Design and Analysis of Drilling Cum Riveting Machine

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***Abstract*— The objective is to design and analyse the drilling cum riveting machine which reduces the operation as well as transportation time required for completing the job. Riveting operation is till now performed manually, but by using Orbital Riveting Machine (ORM) it can be performs automatically. The concept is that the plate (raw material) having different size and thickness are drilled on drilling spindle first and then riveted on orbital riveting spindle. Both the operations perform on same machine having two separate spindles. The purpose of this machine is to replace manual hammering into automation, to increase productivity in operation also to reduce cost. To get accuracy in riveting the spindle is offset by 3 to 6 degree, the upper part of rivet stud is expanding over plates without hammering. It is more beneficial to use in workshops, industries where drilling and riveting operations can perform simultaneously.**

***Index Terms*—Automation[1], Drilling cum orbital riveting[2], increase productivity[3], separate spindles[4], 3 to 6 degrees offset spindle[5], etc, (Keywords)**

I. INTRODUCTION

The conventional riveting process consists of pull riveting and push or hammer riveting was referred to as impact riveting, usually done by manually or machining operation. This machine is used for drilling and riveting the workpiece having different size thickness and material on the same machine having two separate spindles. By riveting we mean the upsetting of a rivet to form a head to hold several assembled parts together. The rivet can be in the form of a pin or an eyelet. Orbital forming uses a spinning tool mounted in a rotating spindle and inclined at an angle about 3 to 6 degrees toward the center of the spindle as shown in figure1.

Orbital forming is a quiet, non-impact process of cold forming fastening operations. The tool (peen) which is gradually lowered into the rivet head and spreads the material of rivet into a desired shape is depending upon the design of the tool. The orbital riveting is one of the best machines which have higher accuracy in rivet forming.The machine consist of single phase induction motor transmit power to drive mechanism by pulleys through V-belt and a pneumatic cylinder which drive the process unit. With help of CAD modelling software (NX) solid model of the machine is developed. The static structural & modal analysis is done on the machine parts, by using the Ansys-13 software; find out the stresses generated in the material and deformation of tool also finding the different vibration frequencies at various speed. Selected the material for drilling is Ferrium C64 (HSS) for drill Bit, A36 Steel (Mild steel) for workpiece and Mild Steel for base mounting.

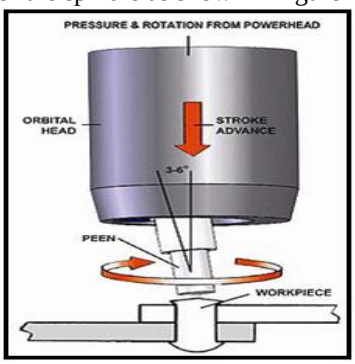


Figure 1 Orbital forming

II. DESIGN OF MACHINE COMPONENTS

Induction Motor

An electric motor is a machine that converts electrical energy into mechanical energy. The power from electric motor is used to rotate both the spindles through V-belt drive by which drilling and riveting operation takes place. The specification of electric motor is given below table,

Table 1 Single Phase Induction Motor Technical Data Sheet

Specifications	
Product	Multiple Horsepower Motor
Rated Horsepower	1/2 Horsepower
Supply Voltage	115 or 208/230 VAC
Supply Frequency	60 hertz
Current	1.2 to 8.1 amps at rated speed and horsepower
Temperature Rating	60°C / 140°F
Rated Speed	1075 rpm (825 for WG840469)
Mounting	Shaft up, shaft down, or belly band
Bearings	Ball bearing
Rotation	CW/CCW (electrically reversible)
Shaft Length	5" (5-1/2" for WG840466 and 67)
Shaft Diameter	1/2"

Belt Pulley

Pulleys were used for narrow-section CONTI FO-Z heavy-duty cogged raw edge V-belts. The efficiency of a V-belt drive is influenced by the pulleys, which are standardized to B.S. 3790 and to DIN 2211 and DIN 2217 specifications. These standard specifications are in line with the corresponding ISO standards. V-belt pulleys are manufactured mainly from cast iron GG-20 or from other materials to customer's specifications in different constructions.

1. Pulleys must be clean and free of burr. They must be correctly aligned.
2. Damaged pulleys, e.g. pulleys with damage caused by uneven wear, should be replaced without delay.
3. The spindle pulley has a single grove to receive the power from motor pulley through a V- belt. Figure 2 shows it has an integral vertical groove so that the pulley is fixed with the spindle firmly by inserting the keyway in that.

Table 2 Belt Pulley Specifications

Belt Section to DIN 7753	Symbol	SPZ
Pitch Width	bw	8.5
Top groove width	b1	9.7
	c	2
Groove spacing	e	12±0.3
	f	8±0.6
Groove Depth	t	11+0.6
α 34 degree	dw	< 80
38 degree	dw	> 80
Pulley Face width b2 for no. of grooves Z, B2= (Z-1) . e + 2 . f	1	16
	2	28
	3	40

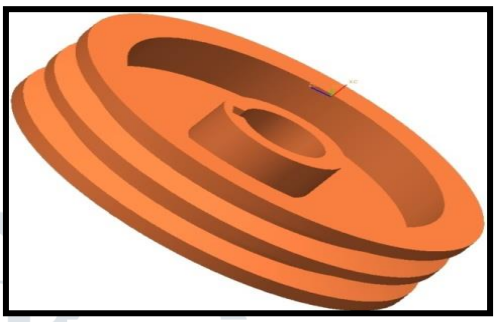


Figure 2 Belt Pulley

The spindle pulley has a single grove to receive the power from motor pulley through a V- belt. Also it has an integral vertical groove so that the pulley is fixed with the spindle firmly by inserting the keyway in that.

Frame

Figure 3 shows the basic structure of machine on which entire assembly of machine is fixed. The plate is made of Mild steel and the angles used are of 5 mm thickness.

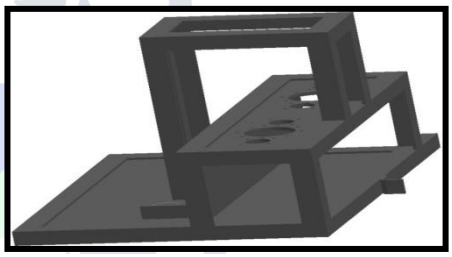


Figure 3 Machine Frame

Selection of V-Belt

The belt used for power transmission in the machine is Conti Fo- XPZ 975 mm stands for Conti Fo – XPZ - heavy-duty cogged raw edge V-belts in section FO – XPZ with pitch length 975 mm. Their construction and the materials used in them permit extremely high power transmissions with compact drives. They are manufactured in a raw edge finish by a new production process from high-grade materials with fabric jackets and high strength, low-stretch polyester load-bearing members, the most suitable material for the specific application being selected for elastomer compounds, tension members.

Pneumatic System

In a pneumatic system, energy that will be used by the machine and transmitted through the system is stored as potential energy in the compressor in the form of compressed air. A compressor is a machine that takes an air, gas or vapours at any certain pressure and delivers this air at a very high pressure. Pneumatic systems operate on a supply of compressed air, which must be made available in sufficient quantity and at a pressure to suit the capacity of the system. Working energy (kinetic energy and pressure) results in a pneumatic system when the compressed air is allowed to expand. For operation the machine required a compressed air of pressure 7.2 bar for operating a drilling spindle and pressure of 3.2 bar for actuating the riveting spindle. The constant air supply is required for the operation of machine.

Pneumatic Cylinder

A pneumatic air cylinder is an operative device in which the state input energy of compressed air; (i.e.) pneumatic power is converted into mechanical output power, by reducing the pressure of the air to that of the atmosphere. The bore of the cylinder has very smooth finishing reduces friction and losses. All the cylinders are of two way acting cylinders having inlet and outlet ports, the machine has two large pneumatic air cylinders for actuating the drilling as well as riveting spindle with the help of Z flange, and four small pneumatic air cylinders for clapping the workpiece.

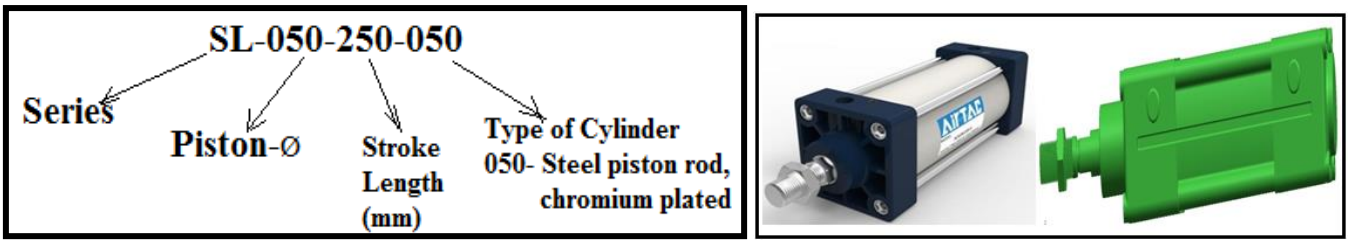


Figure 4 Technical Data Series for Pneumatic Cylinder

Pneumatics Tubing System

Polyethylene (PE) is one of the most common thermoplastic materials typical applications for low pressure head. PE80 has fairly good chemical resistance to strong and weak acids, as well as many base chemicals. It has a maximum operating temperature range of 140° F. The tubing's are connected to both the ports of cylinder as shown in figure.

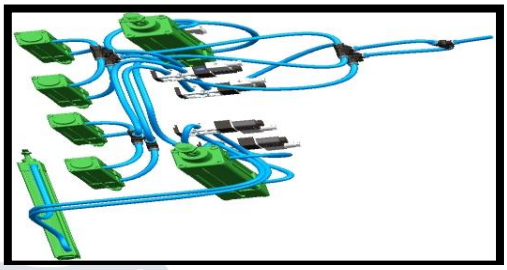


Figure 5 Compressed Air Tubes Connection to Cylinders

Directional Control Valves

The directional valve is one of the important parts of a pneumatic system. Commonly known as DCV, ensure the flow of air between air ports or to change the direction of flow path of working medium by opening, closing and switching their internal connections by changing the position of its internal movable parts called spool. The 5/2-way valve has five ports and two positions. This valve was selected for speedy operation and to reduce the manual effort and also for the modification of the machine into automatic machine by means of using a solenoid valve.

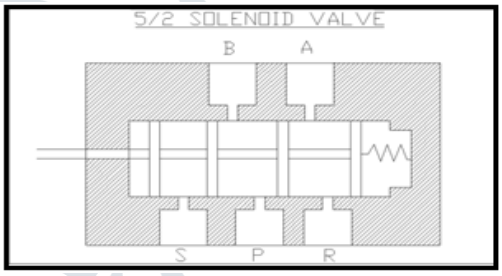


Figure 6 Line Diagram of 5/2 Directional Control Valve

III. DESIGN AND CALCULATIONS

Selection of Prime Mover

Considering one problem and calculating the power required for the motor to perform the operations.

Given: - Diameter of hole (d) = 06 mm
Drill speed (N) = 800 rpm
Shaft power (S.P) = 0.035 kW
Thickness of plate (t) = 08 mm
Feed (f) = 0.2 mm/revolution
Mechanical efficiency (ηmech) = 0.90%

Solution: -

Volume of metal removal per minute (V1) = Area of drill × feed × speed = 4525 mm3 = 4.525 cm3
Power available at drill = V1× shaft power = 4.525 × 0.035 = 0.16 kW
Power of electric motor = Power available at drill / Mechanical efficiency = 0.16 / 0.90 = 0.18 kW
Similarly, we can calculate power required for riveting to electric motor is 0.15 kW.
We know, Power of electric motor = Power required for drilling + Power required for riveting
Power of Electric motor = 0.33 kW

Design of Belts

Design procedure

(Pd) - Design power to be transmitted
(fa) - Correction factor for Industrial Service (T- 13.15)
(Pr) - Power rating of Single V-Belt (T- 13.16)
(fc) - Correction factor for Belt length (T- 13.21)
(fd) – Correction factor for arc of contact (T - 13.22, Book - V.B.Bhandari)

Table 3 Designed Belt Specifications

Sr	Design Calculations	Description	Symbol	Dimensions
1	Correction factor for Industrial Service	Heavy duty, Operating hours per day is 16 hr.	fa	1.5
2	Design Power		Pd	2.25 kW
3	Type of c/s of belt	type of C/S of belt is 'Z'		
4	Pitch diameter of smaller and bigger pulley		Dp and dp	95 mm & 80 mm
5	Pitch Length of the Belt		Lp	975 mm
6	Correct Centre distance		C	350 mm
7	Correction Factor for belt pitch length		fc	1.05
8	Arc of contact betn belt and motor pulley	αs = 1770		αs= 3.1 radian
9	Correction factor for arc of contact	αs = 1770	fd	fd = 0.99
10	Power rating	for Z c/s and N= 1440 rpm.	Pr	Pr = 1.04 kW
11	No. of belts			1 belt.
13	Area of the Belt			127 × 10-6 m2
14	Mass of the belt per meter length			m= 0.15 kg/m3
15	Centrifugal Tension		Tc	5.4 N
16	Maximum Tension in the belt		Tmax	254 N
17	Tension in tight side of the belt		T1	248.6 N
18	Tension in Slack side of the belt		T2	20 N
19	Top Belt Width		bo	12.7 mm
20	Pitch Width		bw	11.0 mm
21	Bottom belt width		bu	5.6 mm
22	Height of the belt		h	10 mm
23	Pitch height		hw	2.8 mm
24	Max. Belt speed		Vmax	6 - 20 m/s
25	Weight per meter		W	0.15 kg / m3

Design of Pulley

The efficiency of a V-belt drive is influenced by the pulleys. V-belt pulleys are manufactured mainly from cast iron GG-20 or from other materials. Minimum pulley diameter should be adhered to pulley diameters below the recommended dimensions affect the service life of the V belt and consequently the economic efficiency of the drive.

Table 4 Pulley Specifications

Pulley Section		XP (Z section)
Pitch Width	bwidth	11.0 mm
Top groove width	b1	12.7 mm
	C	2.8 mm
Groove Spacing	E	15 + 0.3
	Fg	10 + 0.6
Groove depth	Tg	14 + 0.6

IV. Construction And Working of Drilling Cum Riveting Machine

The figure shows the diagram of drilling cum riveting machine here the compressed air from the compressor is used as the force medium for both the operation.

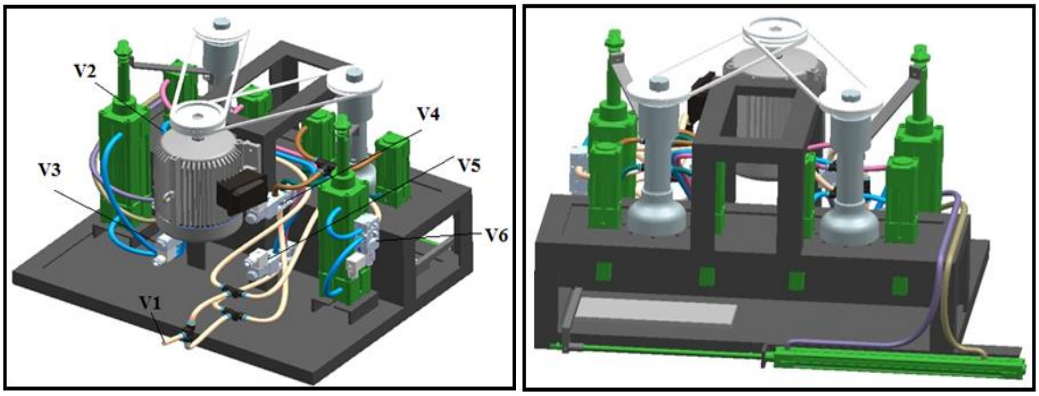


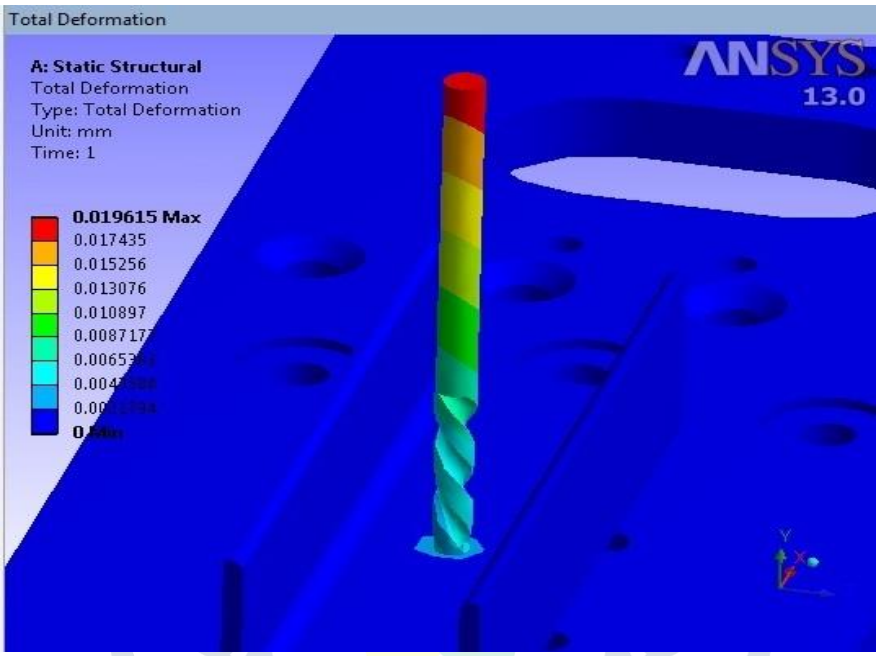
Figure 7 Drilling cum Riveting Machine

The air from the compressor enters into the flow control valve which gives directions to the flow of air and duration of flow is controlled by programmable logic controller. First the air enters into the small pneumatic cylinder to hold the workpiece and then air enters into the large pneumatic double acting cylinder from lower port through the pipe linings pushes the piston outwards and move drilling spindle with the help of flange attached to stroke of pneumatic cylinder and spindle, this causes the application of gradual force to drilling spindle which drills the holes into the workpiece. After completion of drilling operation the compressed air comes inside to the pneumatic cylinder from another port and drilling spindle comes upward. Now the air passes to the feeding cylinder which moves predrilled job below the riveting spindle which is 3 to 6 degree inclined to the axis of the spindle applying the gradual force on the rivet stud till the snap head is formed. After completion of both the operation the job is complete and another job follows the same process.

V. FEM ANALYSIS OF DRILLING CUM RIVETING MACHINE

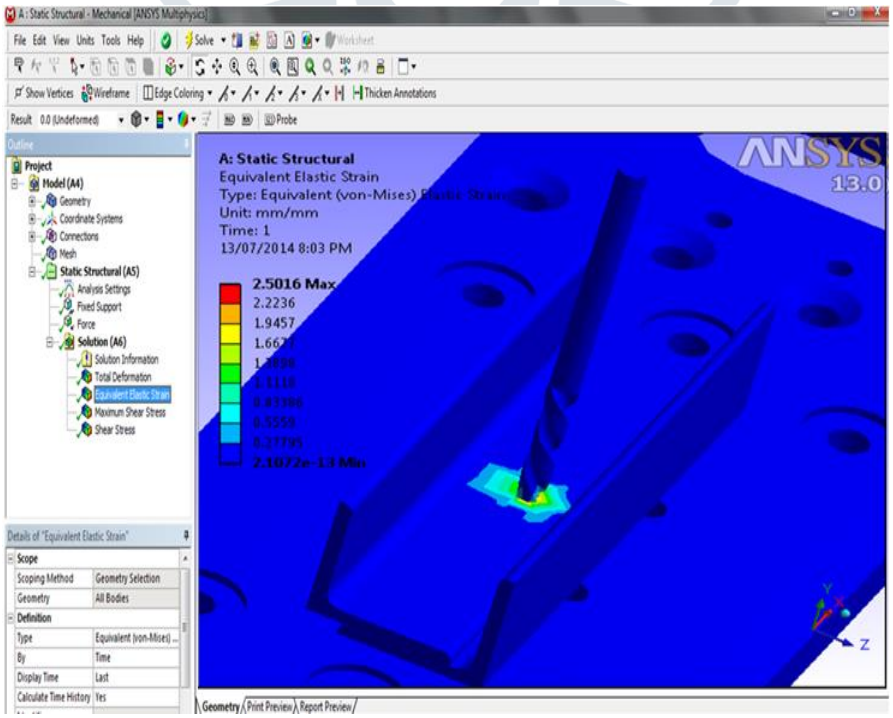
The analysis of this machine is done with the help of Analysis software and the results were obtained for total deformation, Von-Misses Strain, Max. Shear Stress, Shear Stress is illustrated below:

Evaluation of the total deformation Result



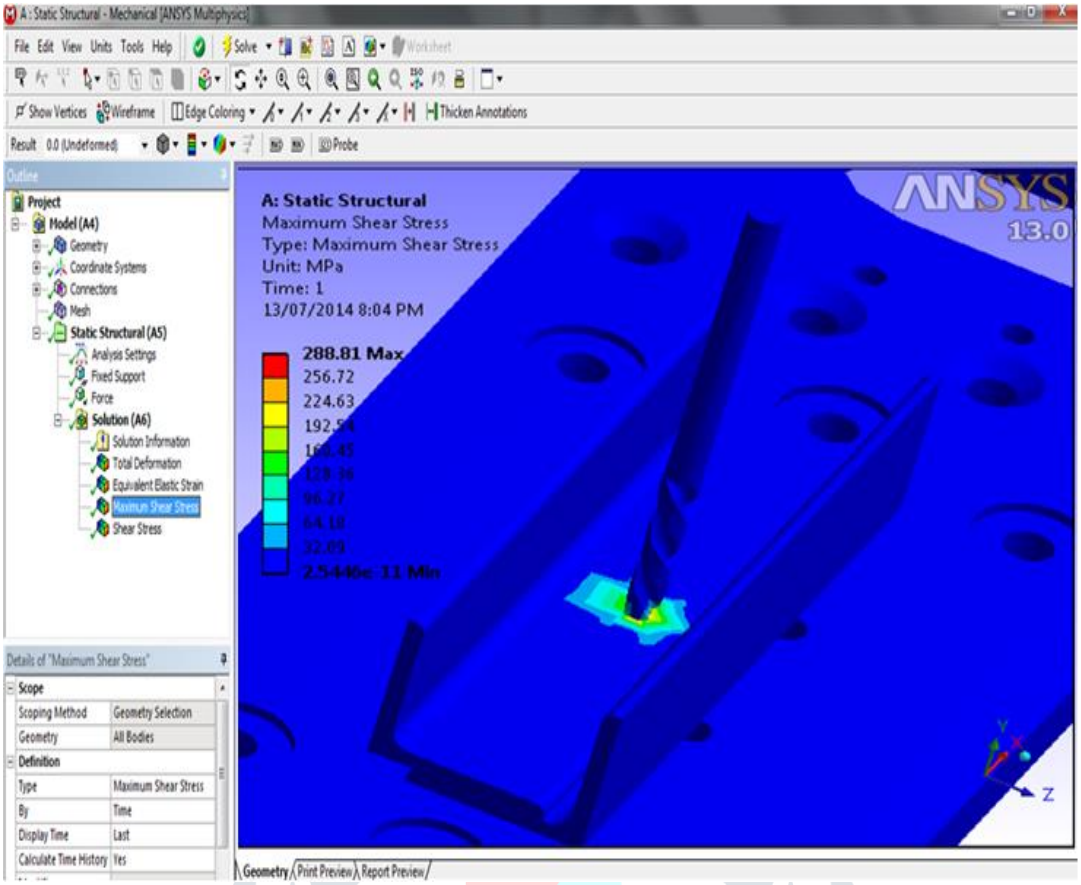
The total deformation is found to be 0.019615 mm

Evaluation of the Von-Misses Strain Result



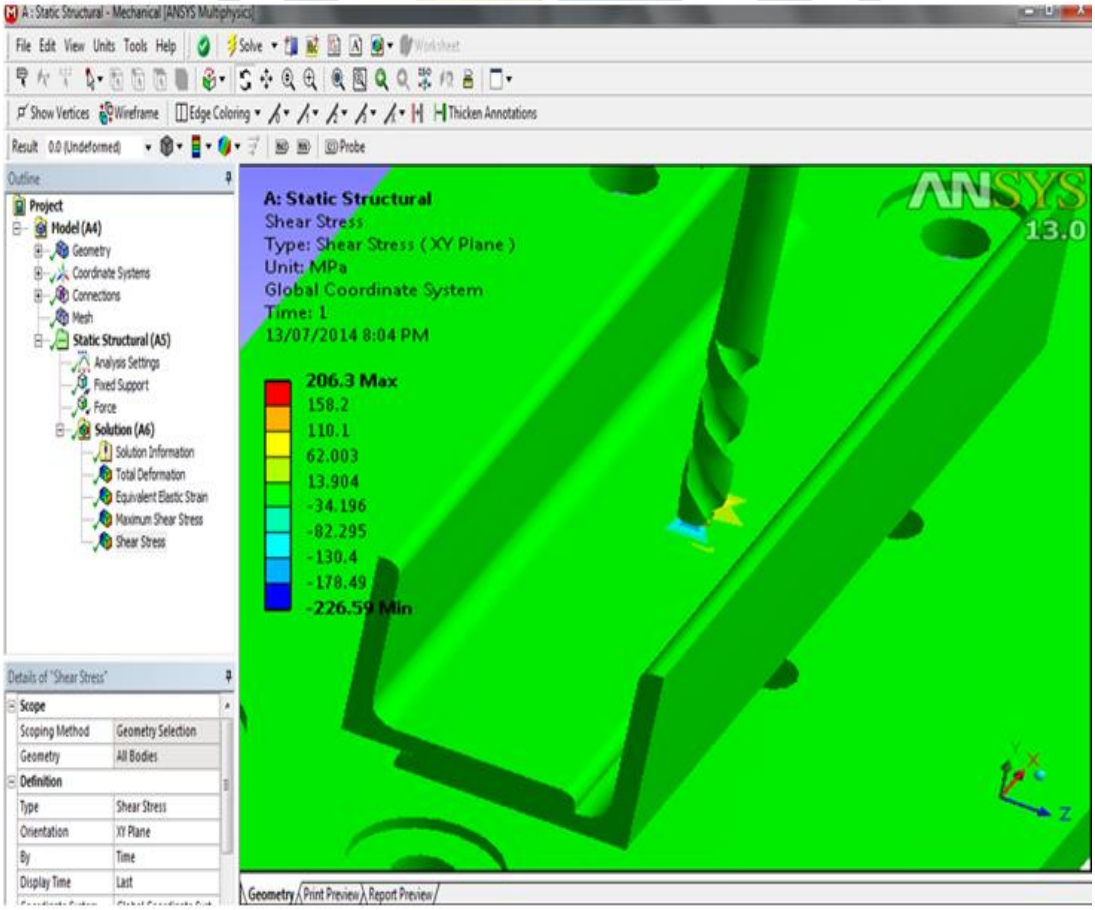
The equivalent Von-Misses strain is found to be 2.5016. It is shown by the red colour in the diagram.

Evaluation of the Max. Shear Stress Result



The maximum shear stress is found to be 288.81 Mpa.

Evaluation of the Shear Stress Result



The Shear stress is found to be 206.3 Mpa on the periphery of hole.

The solutions/results were found in following two cases and the results were discussed in the table below,

1. Without inserting the tool inside the workpiece
2. With inserting the tool inside the workpiece

Table 5 Comparison of Results

Parameters	Without Insertion of Tool		After insertion of Tool	
	Max	Min	Max	Min
Total Deformation (mm)	0.0027301	00	0.019615	00
Max Shear Stress (N/mm2)	773.3	00	288.81	2.544 E-11
Shear Stress (N/mm2)	138.08	-120.57	206.3	-226.59
Von-Mises Strain	2.803 E—6	00	2.5016	2.1072 E-13

Table 6 Comparative Study of Manual Riveting & Orbital Riveting Machine

Sr. No.	Characteristic	Manual Riveting / Impact Riveting	Orbital Riveting Machine
1.	Definition	A hammer is used to form a rivet.	3-6 degree offset spindle is used to form the rivet.
2.	Force required	More forces	Less force
3.	Noise pollution	Noise operation	Less noisy operation
4.	Accuracy	Less accuracy	Accuracy is more
5.	Production rate	Production rate is less	Production rate is high
6.	Vibration	Vibration created is too more	Less vibration is created
7.	Time required to form a rivet	More time	Less time
8.	Cost per unit	More	Less
9.	Operation	Difficult operation	Easy operation
11.	Effort required for per unit formation of rivet	More effort is Required	less effort is Required
12.	Material wastage	More material wastage during manual operation of riveting	less material wastage during ORM operation of riveting
13.	Finishing	Due to manually riveting a rough surface finish is obtained	In the actual ORM , the excellent finishing is obtained
14.	Safety and clean	Operation is not safety & clean. Because while manually hammering there is chances of accident	Operation is safe, clean & no effect on rivet
15.	Forces & stress acted on rivet	Due to uneven forces acted on rivet a different stress will acted on rivet	A particular amount of force is acted on whole rivet circumference so less stress is acted on rivet.

VI. CONCLUSIONS

It is found that the drilling cum riveting machine is beneficial for mechanical work shop, small scale industries where drilling and riveting operations perform on the same job. This machine reduces transportation and operation time and increases the efficiency as well as accuracy of the product. By using conventional machining processes for making the hole of 6 mm diameter in a 8 mm thick plate, the time required for drilling and riveting operation is about to be 2 min. But we found that by using drilling cum riveting machine the time required is 1 min. Therefore there is 1 min i.e. 60 sec less time required for producing one complete job with this machine for the same period of time. The comparison between conventional machines and designed machine is shown in below table.

Table 7 Comparison between Conventional Machines

Descriptions	Conventional Machines	Designed Machine
Total time required for producing one job.	120 Sec i.e. 2 min	60 Sec i.e. 1 min
Job / Hour	30 Job / Hour	60 Job / Hour
Job / Day	720 Job / Day	1440 Job / Day
Job /Month	21,600 Job /Month	43,200 Job /Month
Job /Year	2,59,200 Job /Year	5,18,400 Job /Year
Job more /Year	5,18,400 - 2,59,200 = 2,59,200 More Jobs / Year	

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