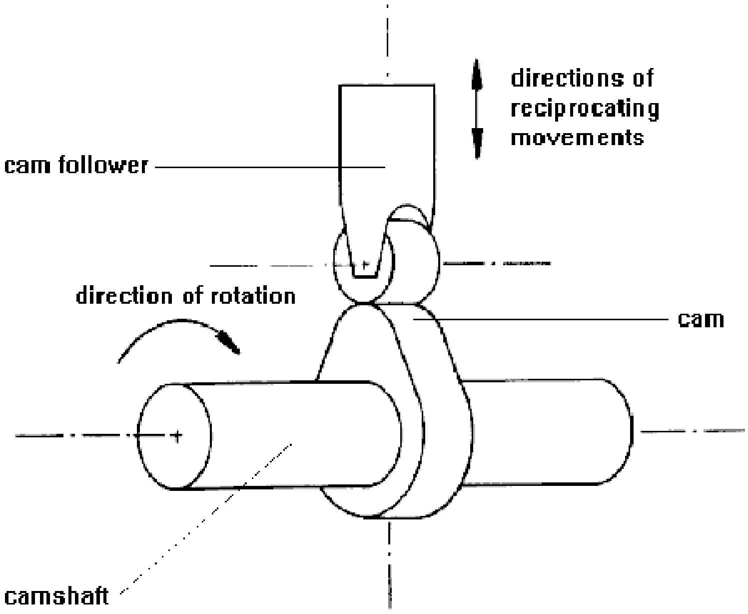


Figure 08: Cam and follower [10]

DC motors

Two dc motors are used in the valve lapping machine, one as the drive for cam system and one as the motor for valve lapping.

1. High torque mini 12V dc gear motor

- Horse power - 0.8W(60mA, no load)
- Gear ratio - 1:20
- RPM - 200
- Reversibility - reversible
- Length of motor - 54mm
- Diameter of motor - 25mm
- Length of spindle - 8mm
- Diameter of spindle - 4mm

Figure 09: High torque mini 12V dc gear motor,200 rpm [11]

2. High torque, heavy duty 12V dc gear motor

- Model - JGB37
- RPM - 20
- no load current - 120mA
- load torque - 10-19 Kg.cm
- load current - 400mA
- Length of motor - 29mm
- Diameter of motor - 33mm
- Spindle length - 15.5mm
- Spindle diameter - 6mm

Figure 10: High torque, heavy duty 12V dc gear motor, 20rpm [12]

2 DESIGN OF VALVE LAPPING MACHINE FOR INTERNAL COMBUSTION ENGINES

This section includes designs of all the parts of the valve lapping machine and their functions in the machine.

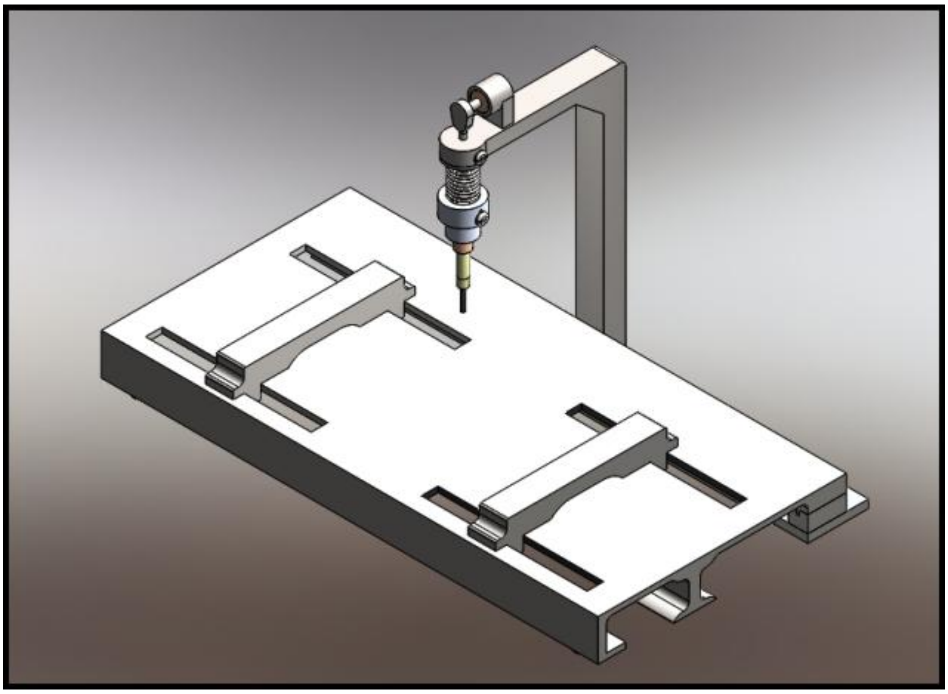


Figure 11: Trimetric view of the 3D model of valve lapping machine for internal combustion engines

2.1 Machine bed

Machine bed is the base of the valve lapping machine. The cylinder head can be initially kept on the machine bed for measuring or observing purposes and the bed is designed to accommodate a cylinder as large as TATA 1030 cylinder head(cylinder head of a in-line 6 cylinder engine) without any problem.

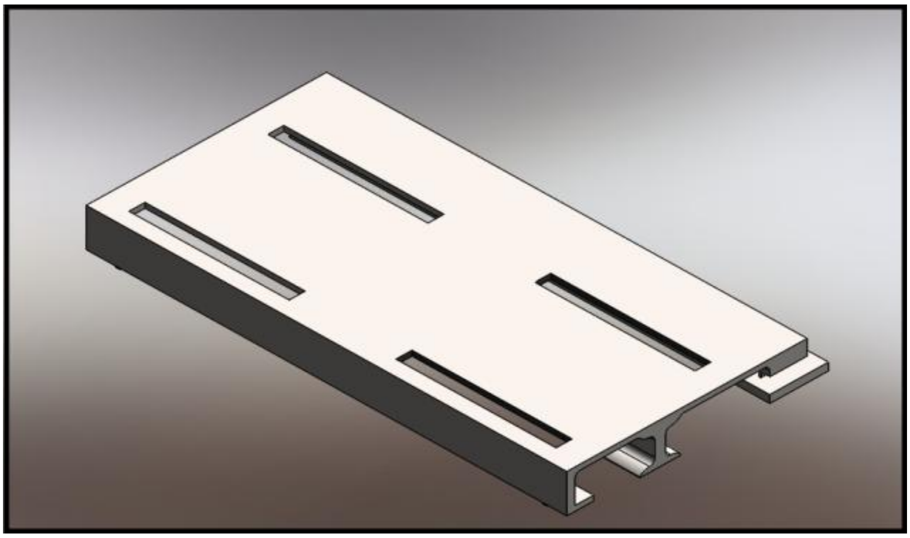


Figure 12: Isometric view of machine bed

Four rubber grips are mounted on the four corners of the machine bed in order keep it in a steady position even on a surface having less friction co-efficient. The machine stand which holds the valve lapping mechanism also assembled to the machine bed. It also facilitate two cylinder head supports.

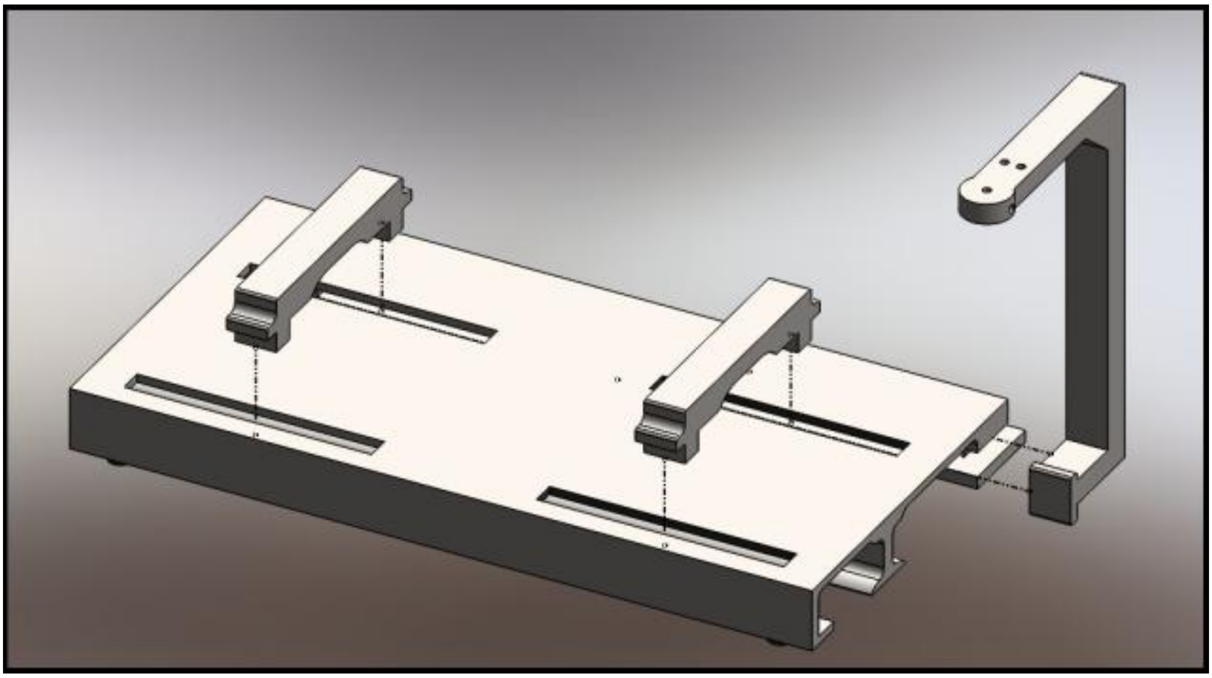


Figure 13: Exploded view of machine bed, cylinder head support and machine stand assembly

The machine bed has a total surface are of 900×450 mm^2 without considering the area given for mounting of the cylinder head supports and its moving purposes and the material assigned for the machine bed is AISI 1020 steel which has a mass density of 7900 $Kg.m^{-3}$ and the machine bed weighs about 79.8 Kg. The reason for picking AISI 1020 steel is its formability, workability and weld-ability was very good comparatively.

2.2 Cylinder head supports

The cylinder head supports are designed to accommodate the cylinder head while the valve lapping process. This extra feature is added to the design because it is hard to move a cylinder head(specially a large heavy one) sometimes when the cylinder head needed to be adjusted to a different position. Since this cylinder head supports are movable along the machine bed, it is very easy to adjust the cylinder head position. As an example, think that a specific point of the cylinder head is initially positioned in the coordinate (300,280) if we assigned a coordinate system to the machine bed. And we need to change its position to (550,280), that means without compromising the Y coordinate, we can move the cylinder head 250 units smoothly along the bed(X axis). This feature is very important when lapping the same type of engine valves in an in-line cylinder head.

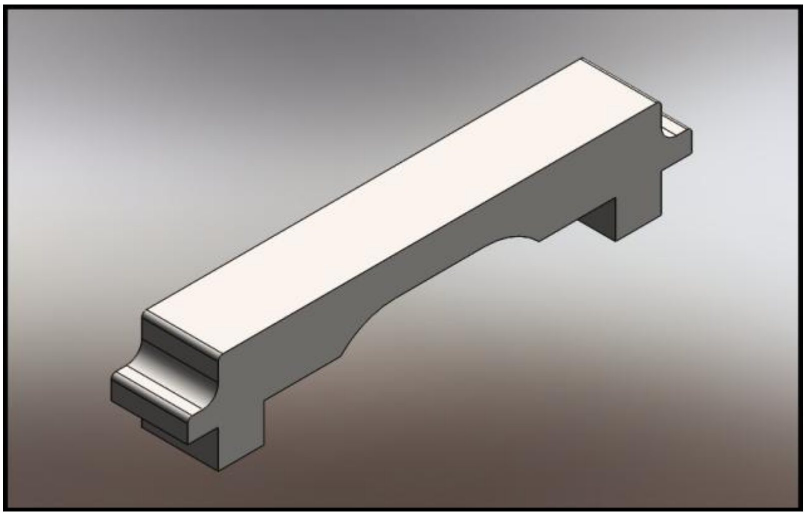


Figure 14: Isometric view of a cylinder head support

The cylinder head supports also allow easy access to the valve seat area of the engine valves by having a 40mm clearance between the machine bed and cylinder head while the valve lapping process. This feature is important because the technician has to observe the valve seat surface from time to time and apply lapping compound if needed. Each cylinder head support has a surface area of 290×50 mm^2 to accommodate 2 cross sections of a cylinder head. The material assigned to this part is also AISI 1020 steel and weighs about 4.8 Kg per unit.

2.3 Machine Stand

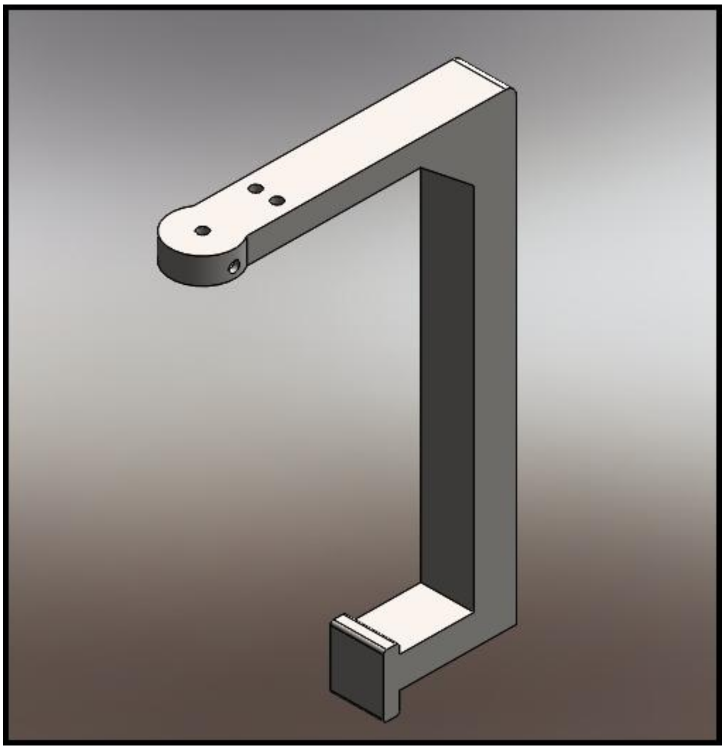


Figure 15: Isometric view of Machine stand

Machine stand is assembled to the machine bed in one end as in figure 13. Other end of the machine stand is the mounting for the valve lapping mechanism and also the holding bracket for High torque, heavy duty 12V DC gear motor, mounted near the same end. Machine stand is designed to move(slide) 710mm along the machine bed, therefore allowing the access to any valve position of a cylinder head placed on cylinder head supports. The load generated while the valve lapping process is transmitted to machine bed through the machine stand and the integrity of the structure is a very important factor to consider when designing. Lower end of machine stand which is assembled to machine bed is one of the areas of the machine with highest stress concentration.

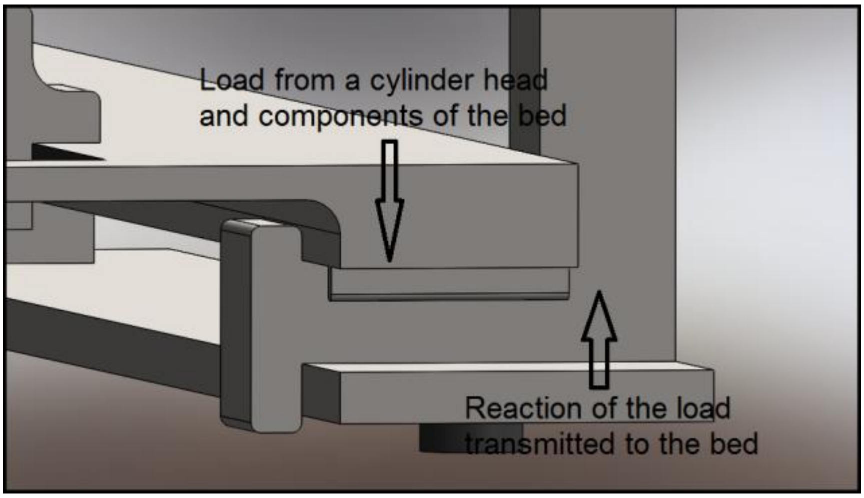


Figure 16: Forces affecting the machine stand from the lower end

As can be seen in figure 16, the assembly area of the machine stand to machine bed is subjected to loads from machine bed surface and valve lapping process. And because valve lapping is a cyclic process(explained further in the text), the load from valve lapping process is a fatigue load and therefore the chances of failing the structure of machine stand is more. So it is important to keep this structure in shape. The material assigned for this part also is AISI 1020 steel and it weighs about 10.9 Kg.

The two surfaces where the machine stand comes to contact when assembling to the bed must have less friction coefficient in order to move the stand easily. Use of a semisolid lubricant like grease is a good solution for that task.

2.4 20 RPM, high torque and heavy duty DC motor fixing bracket

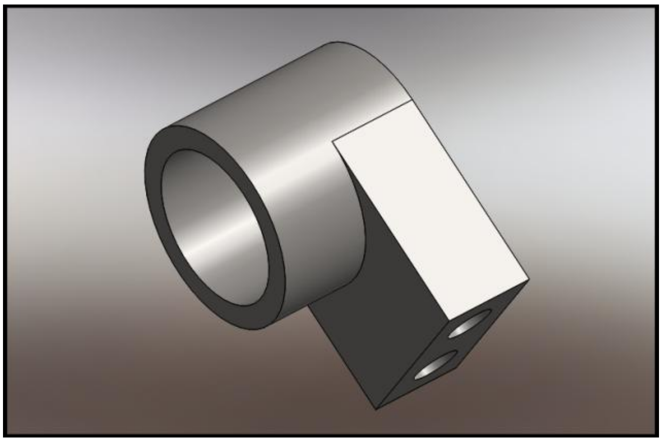


Figure 17: 20 RPM, high torque and heavy duty DC motor fixing bracket

This bracket holds the motor which transmit motion to the cam and as the cam subjects to some amount of torque, the same torque is transmitted though the motor to the bracket and therefore bracket is also subjected to the same torque. This bracket is fixed to the machine stand using two pan slot head bolts made using stainless steel. When made using AISI 1020 steel, this bracket weighs about 379g.

2.5 Cam and Cam Follower

Cam is the main part responsible for the vertical movement of the valve lapping mechanism. Actually a cam works as a system that consist with a follower, a cam drive and a follower system.

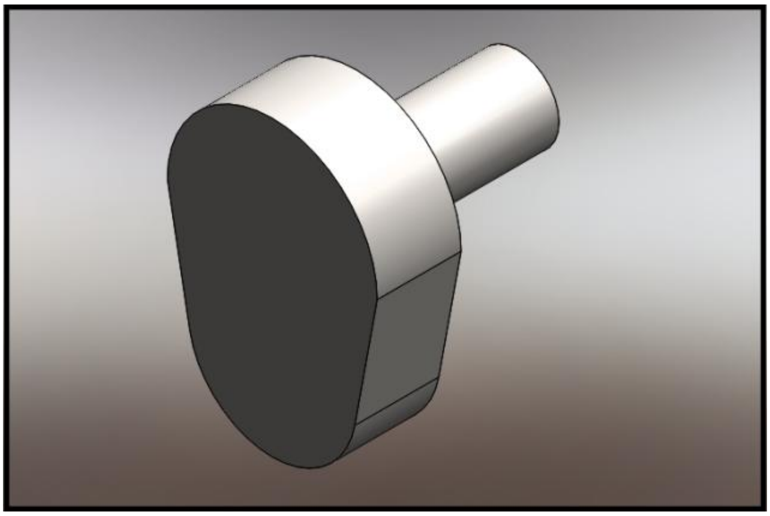


Figure 18: Cam

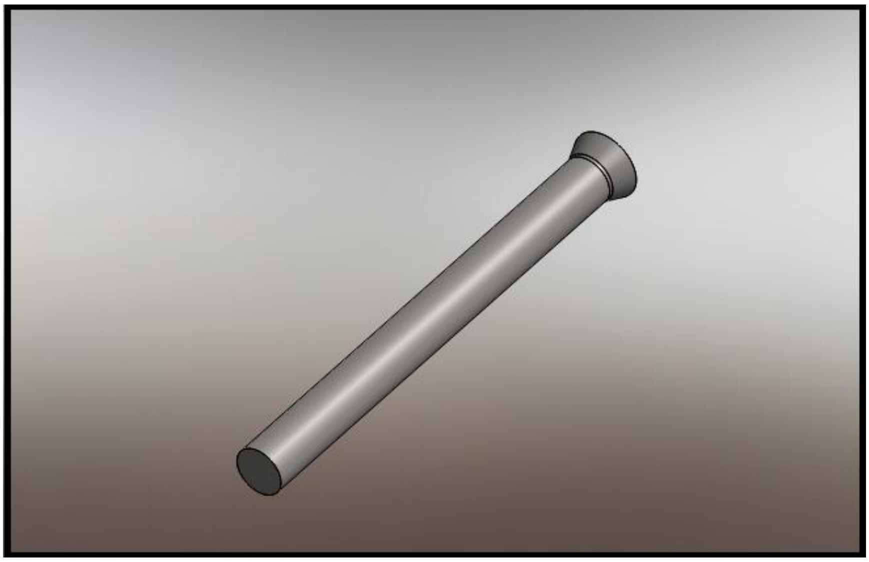


Figure 19: Cam Follower

The vertical motion is gained by the valve lapping mechanism(follower system) when the cam is rotated by the rotary motion of the 20 RPM, high torque and heavy duty DC motor which is the cam drive and the rotary motion is then converted in to linear(vertical) motion using the shape of cam nose and it is transmitted to the valve mechanism through the cam follower. The vertical motion of the valve lapping mechanism helps to break the contact between valve seat and the corresponding surface of a cylinder head. The importance of this action is described further in the text.

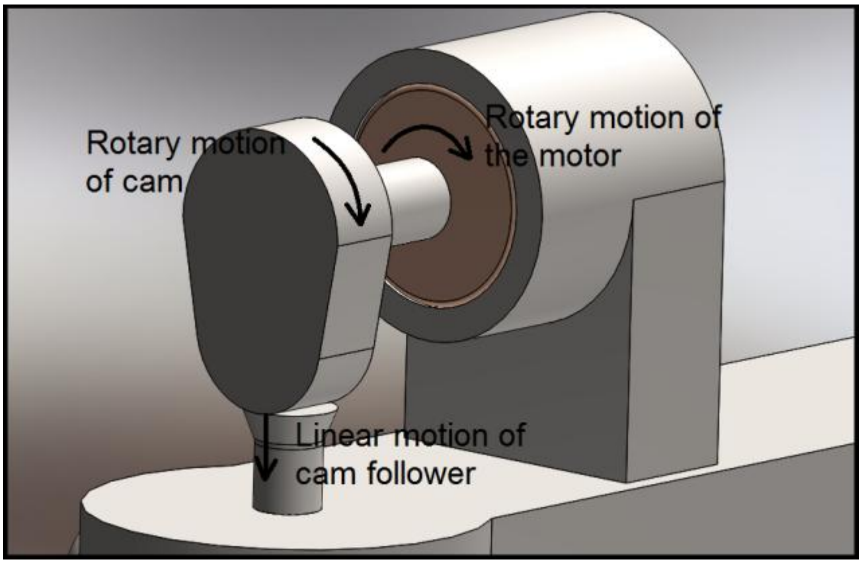


Figure 20: Conversion of motion through the cam system

Figure 20 shows how the rotary motion is converted into linear motion. Cam follower is tensioned using a spring in the valve lapping mechanism and as the cam rotates, follower gain space to move upwards and when the cam nose area returns follower move downwards creating a linear motion.

Cam Classification [13]

Cam systems are classified using a standard classification method. Following text includes the classification of the cam system used in the valve lapping machine.

1. Sequence of follower operation:

   Dwell - Rise - Return - Dwell cam(DRRD) - In this type of cam, there is no dwell between rise and return.

2. Follower shape:

   Flat - face follower

3. Follower motion:

   Translating follower - Follower moves in a straight line.

4. Follower position:

   On - Center follower - Line of motion passes through the cam axis.

5. Cam motion:

   Rotating cam - Rotation is done at constant angular velocity.

6. Cam shape:

   Open cam (disk or plate cam)

7. Follower Constraint:

   Spring constraint - The contact between follower and cam profile is maintained by spring.

The valve lapping machine for internal combustion engines is mainly consist of three main units. The base, the sliding stand and the valve lapping mechanism. The next section of this text is about the parts and operations of the valve lapping mechanism. Parts that belong to the valve lapping mechanism are upper spring mounting bracket, tension spring, lower spring mounting bracket, 200rpm 12V dc gear motor fixing bracket, 200rpm 12V dc gear motor, valve holding piece mounting screw, 40mm extension piece and valve holding piece.

2.6 Upper spring mounting bracket

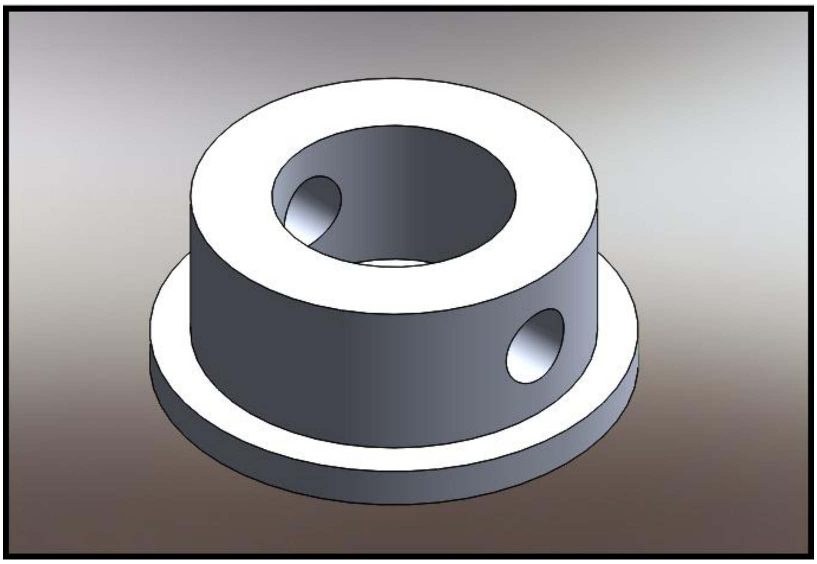


Figure 21: Upper spring mounting bracket

Upper spring mounting bracket is assembled to the upper end of the machine stand by two pan slot head bolts. The main function of this part is connecting the valve lapping mechanism and machine stand together. One side of the tension spring also welded to this part.

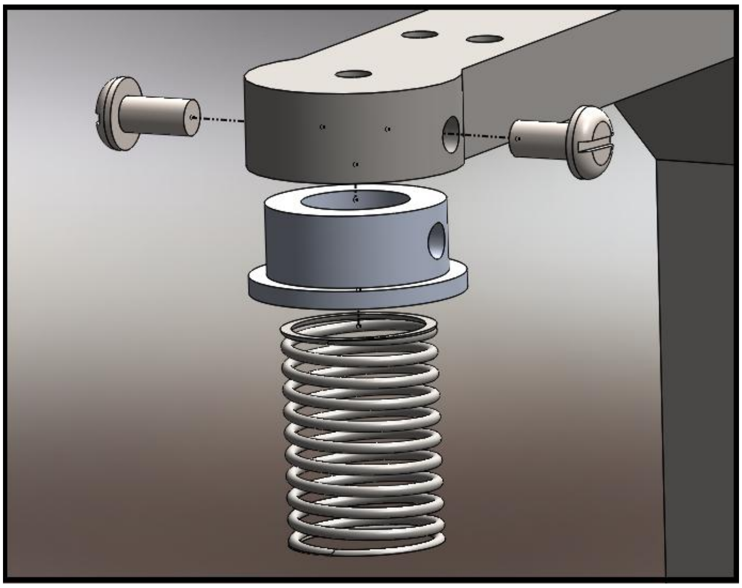


Figure 22: Exploded view of upper spring mounting bracket assembly

The material assigned for this part is Aluminum alloy 1100. The reason for choosing an aluminum alloy is the lower mass density. Therefore the part will be of less weight. The upper spring mounting bracket only weighs about 102g when machined from aluminum alloy 1100. When Originally assigning the materials for parts, the choice was between 3 aluminum alloys. They were alloy 1100, alloy 2011 and alloy 3003. Following are some factors considered when choosing an aluminum alloy from above mentioned three.

1. Formability and Workability [14]
    - Alloy 1100 - excellent formability and workability
    - Alloy 2011 - good formability and workability
    - Alloy 3003 - excellent formability and workability
2. Weldability
    - Alloy 1100 - excellent weldability
    - Alloy 2011 - poor weldability
    - Alloy 3003 - excellent weldability
3. Machinability
    - Alloy 1100 - good machinability
    - Alloy 2011 - excellent machinability
    - Alloy 3003 - good machinability
4. Corrosion Resistance
    - Alloy 1100 - excellent corrosion resistance
    - Alloy 2011 - poor corrosion resistance
    - Alloy 3003 - good corrosion resistance

Out of the three alloys, alloy 1100 is excellent at the key features that can be considered as benefits in the developing process. The same aluminum alloy is used in two more parts of this machine.

2.7 Tension spring

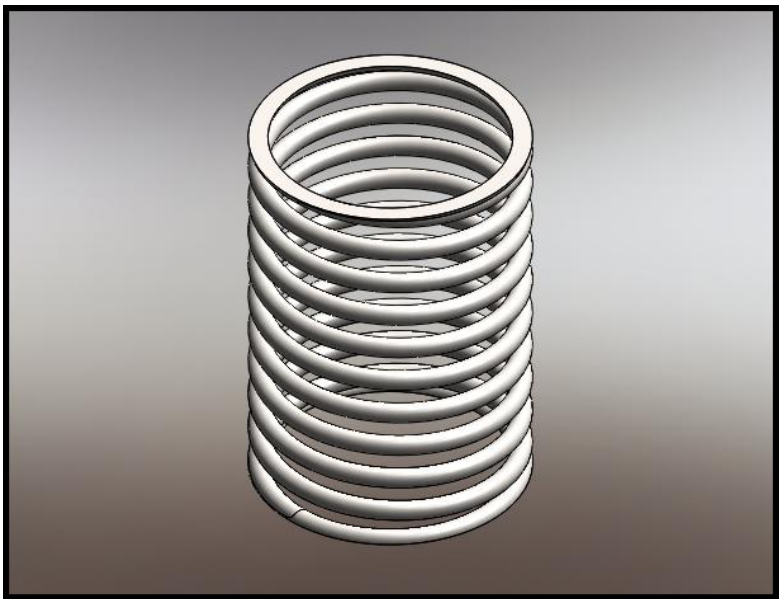


Figure 23: Tension spring

Tension spring is the link between upper spring mounting bracket and lower spring mounting bracket. They are connected by welding both ends of the spring to the two brackets. And the key function of the tension spring is to participate in the task of creating the linear(vertical) motion of the valve lapping mechanism. The spring diameter is 40mm, it has a pitch of 6 mm with 10 coils. Spring is made from a wire of 3mm diameter and it has a spring constant of 3.164 N/mm. The spring is made up of steel and weighs about 75g.

2.8 Lower spring mounting bracket.

This part can be referred as the center of the valve lapping mechanism. That is because almost every part that makes the valve lapping mechanism functional connects with this part. The cam follower makes contact with this part according to the cam's motion, tension spring is welded to this part and the fixing bracket of the 200rpm 12V dc gear motor which actually do the lapping of valves is also assembled to this part.

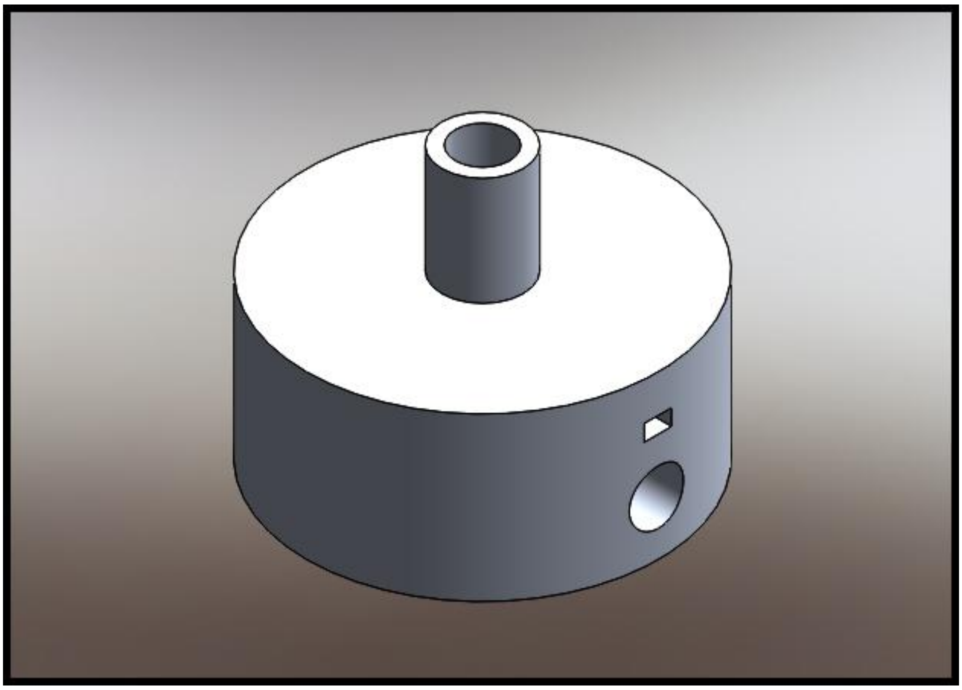


Figure 24: Lower spring mounting bracket

The top face of the lower spring mounting bracket has a guide, to guide the cam follower and the lower end of cam follower always moves in this guide. When the cam system is working, the cam follower moves downwards and push the lower spring mounting bracket. As the bracket moves downwards, tension spring welded to it begins to deform and therefore a reaction force is creating. This force is directly transmitted to the cam through the follower and as the cam rotates, the follower moves upward using the force created by the spring while the spring takes its original structure. This process happens over and over when the machine is on and the linear motion is created by this process.

Material assigned for lower spring mount is aluminum alloy 1100 because the reasons mentioned above in the text and one other reason to choose this light material is that tension spring has to hold the entire weight of the parts assembled to lower spring mounting bracket. This part weighs about 171g.

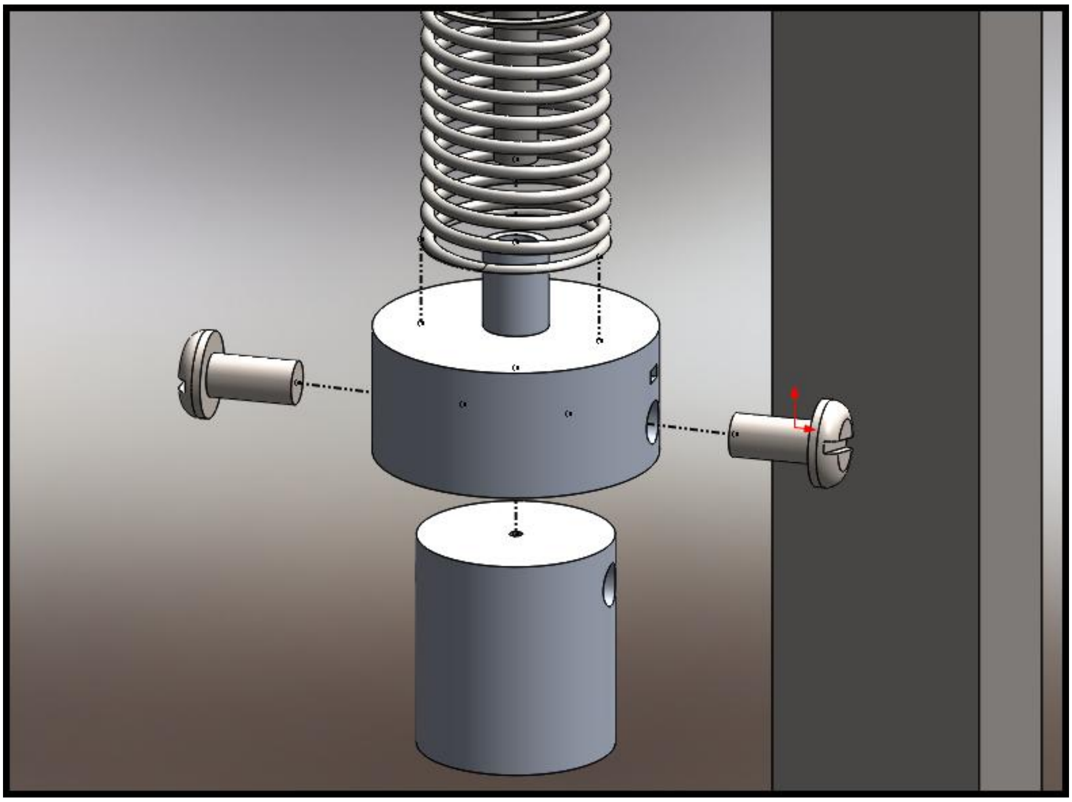


Figure 25: Exploded view of lower spring mounting bracket assembly

2.9 200RPM, heavy duty 12V dc gear motor fixing bracket

The motor that does the valve lapping is fixes to this bracket and this bracket is assembled to lower spring mounting bracket using two pan slot head bolts. This bracket subjects to a torque when the machine is on. That torque generates from the valve seat and the reciprocating surface on the cylinder head. This part is also assigned to be developed in aluminum alloy 1100 and weighs about 169g.

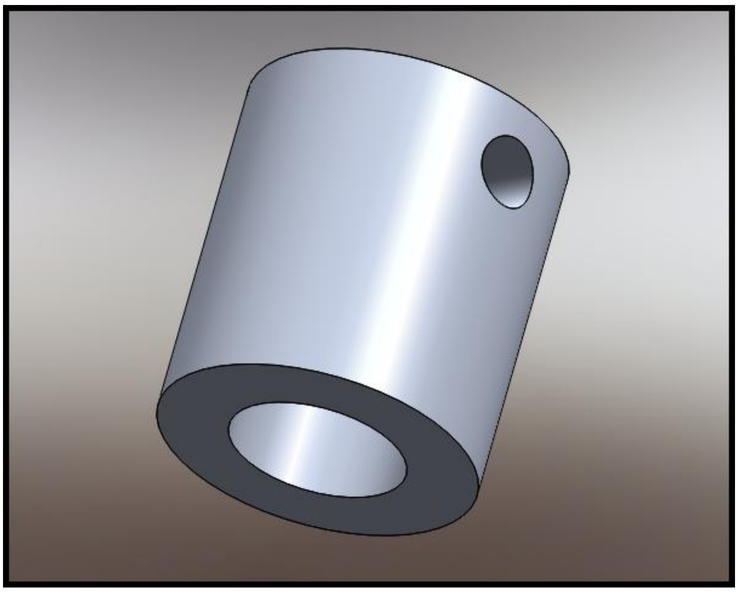


Figure 26: 200RPM, heavy duty 12V dc gear motor fixing bracket

2.10 Valve holding piece mounting screw

Fixing of engine valves to the machine in order to lap them is another important task that has to be completed before the valve lapping process begin. This small screw is the first part of the unit designed to hold any king of valve. This mounting screw is fixed to the spindle of the 200 rpm motor and one of the valve holding pieces or the extension piece can be mounted to this screw. This part is made from steel and weighs about 5g.

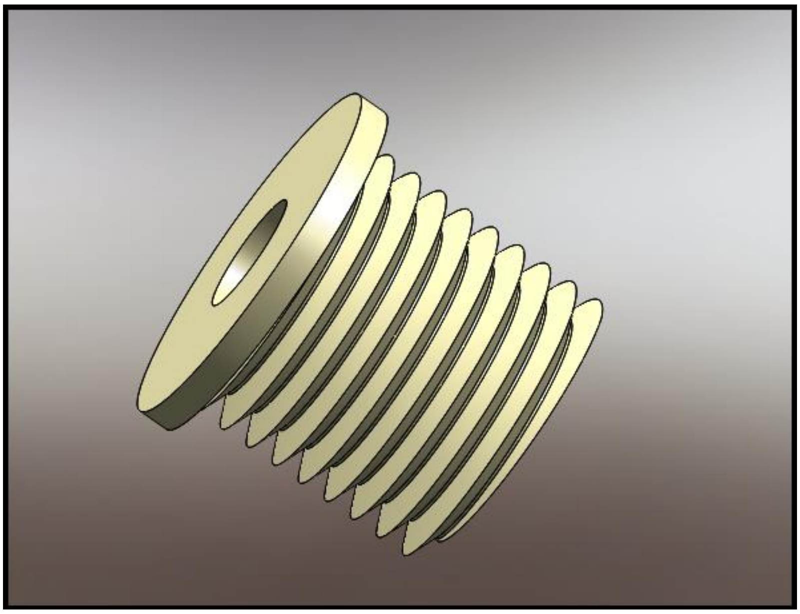


Figure 27: Valve holding piece mounting screw

2.11 40mm extension piece

This extension piece is designed in order to the machine to be compatible with an engine valve which has a short overall length. When needed, the extension piece is assembled to the valve holding piece mounting screw and then the valve holding piece is assembled to the extension piece. This part also made from steel and has a mass of 65g.

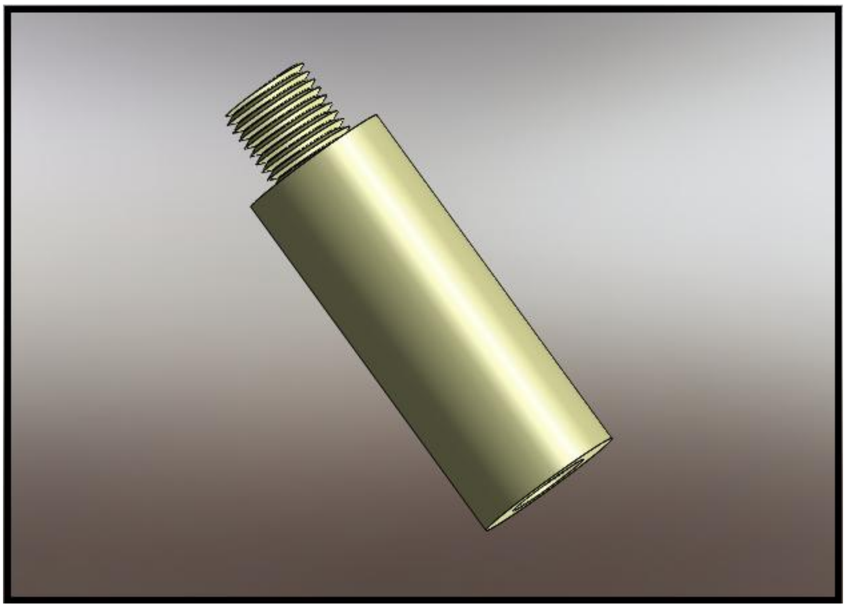


Figure 28: 40mm extension piece

2.12 Valve holding piece

This is one of the most important parts in this machine. Most of the valve lapping power tools and valve lapping sticks doesn't have an effective valve holding unit. Due to that reason, sometimes while the valve lapping process is going on, the engine valve disconnects from the valve holding unit. This is a real inconvenience. To prevent that from happening, valve lapping machine for IC engines has a special valve holding piece.

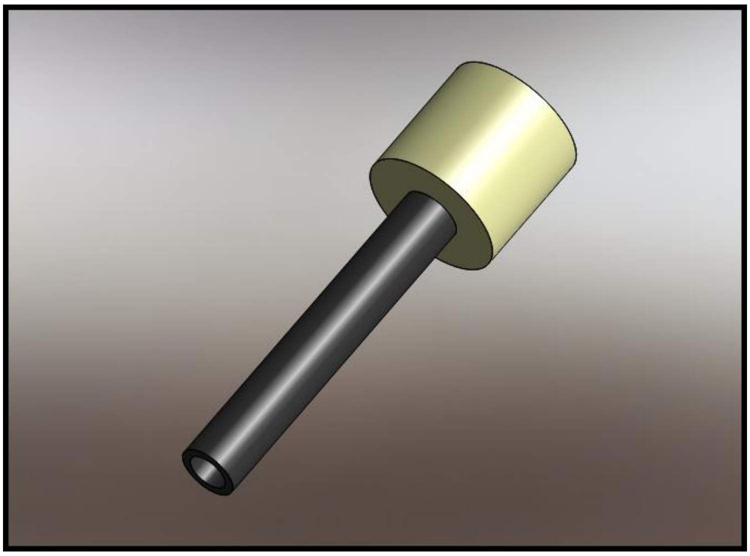


Figure 29: Valve holding piece alpha

Shown in figure 29 is a valve holding piece that can be either assembled to the valve holding piece mounting screw or the extension piece. The head of this part is made from steel and body is made from natural rubber since natural rubber has the best elasticity of all rubber types. The head and the body is merged together using an industrial grade adhesive(Urethane or Methacrylate).

Body of the valve holding piece is 40mm long. An engine valve can be fixed to the valve holding piece by using only 10mm. That gives a height adjusting space of 30mm for an engine valve. And when the extension piece is used, the overall height adjusting space is 70mm. So the valve lapping machine is capable of lapping any engine valve with the overall height between 140mm and 70mm.

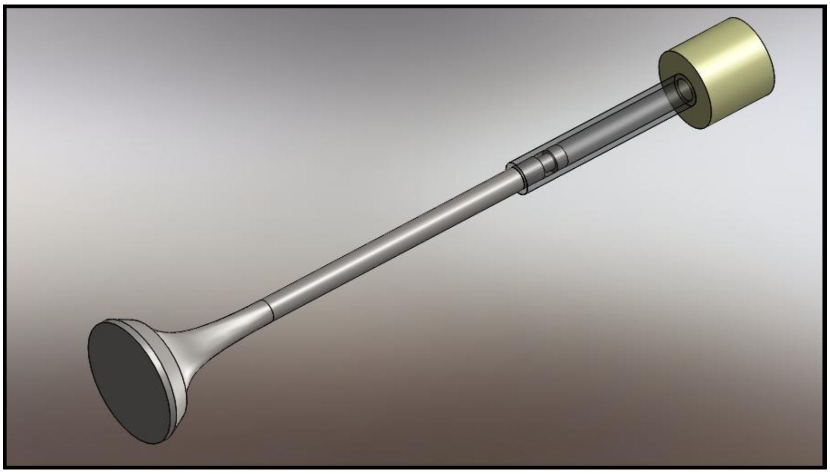


Figure 30: An engine valve fixed to a valve holding piece

The specialty about these valve holding pieces are that there are 5 types of valve holding pieces designed to be compatible with a wide range of engine valves. Specifications for the 5 types of valve holding pieces are obtained by analyzing over 300 valves made by different manufacturers such as Acura, Audi, BMW, Chrysler, FIAT, Honda, Hyundai, Mazda, Mini Cooper, Mitsubishi, Nissan, Subaru and Toyota. The analyzing of engine valve data and categorization is included in appendix 1. Given below is the 5 categories of valve holding pieces and the stem diameter each category can handle.

Category	Stem diameter(mm)
α	5.00 - 5.99
β	6.00 - 6.99
γ	7.00 - 7.99
δ	8.00 - 8.99
ε	9.00 - 9.99

Table 1: 5 categories of valve holding pieces

There are 5 valve holding pieces designed for each of the category mentioned in table 1. Figure 31 shows those valve holding pieces.

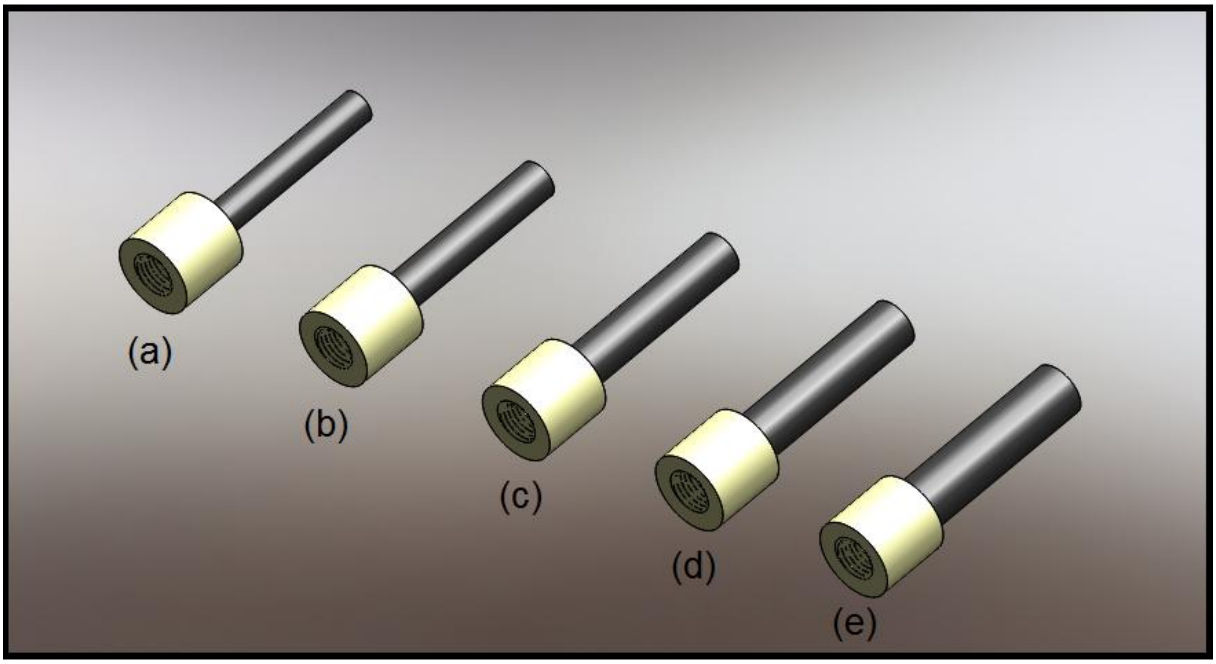


Figure 31: 5 valve holding pieces. (a) α piece, (b) β piece, (c) γ piece, (d) δ piece, (e) ε piece

Note: Engineering drawings of all the parts are included in appendix 2.

3 CALCULATIONS AND RESULTS

3.1 Tension spring calculation

Total mass of the parts below the tension spring

Lower spring mounting bracket	- 171.29g
20 RPM motor holding bracket	- 168.72g
Two pan slot head bolts	- 49.04g
20 RPM motor	- 84g
Valve holding piece mounting screw	- 4.64g
40 mm extension piece	- 65.12g
Valve holding piece ε	- 21.20g
	539.49g

Total mass of the parts below the tension spring = 0.5395 Kg

Spring constant(k)

The equation for calculating spring stiffness using the external dimensions of the spring

$$k = \frac{G.d^4}{8.n.D^4} \quad (1)[15]$$

k - Spring constant (N/mm)

G - Modulus of elasticity (Mpa)

D - Mean spring diameter (mm)

d - Wire diameter (mm)

n - number of active coils

$$k = \frac{G.d^4}{8.n.D^4}$$

$$k = \frac{200000 \times 3^4}{8 \times 10 \times 40^4}$$

$$k = \underline{\underline{3.164 \text{ N/mm}}}$$

Force on the upper spring mounting bracket(f)

The total force acting on the upper spring mounting bracket is obtained by considering the total mass of the parts below the tension spring and the force needed for the tension spring to reach the required deformed status(15mm stretched).

$$\mathbf{F} = \mathbf{F_0} + sk \qquad (2)$$

F - Total force acting on the upper spring mounting bracket (N)

F_0 - Total mass of the parts below the tension spring (N)

s - deformed(stretched) length of the tension spring) (mm)

$$\mathbf{F} = \mathbf{F_0} + sk$$

$$\mathbf{F} = 0.5395 \times 10 + 15 \times 3.164$$

$$\mathbf{F} = \underline{\underline{52.86\ N}}$$

3.2 Torque affecting the 20 RPM DC motor

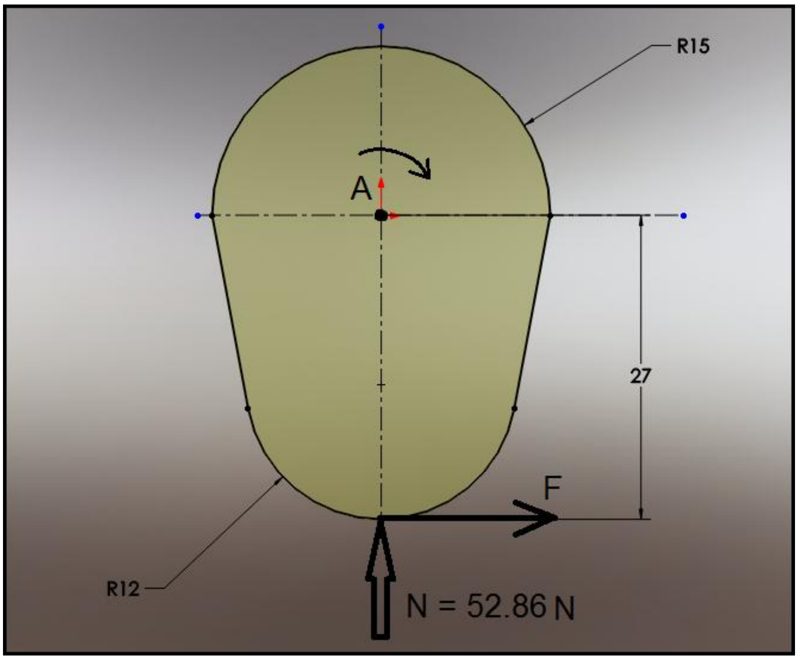


Figure 32 : Forces acting on cam

The force N is applied by the cam follower when the tension spring stretches 15mm and the moment around point A is calculated using friction forces generate on the surfaces of cam and follower.

Friction forces generated in static and kinetic status

$$\mathbf{F_f} = \mu.\mathbf{N} \quad (3)$$

F_f - Friction force acting on cam
μ - Coefficient of friction
N - Force acting on cam from the cam follower

- Let's consider a situation when the cam is moving(kinetic status)

Coefficient of friction for steel on steel, μ_k = 0.6 [16]

$$\mathbf{F_{fk}} = \mu_k.\mathbf{N}$$

$$\mathbf{F_{fk}} = 0.6\times52.86$$

$$\mathbf{F_{fk}} = 31.72N$$

Torque at point A when the cam is moving = $\mathbf{T_{Ak}}$

$$\mathbf{T_{Ak}} = \mathbf{F_{fk}}\times0.027m$$

$$\mathbf{T_{Ak}} = 31.72\times0.027$$

$$\mathbf{T_{Ak}} = 0.85644Nm$$

$$\mathbf{T_{Ak}} = \underline{\underline{8.5644Kg.cm}}$$

- Let's consider a situation when the cam is not moving(static status)

Coefficient of friction for steel on steel, μ_s = 0.7

$$\mathbf{F_{fs}} = \mu_s.\mathbf{N}$$

$$\mathbf{F_{fs}} = 0.7\times52.86$$

$$\mathbf{F_{fs}} = 37.00N$$

Torque at point A when the cam is moving = $\mathbf{T_{As}}$

$$\mathbf{T_{As}} = \mathbf{F_{fs}}\times0.027m$$

$$\mathbf{T_{As}} = 37.00\times0.027m$$

$$\mathbf{T_{As}} = 0.9999Nm$$

$$\mathbf{T_{As}} = \underline{\underline{9.999kg.cm}}$$

As can be seen from above results, the maximum torque that has to be handled by the 20RPM DC motor is 9.999Kg.cm . As the motor is compatible with torques between from 10-19kg.cm, the motor and therefore the cam will work fine.

4 3D MODEL SIMULATIONS OF VALVE LAPPING MACHINE FOR INTERNAL COMBUSTION ENGINES

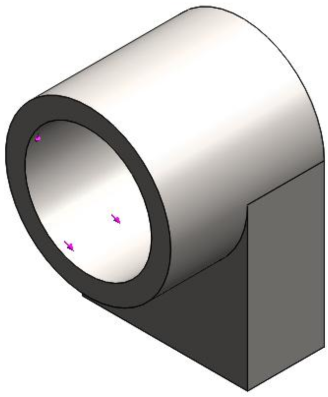
This chapter includes stress, strain and displacement simulations of various parts of the valve lapping machine where loads or torques are applied using finite element analysis methods. The point of these simulations are to examine the integrity of the structure of the machine before developing it and if any faults are found, to correct them and optimize. The parts and assemblies mentioned below will be analyzed.

1. 20 RPM DC motor fixing bracket (loaded with 0.9999N.m torque)
2. Tension spring (loaded with 52.86N force)
3. Cam (loaded with 52.86N force and 0.9999N.m torque)
4. Machine bed assembly

Note: All the simulations are done using **SolidWorks Simulations**.

4.1 20 RPM DC motor fixing bracket

Model Information



Model name: 20RPM high torque and heavy duty 12V motor fixing bracket
Current Configuration: Default

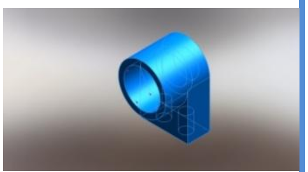
Solid Bodies			
<L_MdInf_SldBd_Nm/>	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Cut-Extrude1 	Solid Body	Mass:0.378852 kg Volume:4.7956e-005 m^3 Density:7900 kg/m^3 Weight:3.71275 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\2nd motor holding bracket.SLDPRT Jul 08 18:33:49 2015
<L_MdInf_ShlBd_Nm/>	<L_MdIn_ShlBd_Fr/>	<L_MdInf_ShlBd_VolProp/>	<L_MdIn_ShlBd_DtMd/>
<L_MdInf_CpBd_Nm/>	<L_MdInf_CompBd_Props/>		
<L_MdInf_BmBd_Nm/>	<L_MdIn_BmBd_Fr/>	<L_MdInf_BmBd_VolProp/>	<L_MdIn_BmBd_DtMd/>

Table 2: model information of 20 RPM DC motor fixing bracket

Study properties

Study name	motor fixing bracket
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\20RPM high torque abd heavy duty 12V motor fixing bracket)

Table 3: study properties of 20 RPM DC motor fixing bracket

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Table 4: units for 20 RPM DC motor fixing bracket simulation

Material properties

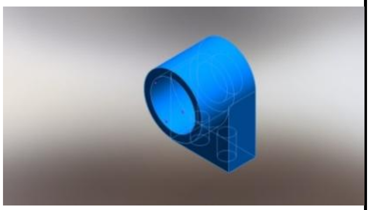
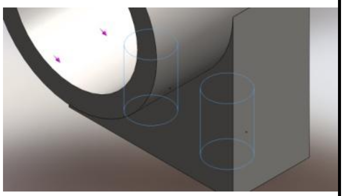
Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **351.571 N/mm^2** Tensile strength: **420.507 N/mm^2** Elastic modulus: **200000 N/mm^2** Poisson's ratio: **0.29** Mass density: **7900 g/cm^3** Shear modulus: **77000 N/mm^2** Thermal expansion coefficient: **1.5e-005 /Kelvin**	**SolidBody 1(Cut-Extrude1)(2nd motor holding bracket-1)**
Curve Data:N/A		

Table 5: material properties of 20 RPM DC motor fixing bracket

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: **2 face(s)** Type: **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.00108176	0.00122023	-0.000446364	0.00169068
Reaction Moment(N.m)	0	0	0	0

Table 6: fixtures of 20 RPM DC motor fixing bracket

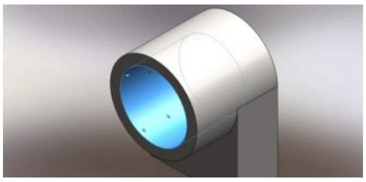
Load name	Load Image	Load Details
Torque-1		Entities: **1 face(s)** Type: **Apply torque** Value: **-0.999 N.m**

Table 7: loads of 20 RPM DC motor fixing bracket

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	3.63433 mm
Tolerance	0.181717 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Total Nodes	13686
Total Elements	8361
Maximum Aspect Ratio	16.476
% of elements with Aspect Ratio < 3	99.7
% of elements with Aspect Ratio > 10	0.0598
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:01
Computer name:	AYO-PC

Table 8: mesh information of 20 RPM DC motor fixing bracket

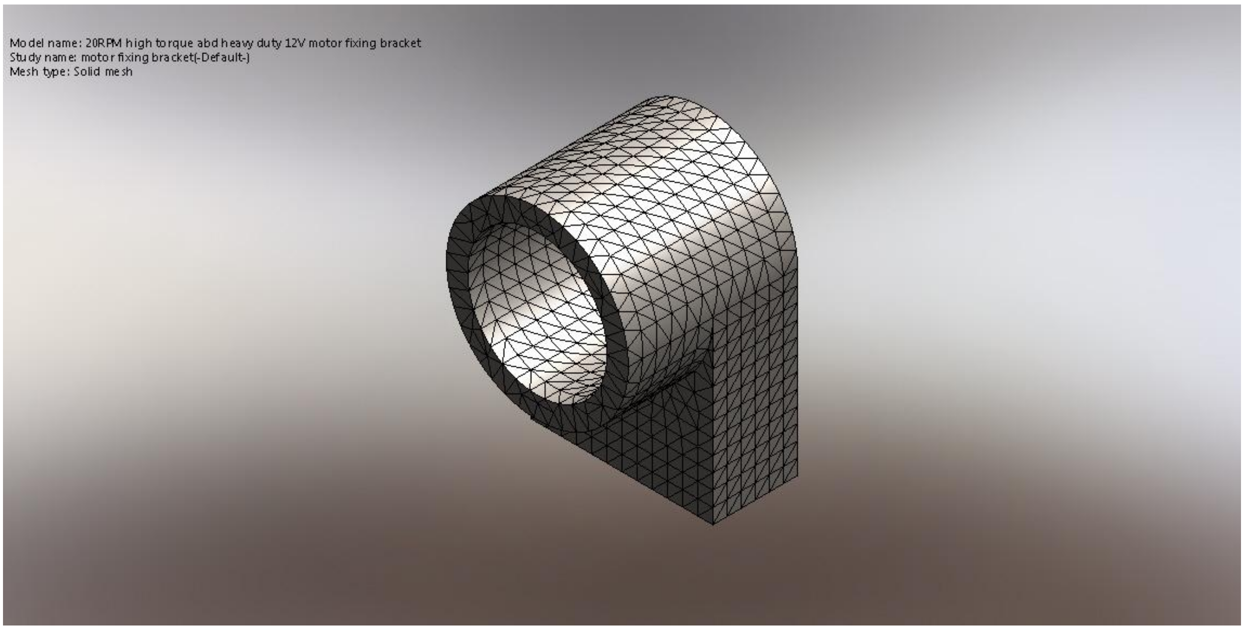


Figure 33: solid mesh of 20 RPM DC motor fixing bracket

Resultant forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00108176	0.00122023	-0.000446364	0.00169068

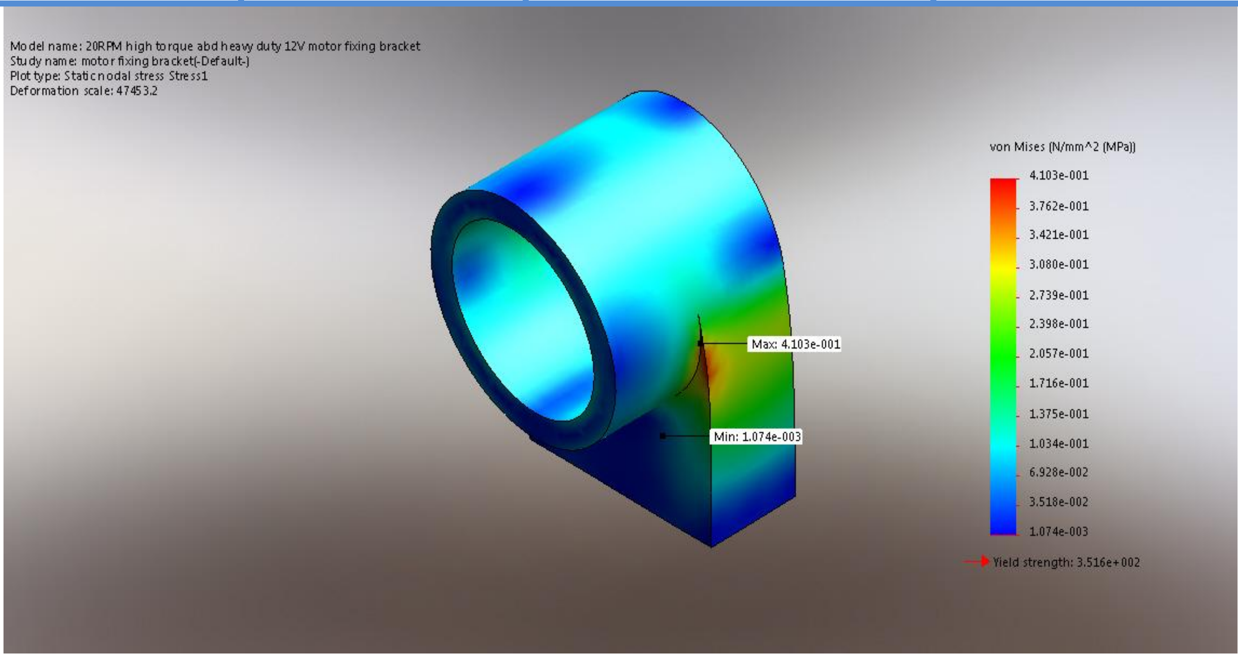
Table 9: Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Table 10: Reaction moments

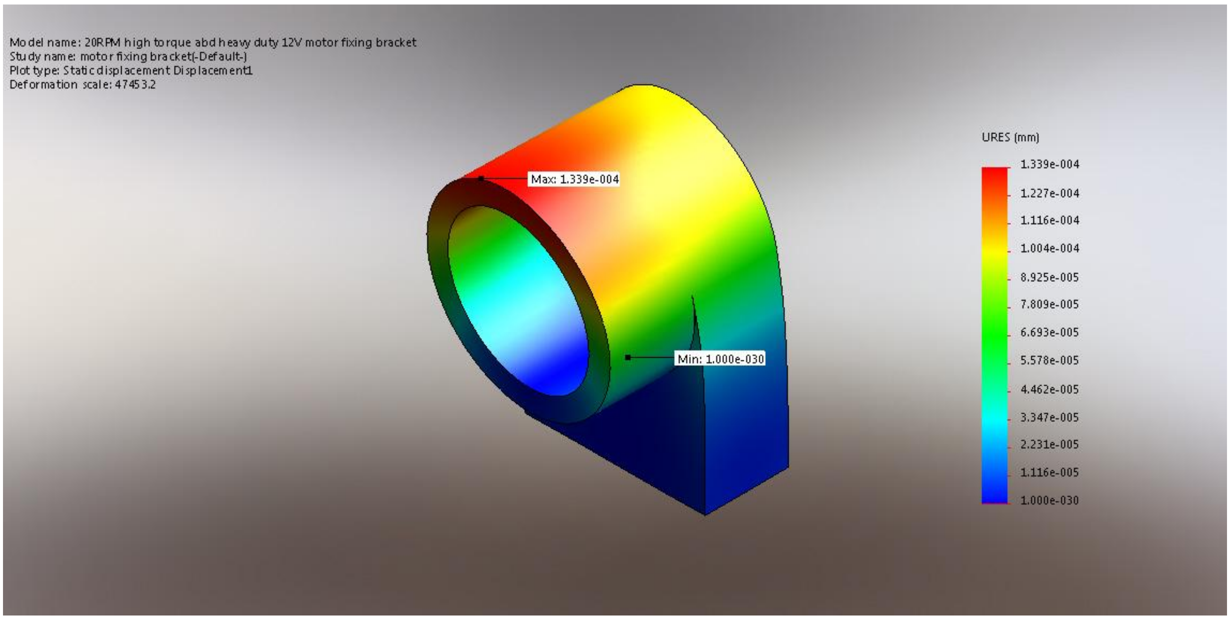
Study results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0010742 N/mm^2 (MPa) Node: 5067	0.410296 N/mm^2 (MPa) Node: 10098



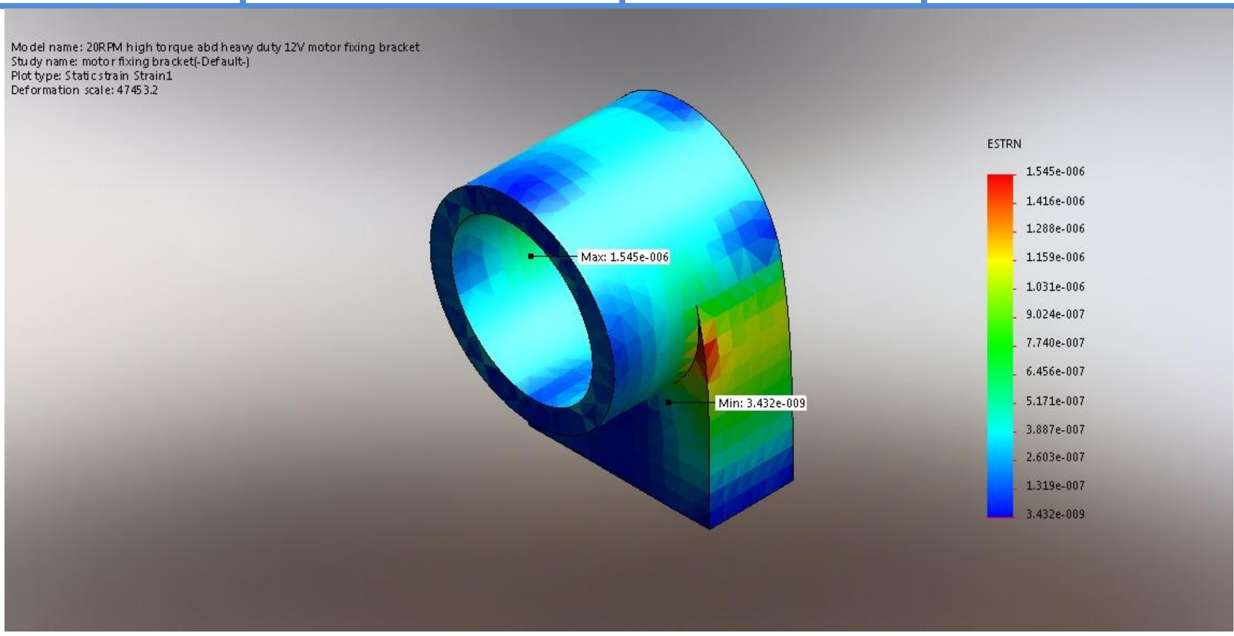
20RPM high torque abd heavy duty 12V motor fixing bracket-motor fixing bracket-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.000133868 mm Node: 9678



20RPM high torque abd heavy duty 12V motor fixing bracket-motor fixing bracket-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.4324e-009 Element: 6323	1.54453e-006 Element: 566



20RPM high torque abd heavy duty 12V motor fixing bracket-motor fixing bracket-Strain-Strain1

4.2 Tension spring

Model information

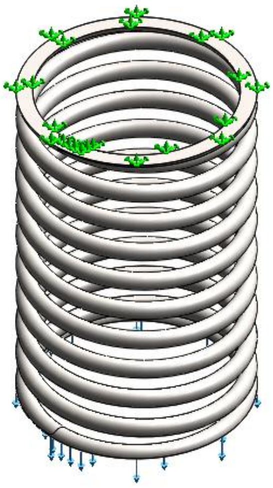
<table>
<tr><td colspan="4">
Model name: spring 1
Current Configuration: Default</td></tr>
<tr><td colspan="4">Solid Bodies</td></tr>
<tr><td><L_MdInf_SldBd_Nm/></td><td>Treated As</td><td>Volumetric Properties</td><td>Document Path/Date Modified</td></tr>
<tr><td>Cut-Extrude3
</td><td>Solid Body</td><td>Mass:0.0741742 kg
Volume:9.38913e-006 m^3
Density:7900 kg/m^3
Weight:0.726907 N</td><td>E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\Tension spring\spring 1.SLDPRT
Jul 07 19:54:52 2015</td></tr>
<tr><td><L_MdInf_ShlBd_Nm/></td><td><L_MdIn_ShlBd_Fr/></td><td><L_MdInf_ShlBd_VolProp/></td><td><L_MdIn_ShlBd_DtMd/></td></tr>
<tr><td><L_MdInf_CpBd_Nm/></td><td colspan="3"><L_MdInf_CompBd_Props/></td></tr>
<tr><td><L_MdInf_BmBd_Nm/></td><td><L_MdIn_BmBd_Fr/></td><td><L_MdInf_BmBd_VolProp/></td><td><L_MdIn_BmBd_DtMd/></td></tr>
</table>

Table 11: model information of tension spring

Study properties

Study name	Tension spring
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	On
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\Tension spring)

Table 12: study properties of tension spring

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Table 13: units for tension spring simulation

Material properties

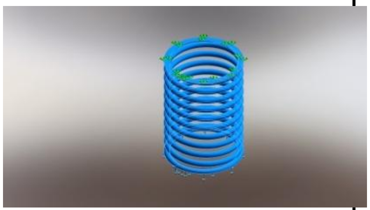
Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **351.571 N/mm^2** Tensile strength: **420.507 N/mm^2** Elastic modulus: **200000 N/mm^2** Poisson's ratio: **0.29** Mass density: **7900 g/cm^3** Shear modulus: **77000 N/mm^2** Thermal expansion coefficient: **1.5e-005 /Kelvin**	**SolidBody 1(Cut-Extrude3)(spring 1)**
Curve Data:N/A		

Table 14: material properties of tension spring

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **1 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**-0.00734208**	**52.7843**	**0.0170111**	**52.7843**
Reaction Moment(N.m)	**0**	**0**	**0**	**0**

Table 15: fixtures of tension spring

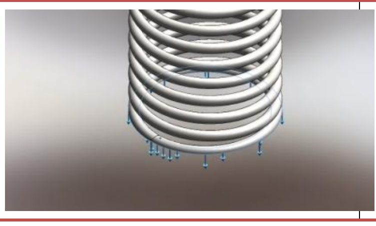
Load name	Load Image	Load Details
Force-1		**Entities:** **1 face(s)** **Type:** **Apply normal force** **Value:** **-52.86 N**

Table 16: loads of tension spring

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	2.28217 mm
Tolerance	0.114109 mm
Mesh Quality	High

Total Nodes	23533
Total Elements	11014
Maximum Aspect Ratio	13.211
% of elements with Aspect Ratio < 3	87.7
% of elements with Aspect Ratio > 10	0.272
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:19
Computer name:	AYO-PC

Table 17: mesh information of tension spring

Figure 34: solid mesh of tension spring

Resultant forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00734208	52.7843	0.0170111	52.7843

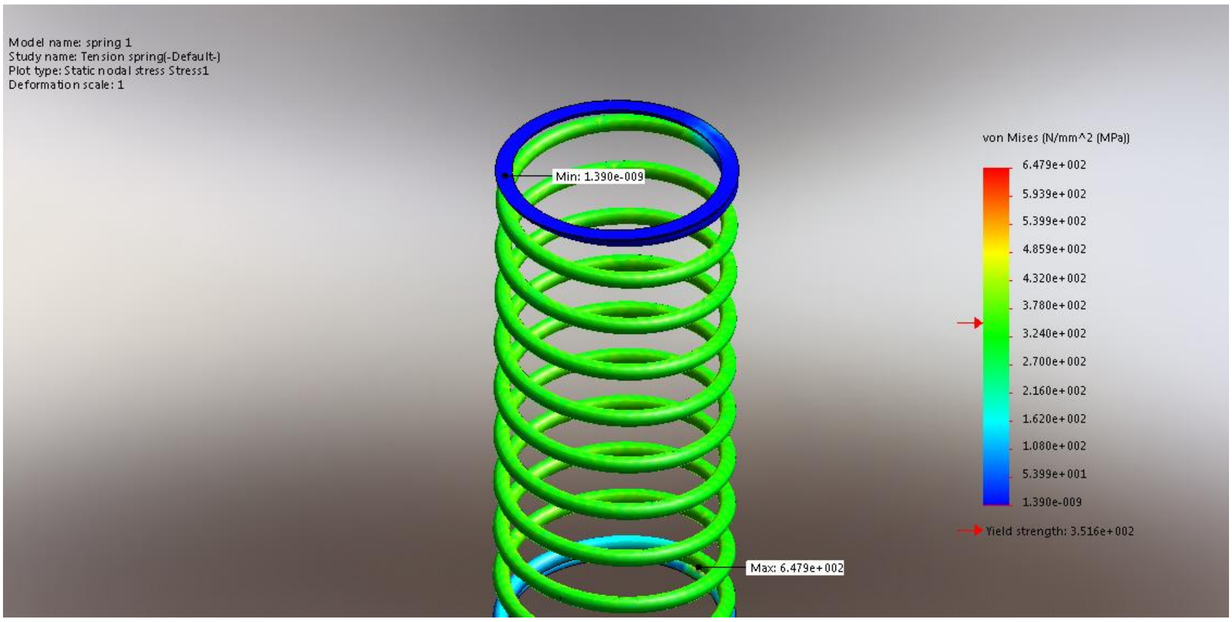
Table 18: reaction forces of tension spring

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Table 19: reaction moments of tension spring

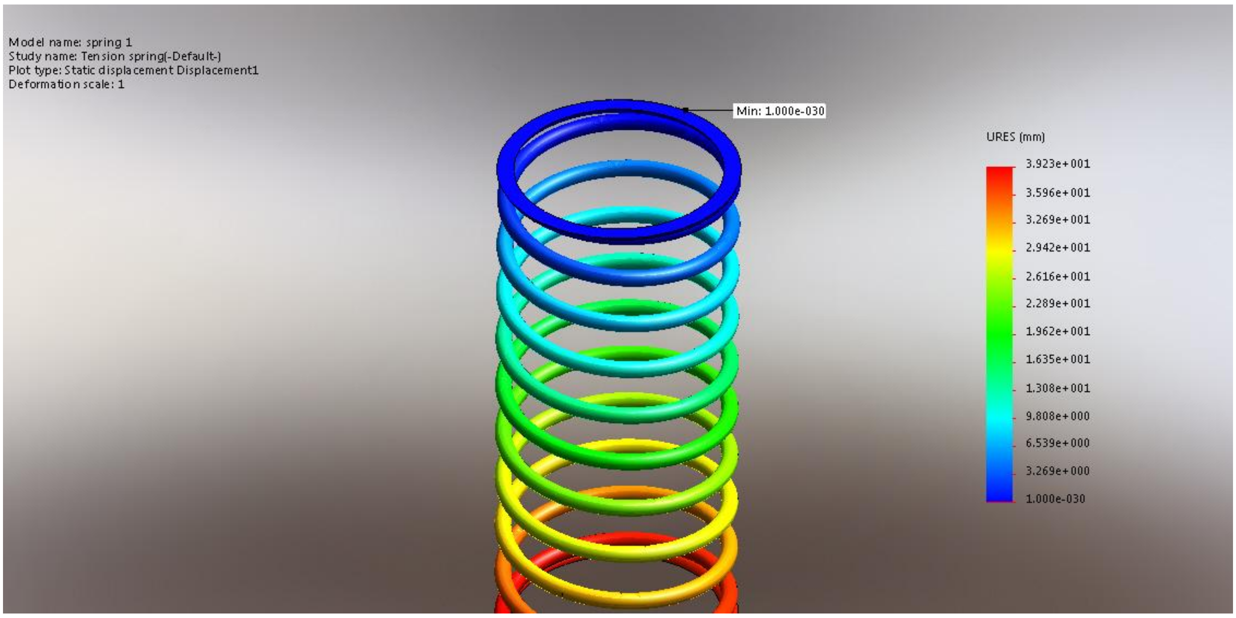
Study results

Name	Type	Min	Max
Stress-tension spring	VON: von Mises Stress	1.38979e-009 N/mm^2 (MPa) Node: 6259	647.925 N/mm^2 (MPa) Node: 3514



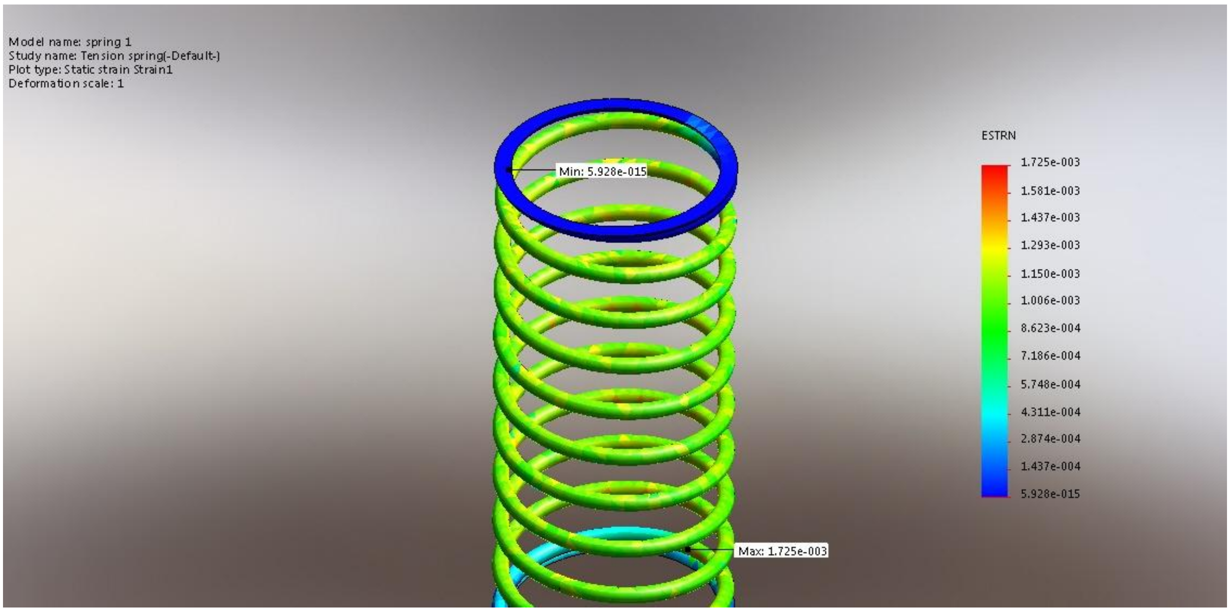
spring 1-Tension spring-Stress-Stress1

Name	Type	Min	Max
Displacement- tension spring	URES: Resultant Displacement	0 mm Node: 3409	39.2326 mm Node: 3572



spring 1-Tension spring-Displacement-Displacement1

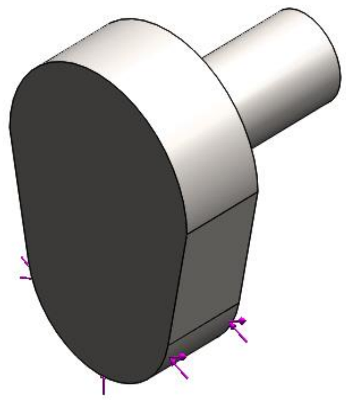
Name	Type	Min	Max
Strain- tension spring	ESTRN: Equivalent Strain	5.92779e-015 Element: 2415	0.00172455 Element: 10215



spring 1-Tension spring-Strain-Strain1

4.3 Cam

Model information



Model name: cam
Current Configuration: Default

Solid Bodies			
<L_MdInf_SldBd_Nm />	Treated As	Volumetric Properties	Document Path/Date Modified
Cut-Extrude1 	Solid Body	Mass:0.111377 kg Volume:1.40983e-005 m^3 Density:7900 kg/m^3 Weight:1.09149 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\cam.SLDPRT Aug 06 12:02:53 2015
<L_MdInf_ShlBd_Nm />	<L_MdIn_ShlBd_Fr/>	<L_MdInf_ShlBd_VolProp/>	<L_MdIn_ShlBd_DtMd/>
<L_MdInf_CpBd_Nm />	<L_MdInf_CompBd_Props/>		
<L_MdInf_BmBd_Nm/>	<L_MdIn_BmBd_Fr/>	<L_MdInf_BmBd_VolProp/>	<L_MdIn_BmBd_DtMd/>

Table 20: model information of cam

Study properties

Study name	cam
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts)

Table 21: study properties of cam

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Table 22: units for cam simulation

Material properties

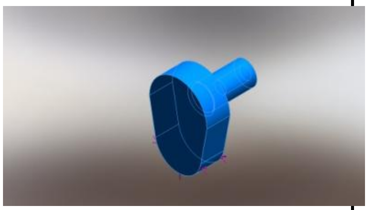
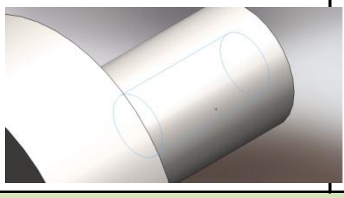
Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **351.571 N/mm^2** Tensile strength: **420.507 N/mm^2** Elastic modulus: **200000 N/mm^2** Poisson's ratio: **0.29** Mass density: **7900 g/cm^3** Shear modulus: **77000 N/mm^2** **1.5e-005 /Kelvin**	**SolidBody 1(Cut-Extrude1)(cam)**
Curve Data:N/A		

Table 23: material properties of cam

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed Hinge-1		Entities: **1 face(s)** Type: **Fixed Hinge**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	1.04323e+008	2.37755e+007	-1.20605e+006	1.07005e+008
Reaction Moment(N.m)	0	0	0	0

Table 24: fixtures of cam

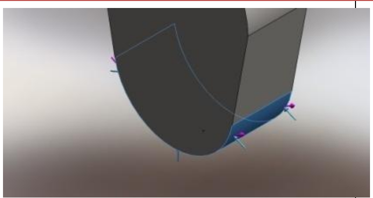
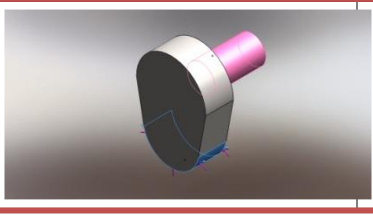
Load name	Load Image	Load Details
Force-1		Entities: **1 face(s)** Type: **Apply normal force** Value: **52.86 N**
Torque-1		Entities: **1 face(s)** Reference: **Face< 1 >** Type: **Apply torque** Value: **0.9999 N.m**

Table 25: loads of cam

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	2.41667 mm
Tolerance	0.120834 mm
Mesh Quality	High

Total Nodes	12097
Total Elements	7820
Maximum Aspect Ratio	4.6629
% of elements with Aspect Ratio < 3	99.8
% of elements with Aspect Ratio > 10	0
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:01
Computer name:	AYO-PC

Table 26: mesh information of cam

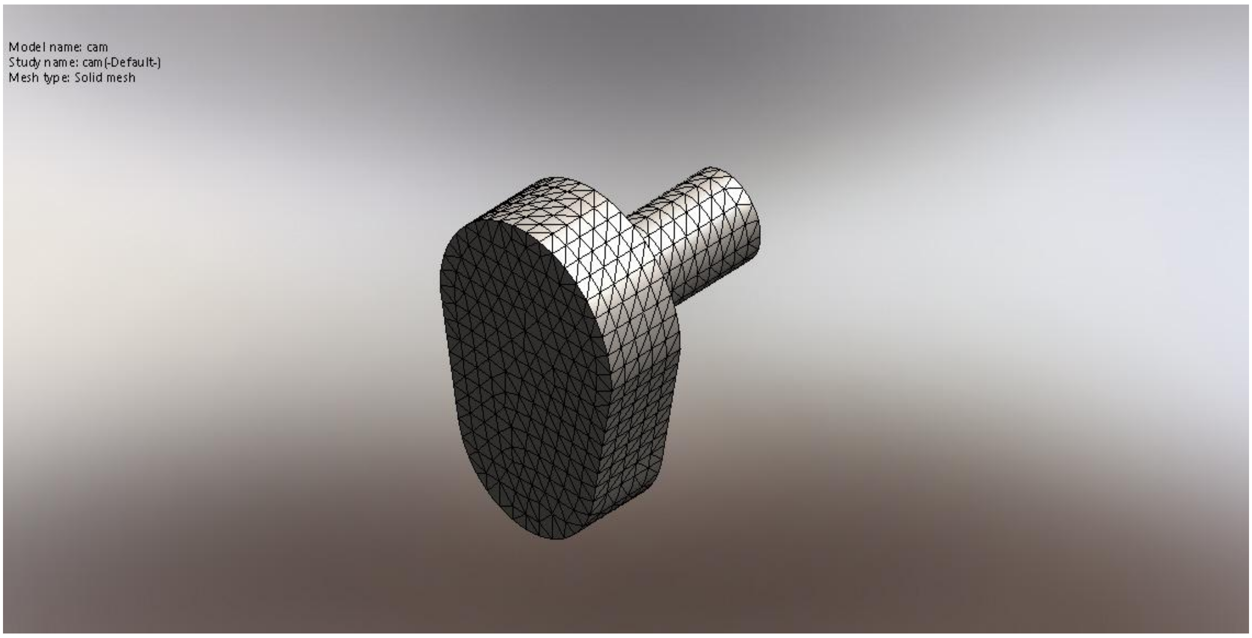


Figure 35: solid mesh of cam

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	1.04323e+008	2.37755e+007	-1.20605e+006	1.07005e+008

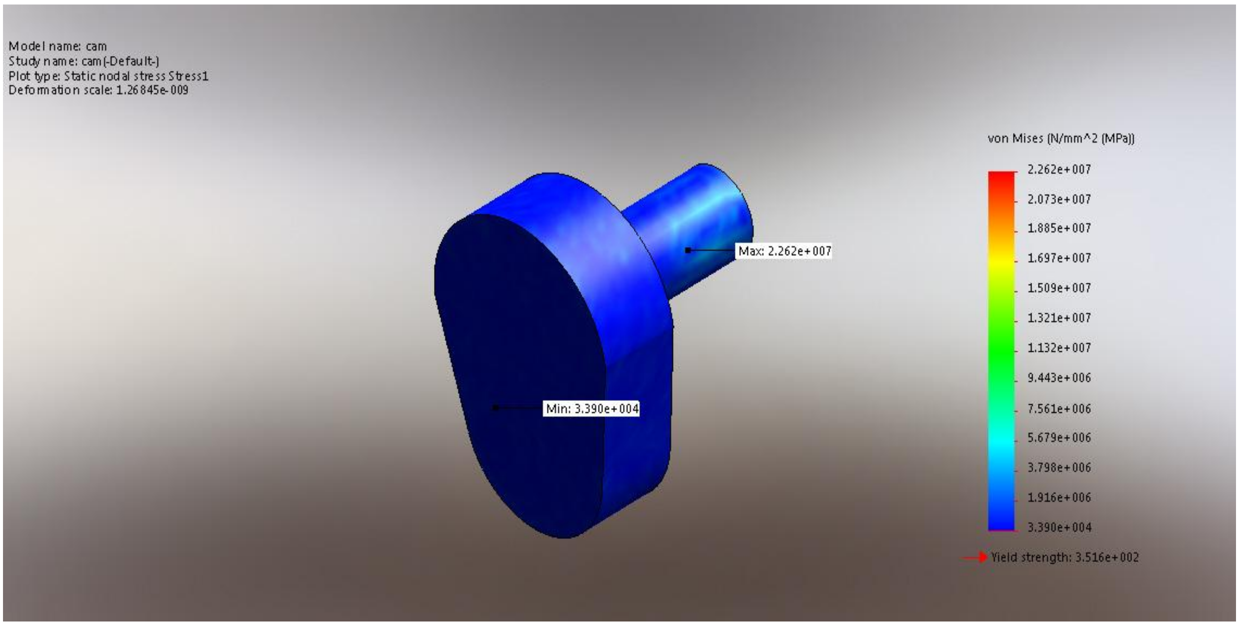
Table 27: reaction forces of cam

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Table 28: reaction moments of cam

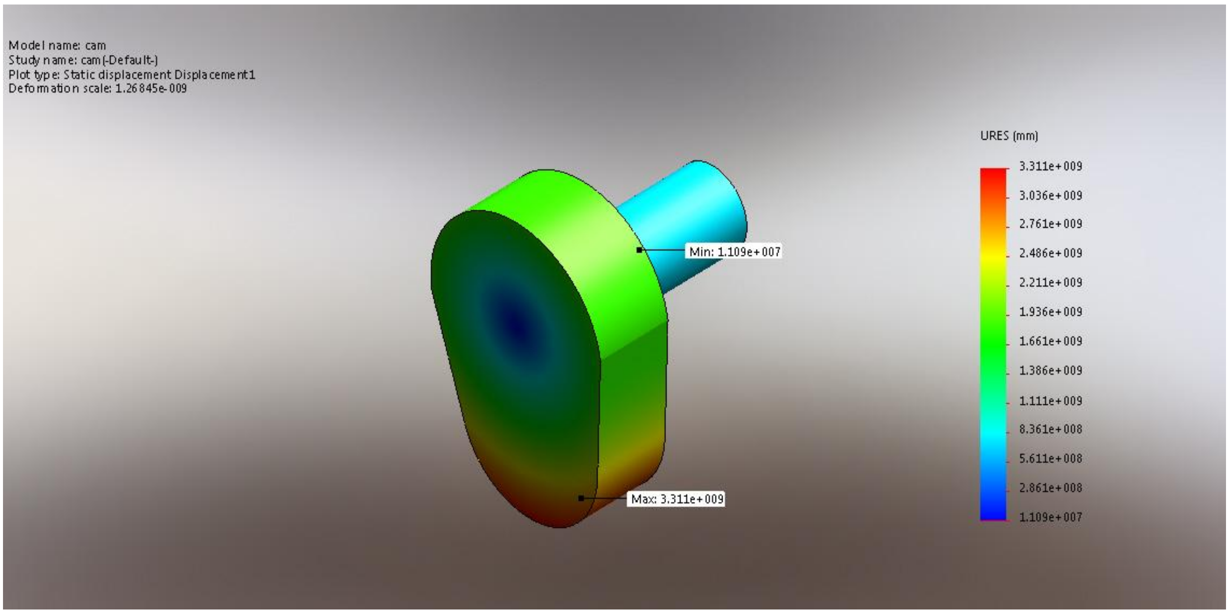
Study results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	33904.4 N/mm^2 (MPa) Node: 7238	2.26159e+007 N/mm^2 (MPa) Node: 11920



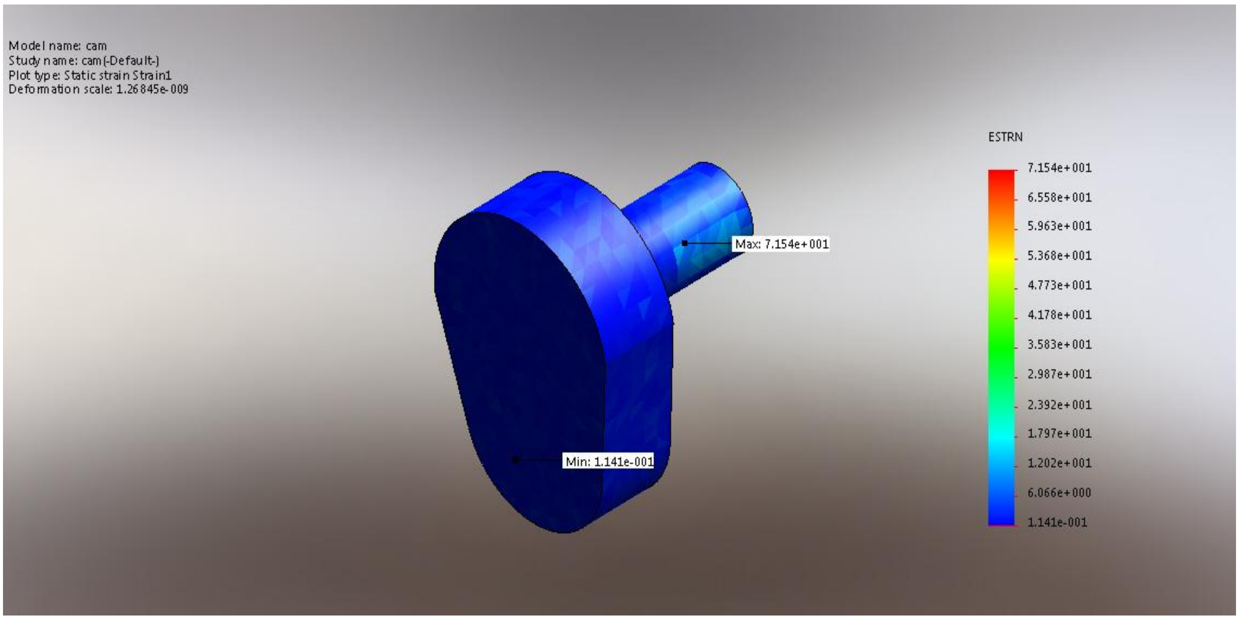
cam-cam-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	1.10936e+007 mm Node: 816	3.31112e+009 mm Node: 205



cam-cam-Displacement-Displacement1

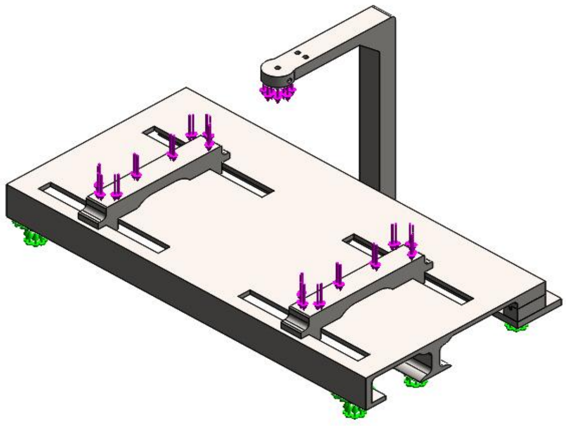
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	0.114081 Element: 5573	71.5363 Element: 3170



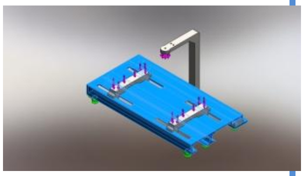
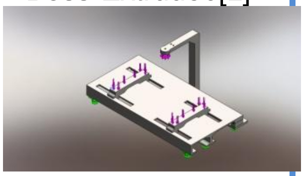
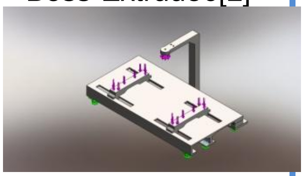
cam-cam-Strain-Strain1

4.4 Machine bed assembly

Model information



Model name: bed assembly
Current Configuration: Default

Solid Bodies			
<L_MdInf_SldBd_Nm/>	Treated As	Volumetric Properties	Document Path/Date Modified
Fillet7 	Solid Body	Mass:79.7336 kg Volume:0.0100929 m^3 Density:7900 kg/m^3 Weight:781.39 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\bed.SLDPRT Jun 30 11:33:08 2015
Boss-Extrude6[1] 	Solid Body	Mass:0.0558418 kg Volume:7.06858e-006 m^3 Density:7900 kg/m^3 Weight:0.54725 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\bed.SLDPRT Jun 30 11:33:08 2015
Boss-Extrude6[2] 	Solid Body	Mass:0.0558418 kg Volume:7.06858e-006 m^3 Density:7900 kg/m^3 Weight:0.54725 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\bed.SLDPRT Jun 30 11:33:08 2015

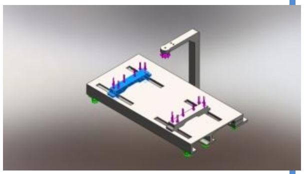
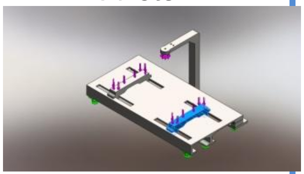
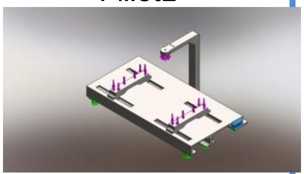
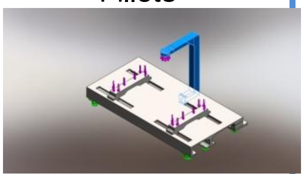
Fillet5 	Solid Body	Mass:4.78648 kg Volume:0.000605883 m^3 Density:7900 kg/m^3 Weight:46.9075 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\movable cylinder head support.SLDPRT Jun 29 23:17:51 2015
Fillet5 	Solid Body	Mass:4.78648 kg Volume:0.000605883 m^3 Density:7900 kg/m^3 Weight:46.9075 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\movable cylinder head support.SLDPRT Jun 29 23:17:51 2015
Fillet1 	Solid Body	Mass:0.553949 kg Volume:7.01202e-005 m^3 Density:7900 kg/m^3 Weight:5.4287 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\support block for the stand clearance.SLDPRT Jun 29 13:37:50 2015
Fillet3 	Solid Body	Mass:10.9933 kg Volume:0.00139155 m^3 Density:7900 kg/m^3 Weight:107.734 N	E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Parts\valve lapping mechanism mount and stand.SLDPRT Jul 01 09:02:48 2015
<L_MdInf_ShlBd_Nm/>	<L_MdIn_ShlBd_Fr/>	<L_MdInf_ShlBd_VolProp/>	<L_MdIn_ShlBd_DtMd/>
<L_MdInf_CpBd_Nm/>	<L_MdInf_CompBd_Props/>		
<L_MdInf_BmBd_Nm/>	<L_MdIn_BmBd_Fr/>	<L_MdInf_BmBd_VolProp/>	<L_MdIn_BmBd_DtMd/>

Table 29: model information of machine bed assembly

Study properties

Study name	Machine bed assembly
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SolidWorks document (E:\Work\Documents\CINEC\Final Year Project\Parts and assembly of valve lapping machine\Assembly\Bed assembly)

Table 30: study properties of machine bed assembly

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/mm^2 (MPa)

Table 31: units for machine bed assembly simulation

Material properties

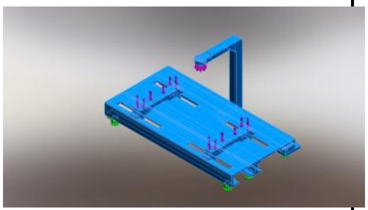
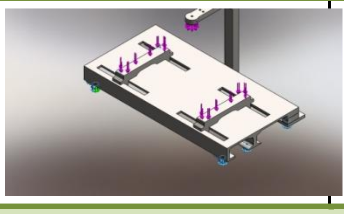
Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Yield strength: **351.571 N/mm^2** Tensile strength: **420.507 N/mm^2** Elastic modulus: **200000 N/mm^2** Poisson's ratio: **0.29** Mass density: **7900 g/cm^3** Shear modulus: **77000 N/mm^2** Thermal expansion coefficient: **1.5e-005 /Kelvin**	**SolidBody1(Fillet7)(bed-1), SolidBody 2(Boss-Extrude6[1])(bed-1), SolidBody 3(Boss-Extrude6[2])(bed-1), SolidBody1(Fillet5)(movable cylinder head support-1), SolidBody1(Fillet5)(movable cylinder head support-2), SolidBody1(Fillet1)(support block for the stand clearance-1), SolidBody1(Fillet3)(valve lapping mechanism mount and stand-1)**
Curve Data:N/A		

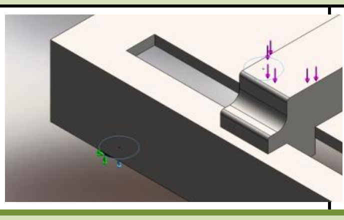
Table 32: material properties of machine bed assembly

Loads and fixtures

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **6 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-0.00489616	349.133	-0.0881701	349.133
Reaction Moment(N.m)	0	0	0	0

Fixture name	Fixture Image	Fixture Details
Fixed-2		**Entities:** **2 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	211.918	146.563	-17.4906	258.256
Reaction Moment(N.m)	0	0	0	0

Table 33: fixtures of machine bed assembly

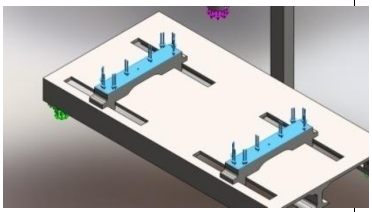
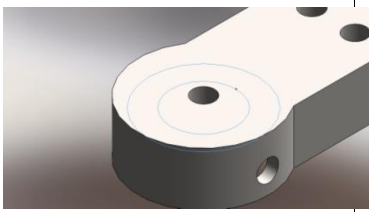
Load name	Load Image	Load Details
Force-1		**Entities:** **2 face(s)** **Type:** **Apply normal force** **Value:** **35 kgf**
Force-2		**Entities:** **1 face(s)** **Type:** **Apply normal force** **Value:** **-0.613 kgf**

Table 34: loads of machine bed assembly

Mesh information

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	26.2679 mm
Tolerance	1.3134 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Total Nodes	22131
Total Elements	11127
Maximum Aspect Ratio	23.563
% of elements with Aspect Ratio < 3	78.1
% of elements with Aspect Ratio > 10	0.494
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:05
Computer name:	AYO-PC

Table 35: mesh information of machine bed assembly

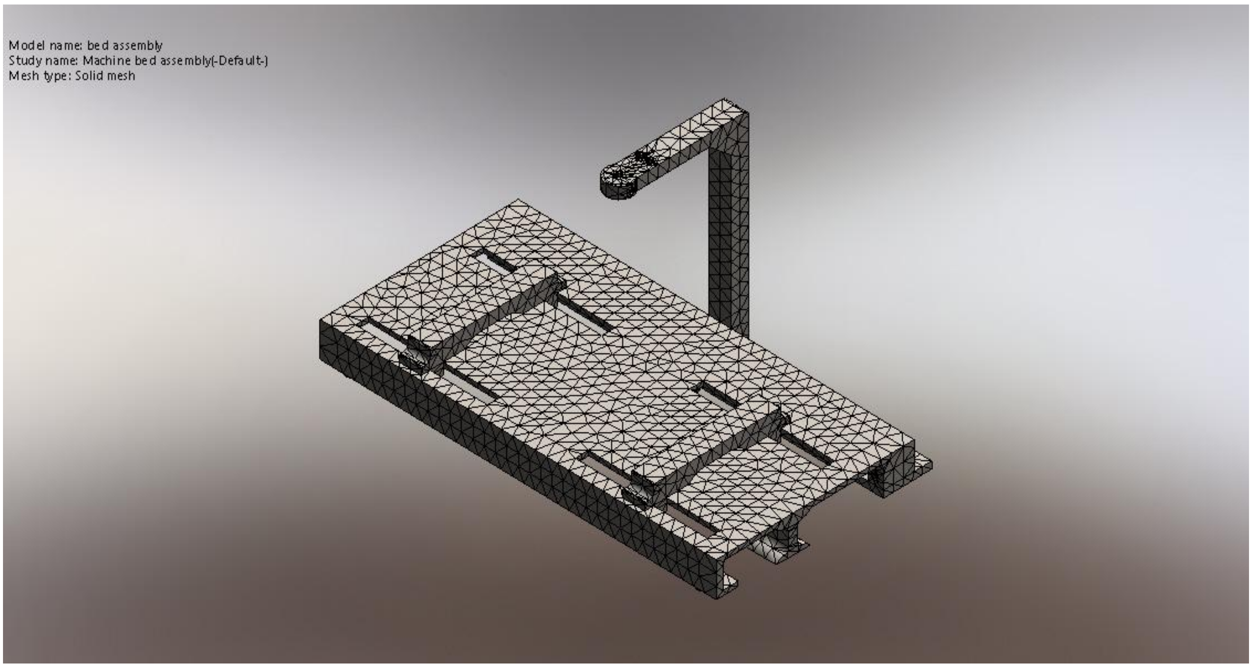


Figure 36: solid mesh of machine bed assembly

Contact information

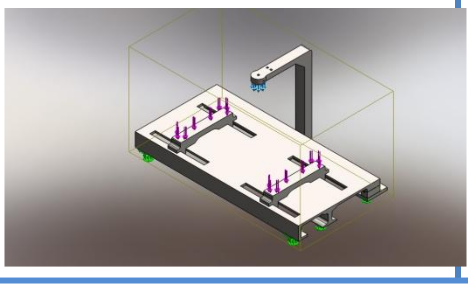
Contact	Contact Image	Contact Properties
Global Contact		**Type:** **Bonded** **Components:** **1component (s)** **Options:** **Compatible mesh**

Table 37: contact information of machine bed assembly

Resultant forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00489616	349.133	-0.0881701	349.133

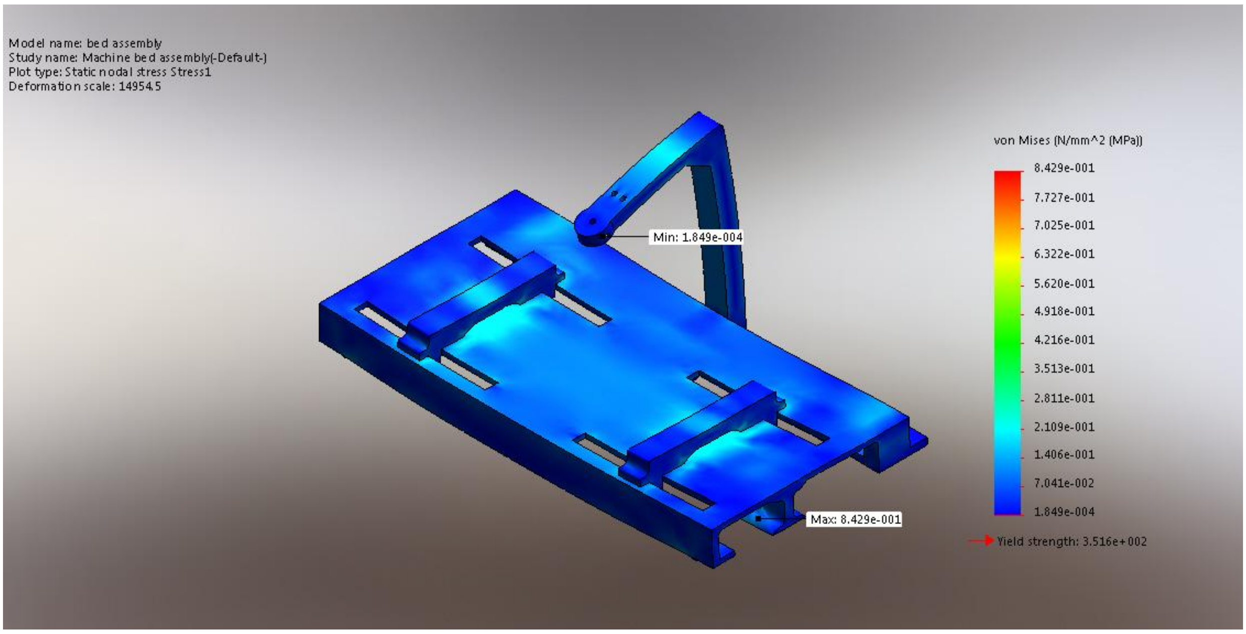
Table 38: reaction forces of machine bed assembly

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Table 38: reaction moments of machine bed assembly

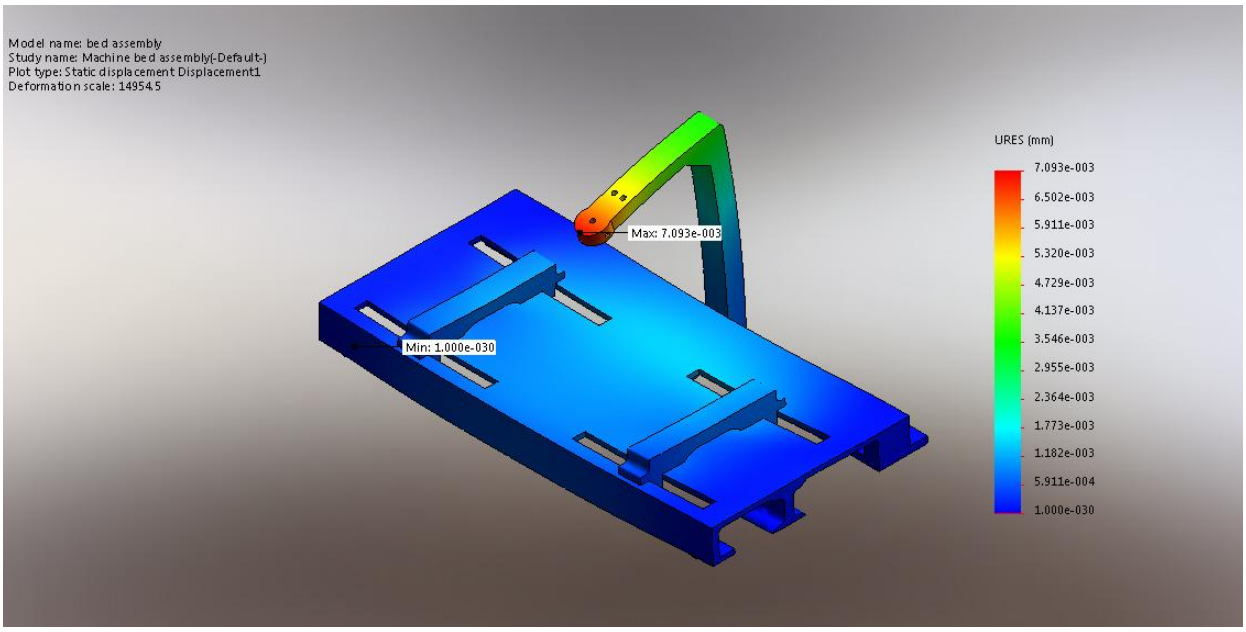
Study results

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000184927 N/mm^2 (MPa) Node: 18640	0.842925 N/mm^2 (MPa) Node: 16084



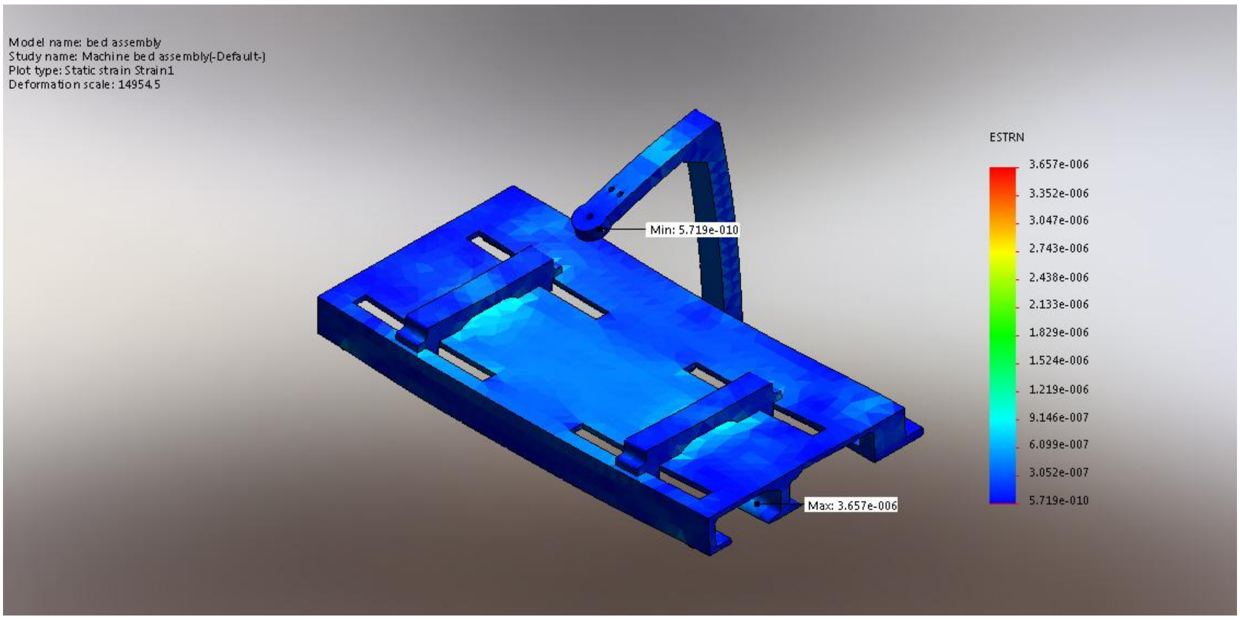
bed assembly-Machine bed assembly-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 763	0.00709276 mm Node: 18651



bed assembly-Machine bed assembly-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	5.71887e-010 Element: 10498	3.65668e-006 Element: 7883



bed assembly-Machine bed assembly-Strain-Strain1

5 ANALYSIS AND DISCUSSION OF RESULTS

Design of valve lapping machine for internal combustion engines was a huge task to undergo since the designing has to begin from scratch. In this section the problems and challenges like alterations made to the design, failure of some structures when analyzed, problems with designing the valve lapping mechanism, ideas that came along while doing the design and the integrity of designs are discussed.

After the project for design of valve lapping machine for internal combustion engines was approved the first challenge was to combine the existing calve lapping power tool and hand motion used when doing that same process by a valve lapping stick. The first design for calve lapping mechanism was a part that has a motor for valve lapping task and wheel to operate manually in order to move the motor vertically adapting the hand motion. Rack and pinion was used to convert circular motion of wheel to a vertical motion. Problem with this design was that since employing a rack and pinion made it a little hard for the wheel to operate and in order lap a valve, it needs a sensible system that minimizes the damage to valves, this way that goal could not be achieved. The implemented design was finalized after considering two other designs for valve lapping mechanism. The existing design of calve lapping mechanism was inspired by the valve operating mechanism of a internal combustion engine where valves open and close by a system implemented with valve springs, pushrods, rocker arms and a cam shaft.

After finalizing the valve lapping mechanism, the next task was to design a structure to hold the valve lapping mechanism. Machine bed and machine stand was designed in this stage. Design of machine bed was quite easy while designing machine stand was very challenging. First design for machine stand included two adjustable arms to adjust vertical height from valve lapping mechanism to cylinder head and to adjust horizontal distance without moving the cylinder head. But that design was too heavy and little complex to be proceeded with. After giving much thought, a design of a solid machine stand was done and the horizontal adjustment problem was addressed by making the machine bed wider and vertical adjustment problem was solved by designing a 40mm extension piece.

Simulations were done after finishing initial designs and structural integrity of machine stand was good and capable of handling the necessary load. But machine bed and cylinder head supports showed weaknesses. Stress concentration of some places were too much and showed a visible deformation loaded. These simulations led to new designs of machine bed and cylinder head supports. Following figures(figures 37, 38 and 39) shows simulations of stress, strain and displacement of initial designs of bed and cylinder head supports.

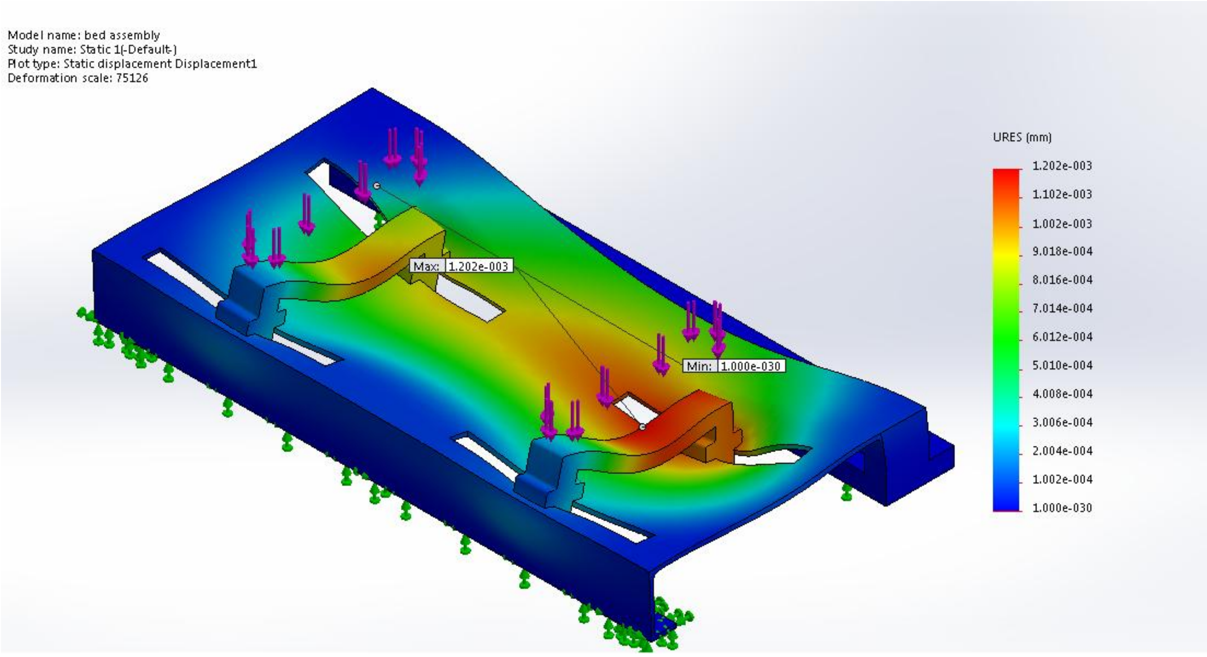


Figure 37: displacement simulation of initial design of machine bed

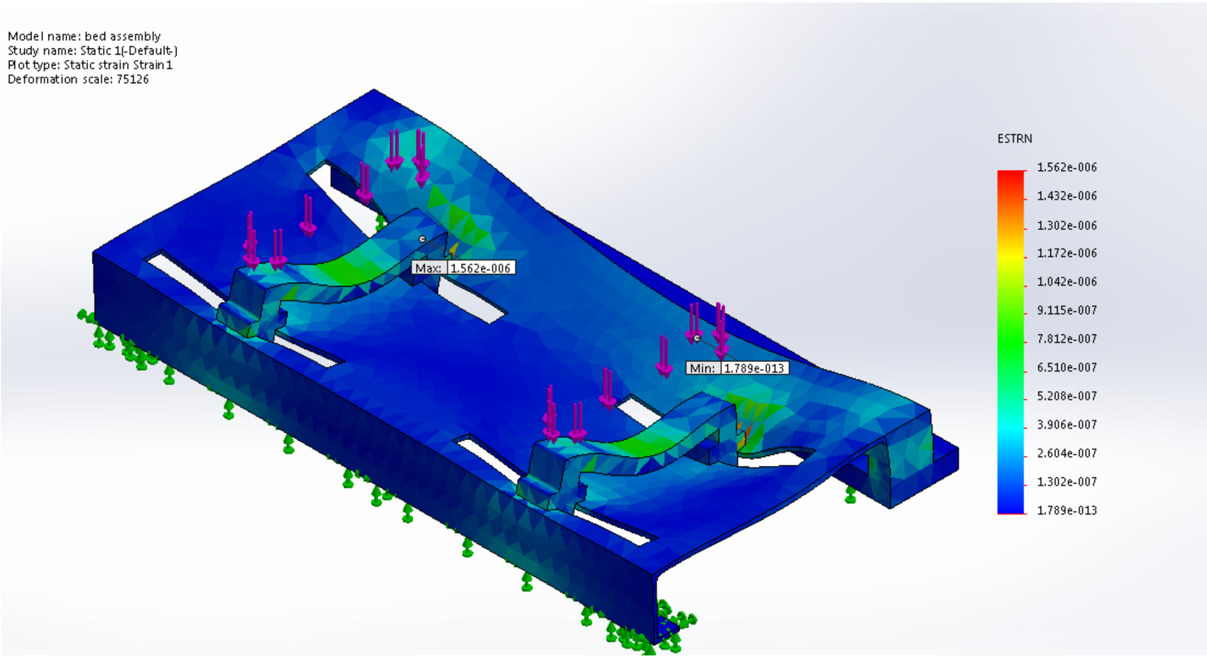


Figure 38: strain simulation of initial design of machine bed

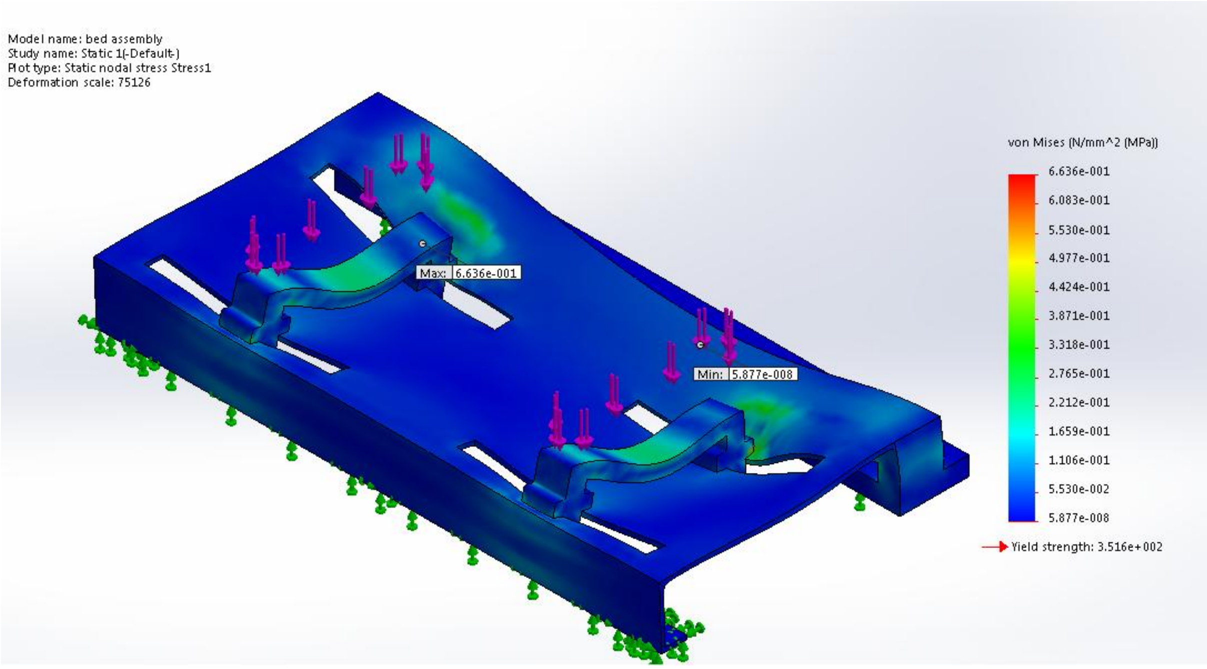


Figure 39: stress simulation of initial design of machine bed

The vertical movement of valve lapping mechanism is done using a tension spring(function of tension spring is explained in the text). Calculations showed that the initial design of tension spring has a very high spring coefficient which cannot be operated using the selected motor and could not reach the expected deformed status(15mm). Figure 40 shows the initial design of tension spring.

Figure 40: initial design of tension spring

New design of the tension spring was done by considering all necessary factors like the torque range of motor, deformation range of tension spring and height of the spring. After finishing the design of the tension spring, calculations were done in order to make sure that the motor can handle the torque. These calculations included tension spring, cam and 20RPM DC motor. According to the calculations, the maximum torque that has to be handled by the motor is 9.999kg.cm and the motor is capable of handling a torque range between 10-19kg.cm .

Design of valve holding piece was the most hard task. This design is an answer to the most common problem in valve lapping process. The problem is that the valve falls off from the plastic tube of power tool and also falls off from valve lapping stick. There were many ideas for this design and not one of them was simple and easy. So after discarding many designs, the final choice was to analyze few hundred valves used in different vehicle brands and categorize them by valve stem diameter. This way 5 valve holding pieces of different sizes were designed that will be suitable for any commercial automobile engine valve.

After finalizing all the designs, major parts of the machine were simulated.

6 CONCLUSION

- The problem of holding engine valves was solved by designing valve holding pieces.
- Valve lapping mechanism was implemented replacing manual labor.
- Cylinder head supports has eased the moving of cylinder heads horizontally.
- Vertical height adjustment problem was solved by introducing 40mm extension piece.
- 20 RPM DC motor is able to handle the torque necessary to valve lapping process.
- Valve lapping mechanism was designed as a assembly of several parts easing any maintenance to the machine.
- Structural integrity of machine bed, machine stand, cylinder head supports, tension spring and cam against loads and torques were fine and the designs are successful.
- Weight of the whole machine is somewhat higher than anticipated.
- All the designs could be completed successfully.
- To observe the functionality and the efficiency of the valve lapping machine, it is needed to be developed. This task could not be achieved.

7 ACKNOWLEDGEMENT

First of all I would like to thank my parents for providing me with everything necessary and helping me throughout my life and for the guidance.

I would like to express my sincere gratitude and appreciation to my project supervisor, Mr. Kapila Elkaduwe for his valuable guidance and support.

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Last but not least, I take this opportunity to express my gratitude to university of Wolverhampton for providing this priceless education and I would like to thank all my lecturers and administrative staff of CINEC campus, engineering and technology department for their support.

8 REFERENCES

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[2] Figure of lapped and non-lapped valves available at http://s858.photobucket.com/user/1fuzzydunlop1/media/Valve%20Lapping/IMGP3839-1.jpg.html

[3] Figure of a valve seat surface available at http://www.mre-books.com/ford/engines/images/chamber_large_valve.JPG

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