Design and Analysis of SPM for Wheel Hub Spot Welding

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Abstract— Nowadays industry is facing a problem of skill operators for spot welding because spot welding is limited to one or more spots, with the work pieces usually overlapped. It is produced by the generation of heat and pressure, without filler metal, in a localized area in comparison to other welding processes. This research presents work on the design, analysis and implementation of low cost automation of spot weld special purpose machine (SPM) for hub of 3wheel vehicle. The hub welding of Studs (8 no's) at 45º is difficult to achieve by unskilled operator with speed and accuracy. The designed SPM reduces operating cost and becomes important for productivity, quality and safety. During manual operation cycle time required for Hub welding of studs is 45 sec. This low cost automation project has been successful in reduction of cycle time by 33.33%. It is an SPM with pick and place system operated by loading and unloading the Hub which not only improves the productivity, quality and efficiency but also helps to achieve repeatability with greater accuracy.

Key words: Cycle Time, Automated welding, Picking and placing System, SPM

I. INTRODUCTION

Now a days, industries are changing toward automation. In industry many processes such as welding, painting, hazardous chemical handling etc are required skilled labor and it has to pay higher cost. During welding process spatters are fall down so part or work piece may get hot so it becomes difficult to handle manually. These welding processes are manual and it takes more cycle time therefore industries are unable to reach daily production within time. Although the initial cost of automation is high but for long term this processes is necessary. The introduction of automation will replace few or all of the manual process. However, its primary effect on costs of operator particularly it affects on the following factors must be considered safety and health of operator; quality of product and productivity. To overcome above mentioned problem special-purpose machine has been designed for particular applications where similar welding joints are to be weld for mass production.

For automobile part of wheel hub it required spot welding. This wheel hub consists of eight studs. For spot welding of studs currently industry is using a manual processes. This spot welding required a skilled operator and it needs to pay cost. Therefore industry wants automation for wheel hub welding. While survey it was observed that industry is using a stepper or servo motors with PLC system but it is very costly. This research work has been successfully designed and implemented for welding of wheel hub with a low cost. This low cost automation will overcome above mentioned problem like safety of operator, accuracy and productivity. As already stated wheel hub required a spot welding and it required a indexing during welding. This spot welding is required indexer with pick and place system by PLC operated is designed. This indexer consists of ratchet and pawl mechanism, locating device, octagonal plate and pneumatic cylinders. Pick and place system consist of linear movement guides way, pick and plate with pneumatic cylinders. This low cost automation is affordable to small and medium scale industries. Figure shows a conceptual design of the system design. The system consists of ratchet and pawl mechanism, octagonal plate, pneumatic cylinders, gripper, linear movement-guides ways and programmable logical control (PLC).

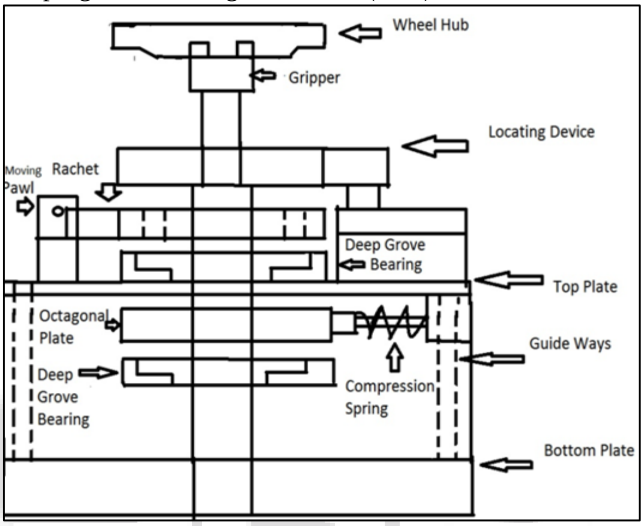

Fig. 1: Conceptual Design of SPM

In this SPM ratchet and pawl is used for indexing while welding, locating device and locating plate will help to stop the ratchet if any backlash during indexing that can be overcome by using this. If this locating device and plate failed to stop indexer then octagonal with spring loaded device will overcome this problem. With the helped of SPM accuracy, productivity, low cycle time is achieved. This automation welding process is very simple compare to manual welding process simply by loading and unloading the hub by any operators.

II. LITERATURE REVIEW

In Automation field, lot of work has been done. For this paper basic information has been carry. Paper presents work on design of robot arm with gripper and end effector for spot welding. It was found that robotic technology makes the spot welding operations more flexible and time oriented [1]. This paper was briefly described the used of robot in different field of life such as sensing, measurement technology, control technology, mechanics technology and to automate operations with the efficiency, reliability and performance of the system [2]. Automation spot welding processes using robots compared to manual welding and its results speed, precision, efficiency and the resulting cost reduction due to mass production [3]. Automation study for an Industrial application was important for to increase quality, accuracy, to increase the productivity for this a simple robot part programming for material handling in

FMS using ARISTO ROBOT has been done [4]. Robotic arm was designed and implemented for accomplishing simple tasks, such as light material handling and which was built from acrylic material [5]. The paper was dealing with Multiple Sensor Integrated used for Robotic End-effectors for Assembly in industries. The sensor such as force/torque, Proximity, Ultrasonic and tactile was used and they were control by PLC and Microcontroller. This helped the assembly robot in identifying the correct part and inspecting the assembly for its correctness [6]. For Minimization of dimensional variation and robot traveling time in welding stations a systematic search algorithm was presented. In this study first step was to optimized geometry stations with respect to both dimensional quality and cycle time, proposed with next step to extend to full geometry stations to include load balancing, coordination of several robot sharing space and the welding work [7]. Automation technique was implemented for spot welding processes, with control strategy which was based on PLC automation and which gives improvement in the product quality, operator safety and better control over production operation [8]. For Picking and placing the part, pick and place robot was used. Which was increased the productivity, high speeds, and consistency with repeatability and quality [9]. 4-DOF Pick and Place robotic arm was designed and implemented for doing simple tasks such as Gripping, Lifting, Placing and Releasing [10]. The proposed system mentioned a new methodology for the integrated design of a 4-DOF SCARA pick and place parallel robot. This parallel robot achieved good and comprehensive performance with accuracy and service life of robot [11]. Two-Jaw parallel pneumatic gripper for the robotic Manipulation was Designed and implemented for pick and place work. This was easier and much faster than the conventional technique with least cost [12]. It was found that the industrial robot development is far away from its limits and that a lot of research and development is needed to obtained a more widely use of robot automation in industry [13].

III. METHODOLOGY

A. *Different Components used for SPM*

1) *Ratchet and Pawl*

Ratchet and Pawl have been made EN 31 material. A ratchet having an eight teeth and it will transmit intermittent motion. Pawl is pivoted at one end and other end which being a shaped to engage the ratchet tooth flank. In this mechanism pawl will push the ratchet using a pneumatic cylinder. While designing a pawl and ratchet should be such that the pawl remains engage with ratchet. Ratchet and Pawl is made by same material that is EN31. This SPM used for automobile part of wheel hub. It required indexing at eight stations therefore eight teeth are design on ratchet. Here pawl will operate linearly with the help of LM-Guides way and pneumatic cylinder is selected based on the force that is calculated from pawl and ratchet design with considering industrial practices.

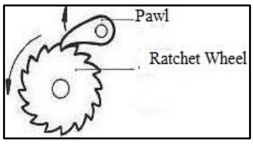

Fig. 2: Schematic Diagram of Ratchet and Pawl [14].

2) *Octagonal Plate*

This octagonal plate has eight faces and having material EN31 with hardening up to 32HRC. It is engage with spring loaded device for stopping octagonal plate. Once it stops then automatically ratchet will achieve positioned that is desired. If any play occurred in spring then we may not achieve positioned exactly. So for overcoming this problem indexing plate with locating device has been introduce.

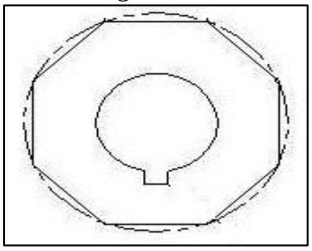

Fig. 3: Octagonal Plate

3) *Indexing Plate with Locating Device*

This indexing plate with locating device is made of material EN31 with hardening up to 32HRC. For engagements of locating device with indexing plate pneumatic cylinder is to be used. Linear movements of locating device LM-Guide ways are used.

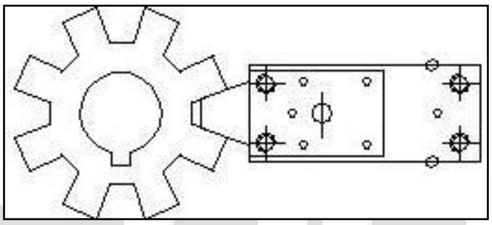

Fig. 4: Indexing Plate with Locating Device

4) *Gripper*

Gripper is used to hold the hub while doing welding operation. This gripper is made of material WPS with hardening up to 32 HRC. Holding of hub is performed by operating the gripper using pneumatic cylinder.

5) *Pick and Place Plate*

Loading and unloading of Hub is done on this plate and which is made of material MS .Here the plate is moved along three mutually perpendicular directions for this it require a three pneumatic cylinders. Pick and place plate is mounted on LM-Guide ways for operating along the X-direction one cylinder is used. Second cylinder which helps to move the plate towards the indexer long the Y-direction and third cylinder will lift the plate up and down along the Z-direction, so that it will load and unload the hub securely on the indexer.

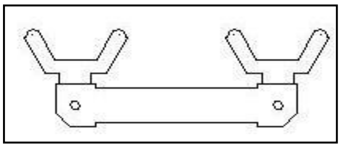

Fig. 5: Pick and Place Plate

B. *Design calculation and Validation*

1) *Analytical Design of Pawl*

a) Material Selection

Designation	Tensile Strength (N/Mm2)	Yield Strength (N/Mm2)
En31	750	450
Stainless Steel	515	207

Table 1:

Factor of Safety is taken as 20
For En31 material
Fc_{all} for pawl body is,

$$fc_{all} = \frac{Ultimatete\ \ nsilestren\ \ gth}{Factorofsa\ \ fety} = \frac{750}{20} = 38\ N\ /\ mm^{2}$$

Direct Tensile or Compressive stress due to an axial load
Cylinder Force= Pressure x Area
= 0.5 x (π/4) 25^2
Cylinder Force = 245.31 N
Calculate Actual compressive stress

$$fc_{act} = \frac{W}{A} = \frac{245.31}{10 \times 9.8} = 2.5031\ N\ /\ mm^{2}$$

As,
$fc_{act} < fc_{all}$
Pawl design is safe in compression for EN31 material as well as for Stainless Steel Material.

C. Analysis Of Pawl Geometry

1) EN 31 material

a) Total Pressure Apply On Pawl Teeth

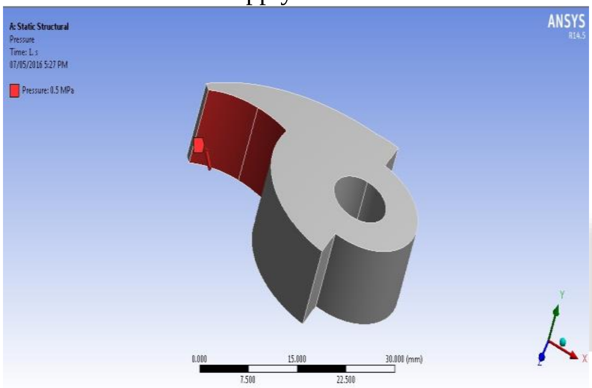

Fig. 6: Total Pressure Apply On Pawl Teeth

b) Equivalent (Von-Mises) Stress

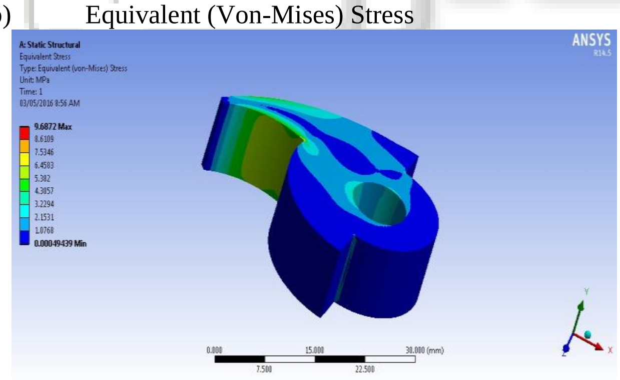

Fig. 7:Equivalent (Von-Mises) Stress

c) Maximum Principal Stress

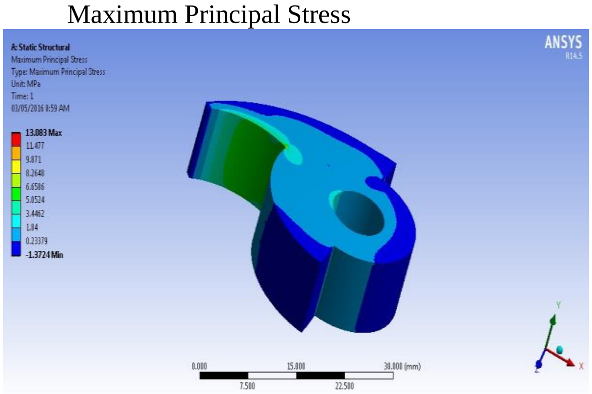

Fig. 8: Maximum Principal Stress

d) Total Deformation

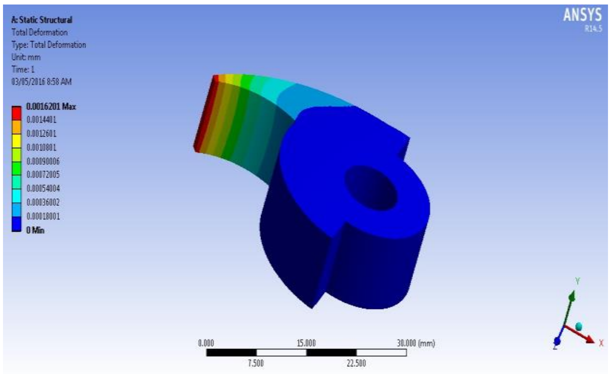

Fig. 9: Total Deformation

2) Analysis of Pawl (Stainless Steel Material)

a) Total Pressure Apply On Pawl Teeth

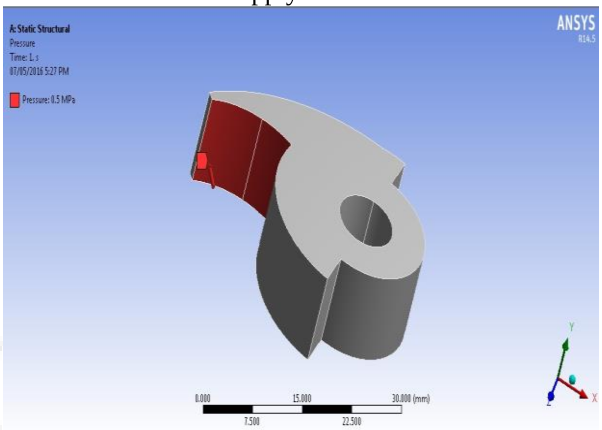

Fig. 11: Total Pressure Apply On Pawl Teeth

Part name	Material	Maximum theoretical stress n/mm^2	Von-misses stress n/mm^2	Maximum deformation mm	Maximum principal stress n/mm^2	Result
Pawl	EN31	2.5031	9.6872	0.0016201	13.083	Safe
	Stainless steel	2.5031	9.6174	0.0018067	13.192	Safe

Table 2: Design and Analysis Result and Discussion

b) Equivalent (Von-Mises) Stress

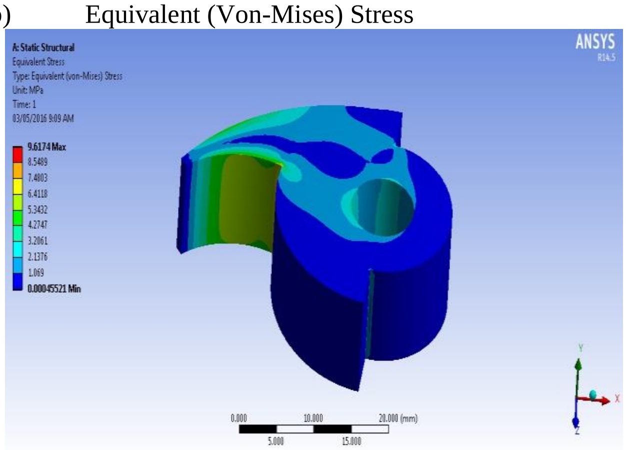

Fig. 12: Equivalent (Von-Mises) Stress

c) Maximum Principal Stress

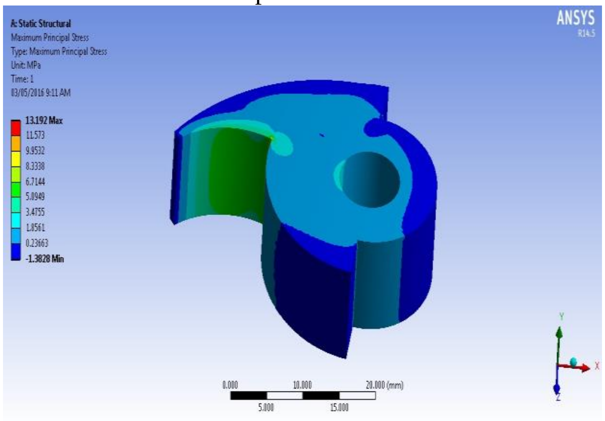

Fig. 13: Maximum Principal Stress

d) Total Deformation

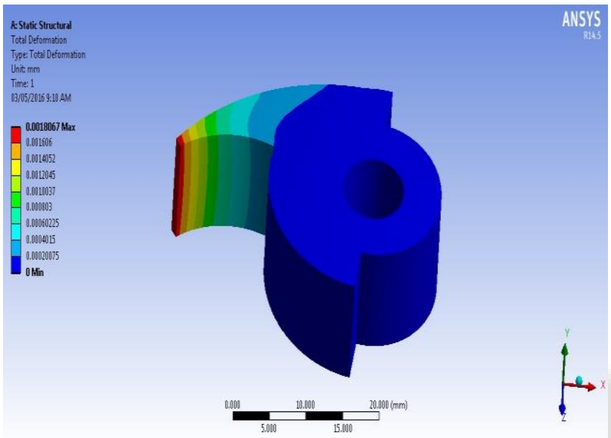

Fig. 14: Total Deformation

IV. Conclusion

Maximum Stress by theoretical method, von-misses stress and maximum principal stress are well below the allowable limit; hence the pawl design is safe for above two materials. Pawl design shows negligible deformation under the action of system of forces.

Analysis of pawl design for two materials is safe. But economically EN31 is best as compare to stainless steel. Therefore, EN31 is selected for as material.

V. Conclusions and Future Scope

This research paper presents the design and analysis of special purpose machine for welding of wheel hub. This special purpose machine is accomplishing task such as welding and pick and place the wheel hub. Special purpose machine is designed and observed that the pawl it is critical element. So, based on the pawl analysis material is selected. From analysis it is found that the EN31 material is best and economically is preferable compare to stainless steel. After successful implementation of special purpose machine automation for welding (hub), it is observed that productivity is increase by 32.27%. This automation has been successful in reduction of cycle time by 33.33%. Quality, accuracy and safety are increases. This special purpose machine has been successful in reduction of cost of production and it saved the cost per month is Rs.3280.

Special purpose machine can be designed for welding more than one component (hub) at a time. Special purpose machine can be equipped with sensors so that accidents will be avoided while doing the welding for hub.

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