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Research Paper

Design and development of automatic cold forging machine: Perspective of industry 4.0

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ABSTRACT
Inthecurrentsituation,therearevariousProductionIndustrieswherethecoldforgingoperations are done on a large scale as well as small scale, but there are various problems associated with these cold forging machines. To overcome the problems there is a need for a machine which can able to do the operations more conveniently. The research and innovation are required in a machine which can maximize the productivity by using the latest technologies, such as internet of things (IoT), Artificial intelligence, Deep machine learning and Cloud data. After the critical literature survey, it is been found that there is no such machine developed, these lead to the innovation on the Design and Development of Voice Operated Forging Machine. Voiceoperated machine will consist of Chatterbot which takes input from an operator in verbal form and sends data to the microcontroller. Microcontroller consists of a pre-set logical program in it, according to which machine produces desired output at theend.
After the development of automatic forging machine, the expected outcomes are minimizationin rejection rate, to obtain maximum accuracy, increase in production rate, preventing accidents, industry digitalization and proper utilization of resources. This system will help workers as well as the owner of industries to create a better man and machine relationship and to have a proper workingenvironment.
Keywords: Fully Automatic Forging, Voice Operated, chatterbot, microcontroller, industry digitalization.

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I. INTRODUCTION

1.1 Industry4.0

The world around us has been changing on a daily basis along with the development of human civilization. Therefore, technical and technological developments of production are changing as well. Industry 4.0 is a model that shows how industrial production follows the latest developments and changes over time [3]. Thereby, the man, machine and the production itself constitute the force in one intelligent and independent network.

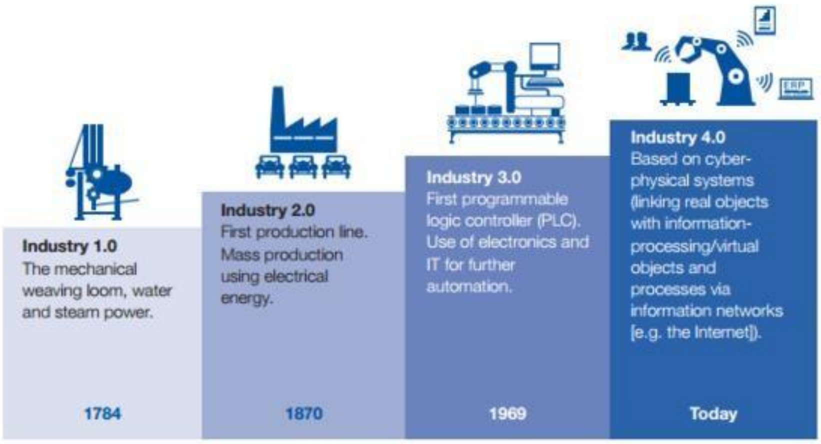


Fig 1. The four stages of the Industrial Revolution

The term “Industry 4.0” means the smart factory in which smart digital devices arenetworked and they communicate with raw materials, semi-finished products, products, machines, tools, robots and men [5]. This industry is characterized by flexibility, efficient use of resources and integration of customers and business partners in the business process [4]. In a networked factory, robots and men are becoming equal partners, having a higher degree of artificial intelligence in relationtothepreviousgenerationofrobots.Thesensesensorsthatrespondtotheslightestsignal are embedded into the robots, which enables the cooperation between robots andworkers [8].

1.2 Enabling Technologies of Industry4.0

1.2.1 Internet of Things (IoT)

IoT systems allow users to achieve deeper automation, analysis, and integration within a system. They improve the reach of these areas and their accuracy. IoT utilizes existing and emerging technology for sensing, networking, and robotics [10,11].

1.2.2 CloudStorage

Cloud storage is a service that maintains data, manages and backup remotely and made data availabletousersoverthenetwork(viatheinternet).Thecloudstorageisdesignedinsuchaway that it is cost-effective, autonomic computable, available, control, efficient [11]. Access to the applicationcanbedoneanytime,anywhereprovidedthattheyshouldbeconnectedtotheinternet.

1.2.3 ArtificialIntelligence

Artificial Intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in a similar manner the intelligent humans think [12]. AI is accomplished by studying how human brain thinks, and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems [13].

1.3 ForgingMachine

Forging is a metalworking process in which compressive force is applied on the workpiece to get the desired shape and size with the use of dies and tools. It is one of the oldest metalworking processes in which forging is performed by hammer and anvil.
Usually forging is the process of shaping the workpiece it is done by two methods: -

Fig. 2: -Hot forging

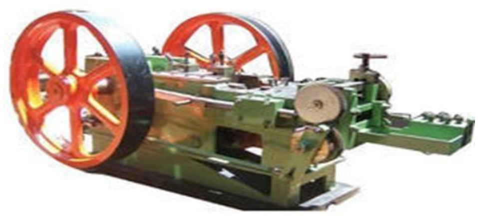


Fig. 3: - Cold forging

“The project aims to eliminate the manual method of Cold Forging into the fully automated machine.”

II. LITERATURE SURVEY

2.1 Problems Associated with Traditional Cold ForgingMachine

2.1.1 High skilledoperator:

As the traditional forging machine is manually operated, the accuracy of the job is completely dependentontheskilloftheoperator.Toproduceaqualityproduct,highskilledandexperienced operators are required, these skilled workers are paid with high incentives and wages which increases the production cost. The industry doesn’t afford to lose their experienced and skilled operator, because recruits require vigorous training to develop a skill which is a time-consuming process and also affects productivity. The above factor leads to rising per capitalcost.

2.1.2 Production risk and Accidents inIndustry:

There is high risk and possibility of accidents while performing a forging operation. As compressive stresses are involved and the operator is very close to the machine any slip or improper working method can cause an accident, which will be fatal for the operator.

2.1.3 LowEfficiency:

After the detailed industrial survey in Raj Surgical it was found that, to complete oneoperation approximately 5 minutes are required, which affects productivity and makes operation time- consuming. The traditional forging machines are manually operated, hence various factors are considered such as human endurance and fatigue, these lead to improper utilization of resources and loss ofenergy.

2.1.4 The higher rejection rate ofproducts:

The manual operations involve various human-related errors called parallax error, which cannotbecontrolledandvariesfromhumantohuman.Theseerrorsinforgingoperationscausea lack of accuracy and hence a large number of products are rejected while testing. During the industrial survey, it was found that approximately 2 products out of 10 get rejected fromselected the sample. The higher rejection rate causes higher energy loss because rejected parts require rework which causes loss of time andcapital.

2.2 Voice Operated Machine

The future of manufacturing depends on better interaction between operators and machines.

Artificial intelligence industry 4.0 addresses the challenges of training new workers and attracting the next generation of machinists [3].

Makino, in collaboration with their digital technology partner iTSpeeX LLC, is the first machine tool OEM to introduce a voice-enabled assistant for machine tool operation. ATHENA is the world's first voice-enabled, interoperable virtual assistant specifically designed for machine tool control and overall operation [18]. With simple commands and little training, operators of all skill levels can interact with ATHENA to more efficiently operate a machine tool. With simple commands and little training, operators of all skill levels can interact with ATHENA. Using ATHENA's voice interaction software, machine operators have access to setup, instructions and inspection diagrams—right at the machine.

III. RESEARCH GAPS

3.1 Traditional cold forging machines V/C Automatic ColdForging Machines

Forging is one of the oldest metalworking processes. Traditionally, forging is performed by a smith using hammer and anvil, though introducing water power to the production and working ofironinthe12thcenturyallowedtheuseofalarge triphammer orpowerhammersthatincreased the amount and size of iron that could be produced and forged. The smithy has evolved over centuries to become a facility with engineered processes, production equipment, tooling, raw materials and products to meet the demands ofcustomers.

In modern times, industrial forging is done either with presses or with hammers powered by compressedair,electricityandhydraulics.Thesehammersmayhavereciprocatingweightsinthe thousands. It also eliminates the weld mates required for operations and also reduces the labor cost. The testing and inspection time also get reduces which helps in maximizing the operation time. The production rate also gets increases which lead to completing before or during delivery time.

3.2 Automatic cold forging machines V/S Voice operated cold forgingmachines.

Automatic cold forging machining involves passing a lump of metal (or a billet as it's known inthetrade)intoamachinetool.Themachinehassensorsbuiltintopositionandguidesthebillet. It is fully motorized and is controlled by a computer panel. The operator has to feed the data to the computer by typing the command for machining. The operator has to be physically present near the machine for changing the commands (like the number of operations required, length of the job, pressing force to be applied, etc.). In case of hazard or accidents, the machine has to be stopped manually by pressing the force stopbutton.

Voice operated cold forging machine is the future of manufacturing industries, they are fully automatedandworksonIoT.Thesemachinescanbeoperatedfromlongdistancethroughasingle lab, which can control the operation required at a particular time. The Operator can change the specification of the operations from a single lab by just giving the voice command. Due to Artificial Intelligence present in the machine, its things on the command given by the operator and gives the desiredoutput.

3.3 Differentiate Between Traditional, Automatic and Voice operated cold forgingMachines.

Parameters	Traditional forging machines	Automatic forging machines	Voice operated forging machines
Range	It has to perform the operation at the workshop.	Commands are feed through a computer screen at workshop or computer lab.	Voice command can be given through long-distance as well as from computer lab.
Control	Operation is controlled manually.	Manually and by feeding commands.	Operation is controlled by the voice assistant.
Human efforts	High.	Moderate.	Less.
Production rate	Less.	Medium.	More suitable for mass production.
Rejection rate	High.	Less as there is some interaction of human.	Very less rejection as it is fully automated.
Skilled operator	Highly skilled operator required.	less-skilled operator required as compared to traditional machine.	less-skilled operator required as compared to a traditional and automatic machine.

IV. RESEARCH PROBLEMS AND OBJECTIVES

4.1 ResearchProblems

To have detailed information on problems associated with forging operation, the industrial survey was carried out at Raj Surgical, Panvel, India. From the survey, we have found problems associated with cold forging machines which they are using in their productionsystem. These problems are asfollows:

1. The higher rejection rate of finalproducts.
2. Lack of accuracy during forging operation.
3. Excess energy requirement due to higher rejection ofparts.
4. Trained manpower to handle forging machine.
5. Hence 100% inspection of the component is to berequired.
6. The accuracy of the components produce is dependent on the efficiency of theoperator.

4.2 Objectives

1. The main objective of this project is to eliminate the manual method of forging into automatic forging machine with the voiceassistant.
2. To prevent accidents with the help ofsensors.
3. To minimize the rejection rate and financial expenditure spent onlabor.
4. To obtain good surface finish as compared to the manualmethod.
5. Automation with minimummanpower.

V. MARKET SURVEY

5.1 For Product

As the Industry required a U-clamp manufacturing machine, we have done the market surveyfordifferentUclampmanufacturingmachines.FollowingaresomeProductavailable in themarket:-

Sr. No.	Product name	Price
1.	ZHENHUAN Automatic U-clamp making machine	5,42,000
2.	HANIXN U-clamp making machine	1,30,000
3.	DO-FIX U-clamp making machine	69,525
4.	Jayson Clamp press machine	62,890
5.	Prusa press machine	61,250

ThereарenumberofU-clampmanufacturingmachineswhichcosabove 60,000.Henceour "Voiceoperatedcoldforgingmachine"whichistheprincipleprojectcostjust 17,850- 18,000 approximately.

5.2 For various partsused

Different parts used in the project is selected depending upon its requirement and its market pricing by visiting different places in Grant Road and online search as well.

Following are the list of parts with their pricing:-

Sr.No.	Product Name	Price
1.	Actuator(1500N)	₹ 6,850-₹ 5,000
2.	Nodemcu ESP8266	₹ 350-₹ 300
3.	Motor driver	₹ 250-₹ 150
4.	Die	₹ 7000-₹ 2500

VI. SPECIFICATIONS OF MACHINECOMPONENTS

6.1. Actuator

A linear actuator is a device which converts electrical energy into mechanical energy to create motion in a straight line, contrasted with the circular motion of an electronic motor.

Fig 4: - Actuator

A selected Actuator Specification is given below: -

Parameters	Specifications
Input	12V
Load	1500N
Stroke sped	1mm/sec
Stroke length	400mm
House material	Aluminum

6.2 Chatterbot

Chatterbotisadevicewhichsimulateshumanconversationthroughvoicecommandsusing AI. It is placed at the top left side of the panel; the panel is positioned on the upper side of the frame. The elements of CHATTERBOT and their position are asfollows:

1] Microphone: A microphone is a device that captures audio by converting sound waves into an electrical signal. They are placed at both ends of CHATTERBOT.

2] Voice to text converter: It is used to convert any voice into plain text. The position of the converter is placed between twomicrophones.

Fig 5: - Chatterbot

6.3 NodeMCUESP8266

NodeMCU is an open-source microcontroller which is used for prototype or build for IoT product. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems. It takes the input from chatterbot and after processing gives output to Motor driver.

Fig 6: -NodeMCU ESP8266

Following are the specifications NodeMCU: -

Parameters	Specification
Operating Voltage	3.3V
Digital I/O pins	12
Built in Wi-Fi	2.4GHz
Clock Speed	80MHz/160MHz
Flash	4mb
Length	64.3mm
Width	29.1mm

6.4 MotorDriver

L293D Motor Driver is a typical Motor driver which allows DC motor to drive on either direction.Itisusedtostartandstopthemotorandtogivedirectionalstability.Thepositionofthe motor driver is between Chatterbot andNodemcu.

Fig 7: - Motor driver

Following are the specifications Motor driver: -

Specifications	Parameters
Model No.	L293D
Operating Voltage	5V-36V
No. of motor control	2
Current supplied	600mA
Weight	10 grams

VII. WORKING

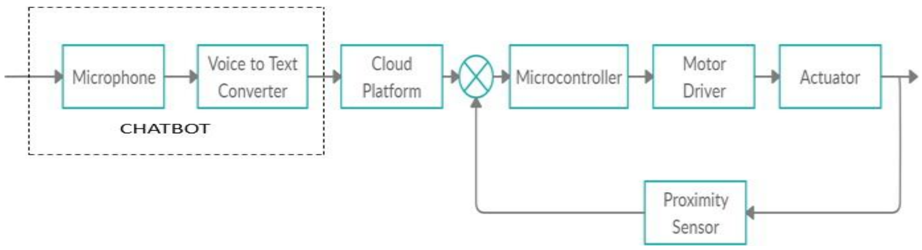


Fig 8: - Architecture diagram of the system

An architecture diagram of control system consists of various electronic devices and sensors that we are using in the control system. Though this machine is voice-operated, the first input will pass from Chatterbot which then it will pass through voice detector where the voice will be detected and from voice detector it will transfer the signal from voice to text converter. Voice to text converter is used to convert voice signal into a text signal this is done because microcontroller cannot sense the signal in a voice form, so it is necessary to convert signal in the form that microcontroller can read and gives output depending on it.

With the help of the Cloud platform, the voice command can be given tomicrocontroller from long distance. The operator can give the voice command through mobile, computer and chatterbot(installatdifferentstations)fromanywheretoperformoperations.Thevoicecommand given from these devices is transferred to the cloud and it saves. The cloud then delivers the data saved from the operator and delivers it to themicrocontroller.

There are two IR sensors which are connected in parallel whose output is taken to the summing point. It controls the direction of the actuator, the ramming length is controlled using this sensor. All signals are taken to the microcontroller, the microcontroller consists of reset program in it, according to which it runs the further operations. From microcontroller the signal goes through the motor driver, it is used to control the speed as well as the direction of the motor. The motor driver is directly connected to the actuator, the actuator is a device which gives output in mechanical form. The upper die connected to actuator moves downward and presses the workpiece in the required shape. When the lower sensor senses the lower die, the motor driver changes the direction of the motor and actuator moves upward. After the operation is done the feedback is taken to the summing point via feedback sensor for further improvement.

VIII. DESIGN OF MACHINE

8.1 Selection ofActuator:

8.1.1 Finding torque ofActuator:

$$T= \frac{0.5\square\square\square}{\square\square\square}$$

Work piece Material- Aluminum 1100.0, BHN 23 and Sy= 310 MPa.

Assume FOS= 3.5.

The shear stress Ţ is given by,

$$Ţ= \frac{0.5\square 310}{3.5}$$

Ţ= 44.28 MPa.

Torque T is given by,

$$T= \frac{\square}{16} X\ ŢX\ 10^3$$

$$T= \frac{\square}{16} X\ 44.28 X\ 10^3$$

T= 8.689 Nm = **9Nm.**

The required speed is 10 rpm, N= 10rpm.

Power P is given by,

$$P= \frac{2\square\square\square}{60}$$

$$P= \frac{2\square 10\square 9}{60}$$

P= 9.42 $\frac{\square\square}{\square}$

8.1.2 Finding pressing force required to press the workpiece:

Pressing force F is given by,

F= Perimeter X Shear stress X thickness of sheet. Perimeter = 10 mm

Thickness = 3 mm

Selection of material of sheet Aluminum- 1100.0, BHN = 23 and Shear stress = 40 MPa.

F= 10 X 42 X 3

F= 1260 N

From above calculations force required for pressing is 1260 N, hence actuator with pressing force 1500 N is selected.

8.2 Designing of critical element i.e.bolts.

8.2.1 Calculating primary forcesFp:

$Fp = \frac{\square}{\square}$

$Fp = \frac{1500}{4}$

Fp = 375N

$F = \frac{\square\square}{\square^2}$

$F = \frac{1500 \square 270}{270^2}$

F = 5.55 $\frac{\square}{\square\square}$

8.2.2 Secondary shear force Fs is given by,

Fs = F X r

Fs = 5.55 X 13.5

Fs = 75 N.

$Fr = \sqrt{\square\square^2 + {}^2 + 2\square\square\square\square \; \square \; \square\square\square(\square)}$

$Fr = \sqrt{375^2 + 75^2 + 2 \square 375 \square 75 \square \square\square\square(0)}$

Fr = 450N

Hence assume Fr = 500N. $\tau = 0.5\frac{\square\square\square}{\square\square\square}$

Sy = 350 MPa --- P.S.G 1.3

$\tau = \frac{0.5 \square 350}{4}$

τ = 43.75MPa.

$\tau = \frac{\square\square}{\square}$

Area A = 11.3 $\square\square^2$

Diameter d = 5 mm

hence select bolt size M5 --- P.S.G 5.42

From imperial relation dc = 0.84 X d

d = 5.95 mm = 6 mm.

IX. Specifications of machine parts

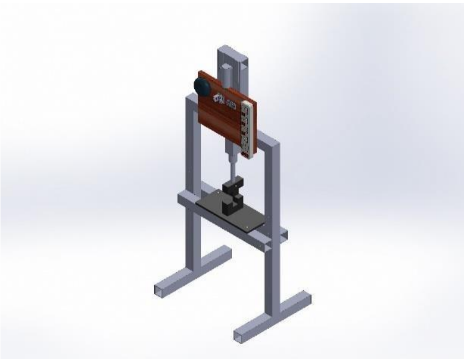


Fig 9: - Isometricview

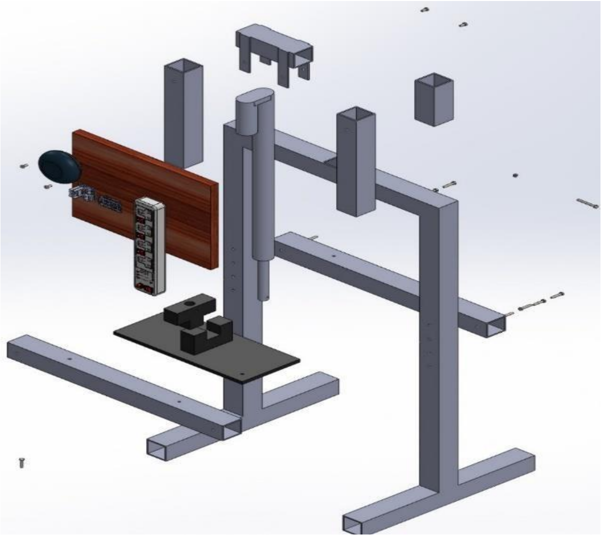


Fig 10: - Explodeview

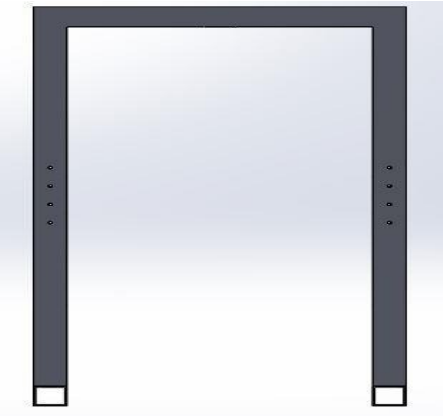


Fig 11: - Base frame

Base frame is the main body of the project model. The whole project lies on the base frame.
It gives the base support as well as stability for the pressing operation

Fig 12: - Bed

Bed is fitted with screw and nut on both side of the base frame. There are 4 stages on which bed can be clamped on the base frame. The bed is used for giving support to the die.

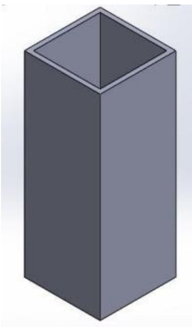


Fig 13: - Piston support

Piston support is used to guide the piston of the actuator for the operation. It is fitted in between on the upper channel of the base frame.

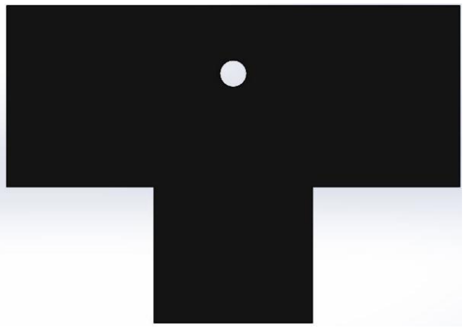


Fig 14: - Upper die

Upper die is used to give the required shape to the workpiece. It is clamped with bolt and screw on the piston of the actuator.

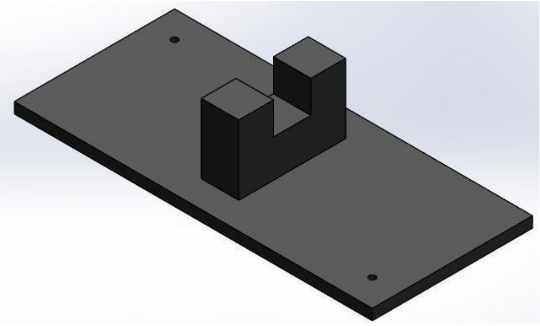


Fig 15: - Lower die

Thelowerdieisfixedonthebedswithnutsandbolts.Itgivesthestrongbaseforperforming pressing operation. The pressed workpiece can be removed from lower die after theoperation.

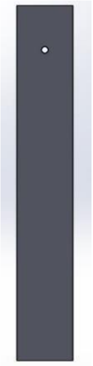


Fig 16: - Actuator support

An actuator support is used for supporting and giving stability to the actuator on the base frame. It is fitted on base frame; an actuator is placed in between the actuator support.

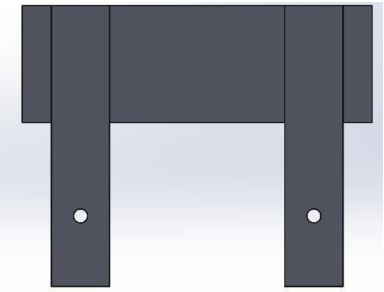


Fig 17: - Actuator Cap

Actuatorcapisusedtofixthelinearmotionofactuatorforgivingstabilityandfixedsupport while performing the operation. It is placed on the actuator support using nut and bolts. With the use of an actuator cap we can easily remove and place an actuator in themachine.

X. ANSYS REPORT

The static analysis on frame is done, while keeping some end conditions which are as follows,

1. Mesh type: SolidMesh
2. Mesher used: Standardmesh
3. Jacobian point: 4points
4. Elemental size: 27.8214mm
5. Tolerance:1.39107mm
6. Total nodes:133488
7. Total element:57072
8. Maximum aspect ratio:44.065

The software used for analysis is Solid works. Here the fixed support is given to the base of the base Frame on which the whole machine is standing. The Actuator applies the load on the lowerdie,sothedownwardforceisappliedonthelowerdieof1500N.Theresultobtainisshown below.

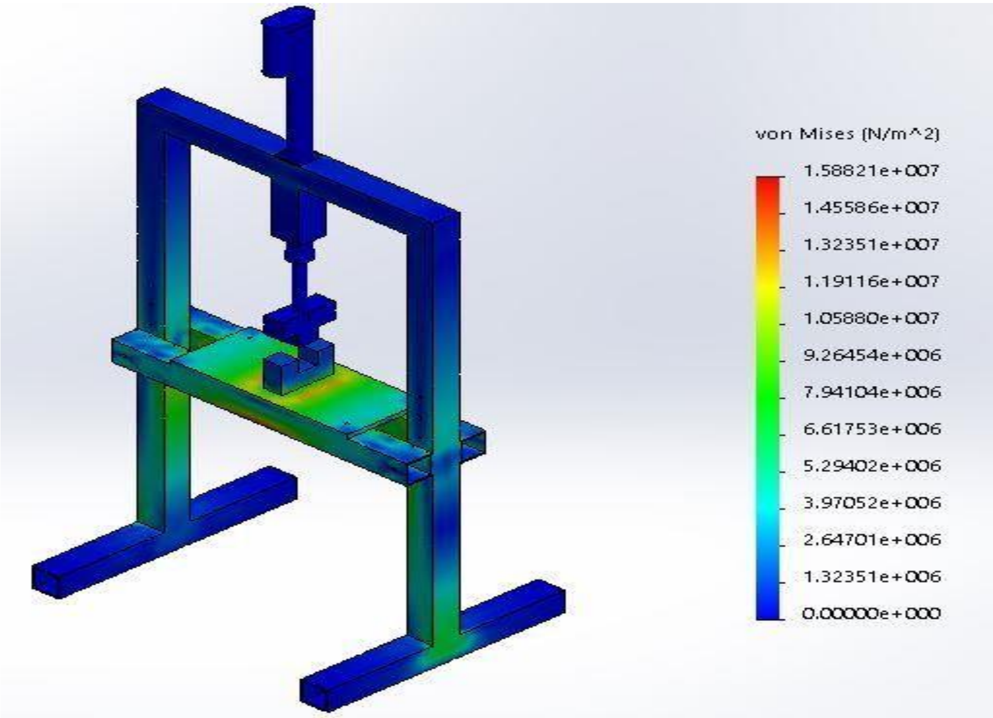


Fig 18: - Analysis of stress

The analysis shows the distribution of stress on a frame, it has been found that the design is safe under the stress condition. The maximum stress induced is on the bed which ranges between 3.9702e+006N/m^2.

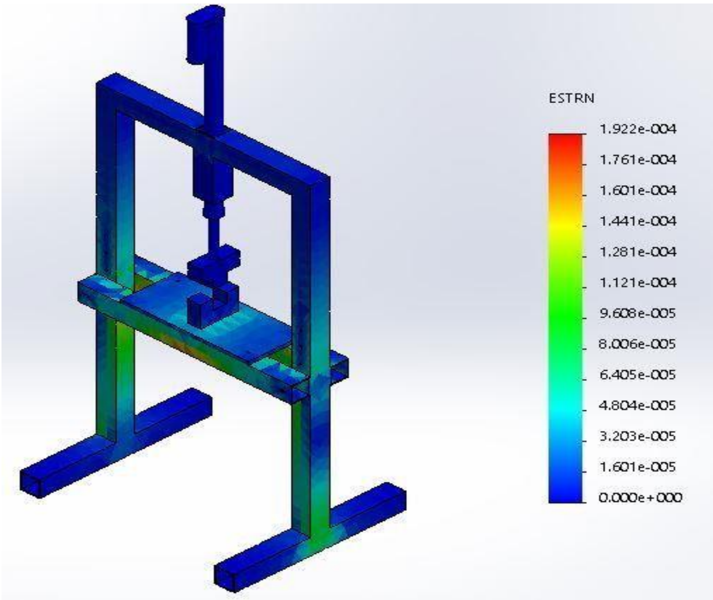


Fig 19: - Analysis of strain

The analysis shows the distribution of strain on a frame. The maximum stress induced is on the bed was found 1.922 x 10^4, it has been found that the design is safe under the strain condition.

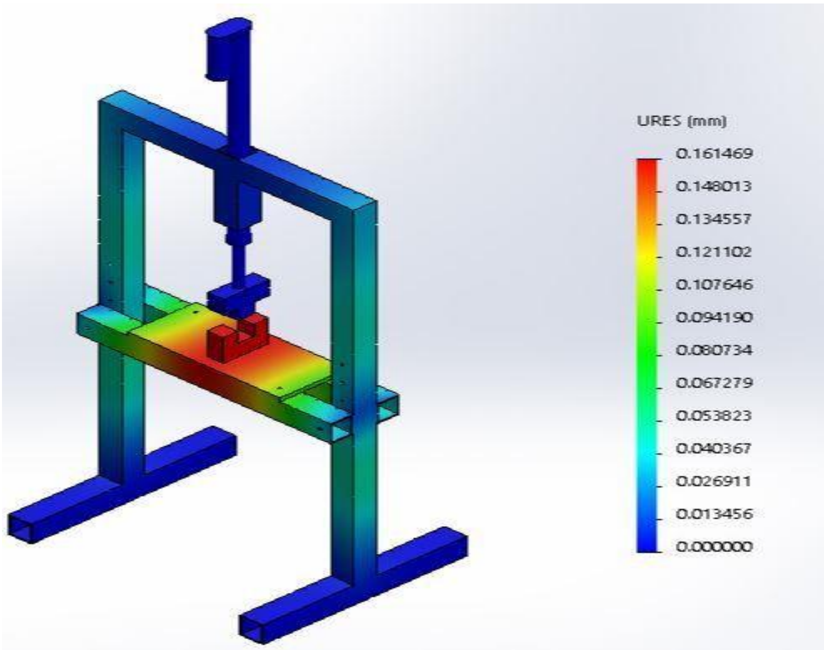
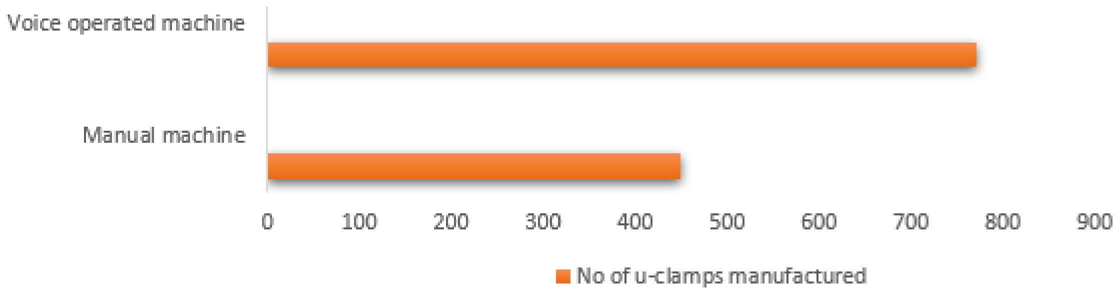


Fig 20: - Analysis of deformation

The third analysis is done to find the deformation in the frame, when stress is induces the maximum deformation of 0.1614mm is taken place at die and on a bed, which is negligible.

XI. CASE STUDY

Aftermanufacturingofthemachine,weinstallthemachineinRajsurgical.Thereweconducted 10 days of trail. After the trail, we came to know that the total time required for manufacturing 1 piece of U-clamp it takes 7 seconds. With the manual method, the time required was 12 seconds. The working hour of the company was 9 hours per day, and weekly 6 days. So the total manufacturing per day using the manual method was 450 pieces, and with the use of voice-operated,itwasincreasedby771pieces.Soduetotheautomaticmachine,theproductionrateper day increased by 321pieces.



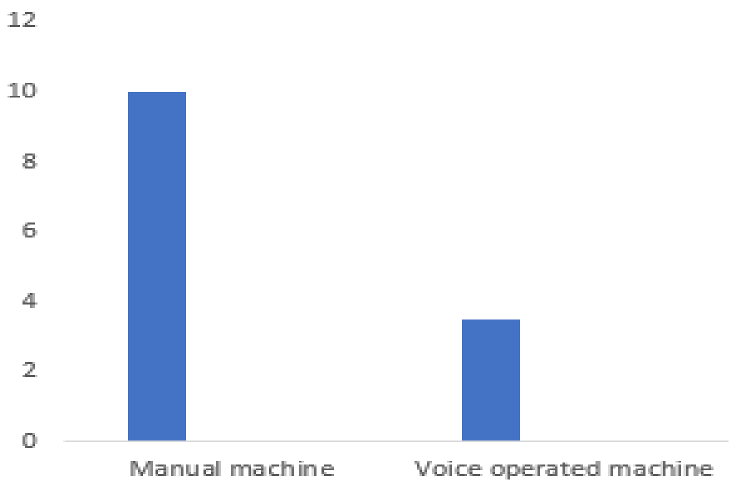
U-clamps manufactured per day

We also observed the rejection rate by comparing it with the manual method. The rejection rate for the manual method was 10%-15%. To overcome this problem, with the help of voice- operated machine we tested for it for 10 days and the result was obtain is given as follow:-

Days	U-clamps manufactured	U-clamps Rejected	Rejection rate
1	771	25	3.24%
2	770	22	2.85%
3	771	24	3.11%
4	768	25	3.24%
5	770	23	2.98%
6	771	22	2.85%
7	770	24	3.11%
8	770	21	2.72%
9	771	23	2.98%
10	770	25	3.24%

Rejection rate per day using Voice operated machine

From the above observation table, it is observed that the rejection rate using Voice operated machine has been decreased by 3.28%-3%, where it was 10%-15% for the Manually operated machine. So the Rejection rate has drastically decreased which helped in maximum utilizationof theresources.



Rejection rate obtained (in percentage)

Duetothenatureofthemanualpressmachineanditsfunctions,themostcommonworkplace injuries involve hands and fingers. Pinching and crushing incidents are common. Using a press requires workers to place and shift metal in the area under the ram or near the bending point, exposing them directly to a high-risk scenario. To overcome this problem, the selected actuator used in a voice-operated machine has comparatively less speed then manually operated machine. When the operator's hands come under the actuator, the sensors detect the hand and the actuator stops.Duetothis,thechancesofinjuriesinvolvehandsandfingershasbeenreduced,astheyget sufficient time for changing workpiece fromdie.

With the use of voice-operated cold forging machine, the working hours of labors have been significantly reduced. The skill required is minimum for the labor for doing an operation on Voice operated machine. Due to all these parameters, the Raj surgical had an effective product layout, which has a clean, healthy and safe working environment. This leads to having less expenditure on labor.

XII. RESULTS ANDDISCUSSION

The result obtained during the 10 days trial in Raj surgicalwas:-

1. this project has eliminated the manual method of forging into automatic forging machine with the voiceassistant.
2. The accidents have been significantly reduced with the help ofsensors.
3. The rejection rate has reduced to 3.28%-3%, where it was 10%-15% for the Manually operated machine. and the financial expenditure spent onlabor.
4. With the help of Voice operated cold forging machine the production rate per day increased by 321 pieces compare to the manual operatedmachine.
5. The effective product layout was established which has a clean, healthy and safe workingenvironment.

11.1 Advantages.

1. Optimum utilization ofresources
2. Smooth productflow
3. Efficient continuous real timetracking
4. Efficient energyconsumption
5. Autonomous controlling
6. Greater flexibility meeting high levelaccuracy
7. Detailed end to end product transparency in realtime
8. Secure and reliable backup system for every step-in cloudstorage

11.2 Limitations.

1. Strong networkinfrastructure
2. Continues need of electricity
3. Highly efficient cybersecurity
4. Effective plantlayout

XIII. Conclusion and future scope

13.1 Conclusions.

This project has met its objective to eliminate the manual method of forging into automatic forging machine with the voice assistant. We can do simple operations like pressing, punching which is very useful and helpful to do small works at Raj surgicals. We chose a simple compact frame machine which occupies less space which any skill operator can operate. We tested our project by pressing the sheet metal for manufacturing U-clamps.

13.2 Future scope.

With the help of this technology in future the following machines can be developed :-

1. Design and Development of Voice operated cuttingmachine.
2. Voice operated lathe and Milling machines.
3. Home automated machines like washing machine, vacuum cleaner, fridge, microwave,etc.

XIV. BILL OF MATERIAL

14.1 Directcost:

Sr.No.	Part Name	Quantity	Cost
1.	Actuator 1500N.	1	5400
2.	frame	1	4000
3.	Google mini	1	4000
4.	Die	1	2500
5.	Nodemcu	1	300
6.	Motor driver	1	200
7.	Cables and wires	12	350
	Total	**18**	**16750**

14.2 Indirect cost:

Sr.No.	Parameters	Cost
1.	Transportation cost	850
2.	Project report cost	250
	Total	**1100**

14.3 Totalcost:

Grand total = direct cost + indirect cost
= 16750 + 1100
∴**Grand total = 17850**

XV. APPENDIX

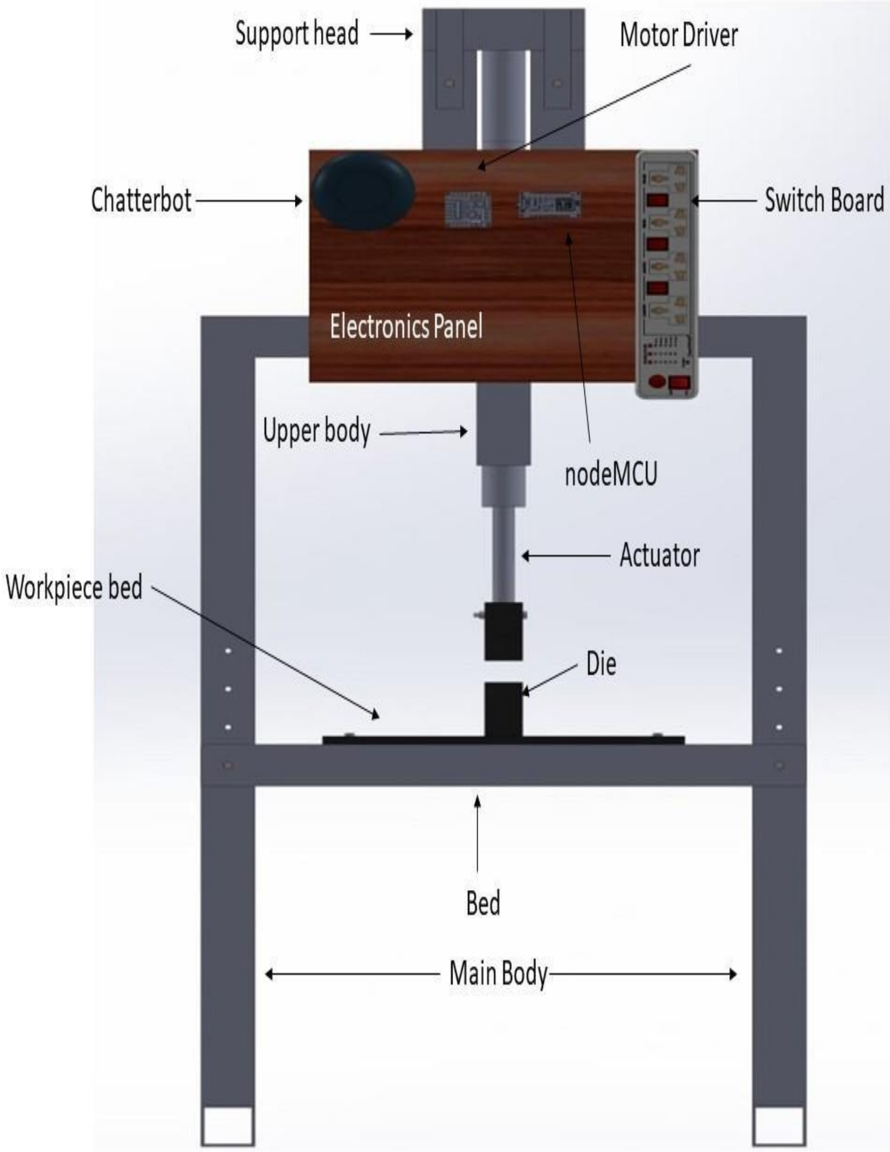


Fig 21: - Detail specification of project

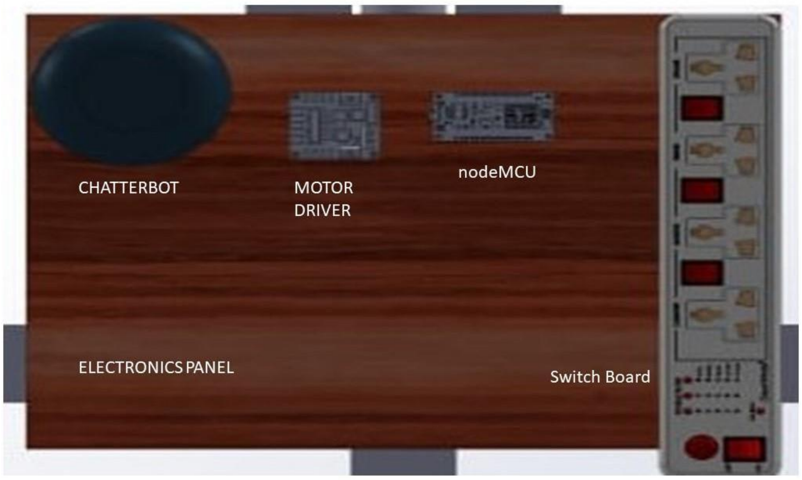


Fig 22: - Detail specification of electronic components

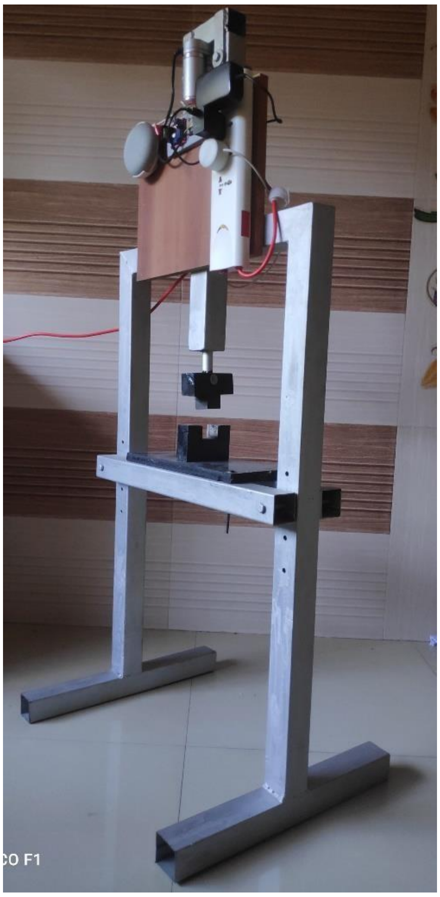


Fig 23: - Isometric view

Fig 24: - Front view

Fig 25: - Back view

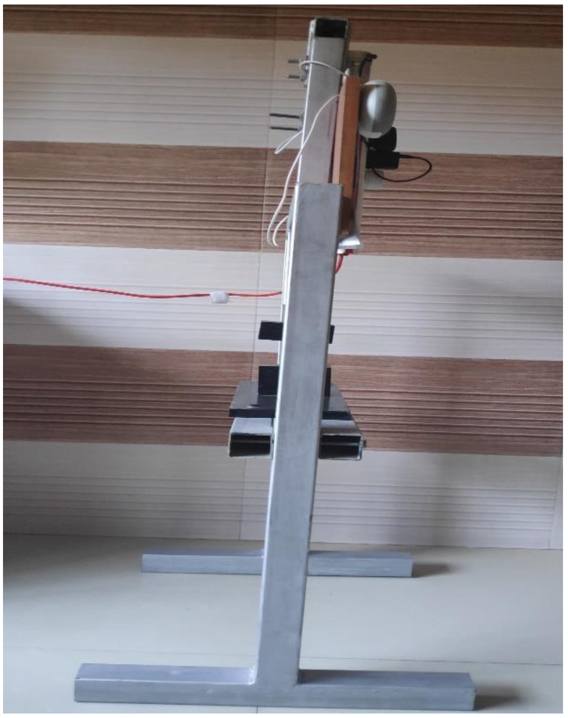


Fig 26: - Left hand view

Fig 27: - Right hand view

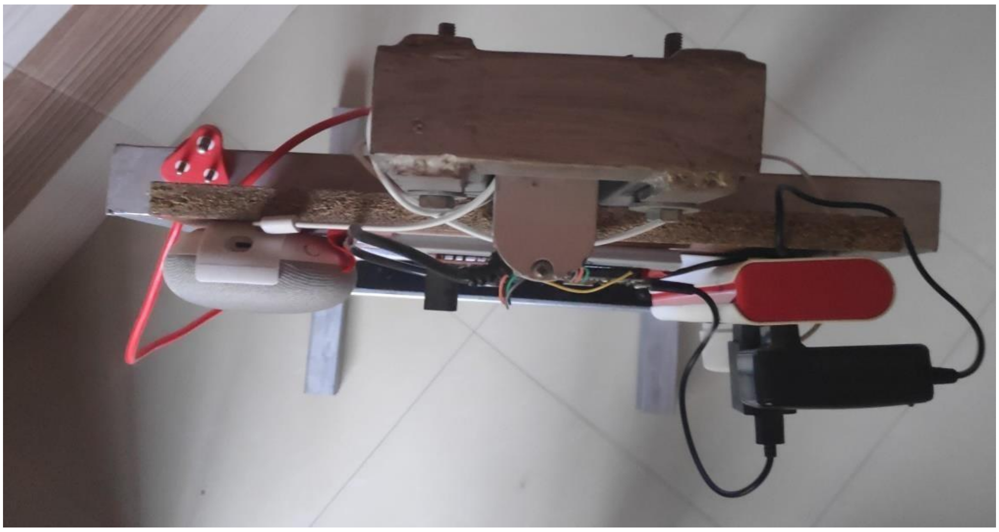


Fig 28: - Top view

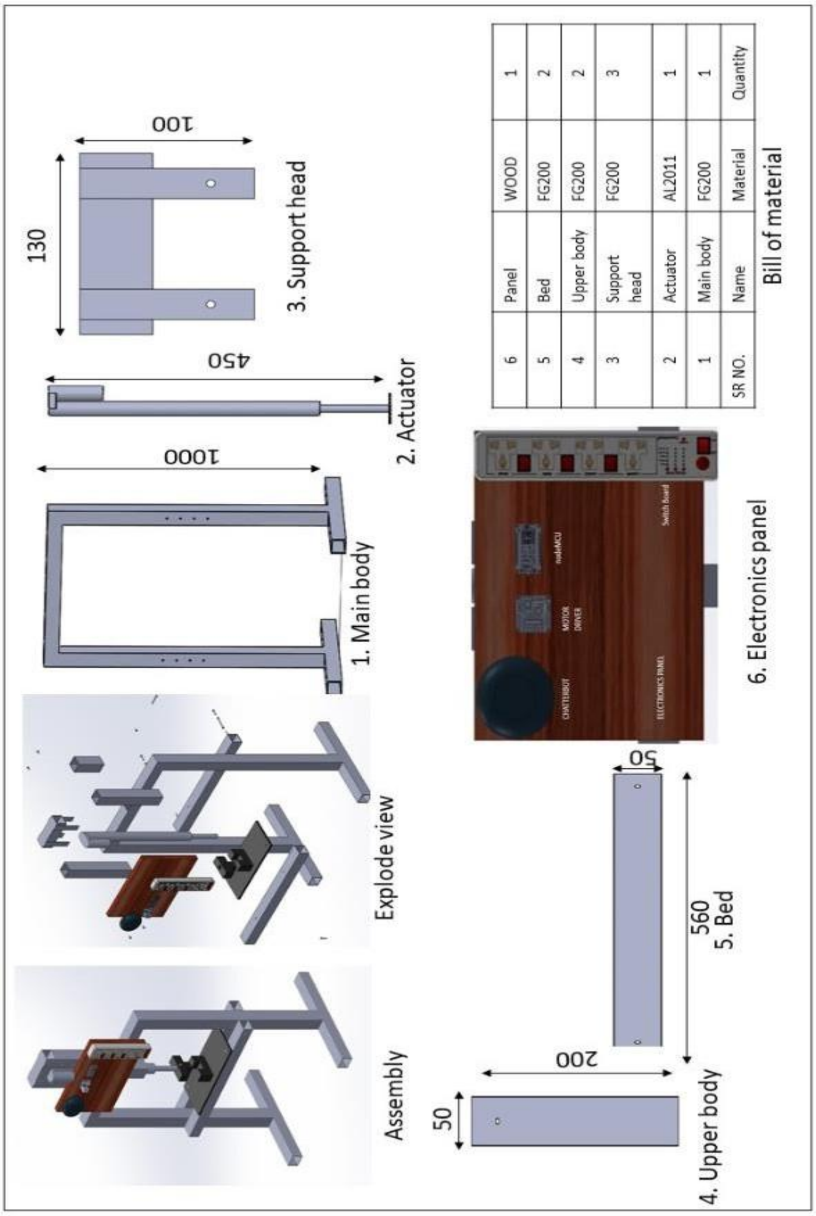


Fig 29: - Detail sheet

Workpiece

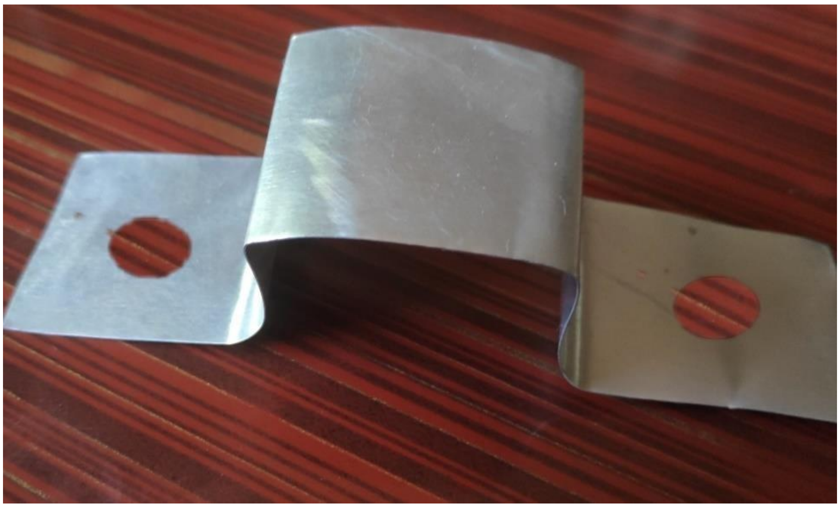


Fig 30: - Isometric View

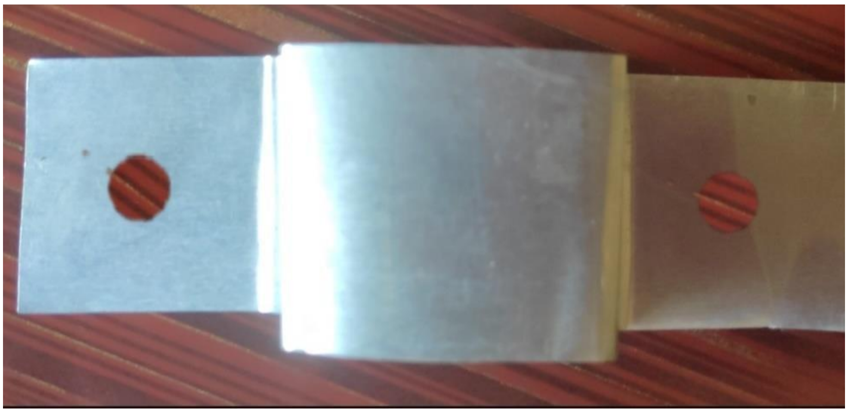


Fig 31: - Top view

Fig 32: - Bottom view

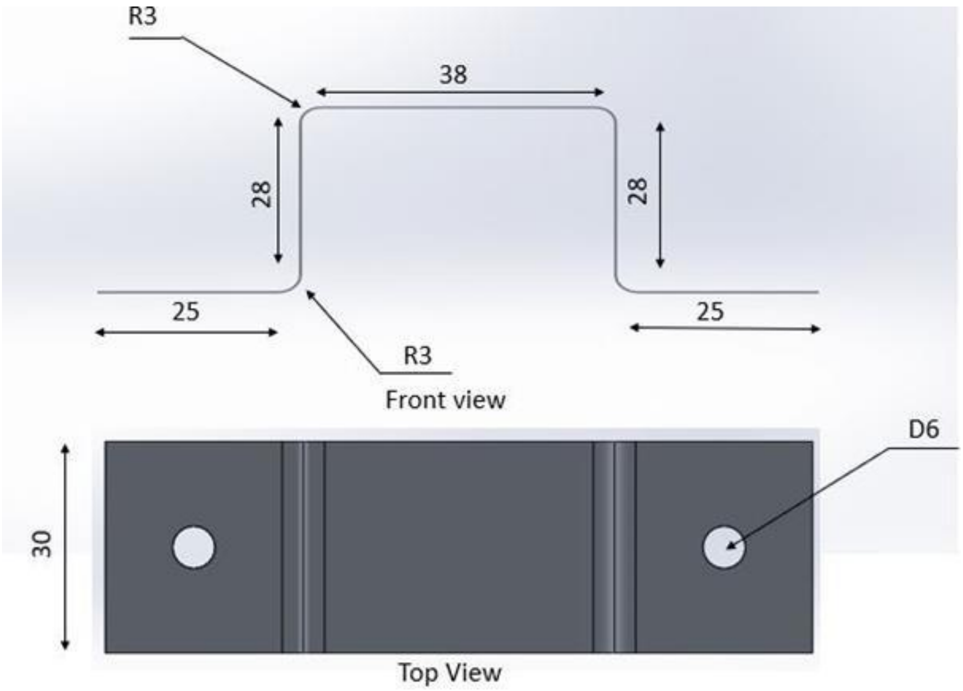


Fig 33: Dimensions of workpiece

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