ORBITAL RIVETING – A DESINE AND DEVELOPMENT OF NEW MACHINE

[1]SACHINKUMAR JAGTAP, [2]MUKUND KAVADE

[1]PG Student, Mechanical Department, R.I.T Islampur, India.
[2]Associate Prof, Mechanical Department, R.I.T Islampur, India.

Abstract- Orbital riveting is a relatively new technology in which parts are produced by specific movement of tools. Special incremental motion enables smaller contact area between tool and workpiece and Therefore, lower forming load and friction. Hence, orbital forging in some cases makes it possible to produce a desired part in only one operation, whereas in conventional riveting two or more operations would be required. However, orbital riveting has number of setbacks, such as more complex machine maintenance and production times. This paper presents a brief overview of Design and Development of Orbital Riveting machine main orbital riveting characteristics and comparison with conventional riveting machine. Auto-cad drawing, 3D model, Actual diagram for specific machine for orbital riveting is present as well.

Index Terms- orbital riveting, design, development, cost.

I. INTRODUCTION

Rivet is set at the joint such that the rivet set angle is from 1^0 to 8^0 depending upon the joint to be obtained. It turns around the vertical axis at about 2000 to 3000 rpm and describes a cone whose apex corresponds to the centre of gravity of the joint formed. It is the tool which gives the shape. Orbital riveting an unconventional fastening technique cuts the cost of many material forming and assembly applications. Most engineers tend to rely on traditional fastening methods to join parts, but a lesser-known technique, orbital forming, often provides better results at lower costs. Orbital forming, as the name implies, is a cold-forming process that uses an "orbiting" tool. Sometimes called spinning, radial riveting, or spin riveting, orbital forming is most often used to head, swage, crown, flare, or form a column or projection of material in fastening and assembly operations. The process is somewhat similar to impact and compression forming, where the tool applies a compressive axial load to plastically deform the part. The difference is that in orbital forming, the tool rotates at a fixed angle typically 3 to 6°and applies both axial and radial forces to progressively move malleable material into a desired, predetermined shape. Unlike impact or compression forming, where the process is complete in a single pass, orbital forming requires several tool revolutions and typically takes 1.5 to 3 sec to complete. Most of the work during orbital forming is focused at the tool's line of contact, not along the entire tool surface. This reduces axial loads by as much as 80%, which has several advantages. Fasteners and mating parts see less stress. Orbital forming produces a smooth surface finish and, in some applications, eliminates cracks caused by impact riveting. Since the effective forming load typically does not exceed the fastener's column strength, cold-head forming is possible without bending or swelling the fastener shank. Because less axial load is required for forming, a smaller press can be used, which reduces equipment tonnage, floor space, and costs typically associated with producing large parts. Due to lower forming forces, less rigid fixturing is required, and tools last longer. Orbital forming is quieter than other cold-forming processes such as impact forming or peening. The process is suited for many materials, from metals to plastics, including virtually all grades of mild steel, most stainless steels and heat-treated alloy steels, case-hardened materials, and nonferrous metals such as aluminum, brass, and copper. Even high-alloy steel hardened to Rockwell 54C can be orbitally formed. Standard machines are available that can handle up to 1.5-in. diameter parts in solid mild steel, and larger diameters in softer materials. Still, the ultimate physical size limit of orbital-forming applications is constantly being expanded. New customer applications are resulting in larger orbital forming machines. Although riveting is by far the most common use for orbital forming, any application with a symmetrical or near symmetrical structure that requires material forming is a candidate.

In fact, the process has been successfully used in many nontypical applications such as crimping and sealing end caps in air-bag gas generators, roller retention in cam followers and rocker arms, and sealing and retaining the assembly of tie-rod ends, ball joints, and idler arms. It has also been used to seal antilock brake manifolds, join tubes to mating end plates, attach gears to shafts, seal welch plugs in driveshaft yokes, and retain nuts in reinforcing plates.

II. PROBLEM STATEMENT

After doing the above literature survey it is decided to develop a new machine. In consultation with Sponsor Company it is decided to design and develop a riveting machine with following features as per product development need:

i) Indexable table for multiple orientation positions, namely inclined positions, horizontal position
ii) Quick change riveting head, to enable the operator to quickly change the tool set for riveting three forms

Riveting produces dents in the product and deforms the product.
Iv) Fast production rate with the least cycle time.

III. DESIGN

Design consists of application of scientific principles, technical information and imagination for development of new or improvised machine or mechanism to perform a specific function with maximum economy & efficiency .Hence a careful design approach has to be adopted. The total design work, has been split up into two parts

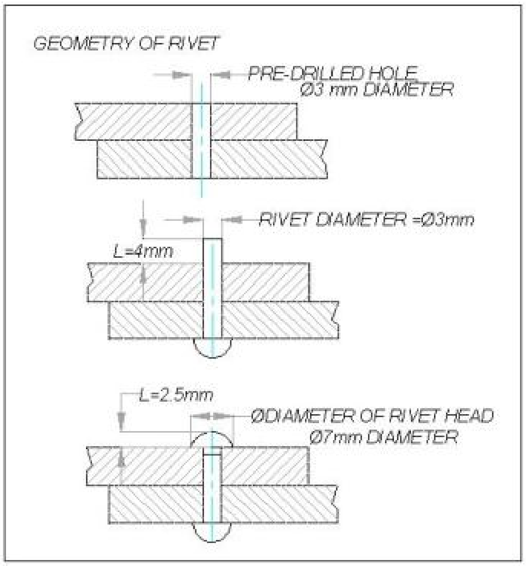
- System design
- Mechanical Design.

System design mainly concerns the various physical constraints and ergonomics, space requirements, arrangement of various components on main frame at system, man, machine interactions, No. of controls, position of controls, working environment of machine, chances of failure, safety measures to be provided, servicing aids, ease of maintenance, scope of improvement, weight of machine from ground level, total weight of machine and a lot more. In mechanical design the components are listed down and stored on the basis of their procurement, design in two categories namely,

- Designed Parts
- Parts to be purchased

For designed parts detached design is done & distinctions thus obtained are compared to next highest dimensions which are readily available in market. This amplifies the assembly as well as postproduction servicing work. The various tolerances on the works are specified. The process charts are prepared and passed on to the manufacturing stage. The parts which are to be purchased directly are selected from various catalogues & specified so that anybody can purchase the same from the retail shop with given specifications. Materials commonly used for orbital riveting: The material commonly used for orbital riveting rivet material includes: Low and medium carbon stee.(C07 or C10), Low alloy steels, Copper, Aluminium, Light alloys such as Magnesium, Titanium and Berylium. Material Selection and their properties: Steel Designation C07, C10 Used for cold forming and deep drawing. Rimming quality used for automobile bodies, cold heading wires and rivets. Wrought aluminium alloy 5300, Characteristics: Tensile Strength 215 (N/mm^2) Ductile in soft condition, but work hardens rapidly, becoming extremely tough, having high resistance to corrosion attack, especially in marine applications. Typical uses: Ship building; rivets; of rivets in the product. The setting time for the tool set should be minimum.
iii) Modified method of riveting as product line involves hollow sections. conventional pneumatic riveting gun
pressure vessels and other processing tanks, cryogenics and welded structures.

Input Data: Material of Rivet: Empirical Method to Compute Forging Load: Open Die Forging: The load required to forge a flat section in open dies may be estimated by; P = σ A C, N Where, A = Forging projected area; mm^2, σ = mean flow, stress N/mm^2, C= Constant (Constraint factor) to allow for in homogeneous deformation. The deformation resistance increases with Δ which is defined as; Δ = mean thickness of deforming zone / length of deforming zone = h/2L,



Then C is given as; C = 0.8 + 0.2 Δ Δ = mean thickness of deforming zone / length of deforming zone = h/2L = 3/2(4) = 0.375, Δ = 0.375; C = 0.8 + 0.2 Δ = 0.8 + 0.2 (0.375) = 0.875, C = Constant (Constraint factor) =0.875; σ = mean flow stress = 100 N/mm^2; A = Forging projected area= π x D^2 /4 = π x 3^2 /4 =7.06 mm^2; P = σ A C = 100 x 7.06 x 0.875= 617.75 N Most of the work during orbital forming is focused at the tool's line of contact, not along the entire tool surface. This reduces axial loads by as much as 80%, which has several advantages.

Hence, P_{eff} = 0.2 x 617.75= 123.5 P_{eff} = 124 N, This is the load that acts in the downward direction while forming the rivet, where as the rivet head diameter is 6mm, hence the torque required at the spindle is given by: T = P_{eff} x r = 124 x 3 = 372 N-mm = 0.372 N-m. Power required at spindle is given by, P = 2 π N T /6 = 2 π x 900 x 0.372 /60 = 70 watt. Considering 100 % overload power at spindle = 140 watt, considering 60% transmission efficiency of belt drive. Power at motor shaft = 140 + (140 x 0.4) = 196 watt.

Motor Selection: 3- Phase Induction Motor (2 Pole), Make:- 415 V, 50 Hz, Power = 0. 5 Hp (0.375) Kw , Speed = 1440 rpm (Synchronous), Current = 1.70 AMP, Torque= 0.17 Kg. M, Torque Analysis:-Torque at spindle is given by; Ts $= \frac{975N}{n}$ Spindle Torque = Tdesign x 1.6 = 4.973 N-m.

Design of Belt Drive for Machine Spindle: Input Data: Input Power = 0.375 KW, Input Speed =1440RPM, Centre Distance = 300 MM, Max Belt Speed = 1600 M/MIN = 26.67 M/SEC, Groove Angle (2β) = 40^0, Coefficient Of Friction = 0.25 (Between Belt and Pulley), Allowable Tensile Stress = 2.5 N/mm^2 Section of belt section:Ref PSG DESIGN DATA (PG NO. 7.58)

Design Key at Spindle Pulley End: Selecting parallel key (6x6x27) .Both Ends Round Is 2048 – 1962, fs_{all}=Syt/FOS= 380/2 =190 N/mm^2 , Check for Shear Failure of Key: $fs_{act} = \frac{T \times d^3 \times 2}{L \times b \times d} = \frac{4.973 \text{ x } 103 \text{ x } 2}{27 \text{ x } 6 \text{ x} 6} = 10.23$ N/mm^2, ASf s_{act} < f s $_{all}$, Key is safe under shear load.

Check for Crushing Failure of Key: Te = L x t/2 x d/2 x f s $_{act}$, fs $_{act}$ = $\frac{4.973 \text{ x } 103 \text{ x } 2\text{x}2}{27 \text{ x } 6 \text{ x} 6}$ = 20.46 N/mm^2, AS f s_{act} < f s $_{all}$ Key is safe under crushing failure.Similarly Design of Key at Tool Holder End: Selecting parallel key (6x6x20). Both Ends Round Is 2048 – 1962.

Selection of Bearing at top end of main spindle: Spindle bearing will be subjected to purely medium radial loads; hence we shall use ball bearings for our application. Selecting; Single Row deep groove ball bearing as follows. Series 62

IsI No	Bearing of basic design No	d	D 1	D	D 2	B	Basic capacity	
25AC 02	6005	25	28	47	44	12	5200	7800

P = X F_r + Y F $_a$, Neglecting self weight of carrier and gear assembly, For our application F $_a$ =0, P = X F_r, Where, F_r = Ra, As; F_r <e⟹X =1, P = 156.2 N. Calculation dynamic load capacity of bearings L = $\frac{(\ c^P\ )}{P}$, Where, p= 3 for ball bearings, For m/c used for eight hr of service per day; L_H = 12000- 20000hr, But; $L = \frac{60 \text{ n } L_H}{10^6}$ = 648 mrev. Now; 648 = $\frac{C^3}{156.2^3}$, C = 1351.6N, as the required dynamic capacity of bearing is less than the rated dynamic capacity of bearing. Bearing is safe.

Similarly Selection of Bearing at bottom end of main spindle: Spindle bearing will be subjected to purely medium radial loads; hence we shall use ball bearings for our application. Selecting single row deep groove ball bearing as a Series 62.

IV. MODELING OF ORBITAL RIVETING MACHINE

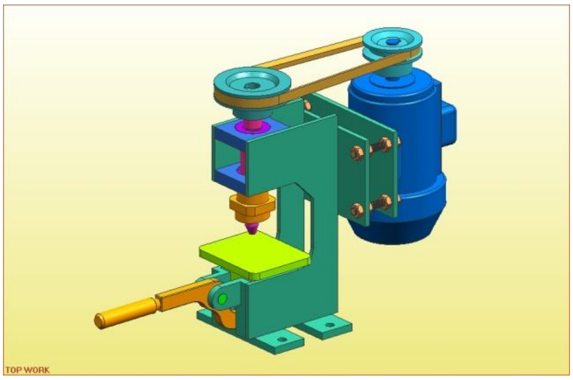


Fig. Manufactured Orbital Riveting Machine

Modeling of orbital riveting machine can be with CatiaV5 software. In this software all part can be modeled and these parts can assemble to formed actual machine. This model gives actual profile of machine. It gives idea of how machine look.

V. PROPOED SKETCH OF ORBITAL RIVETING MACHINE

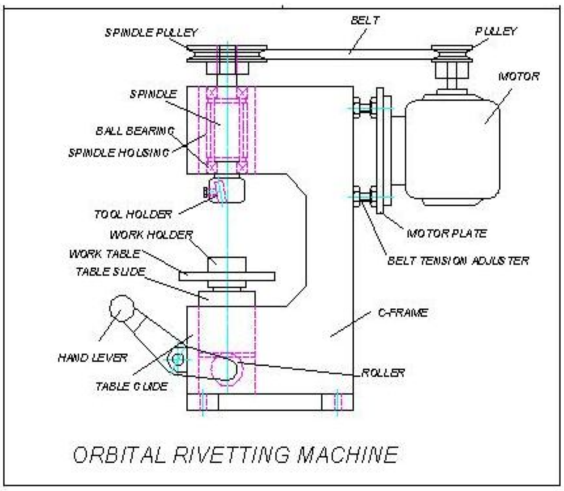


Fig. Orbital Riveting Machine

Construction: The orbital riveting machine consists of the following parts;

1. 3-Phase Induction motor: The motor used in the machine is an 3-phase induction motor, Power-0.5 Hp, Speed-1440 rpm, Foot mounted.
2. Motor pulley: The power transmission from motor to the main spindle is done by an open belt drive. Motor pulley is a cast iron pulley (2.5" diameter), single groove 'A-Section', keyed to the motor shaft.
3. Spindle Pulley: Spindle pulley is a cast iron pulley (4" diameter), single groove 'A-Section', keyed to

the main spindle. Thus the transmission ration 1:1.6, i.e. the spindle rotates at 900 rpm.

4. Belt: Belt is an ‘A-Section’ belt with included angle 40^0 length 29 inches, hence the specification ‘A-29’.
5. Top Spindle housing: The top spindle housing is an rectangular element made from structural steel EN9, bolted to the C-frame. It carries the single row deep groove ball bearing 6005zz.
6. Bottom Spindle housing: The bottom spindle housing is an rectangular element made from structural steel EN9, bolted to the C-frame. It carries the single row deep groove ball bearing 6005zz.
7. Ball Bearings: The spindle is held at the top and bottom ends in single row deep groove ball bearings 6005zz. Internal diameter of bearing is 25mm, outside diameter of bearing is 47mm and the width of bearing is 12mm.
8. Spindle: The spindle is a high grade steel member (EN24), held in heavy duty ball bearings at either ends supported in the bearing housings. The spindle carries the spindle pulley at the top end where as the tool holder at the bottom end. The spindle runs at high speed 900 rpm.
9. Tool Holder: The tool holder is high grade steel member (EN24), keyed to the spindle at the lower end. The tool holder holds the rivet set (tool) at an angle 5^0, to the spindle axis. The rivet set is held in ball bearing 6002 in the tool holder and is held in position by an internal circled.
10. Rivet set (Tool): The rivet set or tool is a hardened steel component OHNS (Oil Hardened Non Shrinkage Steel). The rivet set is provided with a cavity at its lower end according to shape of the rivet head to be formed. It is placed at an angle 5^0, to the spindle axis and is held in the tool holder.
11. Work holder: Work holder is made from structural steel (EN9), it is basically a fixture to the hold the job while carrying out the riveting operation. The work holder is held on the work table.
12. Work table: Work table is made from structural steel (EN9), it is basically a table to the hold the work holder while carrying out the riveting operation. The work table is held on the Table slide.
13. Table guide: Table guide is made from structural steel (EN9), it is basically a guide to the hold the Table slide while it moves up or down while carrying out the riveting operation. The Table guide is bolted to the C-frame.
14. Rollers: Rollers are basically two ball bearings namely 6002 and 6201 held on the end of the Feed handle on the handle roller pin, it moves the table slide up or down when the feed handle is operated. Pin is made from hardened steel (En24).
15. Feed handle: Feed handle is mounted in the handle hinge; it carries the roller at one end and the knob at other end. It moves the table slide up or down when operated.
16. Handle Hinge: Handle hinge is fabricated from MS, it is welded to the C-Frame, it carries the hinge pin on which the feed handle is mounted.
17. C-Frame: The C-Frame is the basic structure of the machine on to which entire assembly of machine is made. It is made of Mild steel.
18. Belt Tension adjuster: Belt tension adjuster is a arrangement to adjust the tension in the open belt drive. It comprises of basically four M10 bolts and motor plate. The position of the lock nuts is adjusted to adjust the belt tension.

VI. MANUFACTURED MODEL AS ACTUAL MACHINE

Fig. Manufactured Orbital Riveting Machine

For designed parts detached design is done & distinctions thus obtained are compared to next highest dimensions which are readily available in market. This amplifies the assembly as well as postproduction servicing work. The various tolerances on the works are specified. The process charts are prepared and passed on to the manufacturing stage. The parts which are to be purchased directly are selected from various catalogues & specified so that anybody can purchase the same from the retail shop with given specifications.
WORKING: Motor is started which rotates the main spindle at high speed. The tool or rivet set mounted in the tool holder rotates at high speed. The job to be riveted along with the rivet is placed in the work holder. The feed handle is pressed in the downward direction to lift the table slide and table in the table guide by means of roller arrangement. The tool spins about the rivet projecting out of the joint thereby cold forming the head on the rivet side. The amount of pressure applied depends upon the type of joint ie, fixed or hinged to be done. After riveting is done, the feed handle is released which brings the table slide down by self weight. Job is replaced in holder to form the next riveting joint. Rivet is set at the joint such that the rivet set angle is from 1^0 to 8^0 depending upon the joint to be obtained. It turns around the vertical axis at about 2000 to 3000 rpm and describes a cone whose apex corresponds to the center of gravity of the joint formed. It is the tool which gives the shape.

VII. FEATURES OF ORBITAL RIVETING

This riveting process allows fixed or hinged assemblies to be made. It allows special shapes to be riveted without difficulty. (eg. Square section tubes as ladder rungs) Due to orbital riveting principle and specific position of tool (rivet set) on the part to be riveted, the upsetting load required is six times lower than for direct thrust(press).

VIII. POSSIBILITIES DUE TO ORBITAL RIVETING AND ITS ADVANTAGES

Fixed or hinged assembled parts can be done. Many types of materials can be riveted eg. Steel, SS, Plastics, aluminium, etc., All working positions possible, All possibilities of automation. Excellent mechanical holding(security), Limited deformation and pressure of the parts to be assembled, Fast and rational implementation, The rivet head is gradually formed into desired shape, hence excellent mechanical holding or security of joint, Resultant joint by orbital riveting machine is more resistant to vibrations, Orbital riveting machine gives quieter riveting, Orbital riveting machine causes limited deformation and pressure on parts to be assembled, Orbital riveting reduces cost of riveting, Fast riveting process, Many types of materials can be riveted, Can make both fixed as well as hinged joints. Leather work, tools, toys, kitchen utensils, general hardware, Scissors, pliers, hinges, Parts subjected to thermal cycling, e.g. , Boiler shells.

CONCLUSIONS

Orbital riveting is a quiet, non-impact process of cold forming - replacing conventional riveting, staking, and crimping, pressing, welding and other are fastening operations. Orbital riveting can accomplish the same amount of forming work with a fraction (20%) of the force of conventional processes like pull riveting and hammer riveting. It can be used to replace loose fasteners, be applied with exacting process control and be used over a wide spectrum of materials. This machine gives many advantages as personal safety and operational safety because of simple in design and construction and also easy to handle and any one can operate. Extreme operating forces these forces sufficient for obtaining permanent joints.

It reduced the cost of machining operation, cost of the assembly operation and cycle time. This can do with orbital riveting machine. We recognize every application is different and there is no one size fits all solution for permanent part assembly.

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