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Orbital Riveting, Design, Development, Cost TRIZ, SPM, Productivity

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Abstract

Orbital Spin riveting is a relatively new technology for bearing locking in which partsare joined by specific movement of tools. Special incremental motion enables smaller contact area between tool and cage and therefore, lower forming load and friction. Hence, orbital spin riveting makes it possible to join a desired part in lower forming force in the operation, whereas in conventional locking more force would be required. The angle of the riveting tool held in the riveting head plays a significant role in the reduction in forming force, whereas the table motion will determine the accurate positioning of the rivet in to tool profile, resultinginto exact shape and size of rivet head formed. This project presents a brief overview of Designand Development of Orbital Riveting machine for Bearing Assembly which leads to improve the product quality and its Productivity.

Keywords: Orbital Riveting, Design, Development, Cost TRIZ, SPM, Productivity

1.INTRODUCTION

1.1 Cylindrical Roller Bearings

Cylindrical roller bearings (CRBs) have a simple structure with their cylindrical rollers in linear contact with the raceways. They offer high load capacity under primarily radial loads. Low friction between the rollers and ring ribs makes these bearings suited for high-speed rotation.

Figure 1 CRB Bearing

Cylindrical roller bearings are available in a wide range of designs, series, variants and sizes. The main design differences are the number of roller rows and the inner/outer ring flanges as well as cage designs and materials.

The bearings can meet the challenges of applications faced with heavy radial loads and high speeds. Accommodating axial displacement (except for bearings with flanges on both theinner and outer rings), they offer high stiffness, low friction and long service life.

1.2 Materials

Following raw materials are being used for cylindrical roller bearings manufacturing toachieve design life of bearing.

1.2.1 Materials for Inner/Outer races and Roller's

Bearing rings and rolling elements can be made of a number of different materials, but the most common is "chrome steel", (high carbon chromium) a material with approximately 1.5%chrome content. Such "chrome steel" has been standardized by a number of authorities, and there are therefore a number of similar materials, such as: AISI 52100 (USA), 100CR6 (Germany), SUJ2 (Japan) and GCR15 (China).

1.2.2 Materials for bearing cages

a. Sheet steel (stamped or laser-cut)

b. Polyamide (injection molded)

c. Brass (stamped or machined)

d. Steel (machined)

The choice of material is mainly done by the manufacturing volume and method. For large- volume bearings, cages are often of stamped sheet-metal or injection molded polyamide, whereas low volume manufacturers or low volume series often have cages of machined brass or machined steel. For some specific applications, special material for coating (e.g., PTFE coated cylindrical bore for vibratory applications) is adopted.

1.3 Types of Cages

Steel Cages Stamped-steel cages for cylindrical roller bearings consist of low-carbon steel and are manufactured using a series of cutting, forming, and punching operations. These cagesare made in a variety of different designs and are suitable for most general-purpose cylindricalroller bearing applications. One specific type is the S-type design for the 5200 series cylindrical roller bearing, which is a land-riding cage piloted on the outer ring ribs. This designhas depressed cage bridges which evenly space the rolling elements and retain them on the outer ring. Stamped steel cages are easily mass produced and can be used in high temperatureand harsh-lubricant environments

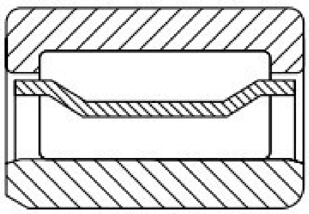


Figure 2 Steel Cage

Pin Type Cage Pin-type cages for cylindrical roller bearings consist of two rings and a series of pins running through the center of the rolling elements. These cages are used for large diameter cylindrical roller bearings where machined brass cages are not available. With this design, additional rollers can typically be added, resulting in increased load capacity.

Figure 3 Pin Type Steel Cage

Machined cages are an option for smaller cylindrical bearing sizes, and are typically made from brass. Machined cage designs for cylindrical roller bearings offer increased strength for more demanding applications. Designs can be one-piece or two-piece cages. One-piece designs can be either a finger-type as shown in fig. 4 or a standard cage configuration having fully milled pockets. The one-piece finger type and the two-piece design with cage ring (fig.5) are more common in standard cylindrical roller bearings. They also are roller-guided designs. The one-piece version with fully milled roller pockets (fig. 6) is our premium cage. This cage is used with our EMA series bearings. Unlike traditional roller-riding cages, it is a land-riding cage which minimizes drag on the roller elements. This reduces heat generation, resulting in improved bearing life. Compared to a two-piece design, this one-piece cage also reduces heat and wear by enhancing lubrication flow.

Figure 4 Machined Cage

1.6 Bearing Application

With their combination of greater radial load capacity, ability to accommodate faster speeds, and other benefits, cylindrical roller bearings are ideal for use in a variety of industries.
Typical markets that can utilize these parts include:

- Locomotive vehicle
- Machine tool spindle
- Internal combustion engine
- Generator
- Gas turbine
- Gearbox
- Rolling mill
- Vibrating screen

Figure 5: Gear Box

Orbital bench spin riveting machine is precision engineered to ensure that theywill perform with unfailing speed, accuracy & consistent repeatability. Quiet electric motorsdrive the silent orbital movement of the tool holder. The machine, using suitable tools can flare & join. Pressure for head forming is generated by either pneumatic or hydraulic power & is fully adjustable. Basically, orbital spin riveting machine is made to join the cage and itscover with help of 5-degree flaring tool by using lower forming force. By using this we could achieve the quality issues occurred during assembly stage. The Orbital spin riveting machine consist of Three phase induction motor transmit power to pinning tool. The material of the rivet can be spread over the work piece in desire shape is mostly depends upon the design of tool.

2 COMPONENT OF ORBITAL RIVETING MACHINE

The system should be compact enough robust so that it can be accommodated at a smaller floor area. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired.

1. Frame: is the basic structure of the machine on to which entire assembly of machine ismade. It is made of Mild steel.

2. 3-Phase Induction motor: is used in the machine is 3-phase induction motor, Power-1Hp, Speed-1420 rpm, Foot mounted.

3. Spindle: is a high-grade steel (En24), The spindle carries the spindle pulley at the top endwhereas the tool holder at the bottom end. The spindle runs at high speed 960 rpm.

4. Top Spindle housing: It is rectangular element made from structural steel. En9, bolted tothe machine frame. It carries the single row deep groove ball bearing 6305-2RS.

5. Ball Bearings: The spindle locates at the top and bottom ends in single row deep groove ball bearing 6305-2rs. Internal & external diameter of bearing is 25mm & 62mm. the width of bearing is 17mm.

6. Tool Locking Device: It is high grade steel member (En24), held to the spindle at thelower end. The device holds the rivet set (tool) at an angle 5˚, to the spindle axis.

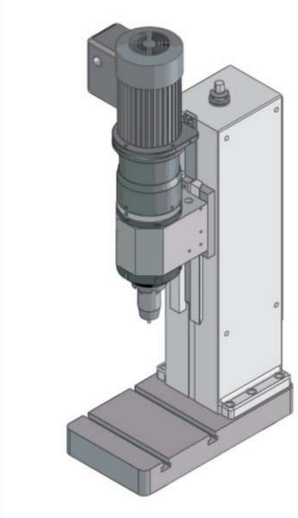


Figure 5 Schematic View of SPM

7. Rivet Tool: The rivet tool is a hardened steel component OHNS. The rivet set is providedwith 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. 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.

8. Servo Motor: provide accurate positioning for quick moves such as indexing. All featurea closed loop configuration ideal for variable loads and offer a wide range of gear options and braking or load holding options. The built-in controller (stored data) FLEX also helps for system configuration considerations.

9. Linear Bearings: Blocks provides smooth and quiet motion in linear direction to the work block; Linear guideways provides linear motion by re-circulating rolling elements between a profiled rail and a bearing block. The coefficient of friction on a linear guidewayis only 1/50 compared to a traditional slide and they are able to take loads in all directions. With these features, a linear guideway can achieve high precision and greatly enhanced moving accuracy.

10. 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.

11. Slide guide Plate: is made from structural steel (En9), it is basically a guide to the hold the Table slide while it moves forward or reverse while carrying out the riveting operation. The Table guide is bolted to the machine frame.

12. Index Plate: is made from structural steel (En9), it is basically a table to the hold the part locating while carrying out the riveting operation. The Index Plate is held on the worktable is index with the help of servo motor.

13. Work-Piece Locating Plate: is made from structural steel (EN31), it is basically aresting plate to the hold the part locating while carrying out the riveting operation.

14. Locking Cylinder Assembly: is made from structural steel (EN31), it is used to lockthe motion of indexing plate while carrying out the riveting operation.

15. Feed handle: is mounted in the handle hinge; it carries the roller at one end and theknow about another end. It moves the table slide up or down when operated.

16. Safety Light Curtain: it protects personnel from injury and machines from damage by creating a sensing screen that guards machine access points and perimeters. They are intuitive, easy-to-use safety light curtains for a wide variety of safety.

17. Tower light with buzzer: Light tower audible combinations provide a visual signal as well as an audible sound, such as a buzzer, to warn of danger or to draw attention to an important aspect in a work environment. They are particularly useful in busy workplaces where loud noise is a factor, enabling workers to be aware of any potential danger

18. Operator Pannel: With the Operator Panel, we can monitor, configure, and operate library functions from the library front panel. The Operator Panel has a Power button, an LCD display, six navigation buttons, and five LEDs.

19. Two Hand Push Button: control panels are protection devices, which require the simultaneous use of both hands for their actuation. By virtue of their forced location, both hands are kept out of the area of danger.

4. DESIGN PROCEDURE

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 carefully design approach has to be adopted.

System design

In system design we mainly concentrated on the following parameters: -

1. System Selection Based on Physical Constraints -While selecting any machine it must be checked whether it is going to be used on regular basis or not. In our case it is to be used on regular basis. So, space is a major constraint. The system is to be kept very compact so that it can be adjusted on smaller area.
2. The mechanical design has direct norms with the system design. Hence the for most job isto control the physical parameters, so that the distinctions obtained after mechanical design can be well fitted into that.
3. Arrangement of Various Components- Keeping into view the space restrictions the components should be laid such that their easy removal or servicing is possible. More over every component should be easily seen none should be hidden. Every possible space is utilized in component arrangements.

4. Components of System -As already stated the system should be compact enough so that itcan be accommodated at a corner of a room. All the moving parts should be well closed & compact. A compact system design gives a high weighted structure which is desired.
5. Man, Machine Interaction- The friendliness of a machine with the operator that is operating is an important criterion of design. It is the application of anatomical & psychological principles to solve problems arising from Man – Machine relationship.
6. Servicing Facility- The layout of components should be such that easy servicing is possible. Especially those components which require frequents servicing can be easily disassembled.
7. First time right- The design must be first time right, Factor of safety while doing mechanical design is kept high so that there are less chances of failure. More over periodic maintenance is required to keep unit healthy.
8. Scope of Future Improvement- Arrangement should be provided to expand the scope of work in future. Such as to convert the machine motor operated; the system can be easily configured to required one. The die & punch can be changed if required for other shapes of notches etc.
9. Height of Machine from Ground-For ease and comfort of operator the height of machine should be properly decided so that he may not get tired during operation. The machine should be slightly higher than the waist level, also enough clearance should be provided from the ground for cleaning purpose.

5. CALCULATIONS

As per the requirement of the use machine has been designed.

Δ = mean thickness of deforming zone / length of deforming zone$\Delta = h/2L$
$\Delta = 4/2(4) = 0.50$ $\Delta = 0.500$
$C = 0.8 + 0.2\ \Delta$

$= 0.8 + 0.2\ (0.500) = 0.900$

Where, C = Constant (Constraint factor) =0.900σ = mean flow stress = 120N/mm^2
A = Forging projected area; mm^2

$= \pi/4 \times D^2$

$= \pi/4 \times 3^2 = 7.06$ mm^2 $P = \sigma\ A\ C$
$= 120 \times 7.06 \times 0.90$

$= 741.03$N

Most of the work during orbital forming is focused at the tool's line of contact, not along theentire tool surface. This reduces axial loads by as much as 80%, which has several advantages.
Hence,

$P_{uff.} = 0.2 \times 741.03 = 148.26NP_{eff.}$ =149 N
This is the load that acts in the downward direction while forming the rivet, whereas therivet head diameter is 6mm, hence the torque required at the spindle is given by:
$T = P_{eff.} \times r$

$= 149 \times 3$

$= 447$ N-mm

T = 0.447 N-m

Power required at spindle is given by,$P = 2\ \pi\ N\ T\ /60$

$= 2\ \pi \times 900 \times 0.447\ /60 = 42.12$ watt.

P= 42.12 watt.

VI. DESIGN OF MAIN SPINDLE.Torque Analysis: -
Torque at spindle is given by;Ts = 975 Δ/n
Ts = 975 x 0.375/1440

Ts = 0.253 kg .mTs = 2.53 Nm
Considering 25 % overload;Design = 1.25 Ts
= 1.25 x 2.53

=3.10 Nm

Design = 3.10 Nm
Planning a 1 stage transmission Spindle transmission speed = 1440 rpm
Spindle Torque = Design x 1.6 = 3.10x1.6=4.973 N-mDesign = 4.973 N-m.
Ultimate Tensile Strength N/mm^2=720Yield Strength N/mm^2=600
Using ASME code of design;

Allowable shear stress; fall is given stress; Fall = 0.30 x sall = 0.30 x 600 =180 N/mm^2
Fall = 0.18 x Sall = 0.18 x 720= 130 N/mm^{2}Considering minimum of the above values; Fall = 130 N/mm^2
As we are providing key way on shaft; Reducing above value by 25%.

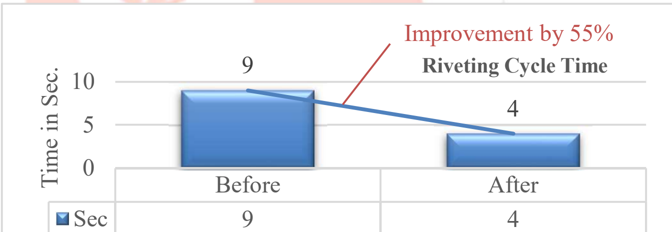
Fall = 0.75 x 130 = 97.5 N/mm^2

a) Considering pure torsional load; Minimum section on the spindle as per system drawingis 20mm
Design = π x fa_{ct} d^3 /16fa_{ct} = 16 x T/π x d^3
fa_{ct} = 16 x 4973/πx20^3fa_{ct} = 3.1659 N/mm^2 As $fa_{ct} < fa_{ll}$
Spindle is safe under pure torsional load.

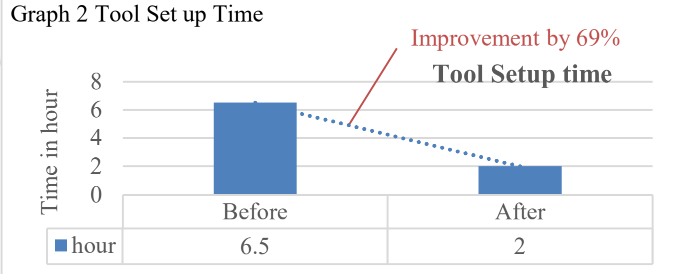
6. RESULTS & CONCLUSION

The growth of any manufacturing industry deals with its market demand also the product Quality. With the help of design machine, we can able to achieve the zero-quality defect in large size bearing and customer satisfaction. After implementation of project model, we got following results through our newly designed Process

Graph 1 - Riveting Cycle Time



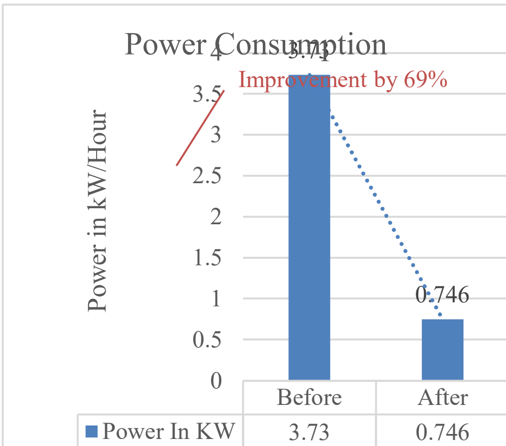
Graph 2 Tool Set up Time



6.1. Cycle Time: - Cycle time is reduced by 5 second for producing a batch of 1000 no's, this means that our process time improved by 55%.

6.2. Tool Set up Time: -
Setting time is reduced by 4.5 hours for producing a batch of 1000nos, this means that our tool set up time improved by 69%.

6.3. Electricity Consumption: -
Power consumption is reduced by 2.98kW/hours for producing a batch of 1000nos, this means that our 2.98kW/hour electricity is saved up it is improved by 69%.



7. CONCLUSION

The growth of any manufacturing industry deals with its market demand also the product Quality. With the help of design machine, we can able to achieve the zero-qualitydefect in large size bearing and customer satisfaction.

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