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Design and Development of Plastic Spin Welding Machine

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ABSTRACT:
A new indigenous spin welding machine for thermoplastics with advanced mechatronic controls is conceptualized, designed in detail and a prototype is developed for joining of two thermoplastic parts in axis-symmetrical fashion. Manual spin welding machines for joining thermoplastic parts in axis-symmetrical manner are generally obtained by modifying drill type machines which causes the relative frictional rotation of parts under contact pressure exerted manually through a lever. The contact under relative motion causes the heat generation and results into fusion of parts. The joints from such machines exhibit inconsistency inherent in the manual process. The indigenous prototype machine is able to perform spin welding process with consistency. It enables the operator to choose and control the process parameters such as rotation velocity, time of rotation, spin pressure and cooling pressure.

Keywords: Design, Spin Friction Welding, Programmable Controls, Human Machine Interface, Thermoplastics.

I. Introduction

One of the major advantages of thermoplastics is the ease with which these can be molded, incorporating small and intricate features integrated within them. However, when the complexity requirement of the thermoplastic product cannot be met in a single molding operation and require multiple parts to be joined into one, joining process such as plastic welding comes handy. Friction spin welding has emerged as a popular method of joining thermoplastic parts axis symmetrically. The process of Friction Spin welding is generally carried out by rubbing, preferably in rotational motion, the two parts surfaces in-coordination against each other. The two plastic parts to be joined using friction spin welding are gripped separately in a rotatable fixture and corresponding mating stationery fixture respectively. The rotary fixture gives rotation to the one part and at the same time presses the rotating part on to the stationery part.

The material at the interface is heated up due to frictional heat and become semi-fluid with the increase in temperature. Interface film and the melt flows out at the joint interface to form the weld bead, finally the rotation of the parts is stopped, the joined parts are allowed to cool and solidify under pressure condition for some time. Thereafter, the welded assembly is removed. The aforesaid process is usually carried out using a modified drill press where the rotary fixture is mounted upon the drill machine spindle and pressure is applied by pressing the lever manually. he aforesaid modified drill press is prone to producing inconsistent weld joints due to manual operation and require skilled operator. Alternative is to import from abroad spin welding machines which are very costly. Therefore, it was desirable to undertake the present work to indigenously develop a spin welding machine equipped with advanced process controls.

Problem Statement: Welding a plastic is a critical task which needs to be done in precise way, also strength of component after welding should meet the customer demand. Need to develop a spin welding system to weld the plastic component.

II. Literature Review

A. Thermoplastic Welding Techniques

1) Hot Plate Welding: Hot Plate Welding is a plastic welding process, utilizing heat of hot plate placed between the surfaces to be joined. The work pieces, pressed to the plate, heat up and soften. After a predetermined time of the plate is removed, the parts are brought to the contact, pressed and fused together. Their polymer molecules are cross-linked when the work pieces cool down, forming a strong joint. Hot plates are made mainly of Aluminum alloys. A hot plate is equipped with an electric heating element and a thermocouple providing temperature control of the plate surface.

Applications of Hot Plate Welding: Components of domestic electric devices (dishwashers, washing machines, vacuum cleaners), Pipes, Automotive components (lights, fuel tanks, reservoirs, batteries).

2) Ultrasonic Welding: Ultrasonic Welding is a plastics welding process, in which two work pieces are bonded as a result of a pressure exerted to the welded parts combined with application of high frequency acoustic vibration (ultrasonic). Ultrasonic vibration transmitted by a metal tool (horn, sonotrode) causes oscillating flexing of the material and friction between the parts, which results in a closer contact between the two surfaces with simultaneous local heating of the contact area. The plastic melts in the contact area, the polymer molecules are cross-linked, forming a strong joint. Ultrasonic Welding cycle takes about 1 sec. The frequency of acoustic vibrations is in the range 20 to 70 kHz (commonly 20-40 kHz). The amplitude of the acoustic vibrations is about 0.002" (0.05 mm). Thickness of the welded parts is limited by the power of the ultrasonic generator. Ultrasonic Welding is used mainly for processing amorphous polymers (Polystyrene (PS), Acrylonitrile-Butadiene-Styrene (ABS).

Application of Ultrasonic Welding: Medical equipment, Automotive components, Electrical equipment, Electronic and Computer Components, Toys.

3) Spin Welding: Spin Welding is a plastics welding process, in which two cylindrical parts are brought in contact by a friction pressure when one of them rotates. Friction between the parts results in heating their ends. After a predetermined time of the rotation stops and the molten regions of the work pieces are fused together under an axial pressure applied until the joint is cooled down. Spin Welding is similar to Friction Welding (FRW). Spin Welding is used for manufacturing aerosol bottles, floats and other circular parts.

Applications of Spin Welding: Automotive components, Toys, Pipes and Containers, Floats, Tanks etc.

B. Need Analysis and Concept Design Generation

The architecture of the machine will enable it to receive fixtures (rotary and fixed) for affixing the different thermoplastic parts, which will be required to be joined together. These fixed and rotary fixtures should be located in axial alignment with each other. The rotatable fixture should be mounted on the spindle which should be part of spindle housing assembly. Spindle housing assembly should be capable of axial linear motion towards and away from the fixed fixture with adjustable pressure through human machine interface (HMI). The fixed fixture would be mounted on the fixed machine bed. For the axially aligned linear motion of spindle housing assembly it requires to be mounted on to a column through a guiding mechanism for enabling the smooth and constrained linear motion during spin welding operation. Rotary motion of rotatable fixture will be adjustable in terms of parameters such as rotations per minute, time of rotation etc. through HMI. The sketch of the proposed concept is depicted in figure1.The machine shall have easily accessible operating interface and control system. The aforesaid basic concept and requirements are further developed, explored, and analyzed. The maximum distance (daylight) between fixed fixture and rotary fixture is ascertained here. It has to be more than the sum of total height of welded components, the insertion depth in the fixed fixture & the rotatable fixture along with a suitable separation gap. The target thermoplastic part is assumed to be of 250mm in length. The insertion depth of fixed part in fixed fixture is taken as 50 mm and its total length to be 100mm. The insertion depth of rotary part in rotatable fixture is 20 mm and rotatable fixture's total length is to be 50mm. The separation gap of 150 mm is assumed for easy accessibility and manual hand part mounting and removal operations. Therefore, the daylight is taken to be 500mm as shown in Fig 1.

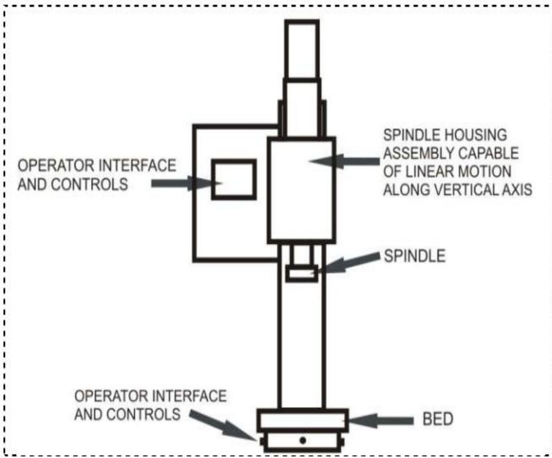


Figure 1. Concept for Machine

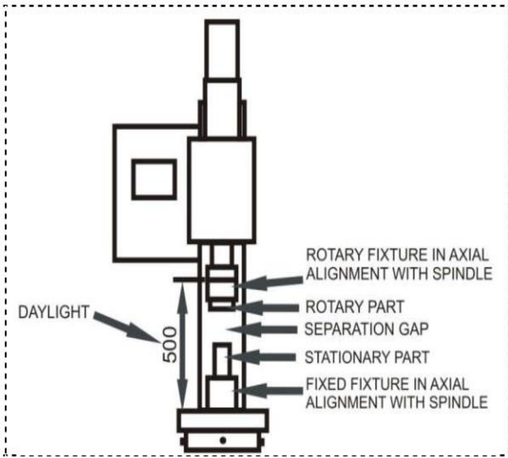


Figure 2. Maximum Daylight Distance

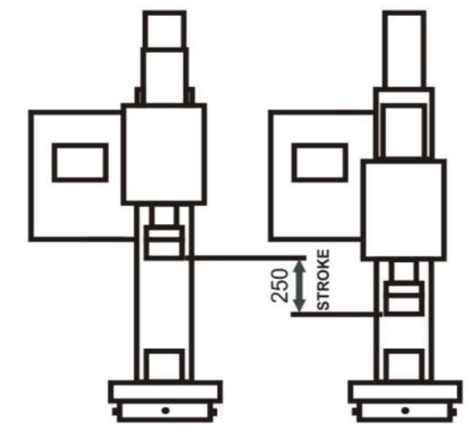


Figure 3. Linear Stroke of Spindle Assembly

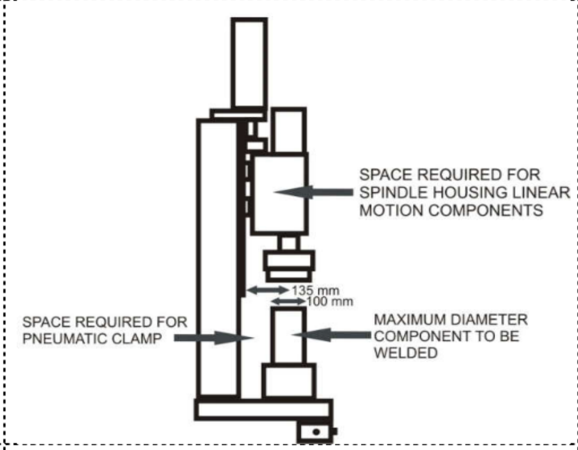


Figure 4. Swing of Rotation

Fig 1. Shows the concept of design

III. Methodology

A. Methodology of Working Process

Study of different Research papers

↓

Framing of project setup (Line diagram of the Model)

↓

Dimensioning of frame, Specification of the Component for setting up a conceptual model

↓

Assembling of different components

↓

Results & disscusion about the error in the conceptual model

B. Methodology of Design and Analysis

A parameter study is done to evaluate the most crucial parameters for FE analysis of axial ball bearings. The parameters that are evaluated are mesh density, contact stiffness, osculation, load level, geometrical nonlinearity and material nonlinearity. The studies are performed by means of the FE software ANSYS. The accuracy of finite element analysis depends on different parameters such as element type, boundary condition and how the loads are applied etc. Therefore, the FE model is nothing else but an approximate realization of the reality. The parameter study can be done by physical tests. However, it will increase the cost, time and resources consumed and therefore FE analysis is more suitable choice, at least for parameter evaluation.

C. Theoretical Aspects of the Work

In this study, the finite element method is adopted using Pro Engineer and ANSYS as a commercial CAD and FE program. The following chapter contains some fundamentals of the applied theories provided that the reader has an initial knowledge of basic structural mechanics, machine components, and fundamentals of the finite element method.

IV. System Design & Component

In our attempt to design a special purpose machine we have adopted a very careful approach, the total design work has been divided into two parts mainly;

- System design
- Mechanical design

A. In system design, we mainly concentrate on the following parameters

1) System selection based on physical constraints: While selecting any m/c it must be checked whether it is going to be used in large scale or small scale industry in our care it is to be used in small scale industry so space is a major constrain. The system is to be very compact it can be adjusted to corner of a room. The mechanical design has direct norms with the system design hence the foremost job is to control the physical parameters so that the distinction obtained after mechanical design can be well fitted into that.

2) Arrangement of various component: Keeping into view the space restriction the components should be laid such that their easy removal or servicing is possible moreover, every component should be easily seen & none should be hidden, every possible space is utilized in component arrangement.

3) Components of System: As already, stated system should be compact enough so that it can be accommodated at a corner of a room. All the moving parts should be well closed & compact A compact system gives a better look & structure.

4) Man –m/c Interaction: The friendliness of m/c with the operation is an important criterion of design. It is application of anatomical.

Following are some e.g. of this section

- Design of machine height
- Energy expenditure in hand operation
- Lighting condition of m/c

5) Weight of machine: The total weight of m/c depends upon the selection of material components as well as dimension of components. A higher weighted m/c is difficult for transportation & in case of major break down it becomes difficult to repair.

B. In Mechanical design, the components are divided in two categories.

1) Parts Design: Mechanical design phase is very important from the view of designer as whole success of the project depends on the correct deign analysis of the problem. Many preliminary alternatives are eliminated during this phase. Designer should have adequate knowledge above physical properties of material, loads stresses, deformation and failure Theories and wear analysis. He should identify the external and internal forces acting on the machine parts.

These forces may be classified as;

- Dead weight forces
- Friction forces
- Inertia forces
- Centrifugal forces

Designer should estimate these forces very accurately by using design equations. If he does not have sufficient information to estimate them, he should make certain practical assumptions based on similar conditions, which will almost satisfy the functional needs. Assumptions must always be on the safer side.

2) Material Selection: The proper selection of material for the different part of a machine is the main objective. In the fabrication of machine. For a design engineer it is must that he be familiar with the effect, which the manufacturing process and heat treatment have on the properties of materials. The Choice of material for engineering purposes depends upon the following factors:

- Availability of the materials
- Suitability of materials for the working condition in service
- The cost of materials
- Physical and chemical properties of material
- Mechanical properties of material

The selection of the materials depends upon the various types of stresses that are set up during operation. The material selected should with stand it. Another criterion for selection of metal depends upon the type of load because a machine part resist load more easily than a live load and live load more easily than a shock load. Selection of the material depends upon factor of safety, which in turn depends upon the following factors

- Reliabilities of properties
- The extent of localized
- Reliability of applied load
- The extent loss of life if failure occurs
- The certainty as to exact mode of failure
- The extent of simplifying assumptions

V. Final Assembled Machine and Manufactured Components

A fully functional prototype of Spin welding machine with advanced control system is developed based upon the above design parameters. Figure 11 shows the final fully assembled and fully functional Spin welding machine. The total weight of the machine is about 250 kgs. The machine is a table top model and can easily be rolled to any point using the rollers provided to the table. The cost incurred to manufacture the machine is about 4.5 lac. The total cost of the machine if manufactured in the bulk and with reasonable profit may be around 5 lac which is around 1/3rd the total cost of the imported machinery from any reputed manufacturer. But as detailed earlier the manufactured machine is robust and is capable of functioning in the Indian conditions effectively. The machine is functioning satisfactorily. Fig 2 shows the design of the machine conducted on the Catia design software. Fig 3 shows the labelled diagram of machine.

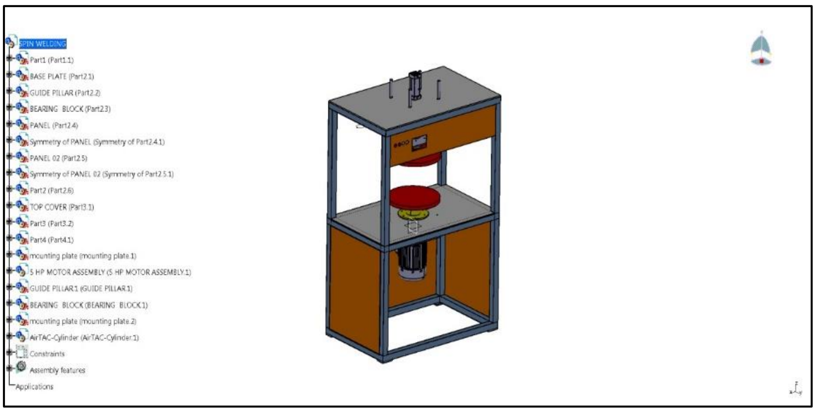
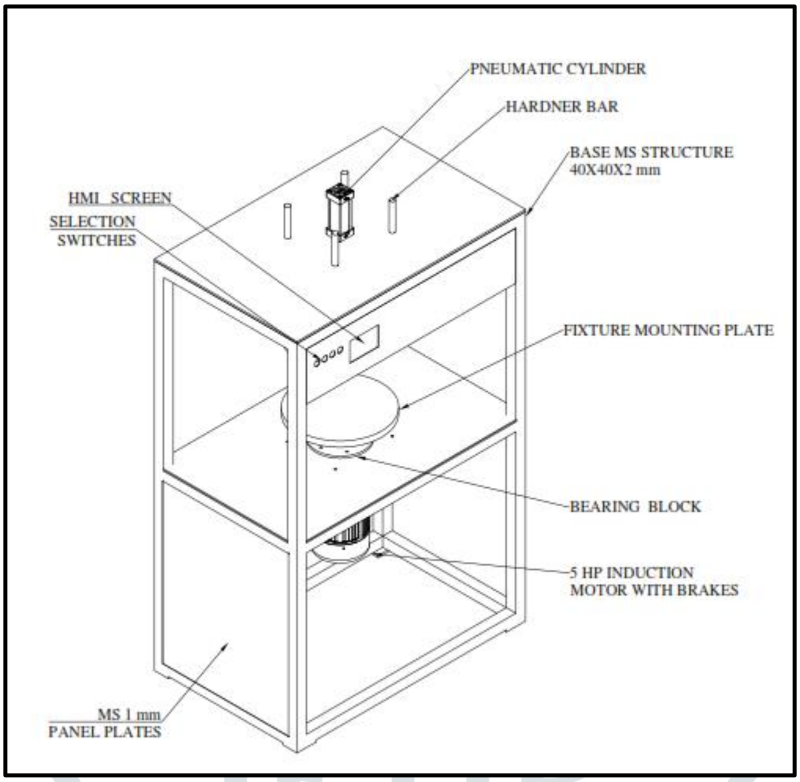


Fig. 2 Shows the actual design of m/c on Catia software



. Fig 3 shows the labelled diagram of machine

Image of Final Fabricated Machine is shown in Figure 4. The different assemblies manufactured using the Spin welding machine using thermoplastic material are shown in figure 5. The machine is capable of controlling typical weld parameters viz. spin pressure, cooling pressure, rotation velocity, rotation time. The final collapse reading of weld joints obtained are within close limits depicting the high degree of consistency achieved in the process.

Fig. 4 Image of Final Fabricated Machine

Fig. 5 Sample Manufactured Assemblies

VI. Future Scope

The Design and Analysis of automatic friction spin welding machine done successfully, which has makes welding of thermoplastics more precise and economical. The future scope of work on the advancement of the friction spin welding machine may include the updated machine with enhanced motor power with higher torque capacity and testing thereon for ascertaining the effect on the weld joint and performance of the produced parts. The main scope of this project is to deliver the high welding strength, simple and economic operation and less costly machine as compared to other plastic welding machines. After experimentation, various symmetric plastic materials are welded such as pipes, discs, toys. In future, there also can be various arrangement for mass production using mechatronics and robotics so that life of machine can be increased.

VII. Conclusion

A newly indigenous Spin welding machine is designed and developed effectively. The machine is robust and capable of performing a wide range of spin weld joints. The cost of the machine is about 1/3rd in comparison to the similar imported machinery. The machine is suitable to Indian conditions and can easily be maneuverer to any desired location. The availability of such reliable spin welding machine with advanced controls to Indian manufacturers will enhance the quality of their welded thermoplastic parts at economical cost. It will further allow the product designers to leverage the technology and design innovative thermoplastic assemblies incorporating spin welding operation.

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