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Modeling of broaching machine case study

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Abstract
Broaching machine is mainly developed for special purposes where main objective is to reduce the cycle times and to increase the production output. Only at such points development of broaching machine is justified.
Design of such broaching machine is totally customized, here modelling of frame, power pack, actuators, valves, pumps, tanks, guideways, chucks, etc. is considered.
Main purpose of modelling the broaching machine is to develop customized machine model and understand its functioning. which includes all its components. Paper also focused on selection and placement of bought out parts too.
Keywords: *design a frame of machine, guideways, hydraulic power pack, broaching machine.*

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I. INTRODUCTION

Broaching is a manufacturing process designed to make custom, precision parts at high speeds. There are many types of broaching machines, but they all use tools to remove a certain amount of material from a blank or machined component. Depending on the broach being used, the process can create a circular hole, irregular exterior shape, a keyway or more irregular shapes.

Similar to reaming, shaping and milling, broaching is a highly specialized, precise manufacturing process. Each broach machine is designed to create a single hole with maximum precision, speed and uniformity. In these regards, broaching is a highly competitive machining process, particularly when using soft metals and plastic components.

Of course, there are certain applications where a broach machine may have reduced efficiency. Particularly hard metals may require routine tool conditioning, and every specialized cut requires a new tool. This can be an issue if company lacks the resources to rebuild and fabricate used broach tools.

Basically, broaching machines are used to increase the production rate and to increase the quality of process. Broaching machines are in actual special purpose machines and can be made for the exact requirement in order tohave higher production yield.

This paper discusses about the development of such broaching machine which is specially developed for one of the market leaders in transmission component design and manufacturing. This paper mainly focuses on basic modelling of machine.

1.1.1 Different types of broaching machineHorizontal Broaching Machine:

Nearly all horizontal machines are of the pull-type. They may be used for either internal or external broaching, although internal work is the most common.
It consists of a bed or a base a little more than twice the length of the broaching stroke, a broach pilot and the drive mechanism for pulling the broach.
Horizontal broaching machines are used primarily for broaching keyways, splines, slots, round holes, and other internal shapes or contours. They have the disadvantage of taking more floor space than do the vertical machines. However, long broaches and heavy workpieces are easily handled.

Vertical Broaching Machine:

The vertical types may be obtained in either push or pull type. Vertical machines are used in multiple operations since they are convenient to pass work from one machine to another. Of the three models available, pull down, pull up, and push down, the pull-up type is most popular. Vertical machines require an operator platform or a pitand are economical of floor space than the horizontal type.

1.1.2 Objectives

1. To understand the various types of broaching machine types.
2. To understand the requirement of various systems and components for required broaching operation.
3. Modelling of machine by considering the cost, safety and reliability.

1.1.3 Methodology

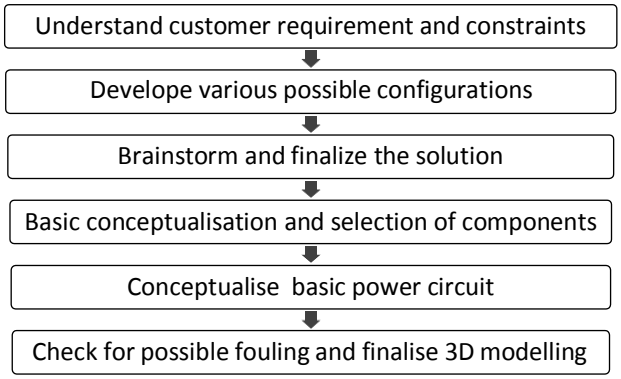

Figure 1.Machine modeling methodology

At first try to understand the actual customer requirements and depending on those inputs from customer various possible machine configurations are decided through brainstorming. Then best optimum configuration is selected. Once the basic configuration is selected which includes the type of machine i.e., whether vertical or horizontal, type of holding arrangements, drive type (hydraulic, pneumatic, electric) etc. component should be selected. Thenbasic power circuit is designed which gives an idea about basic power flow. This must consider the sequence of operations to be performed. After that final assembly has been done and cross checked for various possible fouling.

1.1.4 Actual customer inputs, requirements and selection of configuration

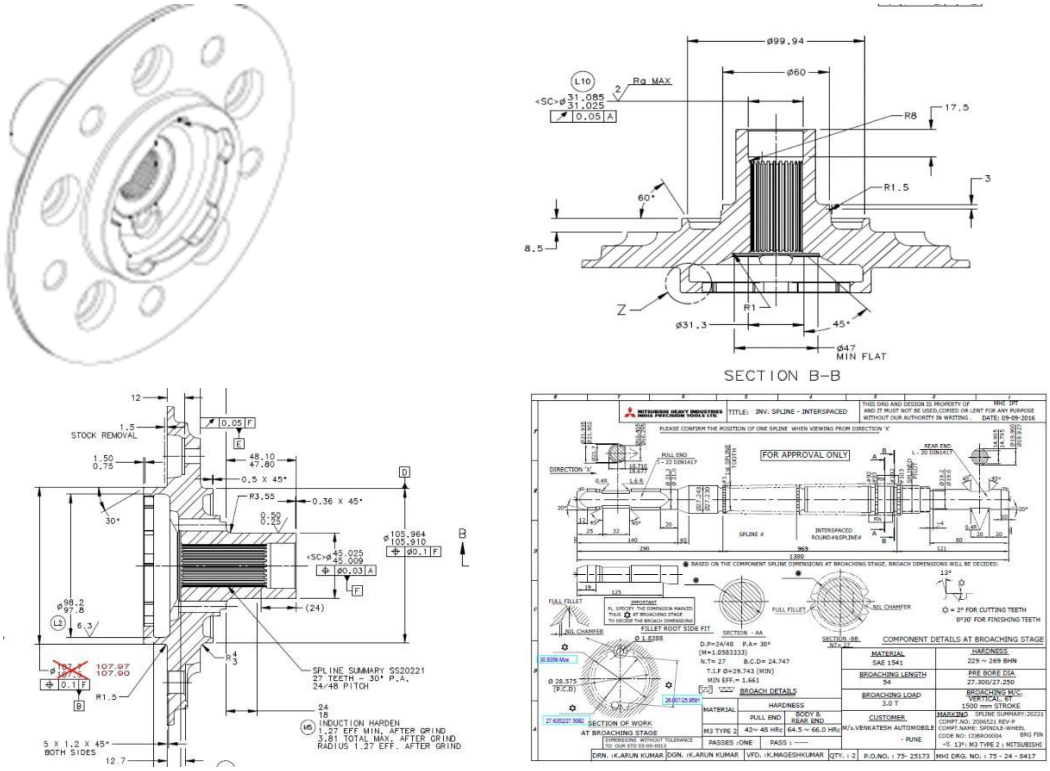

Figure 2.Input drawings from customer

Customer has provided various inputs like material of job, hardness, spline dimensions and specifications, current cycle time, required cycle time, no. of broach teeth, space availability, height of shed available. Some ofthese details are in the drawing and some of them are documented separately. From these inputs basic understanding is that splines are to be made on SAE 1541 material of given dimensions and broaching tool is going to be provided by customer whose dimensions and specifications are given in sheet above. Current cycle time of given job is 100 sec which is supposed to be reduced to 50-60 sec customer also has a space constraint of 100 sq.ft. which is of 18 ft height.

Modern vertical broaches are offered with both hydraulic and electro-mechanical drives. But hydraulic drivesare the most common because they cost less.
Customer is having a floor constraint and wanted the system in affordable price hence vertical broaching machine with hydraulic controls is selected. Pneumatics is used for light operations like door closing and opening, job cleaning, etc.

1.2.1 Basic components of Machine and conceptual design

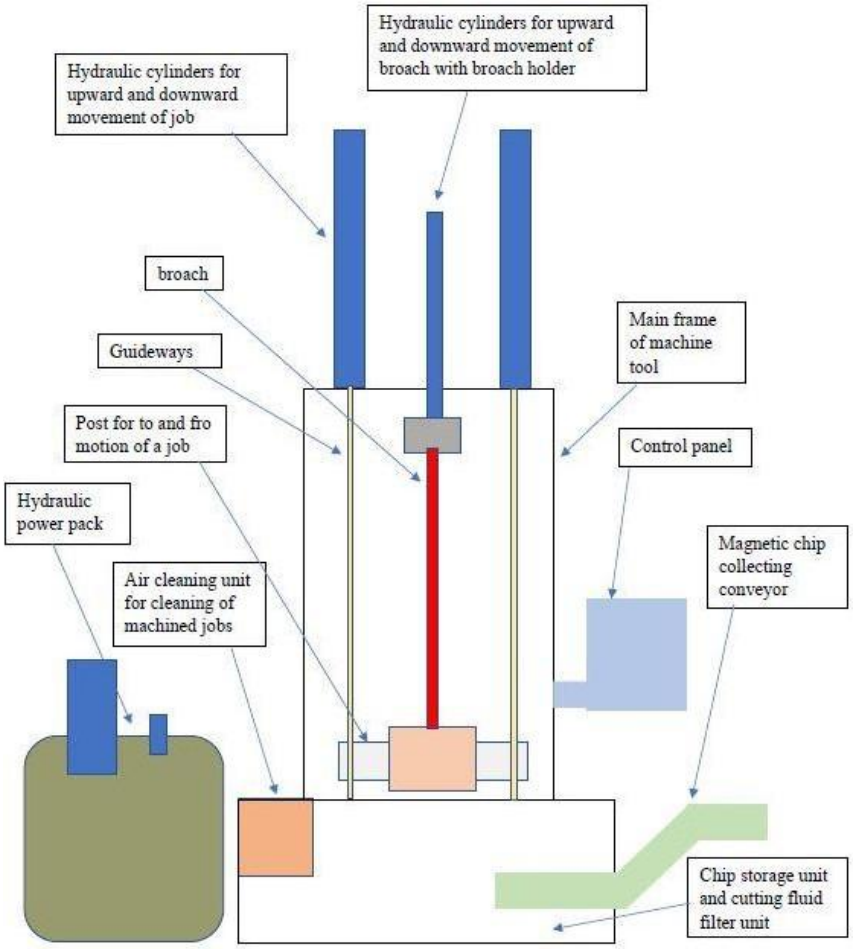

Figure 3.Conceptual design of machine

1. Machine tool frame: this is basically used to sustain all the forces, moments, pressure acting on machinetool.it is designed for allowed deformation, stress and vibrations. Basically, a welded structure in our case. Some surfaces of frame are heat treated and grinded in order to achieve tight tolerances.
2. Broach tool: It is the tool used for broaching which is have many no. of teeth leads to gradual finished cut.For defining the geometry of a broach an internal type is shown below. Note that the geometries of other broaches are similar.
3. Hydraulic cylinders: Basically, used to give motion to tool and used to transfer the power from power pack to workpiece. These are bought out parts in our case we are procuring them depending on pressure, stroke, area requirement.
4. Air cleaning unit: This is basically unit in which we are keeping our final job for cleaning with help of

pressurized air.

5. Linear guideway bearings: These are most important in our case for giving exact motion to tool and workpiece these are actually slipper bearings which are used for sliding. There are generally used to bear various moments and forces that are acting on tool.

6. Hydraulic power pack:

1. Hydraulic fluid container: It is the container containing hydraulic fluid which generally 4 time the required flow rate and it is generally made up of mild steel and welding of the same is ensured properly to avoid its leakage.
2. Fluid level indicator: This indicates the fluid level in the container which needs to be checked simultaneously during preventive maintenance.
3. Fluid filter: This is the mesh type of filter used to filter the fluid while pouring into the container.
4. Solenoid valves: A solenoid valve is an electrically controlled valve. The valve features a solenoid, which is an electric coil with a movable ferromagnetic core (plunger) in its center. In the rest position, the plunger closes off a small orifice. An electric current through the coil creates a magnetic field. The magnetic field exerts an upwards force on the plunger opening the orifice. This is the basic principle that is used to open and close solenoid valves.
5. Electric Motor and Gear pump: This is basically used to power the whole power pack unit and it is connected to hydraulic gear pump which actually increases the pressure of hydraulic fluid which is responsible for ultimate force required for cutting.
6. Heat exchanger: This device is generally used to cool the hydraulic fluid, as the temperature of hydraulic fluid increase its viscosity decrease leads to pressure change in the system which can leads to an abrupt behavior of mechanical systems.
7. Pressure gauge and pressure relief valve: Pressure gauge is used to indicate the system pressure while pressure relief valve is generally used to control the desired pressure in the system.
8. Drain port: This is generally used for removing all the oil through the container.

7. Limit switch: These switches are used for giving the restricted motion to various linear motions in thesystem, these are electrically operated.

8. Control panel: This is a panel where various controls are given in the form of push buttonsAbove are some of the main components of our machine tool.

By taking into consideration all the basic components basic modelling has been done which is as given below.

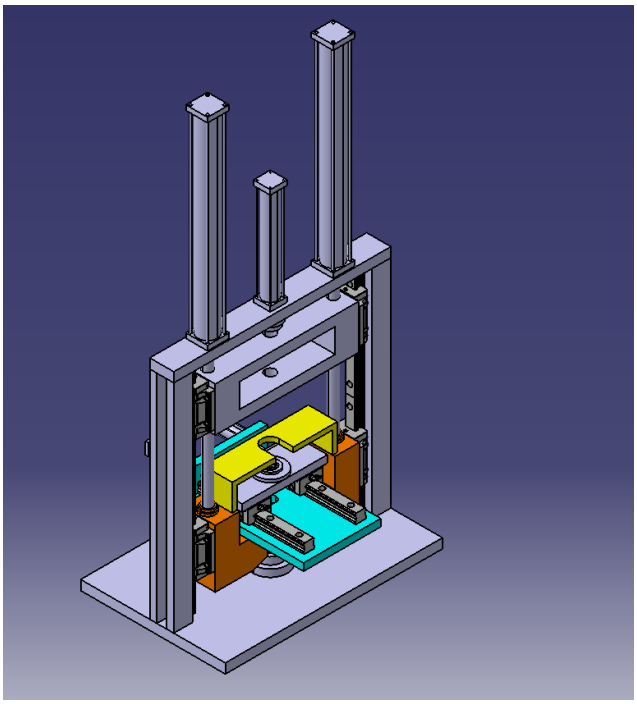

Figure 4.Basic concept drawing

1.2.2 Sequence of operation for Auto Cycle

Auto cycle is basically PLC controlled sequence of operation which is performed continuously after receiving start signal. In order to have autocycle various limit switches and electronically operable solenoid valves are used in the circuit.

Purpose of auto cycle is to reduce the cycle time by eliminating the human response times. Cycle time reduction is made possible in auto cycle with help of overlapping of some sequence of operations which are independent on each other.
Sequence of operations decided are given below:

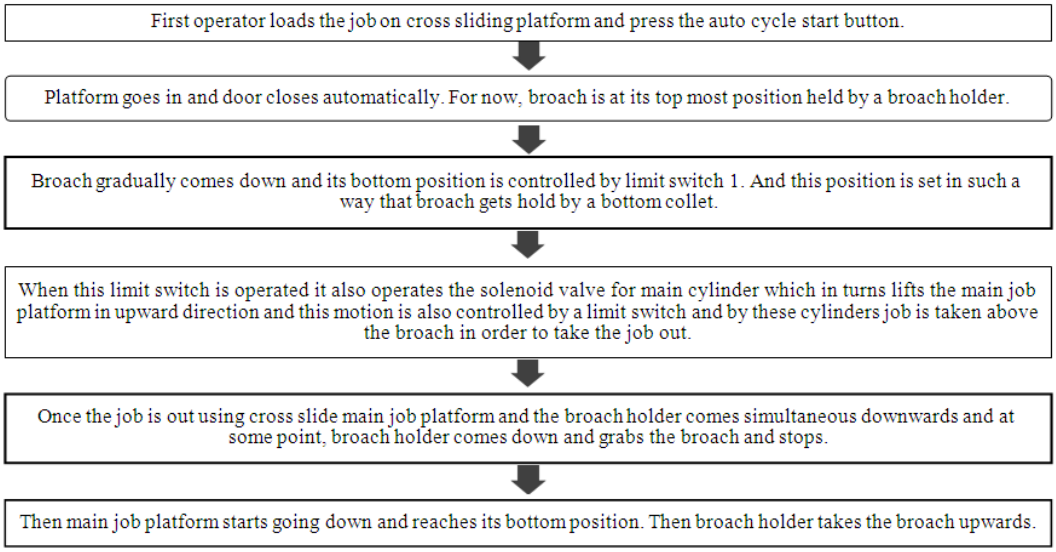

Figure 5.Sequence of operations

1.2.3. Basic hydraulic circuit

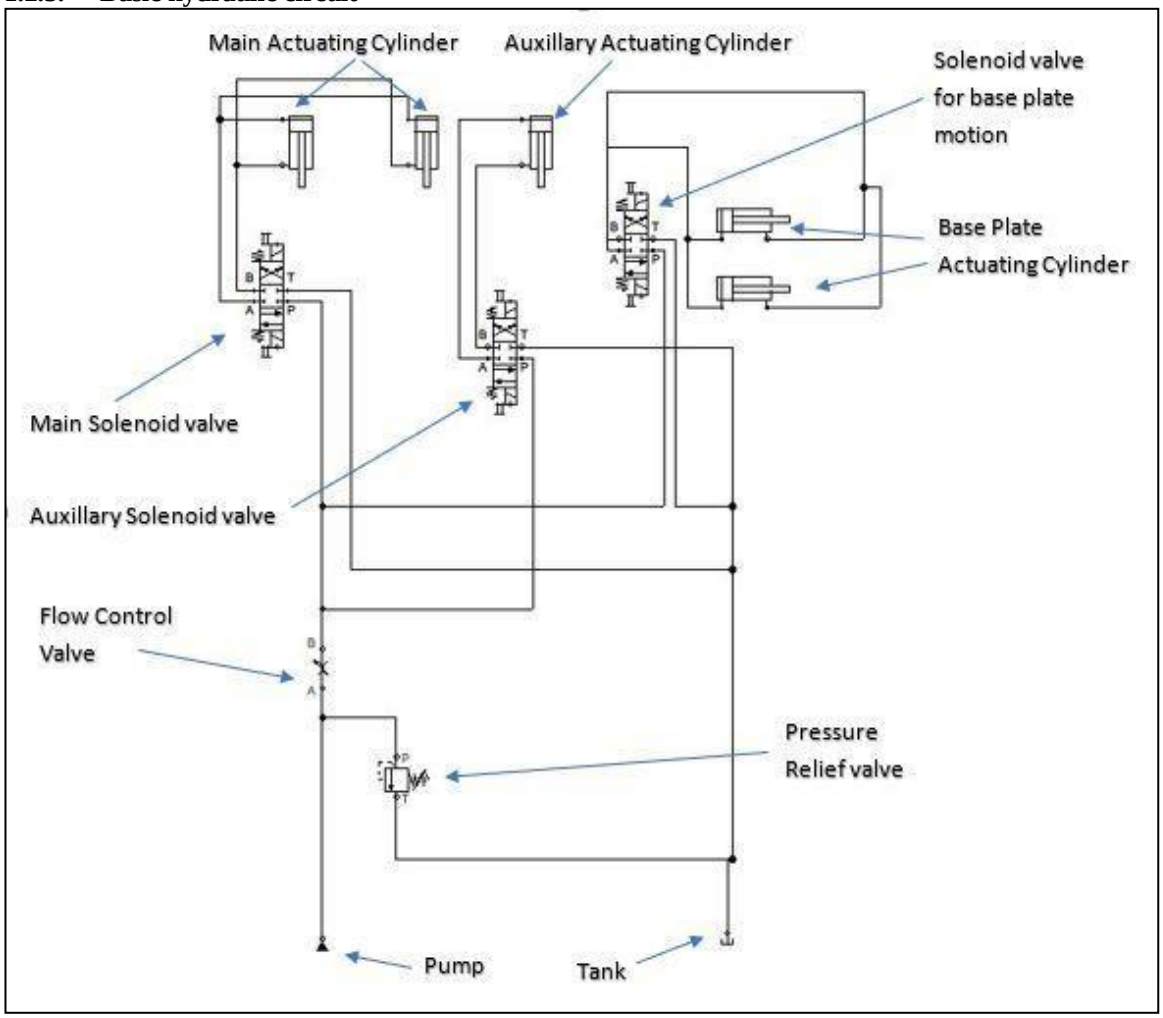

Figure 6.Basic hydraulic circuit

Above circuit diagram gives a basic idea about functioning of broaching machine. This is having two main cylinders for the linear movement of job and whose motion is controlled using solenoid valves which are electronically operable. These solenoid valves are controlled by PLC which are guided by limit switches. This circuit also has auxiliary cylinder which controls the motion of broach tool which is also connected to electronically operable solenoid valve.

This circuit is also comprising of another pair of cylinders which are for the transverse motion of job. Pressure and discharge in the circuit required to maintain the forces and speeds of machining are governed with help of pressure relief and flow control valves. Pump is used for pressuring the fluid and tank is used for containing the fluid.

1.2.4 Modelling of broaching machine

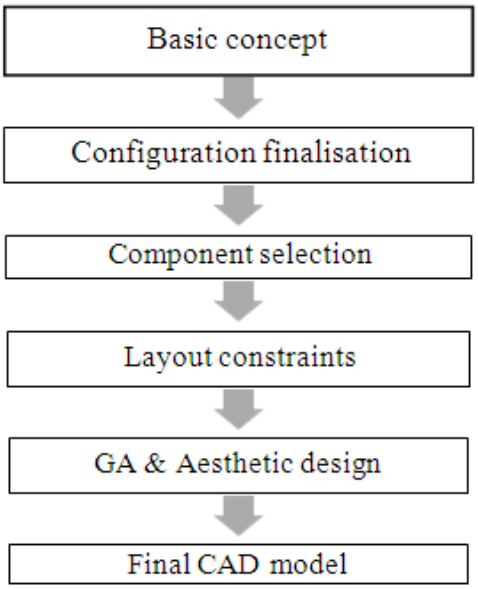

Figure 7.Steps in modeling

Modelling of broaching machine goes through the process given above. First, brainstorming is donefor various possible solutions then after finalizing one of the configuration basic layouts been made. After basic layouting of configurations best suitable configuration is selected, in this stage whether machine is going to be vertical or horizontal, where the power pack is going to be placed, what is going to be base structure of machine such type of decisions been made.

After that component been selected as per the design requirements and their general arrangement is done by keeping in mind the constraints and changed if required. This is a recurring process till our modeling fits the customer requirements. Aesthetic design is also one of the factors while modelling in order to reduce operator fatigue and improve his efficiency.

After meeting all the requirements model is finalized. After going through all the above stepsfinalized model is as follows:

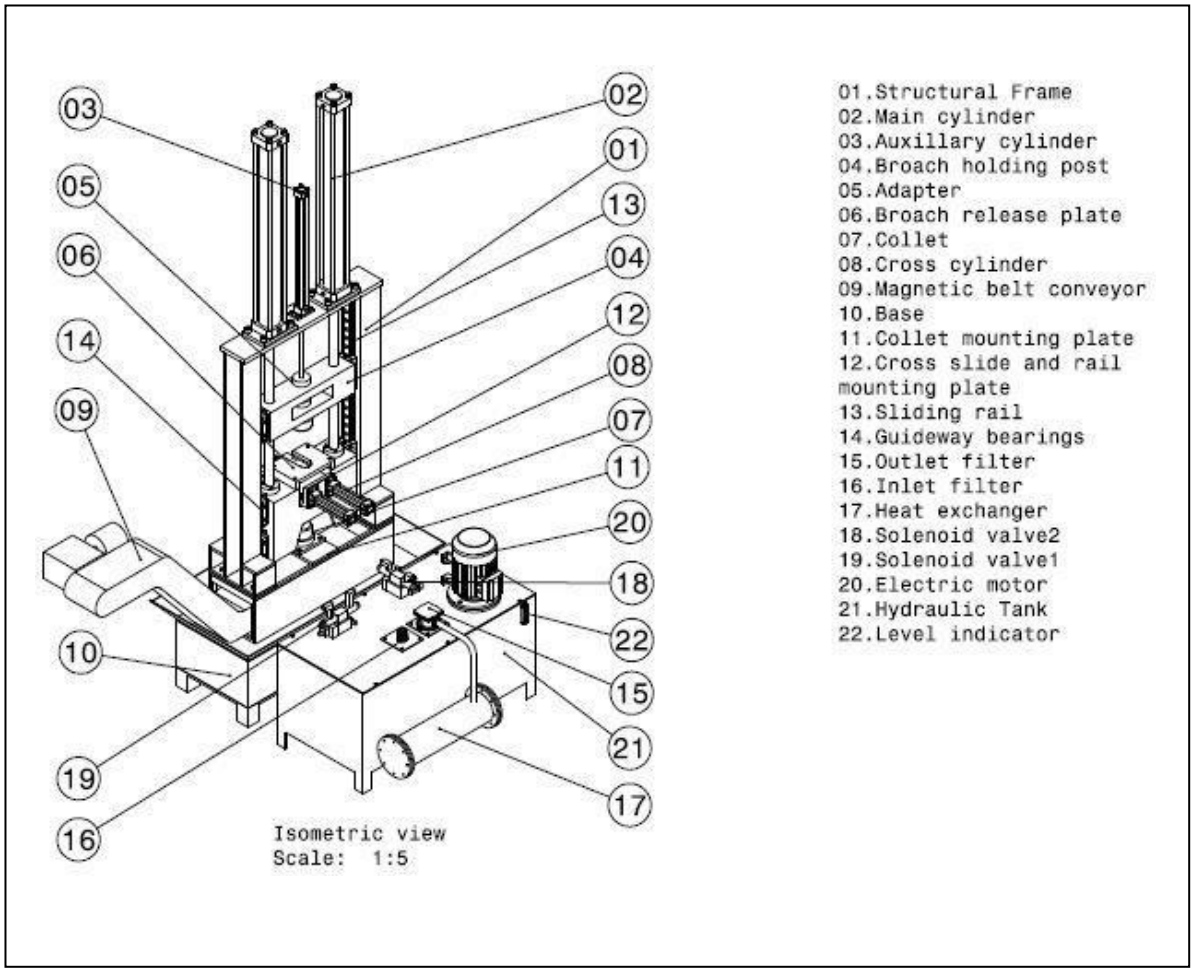

Figure 8.Model with ballooning

Above diagram gives the idea about the various components and their placements.Final 3D model is as follows:

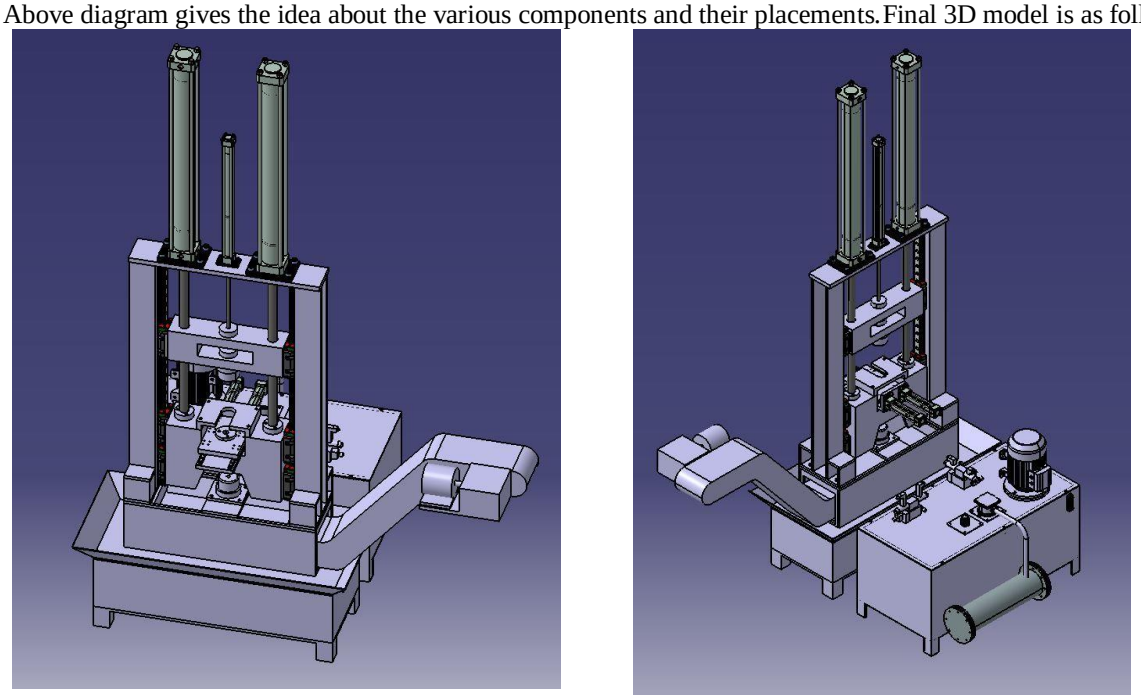

Figure 9.Final 3D model

II. RESULT AND DISCUSSION

2.1.1 Machine constraints and modelling consideration

1) Machine is designed by considering the available floor space and ergonomic considerations have also been made. And they are as follows:

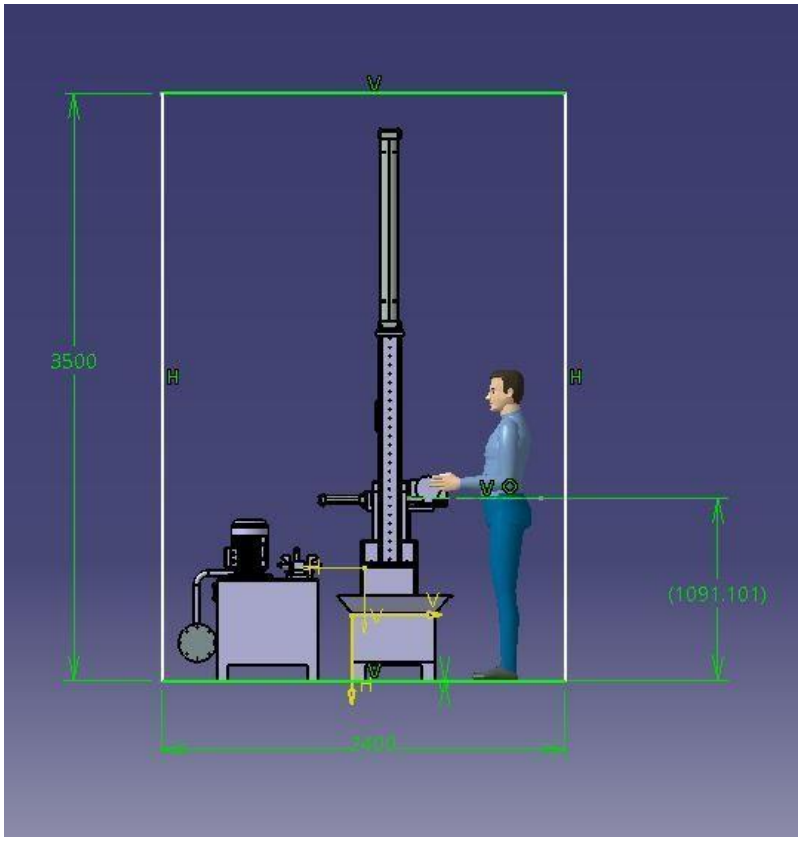

Figure 10.Ergonomic consideration layout

As per ergonomic consideration the normal height for Medium or light work should be between 850 -1100 mm. In our case height is 1091 mm which is appropriate. Minimum shed height required is 3500 mm plus the space for crane boom (1500mm) which is equal to 5000mm (Approx.17 feet).

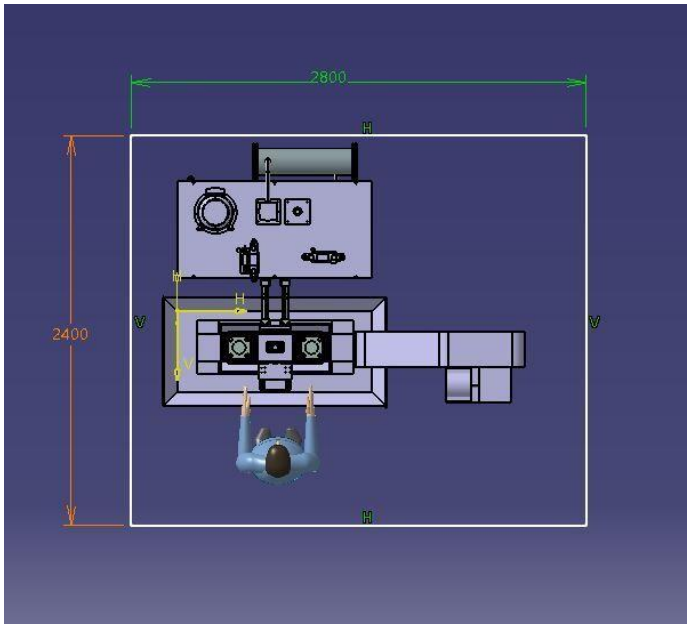

Figure 11.Floor space consideration layout

From above figure floor area required can be calculated which is equal to 6.72 $*10^6$ mm^2 (Approx. 73 Sq.ft.). matches the customer requirement.

2) Broach length given is shank length+ cutting length+ tail length= 290+969+121= Total broach length. Some extracutting relief of 131mm is provided and 1200 mm of stroke length is defined for the machine. This relief is important to remove the job. After deciding the stroke and arrangements for holding devices final height of machine was decided.

3) While deciding the width, modelling is done in such a way that it should be as low as possible in order to reduce the moment loads on structure and linear bearings. So, width is kept as per the assembly space requirement of jobplatform, broach holder, etc.

4) Given broach is having a standard holding arrangement so collet type chucks are used for holding.

5) For safety purpose automatic locking doors are provided to the machine which automatically closed once machining starts and opens once machining is completed. These are pneumatically operated.

III. CONCLUSION

1) Modelling of broaching machine helps to understand the possible fouling which are simultaneously corrected.Hence the costing related to rework of machine reduces to nearly zero. And manufacturer will be able to givethe machine to client at affordable prices.

2) With help of modelling, customers requirement can be easily replicated to design.

3) Final height of machine is 3400 mm, width 1500 mm, breadth 2500 mm with 6-ton capacity and stroke 1200mm which is as per the customer's inputs given.

4) This modelling is done on safer side to accommodate higher size broaches and high load jobs in order to improve its utilization with respect to versatility of jobs.

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