Design, Fabrication and Analysis of Special Purpose Machine for Drilling and Riveting Operation

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Abstract- **Most of the manufacturing industries are going for automation to increase the productivity and to overcome shortage of skill labour. The purpose of this paper is to reduce the cycle time by replacing drilling machine and riveting machine by special purpose machine(SPM) for drilling and riveting operation. The concept is that the plate having different size and thickness are drill on drilling spindle first and then riveted on orbital riveting spindle. Both the operation performs on same machine having two separate spindles.**

In this paper gives the detail information of design, fabrication and analysis of special purpose machine and compare the cycle time with conventional method. This machine is containing automation by using pneumatic system. Modeling is done using CAD software and analysis by FEA tool. The design is analysed for induced stress on work piece due to various load condition.

Keywords- Automation, special purpose machine, fabrication, increase productivity, CAD, FEA.

I. INTRODUCTION

Bridges, buildings, aircraft parts, ship parts and various small parts are assembled by riveting together, beams that have pre-drilled holes in them. These beams are often multi-part assemblies that have been cut out by numerically controlled flame cutters and these beams are transported to the construction site, often hundreds of miles away and riveted together at a factory. This process requires a lot of transportation time, cost and there is a chances of damaging of the parts.

The main concept of this project work is to design & develop a special purpose machine, which can be used for drilling and riveting the work piece having different thickness and material on the same machine. These kinds of special purpose machine are very much required in the mechanical workshops, small scale industries, where it is essential for specific job applications. Orbital forming is a quiet, non-impact process of cold forming - replacing traditional riveting, staking, crimping, pressing, welding and other fastening operations. Orbital forming uses a spinning tool, mounted in a rotating spindle and inclined at an angle about 3 to 6 degrees toward the centre of the spindle.

II. WORKING PRINCIPLE

The compressed air from the compressor is used as the force medium for this operation. The air from the compressor enters into the flow control valve which converts the flow of air and enters into the pneumatic double acting cylinder from lower port through the pipe linings pushes the piston outwards and move drilling and riveting spindle with the help of flange attached to stroke of pneumatic cylinder and spindle, this causes the application of gradual force to drilling and riveting spindle. The drilling tool drills the holes into the workpiece as well as riveting tool applying the gradual force on the rivet till the snap head is to be form. After completion of operation the compressed air comes inside to the pneumatic cylinder from another port and drilling and riveting spindle comes upwards.

III. DESIGN AND CALCULATIONS

A. 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
Thickness of plate (t) = 08 mm
Drill speed (N) = 800 rpm
Feed (f) = 0.2 mm/revolution
Mechanical efficiency (η_{mech}) = 0.90%

Solution: -

$$\text{Power} = \frac{1.25*D^2*K*N*(0.056+1.5f)}{10^5}$$

$$= \frac{1.25*6^2*1.15*800*(0.056+1.5*.2)}{10^5}$$

$$= 0.1473$$

$$\text{Power of electric motor} = \frac{\text{Power available at drill}}{Mechanical\ \ efficiency}$$

$$= 0.1473 / 0.90$$

$$= 0.164 \text{ kW}$$

Required power of electric motor for drilling is 0.164kW.
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 = 0.314 kW

According to this requirement,
We have select an electric motor of 1/2 Hp ≈ 0.350 kW

B. Design of Belts

(P_d): Design power to be transmitted
(fa): Correction factor for Industrial Service
(Pr): Power rating of Single V-Belt
(fc): Correction factor for Belt length
(fd): Correction factor for arc of contact

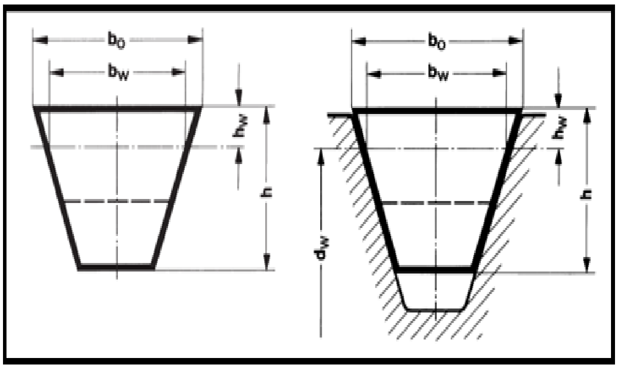

Fig. 1. Cross- Section of V-Belt

1) Correction factor for Industrial Service (fa)
For Heavy duty, AC Induction Motor(1/2 Hp), Operating hours per day is 16 hours (fa) = 1.5
2) Design Power (P_d) = fa × transmitted power
P_d = 0.225 kW
3) Type of c/s of belt
The intersecting point decides the type of C/S of belt is 'Z'
4) Pitch diameter of smaller and bigger
Selected pitch major diameter for pulley is (D_p)= 95 mm
Selected pitch minor diameter for pulley is (d_p)= 80 mm
5) Pitch Length of the Belt (Lp)
Initially assuming centre distance between the both pulleys as 350 mm.

$$\mathrm{Lp} = 2\mathrm{C} + \frac{\Pi\,(\mathrm{Dp}+\mathrm{dp})}{2} + \frac{(\mathrm{Dp}-\mathrm{dp})2}{4\mathrm{C}}$$

Lp = 975 mm
6) Correct Centre distance (C)
Put the value of L=975 mm in bellow equation

$$\mathrm{Lp} = 2C + \frac{\Pi\,(\mathrm{Dp}+\mathrm{dp})}{2} + \frac{(\mathrm{Dp}-\mathrm{dp})2}{4\mathrm{C}}$$

C = 350 mm
7) Correction Factor for belt pitch length (fc) - For belt pitch length 1100 mm
fc = 1.05
8) Arc of contact for belt and motor pulley

$$\alpha s = 180 - 2sin - 1\ \frac{(\mathrm{Dp}-\mathrm{dp})}{2\mathrm{C}}$$

$\alpha s = 177^0$, αs = 3.1 radian
9) Correction factor for arc of contact (fd)
For $\alpha s = 177^0$ fd = 0.99
10) Power rating (Pr)
For Z c/s and speed of the motor shaft is 1440 rpm.
Pr = 1.04 kW
11) No. of belts = $\frac{\mathrm{P} \times \mathrm{fa}}{\mathrm{Pr} \times \mathrm{fc} \times \mathrm{fd}}$ = 1 belt.
12) Speed of the belt

$$\mathrm{V} = \frac{\Pi \times \mathrm{dp} \times \mathrm{N}}{60} = 6\ \mathrm{m/s}$$

13) Area of the Belt
$A_{belt} = h \times bo = 127\ mm^2 = 127 \times 10^{-6}\ m^2$
14) Mass of the belt per meter length
m = A × l × ρ
m = 0.15 kg/m3

15) Centrifugal Tension
$Tc = m\,V^2$
16) Maximum Tension in the belt
Assume Ϭ = 2 mpa = $2 \times 10^6\ N/mm^2$
Tmax = Ϭ × A_{belt}
Tmax = 254 N
17) Tension in tight side of the belt
T1 = T – Tc
T1 = 248.6 N
18) We know that
2.3 log (T1/T2) = μ × Ø ×cosec β
= 0.25 × 3.1 × cosec 17
2.3 log(248.6/T2)=2.535
Tension in Slack side of the belt T2 = 20 N

TABLE 1. BELT SPECIFICATION

Technical Terms	Dimensions
1) Top Belt Width – bo	12.7 mm
2) Pitch Width – bw	11.0 mm
3) Pitch Length – Lp	975 mm
3) Bottom belt width - bu	5.6 mm
4) Height of the belt - h	10 mm
5) Pitch height – hw	2.8 mm
7) Max. Belt speed - V max	6 - 20 m/s
8) Weight per meter –W	0.15 kg / m3
9) Recommended Minimum major and minor pitch diameters of pulley (Dp and dp) mm	70 mm & 90 mm
10) Permissible minimum minor pitch diameter of pulley(dp) mm	80 mm & 95 mm

C. Design of Pulley

Pulleys were used for narrow-section CONTI FO-Z heavy-duty cogged raw edge V-belts. V-belt pulleys are manufactured from cast iron GG-20. 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.

TABLE 2.PULLEY SPECIFICATIONS

Pulley Section		XP (Z section)
Pitch Width	b_{width}	11.0 mm
Top groove width	b_1	12.7 mm
	c	2.8 mm
Groove Spacing	e	15 ± 0.3
	fg	10 ± 0.6
Groove depth	tg	14 ± 0.6

D. Machining Time Calculation

Drill Diameter = d = 06 mm
Thickness of plate = t = 08 mm
Feed = f = 0.2 mm / revolution
Tool overtravel = 6 mm
Cutting Speed = V = 15 m/min = 15 × 1000 mm/ min

Solution: -

We know that Cutting Speed is

$V = \Pi \, d \, N / 1000$

$15 \times 1000 = \Pi \times 6 \times N$

$N = 797$ rpm

Assume $N \approx 800$ r.p.m

Time required drilling a hole: -

$$T = \frac{L}{f\ N} = \frac{\text{thickness} \ + \text{overtravel} \ + 0.3\ d}{f\ N} = \frac{8+6+0.3\times6}{0.2\times800}$$

$= 0.11$ min $\simeq 15$ Sec

IV. WORKING OF SPECIAL PURPOSE MACHINE

The pressurized air from the compressor at the pressure of 5 to 7 bar is passing through the tube to the cylinder connected to the solenoid valve with one input. The solenoid valve (V1) is actuated with control timing unit (Relay and PLC). The Solenoid valve has two outputs and one input. The air entering into the input goes out through the two outputs when the timing control unit is actuated.

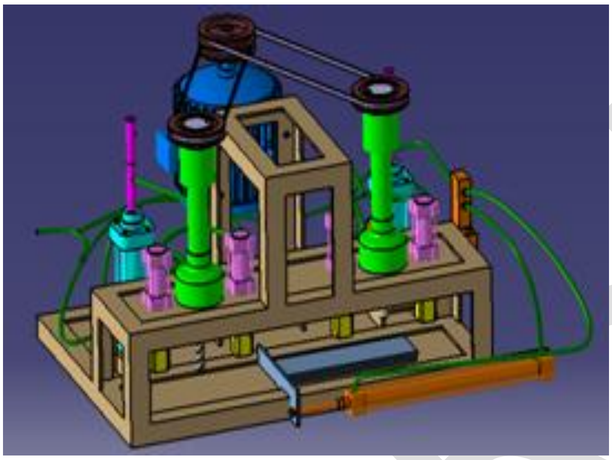

Fig. 2. SPM Isometric View

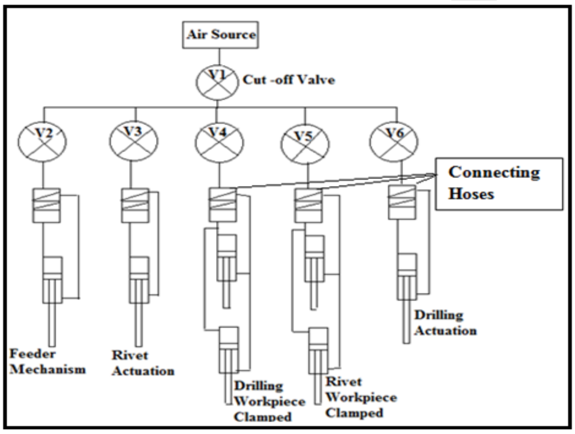

Fig. 3. Flow Diagram of Compressed Air

When motor will start, due to rotation of spindle both the drilling and riveting tool will starts to rotate at different speed. The job which is to be drill is placed on the work table. The air from the compressor enters into the flow control valve (V1 to V4) passes to the two small pneumatic cylinders, due to the pressure difference both the piston goes downwards and workpiece gets clamped. Now the compressed air enters inside the pneumatic double acting cylinder which is placed at the side of drilling spindle through (V2) pushes the piston outwards and moves drilling spindle with the help of flange attached to stroke of pneumatic cylinder and spindle, so both the workpiece gripping cylinder are actuated at a same time through common valve. The amount of pressure applied depends upon the type of joint. The tool is guided such that the drill is clearly projected on the required position. This force acting is passed on to drilling tool and drilling operation takes place on the work piece. Drilled holes are always slightly larger than the diameter of the drill bit. So the one side of the air is pushed the piston in the cylinder outwards and the other side is pull the piston inwards. The drill tool is therefore pulled outwards from the hole.

After completion of drilling operation, inserting a rivet on predrilled hole and place the workpiece on the riveting worktable and clamped by the two separate pneumatic small cylinders by passing the air from valve V5. The tool or rivet set mounted in the tool holder rotates at slow speed with high torque. The tool spins about the rivet 3 – 6 degree offset projecting out of the joint thereby cold forming the head on the rivet side. The orbiting tool rotates at fixed angle during orbital forming and applies radial and axial forces to progressively move malleable material into a desired shape by passing the air from valve V3. The angular tool and progressive motion reduces axial loads by as much as 80 percent.

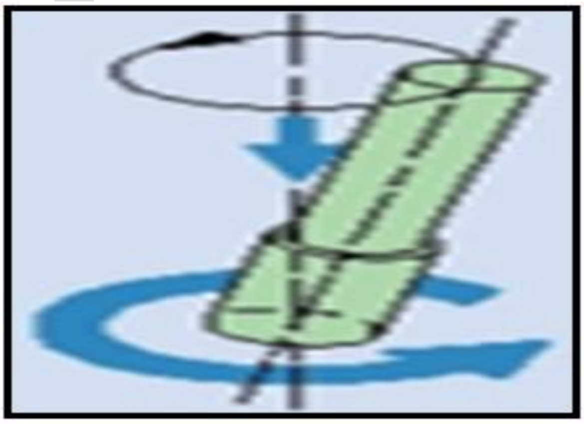

Fig. 4. Orbital Riveting Tool Inclination

Hence by using the conventional or separate drilling and riveting machine requires more cyclic (Transportation and operation) time, due to this the production rate is very low. But by using SPM the total cyclic time is reduced up to only just 60 seconds. Hence greater the production rate, can produce 1440 components in just one day. The 5,18,400 jobs can be competed in one year.

V. FABRICATION OF SPM

SPM is fabricated on the basis of above design. Some parts of this machine i.e. pulley, shaft, riveting tool, etc are manufacture on lathe machine. And remaining parts are porches as per design requirement. The time taken to fabricate this machine is 3 month.

Fig. 5. Actual fabricated SPM

VI. COST ESTIMATION

TABLE 3. COST ANALYSIS OF THE MACHINE

Sr.no.	Name of Components	Material	Qty.	Amount
1.	Compressor	C S	1	7500
2.	Angle	M S	18 ft	850
3.	Steel Plate	M S	4 sq.ft	1485
4.	Electric Motor	CA	1	3500
5.	Electric Wire		40 ft	200
6.	Motor Bolts and Nuts	M S	4	20
7.	Pulley	C S	3	1200
8.	Belt	G R	2	300
9.	Large Pneumatic Cylinder	C A	2	3600
10.	Gripping Pneumatic Cylinder	C A	4	3800
11.	Feeding Pneumatic Cylinder	S S	1	1500
12.	Pressure control Valve		1	150
13.	Solenoid Valves		5	2500
14.	Drilling Spindle		1	2000
15.	Riveting Spindle		1	2000
16.	Drill bit		1	80
17.	Rivet Tool		1	500
18.	PLC		1	2700
19.	Relay		5	250
20.	Cut off Valve		1	250
21.	Compressed air Tube		50 ft	500
22.	Tube Bush/ separators		40	800
23.	Paint		---	50
Total cost	Rs. 35,735 /-			

VII. FEM ANALYSIS OF SPECIAL PURPOSE MACHINE

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

Element: SOLID 186
Young's Modulus (E): 2.1e5
Poisons ratio (μ): 0.29
Density (ϱ): 7.85e-6
Force: 35kN

A. Model

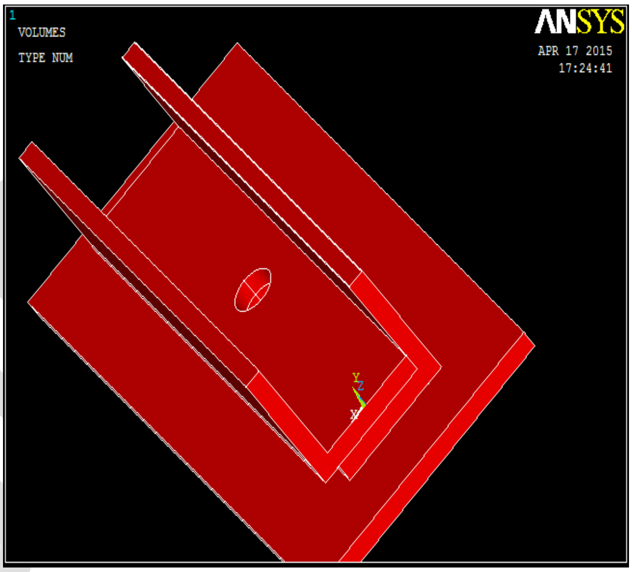

Fig. 6. Model of work piece

B. Meshing model

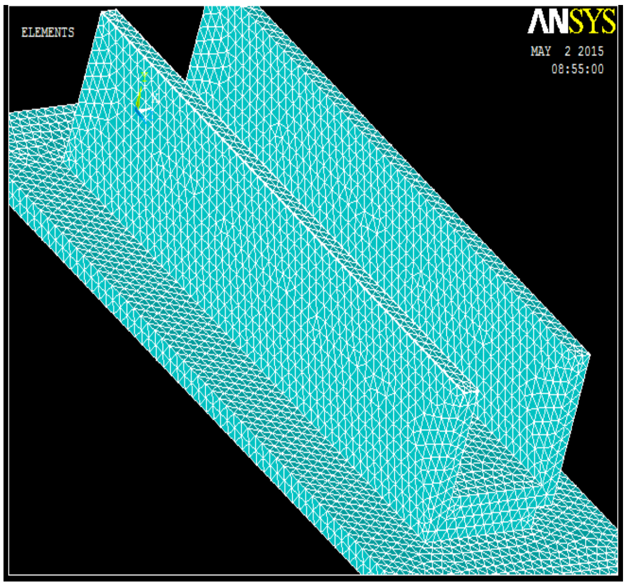

Fig. 7. Meshing model

C. Deformation

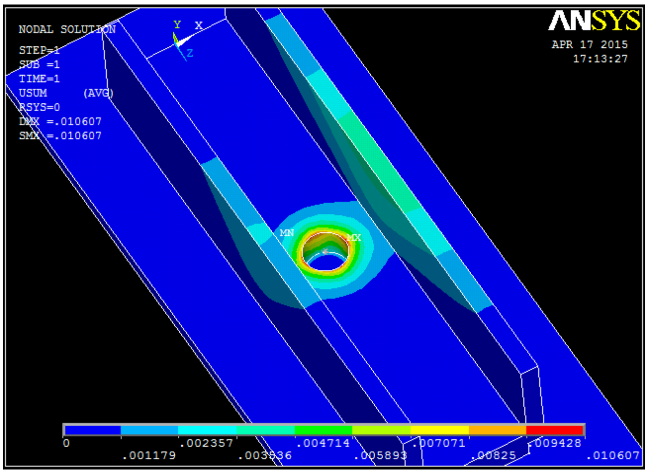

Fig. 8. Deformation

The total deformation is found to be 0.010607 mm

D. Evaluation of the Von-Misses Stress Result

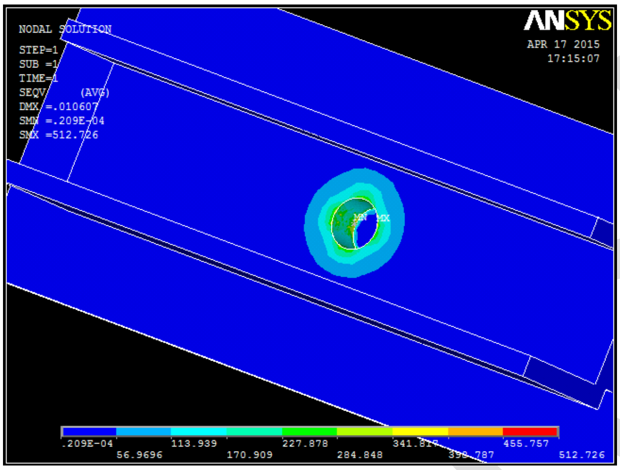

Fig. 9. Von-Misses Stress

The equivalent Von-Misses stress is found to be 512.726N/mm^2. It is shown by the red colour in the diagram.

E. Von-Misses Strain

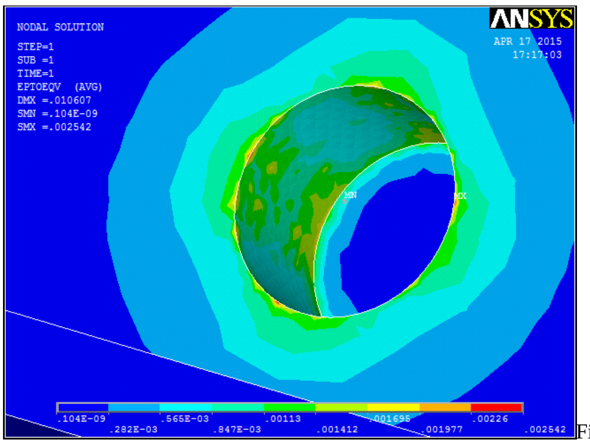

Fig. 10. Von-Misses Strain

The equivalent Von-Misses strain is found to be 0.002542.

VIII. CONCLUSION

It is found that the SPM 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 to 10mm thick plate, the time required for drilling and riveting operation is about to be 2 min. But we found that by using SPM the time required is 1 min. Therefore there is 65 sec less time required for producing one complete job with this machine for the same period of time. The comparison between conventional machines and SPM is shown in below table.

TABLE 4. COMPARISON BETWEEN CONVENTIONAL MACHINES AND SPM

Descriptions	Conventional Machines	SPM
Total time required for producing one job.	120 Sec i.e. 2 min	65 Sec
Job / Hour	30 Job / Hour	55 Job / Hour
Job / Day	720 Job / Day	1320 Job / Day
Job /Month	21,600 Job /Month	39600 Job /Month
Job /Year	2,59,200 Job /Year	475200 Job /Month

More jobs per year is 475200 - 259200 = 216000 Jobs

FEM analysis show the stresses in work piece are within limit means SPM gives correct results.

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