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Analysis & Induction Hardening on Excavator Pins

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Abstract:

Pins require very little service and total failure seldom occurs. Wear, pitting, and scoring are the usual troubles encountered with pins. In this paper, going to apply induction hardening process on pins and its comparison will be done with existing pins. Different hardening thickness or case depth will be applied and analysis will be done to interpret the results. Case depth of 1mm, 2mm or 2.5mm will be taken in induction hardening process. Caterpillar 320dl excavator model is taken for study. Material used for the pins is EN8 grade of steel. And different material used for the pin for analysis purpose will be bronze alloy, Titanium. The main objective in this project is to determine the appropriate induction hardening case depth to be used in manufacturing pins.Three-dimension models of pins used in excavator will be created using CatiaV5 software, meshing will be done using Hypermesh and Ansys will be used to analyze the stress status on the pins. The maximum deformation, maximum stress point and dangerous areas are found by the stress analysis.

Keywords - **Induction Hardening, Excavator Pins, Finite element Analysis**

I. INTRODUCTION

Hardening is a process that is used to improve wearresistance of parts without affecting core of the part. This combination of hard surface and resistance to wear is a very important property of a component. Most surface treatments result in compressive residual stresses at the surface that reduce the probability of crack initiation and help arrest crack propagation at the case-core interface.

Excavator attachment is four degrees of freedom system, because each of the four links (swing link, boom link, arm link and bucket link) are allowed to be rotated with their respective joint axes only. It consist four different mechanisms each of which can be controlled independently (Fig.1) The first mechanism is for the swing motion of the swing link relative to the fixed or base link, and can be actuated by swing cylinders. The second mechanism is for the rotation of the boom, which is actuated by boom cylinder thus forming an inverted slider-crank mechanism relative to the frame. The third mechanism is for the rotational motion of an arm, which is actuated by arm cylinder, and is also an inverted slidercrank mechanism. The fourth mechanism is for the rotational motion of the bucket. Since a large bucket oscillation is required, the mechanism used is a series combination of a four bar mechanism, and an inverted slider-crank mechanism, which forms a six link mechanism relative to the arm as shown in Fig.1.

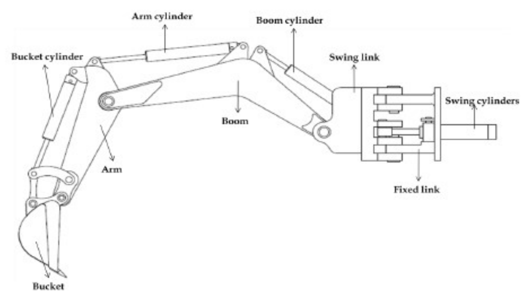

Fig:1 Excavator attachments

Apart from this, the boom assists only in positioning the bucket and the arm for the digging operation; it does not directly contribute in digging operation. On the other hand, the arm and the bucket directly contribute in the digging operation by generating the required digging forces with the help of the hydraulic actuators. The bucket cylinder generates the bucket curl force, and the arm cylinder generates the arm crowd force to excavate the ground. Maximum crowd force is developed when the arm cylinder operates perpendicular to the arm. The ability to break the material is the best at the bottom of the arc because of the geometry of the boom, arm, and bucket and the fact that at that point, the hydraulic cylinders exert the maximum force drawing the arm in and curling the bucket.

II. LITERATURE SURVEY

Casehardening is defined as follows: Case hardening is a feature of dried wood to deform (cup) after resawing and equalizing of the moisture content. Analysis with FE program PEO has shown that casehardening is not only the cupping due to equalization of moisture content gradient after slicing the specimen [1].Hardening analysis, phase transformation was studied and an algorithm was developed to determine volumetric content of micro-structural constituents formed from austenitized phase in quenching process, based on analysis of the interaction between cooling curve and material time-temperature-transformation (TTT) diagram [2].Another work contribution was analyzing the existing design and redesign the excavator boom which is suitable for side digging and also for digging over hanged part of wall.. During operation of excavator at different positions the stresses induced in the attachments varies. The forces applied in the analysis were calculated by using INVENTOR software, and reported that the Arm, Boom and Bucket shows stress in the attachment are coming under allowable limit. For reducing stresses and for optimum weight of the excavator parts, thickness of the material is reduced in the modeling [3].Shape optimization also performed for weight optimization and results are compared with trial and error method which shows identical results. Comparison shows that the variations in results of individual parts are very less and total variation in result is of only 3.93% which reflect that the results of structural weight optimization performed by trial and error method are accurate and acceptable [4].In another paper, it is proposed to study the concept of finite element method and its application to the excavator arm design. As the present mechanism used in excavator arm is subjected to torsional and bending stresses, so it is necessary to design a new mechanism [6]. Author concentrate on the study of the components of the excavator in order to identify the problems faced while performing the lifting and digging operations and to provide a design solution by using CAD-CAE systems. The new mechanism of excavator arm is designed and analysis is done at existing digging force and also at newly calculated digging force. Also the bucket volume is increased to compensate for the loss in production due to the reduction in digging force [7].paper according to the type of YC225LC-8 hydraulic backhoe excavator, mechanical analysis was carried out in three typical work condition of the working device by using the mechanical theory and method[8].New method was developto realize the structural static and dynamic collaborative optimization of hydraulic excavator working equipment. The mathematical model of static and dynamical optimization is developed basing on finite element analysis and testing results of static and dynamical characters of hydraulic excavator working equipment [9].

III. OBJECTIVE

The main objective in this project is to determine the appropriate induction hardening case depth to be used on pins. In order to achieve this main objective, these specific objectives need to be carried out:

a) To design pins using CATIA CAD Software,

b) To conduct design analysis using Hypermesh and Ansys Simulation software.

c) Induction hardening parameters application analysis and interpreting the Ansys results Comparison existing part with hardened pins

d) Fabrication, testing and validation.

IV. PROBLEM STATEMENT

- Expensive damage can be caused if pins are allowed to wear to the point of failure.
- When components on the excavator arm are worn it becomes very difficult to dig or position attachments with accuracy. Ultimately, components failing can cause injury or death.
- It is critical to replace the linkage pins and bushes before they wear out. If you do not do this the structure of the excavator will also wear down and this is a much more costly problem to fix, in comparison to the cost of the pins and bushes which are relatively cheap to replace.
- Pins are subjected to a lot of strain so you do not want these parts breaking early or wearing too fast.

V. CAD MODEL

Caterpillar 320dl excavator is used for the project work. Dimensions are taken through reverse engg i.e. through hand calculations. Dimensions for excavator boom, arm, bucket, bushes etc were measured at site itself.

There are three main pin joints used in the excavators, which are applied between bucket and arm (pin joint of bucket and arm) called as bucket pin, between arm and boom (pin joint of arm and boom) called as arm pin, and between boom and swing link (pin joint of boom and swing link) called boom pin.

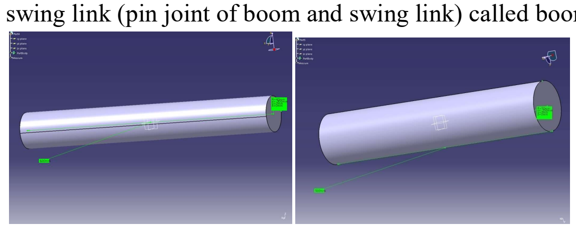

Fig:2CAD model of arm pin and boom arm pin respectively

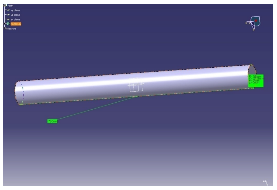
Fig:3 CAD model of boom pin

VI. ANALYSIS OF EXISTING PINS

The CAD data of the pin is imported and the surfaces were created and meshed. Since all the dimensions of pins are measurable (3D), the best element for meshing is the tetra-hedral. Number of nodes and elements for arm pin are 2897 and 11653 respectively, whereas for boom arm pin is 3283 and 13655 respectively, and that for boom pin is 2768 and 10805 respectively.

Force calculation is done by considering maximum bucket digging force to be 54KN. Static forces on joints can be calculated by considering the summation of forces must be equal to zero ($\Sigma F = 0$) and summation of moments equal to zero ($\Sigma M = 0$) for equilibrium condition of the bucket, arm and boom respectively. By carrying out long calculation, the resultant forces come out to be: for boom pin 2.79e5N in horizontal direction, 4.34 e5N in vertical direction, for arm pin 1.1 e5N and 1.02e5N in horizontal and vertical direction respectively, for boom arm pin 3.25e5N and 1.41e5N in horizontal and vertical direction respectively.

Analysis results:

Arm pin:

Von-mises stress

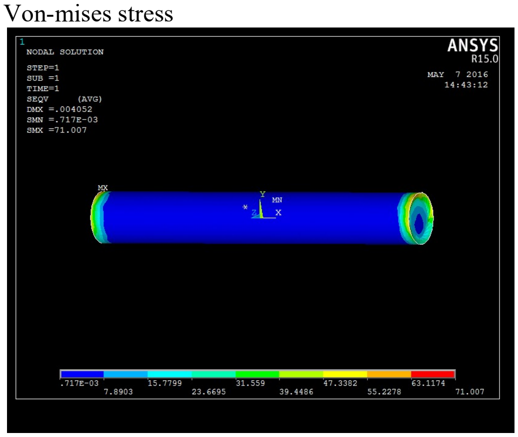

Fig:4 von-mises stress for arm pin.

Above figure shows von-mises stress for arm pin which is 71.007Mpa, this value of stress is less than permissible limit hence it is safe.

Deformation:

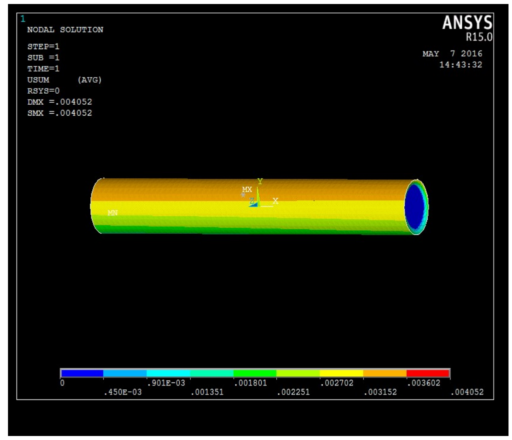

Fig:5 deformation for arm pin

Above figure shows deformation for arm pin which is 0.004mm which is very less.

Boom arm pin:

Von-mises stress

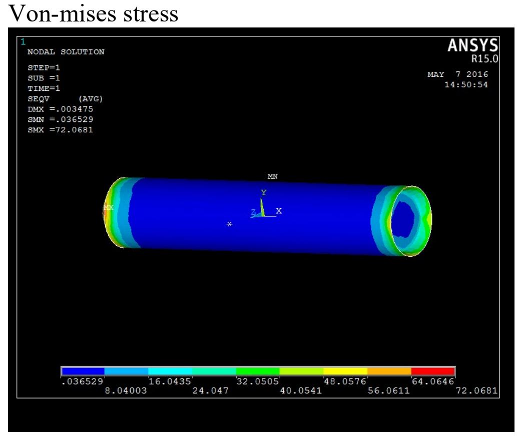

Fig:6 von-mises stress for 11boom arm pin.

Above figure shows von-mises stress for boom arm pin which is 72.06Mpa, this value of stress is less than permissible limit hence it is safe.

Deformation:

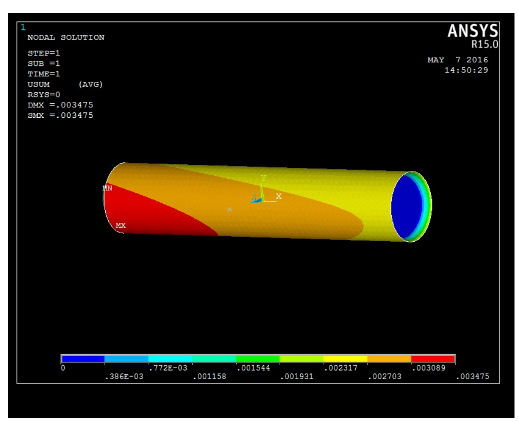

Fig:7deformation for boom arm pin

Above figure shows deformation for boom arm pin which is 0.0034mm which is very less.

Arm pin:

Von-mises stress

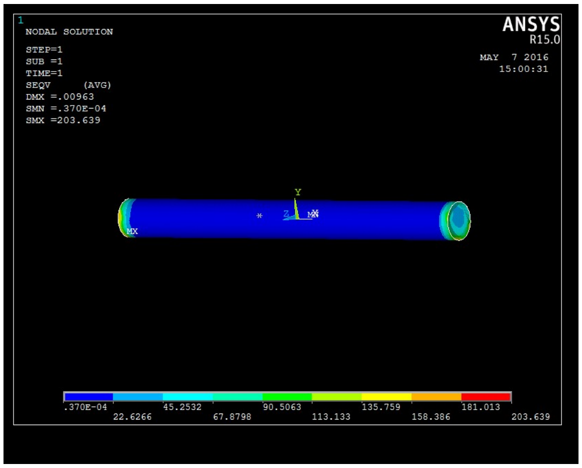

Fig:8von-mises stress for arm pin.

Above figure shows von-mises stress for arm pin which is 203.63Mpa, this value of stress is less than permissible limit hence it is safe.

Deformation:

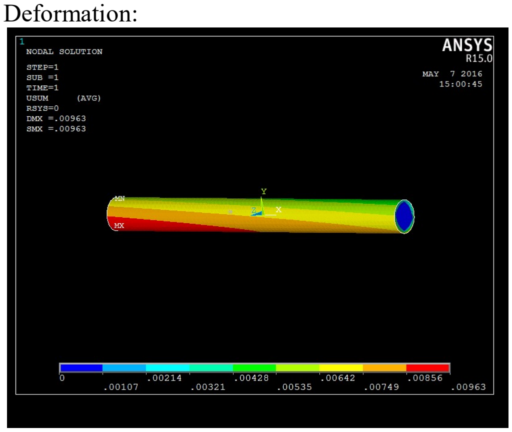

Fig:9 deformation for arm pin

Above figure shows deformation for arm pin which is 0.009mm which is very less.

VII. ANALYSIS OF PINS WITH DIFFERENT CASE DEPTH

Induction hardening:

Induction heating is an extremely versatile heating method that can perform uniform surface hardening, localized surface hardening, through hardening, and tempering of hardened pieces. Heating is accomplished by placing a steel ferrous part in the magnetic field generated by high-frequency alternating current passing through an inductor, usually a water-cooled copper coil. The depth of heating produced by induction is related to the frequency of the alternating current, power input, time, part coupling and quench delay. The higher the frequency, the thinner or more shallow the heating. Therefore, deeper case depths and even through hardening are produced by using lower frequencies. The electrical considerations involve the phenomena of hysteresis and eddy currents. Because secondary and radiant heat is eliminated, the process is suited for in-line production. Some of the benefits of induction hardening are faster process, energy efficiency, less distortion, and small footprints. Care must be exercised when holes, slots, or other special geometric features must be induction hardened, which can concentrate eddy currents and result in overheating and cracking without special coil and part designs.

Various model for arm pin, boom arm pin, and arm pin have been drawn in CATIA with 1mm, 1.5mmm, and 2mm of case depth. These models were separately meshed and analysis is done on each model by considering EN8, bronze and titanium material.

Below are the results of analysis by considering induction hardening effects.

TABLE I

Arm Pin (1mm case depth):

	Stress, MPa	Deformation,mm
EN8	175.58	0.0012
BRONZE	171.87	0.0021
TITANIUM	165.97	0.0021

TABLE II

Arm Pin (1.5mm case depth):

	Stress, MPa	Deformation,mm
EN8	137.14	0.0014
BRONZE	133.69	0.0025
TITANIUM	128.19	0.0024

TABLE III

Arm Pin (2mm case depth)

	Stress, MPa	Deformation,mm
EN8	100.41	0.013
BRONZE	97.17	0.0022
TITANIUM	92.03	0.0022

TABLE IV

Boom Arm Pin (1mm case depth):

	Stress, MPa	Deformation,mm
EN8	221	0.0014
BRONZE	213.51	0.0026
TITANIUM	201.68	0.0025

TABLE V

Boom Arm Pin (1.5mm case depth):

	Stress, MPa	Deformation,mm
EN8	209.7	0.0013
BRONZE	202.25	0.0024
TITANIUM	190.5	0.0023

TABLE VI

Boom Arm Pin (2mm case depth):

	Stress, MPa	Deformation,mm
EN8	160.6	0.002
BRONZE	155.4	0.003
TITANIUM	147.17	0.0023

TABLE VII

Boom Pin (1mm case depth):

	Stress, MPa	Deformation,mm
EN8	607.93	0.0042
BRONZE	590.7	0.0076
TITANIUM	563.5	0.0075

TABLE VIII

Boom Pin (1.5mm case depth):

	Stress, MPa	Deformation,mm
EN8	3434	0.0031
BRONZE	328.9	0.005
TITANIUM	306.2	0.0052

TABLE IX

Boom Pin (2mm case depth)

	Stress, MPa	Deformation,mm
EN8	421.68	0.0058
BRONZE	408.9	0.01
TITANIUM	388.5	0.01

VIII. EXPERIMENTAL WORK

Three main pins where majorly stresses acts are considered for analysis i.e. arm pin, boom arm pin, boom pin. It is clear from analysis results that 2mm case depth shows better results. As titanium is very costly material so it is not economical to use it. While bronze is softer material so it also cannot be used. For experimentation EN8 material with 2mm case depth during induction hardening will be taken. The experimental investigation is performed on fabricated prototype on universal testing machine at Accurate Laboratory services ,Bhosri MIDC, Pune. 3 point bending test has been performed on the prototype of Excavator pins produced. The input conditions are recreated in the lab while the component is being tested. The loading and the boundary conditions are matching the practical working conditions in which the Product is expected to perform. An equivalent maximum load of 435 KN is applied on the prototype for testing purpose.

The prototype is placed in the machine between the grips. The machine itself records the displacement between its cross heads on which the specimen is held.Adjust the load cell to read zero on the computer up to peak load. Once the machine is started it begins to apply an increasing load on specimen.

Throughout the tests the control system and its associated software record the load and displacement of the specimen.Plotted the variation of displacement with load.

Fig.10 Universal Testing Machine

Experimental set up For Excavator Pins

IX. RESULT AND DISCUSSION

1 1.At 110 KN force applied the deformation is found to be 00.012 mm

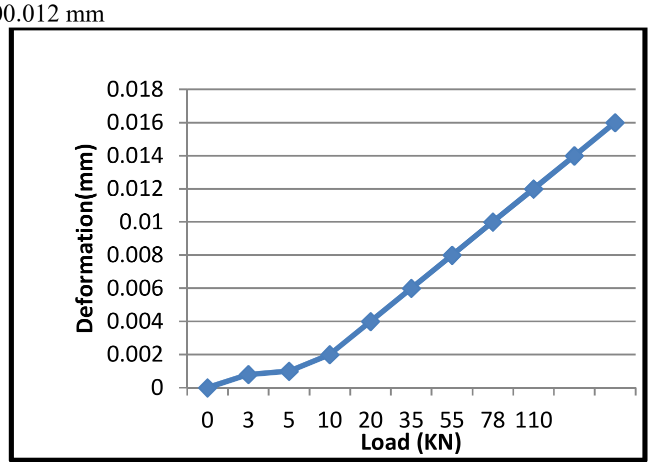

Fig.11 Graph plot for Deformation vs Load For Arm Pin

2.At 325.5 KN force applied the deformation is found to be 0.0022 mm

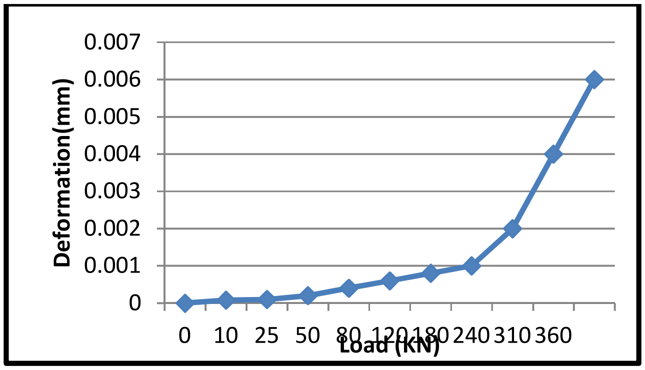

Fig.12 Graph plot for Deformation vs Load for Boom Arm Pin

3.At 435.5 KN force applied the deformation is found to be 0.006 mm

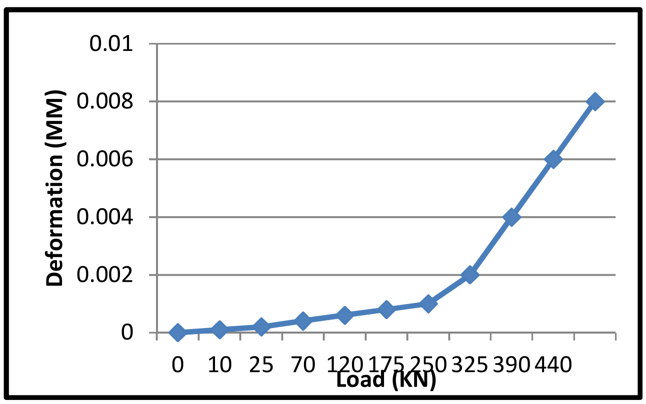

Fig.13 Graph plot for Deformation vs Load for Boom Pin

Experimental Validation

S.No	Results	Deformation Arm Pin	Deformation Boom Arm Pin	Deformation Boom Pin	% error	% error	% error
1	**FEA results**	**0.013 mm**	**0.002 mm**	**0.0058 mm**	**7.6**	**9.6**	**3.3**
2	**Experimental results**	**0.012 mm**	**0.0022 mm**	**0.006 mm**			

Comparison between Existing pin and New pin

S.No	Parameters Observed	Existing pins	New Pin
1	**Hardness**	**50-52HRC**	**60-62HRC**
2	**Deformation**	**0.02 mm**	**0.006 mm**
3	**Case depth**	**1mm**	**2mm**

X. CONCLUSION

Induction hardening is increases the strength and the life span of pins.A comparative study is made for FEA and Experimental values. The validation shows a close resemblance with acceptable % error. Deformation of existing pin is 0.02mm and that of new pin is 0.006mm which is less than the existing one.Hardness of existing pin is 50-52HRC and hardness of new pin is 60-62HRC which is more than the existing one. hencenew pin is more hardened and it will not fail at earlier stage.

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