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Induction Hardening on Knuckle Joint Pin with Various Case Depths and its FEA

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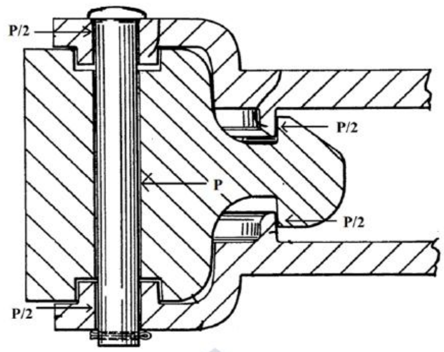
Abstract - *The failure of the knuckle pin in a railway coupling due to Extreme tensile loading and majorly the problem occurs in Pin bending or sheering. To connect coaches, a knuckle joint is used which consist of forks and a pin, a fork is attached to coach rigidly and another fork is attached to the other coach by a pin. During acceleration of train, force acting on the joint is tensile and during deceleration it is compressive. At the time of carrying heavy weights, due to its fluctuation a pin is subjected to high stresses. As the pin is a flexible element which can easily be replaced, it is considered separately for the analysis and finite element analysis is done on it. The aim of the present paper is to study and analyze the stresses in Knuckle pin, and cause if failure. The optimum results are obtained by varying case depth of hardness as per specification, and as per optimum stress and deflection plots, results will be compared to find out the optimum design solution.*

***Key Words*: Knuckle joint pin, Case depths, Tensile failure, Steel 42 Cr4Mo2**

1. INTRODUCTION

Knuckle coupler assemblies are well known in the railway industry to attach one railroad car to another. Each railroad car to be connected to another railroad car has a coupler. The two couplers of adjacent railroad cars that are about to be coupled each have a knuckle attached to them. When the couplers go together and become coupled, the knuckles snap closed. Thus, you have two couplers, two knuckles, and two thereby formed apertures for the knuckle pins to slip into. A railroad pin is inserted into the through apertures of the knuckles to lock shut the knuckles and secure the connection between the two railcars. However, over time, the alignment of the apertures formed by the connection of the two knuckles and coupler bodies are difficult to attain because of metal wear. Misalignment of the apertures of the knuckle and coupler body reduces the area size of the overall aperture for receiving the railroad pivot pin, making installation of the pin more difficult and potentially hazardous to the railroad worker during connection of the railroad cars. In addition, cotter pins have been previously used to hold the pivot pin within the aperture of the railroad car coupler. The continued motion of the railroad cars can wear into a specific area of the pin which can cause fatigue and breakage of the cotter pin material. Another disadvantage of using a cotter pin to secure the pivot pin within the railroad coupler is that installing or removing the cotter pin can be difficult and dangerous to the railroad worker Knuckle joint is a joint among two parts permitting movement in one plane only. It is a type of hinge joint. More often than not two parts of a machine are to be connected and restrained, for example two rods may be joined coaxially and when these rods are pulled apart they should not separate i.e. should not have relative motion and continue to transmit force.



1.1 Sub

fig 1. GA arrangement of knuckle joint in rail coaches

Scope of work

Finite Element Analysis (FEA) is the most powerful technique for strength calculations of the any structures working under known load and boundary conditions. FEA approach can be applied for the optimization. 3D model of a knuckle joint pin will be drawn in CATIA V5R19, Meshing will be carried out in Hypermesh and Ansys will be used for post-processing. Efforts will be taken to increase the strength of the pin by induction hardening with different case depths.

2. LITERATURE REVIEW

In his paper they determine the appropriate induction hardening case depth to be used on pins.In order to achieve this main objective of extreme loafing conditions, 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. [1]

In their research paper the stresses on the knuckle joint and to improve the performance of knuckle joint to a certain extent is going to be studied by using CATIA V5 and FEM will be use in analysis. [2]

The study aims at increasing the strength of a crank pin by induction hardening process. The initial phase follows stress analysis of a single cylinder crank pin by doing static analysis. The FEA analysis of crankpin is carried out over conventional model. The crankpin including the induction hardening with different case depth is analyzed for the given operating conditions. [3]

The aim of the present paper is to study calculate the stresses in Knuckle joint using analytical method. Further study in this direction can made by using various directions of the pin and the capacity to withstand load. The aim of the present paper is to study calculate the stresses in Knuckle joint using analytical method. In this thesis we performed Structural analysis on the Knuckle Joint at loads of 100N, 105N, 110N and 115N on three types of materials Stainless

Steel, AL 6061-T6 and Teflon and the action of various combinations of parameters. [4]

Indian railways schedule of technical requirement no. wd-70-bd-10 (rev.1) for upgraded high tensile centre buffer coupler for boxnhl/bcnhl wagons issued by research design & standards organization ministry of railways lucknow-226011 no. wd-70-bd-10 (rev.1) dec , 2012 schedule of technical requirements for upgraded high tensile centre buffer coupler for boxnhl/bcnhl wagons.[5]

In their research paper they study and calculate the stresses in Knuckle joint using finite element method for different material and out of that one material which satisfy the objective of project is selected as a optimize material. The knuckle joint is analyzed for structural steel, stainless steel, aluminum alloy, teflon, gray cast iron. [6]

The main motive of this paper is to improve the performance of the knuckle pin in the couplings of the railway couplings. The current mechanism of coupling is briefly defined and methodologically treatment is determined for failure of knuckle pin in the coupling. The aim of this chapter is to conceptually define remedy for the failure problem of the knuckle coupling. [7]

PROBLEM IDENTIFICATION

Indian Railways suffers a large number of train partings because of coupler and knuckle breakage which results in heavy losses. Poor quality of CBC components causes large scale premature replacements of components during maintenance in workshop, depots and yards. The manpower and material costs of such replacement is very high. Even after large scale replacement of components during maintenance in workshops depots and yards, train partings are still taking place which reflect on the poor quality of coupler components. The direct and indirect cost of train parting is huge.

And this work is to determine the reason behind the pin failure in railway coach coupling due to bending loads and stress distribution and how heat treatment can affect the mechanical property of the pin judging its stress and deformation plots.

OBJECTIVES

The main objective of the project is to

1) Analyze the knuckle joint pin used in railway coupling under loading conditions.

2) Investigating heat treatment affect on mechanical properties of the pin.

3) Iterative approach to determine the optimum case depth value for hardened pin.

4) Overall project will be compared by reduction in stress and deflection by linear static analysis.

4. METHODOLOGY

- Literature Review
- CAD Model Generation
- Meshing on Hypermesh
- Determination of loads and boundary conditions
- Simulation of model on ANSYS
- Analyzing result

5. DESIGN OF KNUCKLE PIN

The chapter Design Knuckle pin of dissertation includes design of existing pin of Indian railway coaches as per document provided. Dimensions of the existing pin have been measured from drawing and CAD model have been prepared in CATIA V5. The finite element analysis is carried out by using Hypermesh and ANSYS as post-processor.

Computer-aided design (CAD)

Computer-aided design (CAD), also known as computer aided design and drafting (CADD), is the use of computer technology for the process of design and design documentation. Computer Aided Drafting describes the process of drafting with a computer. CADD software, or environments, provides the user with input-tools for the purpose of streamlining design processes; drafting, documentation, and manufacturing processes.

2D drawing of knuckle joint:

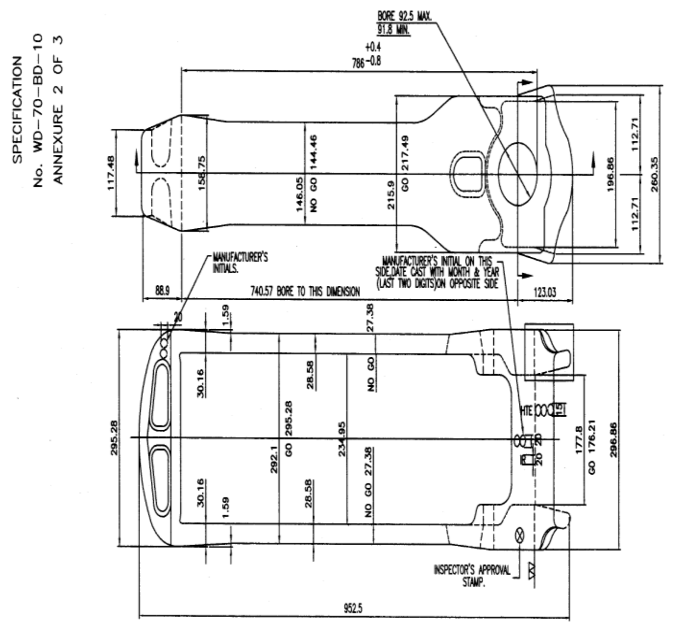


Fig 2. 2D drawing of knuckle joint (ref- CBC Spec No. WD-70-BD-10 (Rev.1)

3D CAD Model

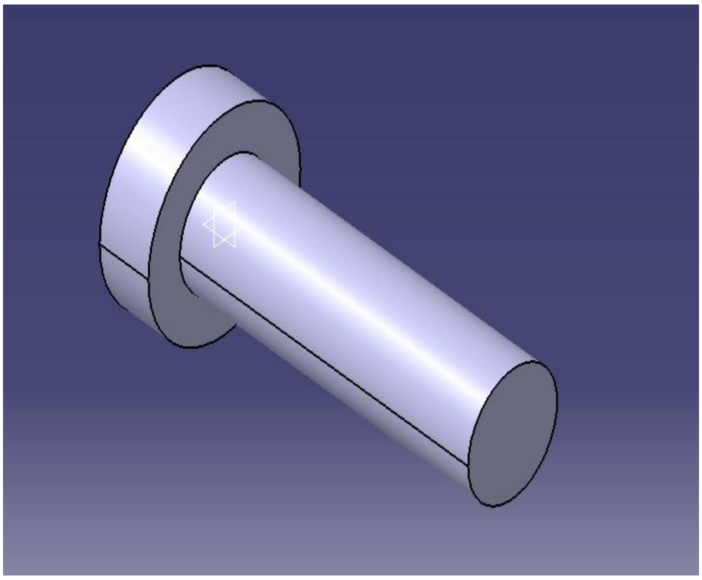


Fig 3. CAD model of pin

For the sake of analysis proceeding we will not be considering head of the knuckle pin as to avoid any cornering stresses.

SPECIFICATIONS OF KNUCKLE PIN

Ref- CBC Spec No. WD-70-BD-10 (Rev.1)

Material

Steel 42 Cr4Mo2 to IS: 5517-1993 shall be used for the manufacture of knuckle pin.

HEAT TREATMENT

Hardness value shall be within the range of 229 to 428 BHN. up to a minimum depth of 0.20 mm.

MECHANICAL PROPERTIES REQUIREMENTS KNUCKLE PIN

Tensile Strength N/mm2 - 1030

Yield Strength N/mm2 - 630

Elongation % 16.5

Reduction in Area % 46.2

Static Test Requirements:

Tensile Load At 181.5 ton

Bending Load at 47 ton

Max deformation 0.76

Material Property

Table 3: Mechanical Properties of heat treated and untreated NST 37-2 steel

Heat treatment	Mechanical properties						
	Tensile strength (N/mm^2)	Hardness (BHN)	Toughness (J)	Percentage Elongation (%)	Percentage Reduction (%)	Yield strength (N/mm^2)	Young modulus (N/mm^2)
Untreated	343.80	100.10	58.88	21.16	63.23	217.31	465.78
Annealed	325.42	95.95	64.10	23.24	71.94	209.47	562.00
Normalised	422.30	188.00	57.26	20.38	71.81	232.75	534.85
Hardened	678.70	460.50	24.67	8.42	41.14	288.05	1235.31
Tempered	385.42	131.00	60.70	21.00	76.92	228.52	535.17

for Hardened steel

Work Scope:

Test Specimen- Dia 91.5 mm, Length 296 mm

Tensile Load At 181.5 ton

Bending Load at 47 ton

Max deformation 0.76

TENSION & BENDING BOTH SEPARATE ANALYSIS

1. Existing analysis with .2 mm case depth
2. Iteration with .5 mm case depth
3. Iteration with 1 mm case depth
4. Iteration with 1.5 mm case depth

6. FINITE ELEMENT ANALYSIS OF KNUCKLE JOINT PIN

Existing Pin Analysis

Boundary Conditions Applied to the knuckle pin when pin under goes bending load.

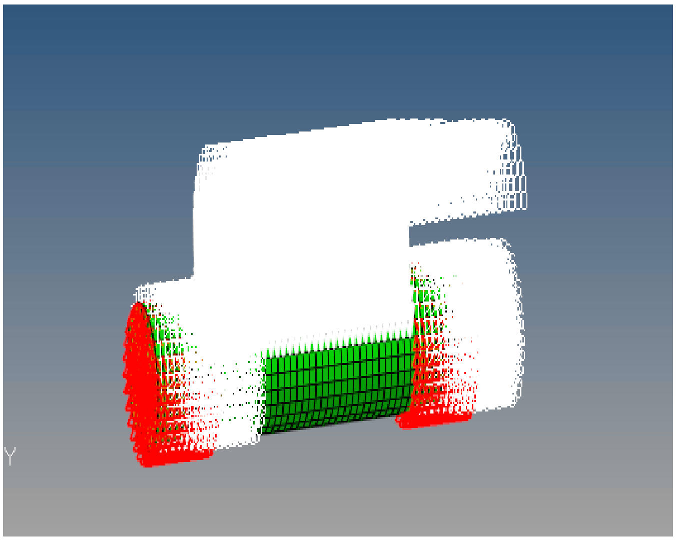


Fig 4. Boundary Conditions Applied to the knuckle pin when pin undergoes bending load

Boundary Conditions Applied to the knuckle pin when pin under goes tensile load.

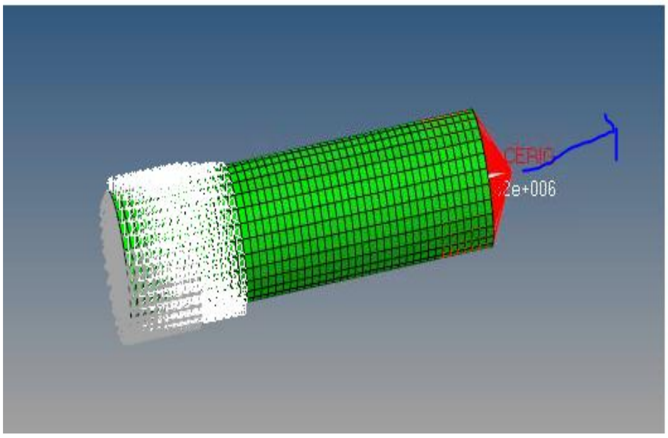


Fig 5. Boundary Conditions Applied to the knuckle pin when pin under goes tensile load

Analysis of Knuckle joint pin with 1.5 case depth hardening for bending load.

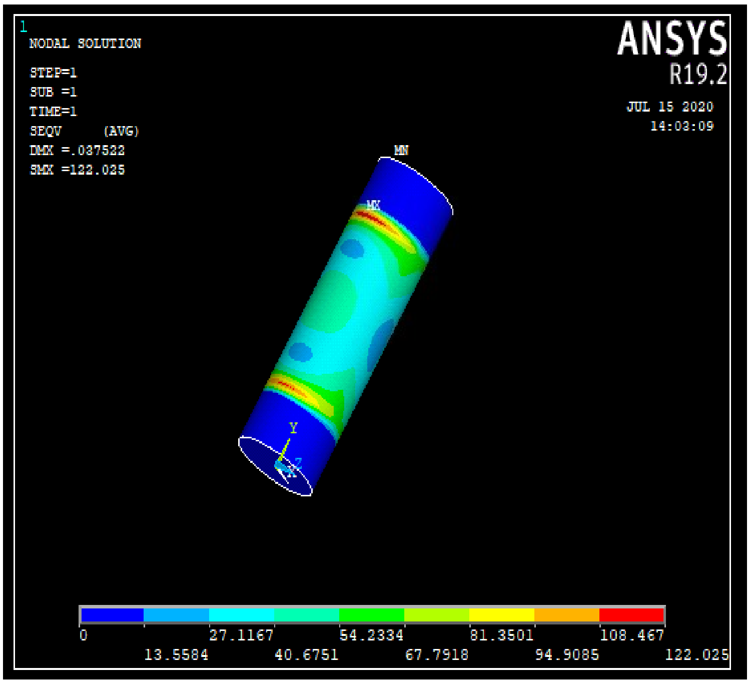


Fig 6. Stress value for pin is 122.025 MPa

Displacement

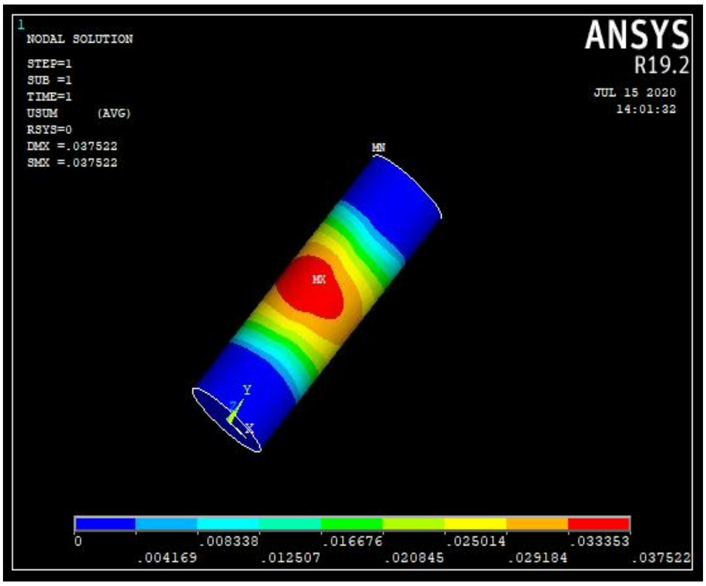


Fig 7. The maximum displacment is coming out to be 0.0375 mm

Analysis of Knuckle joint pin with 1.5 case depth hardening for tensile loading.

Von mises stress plot

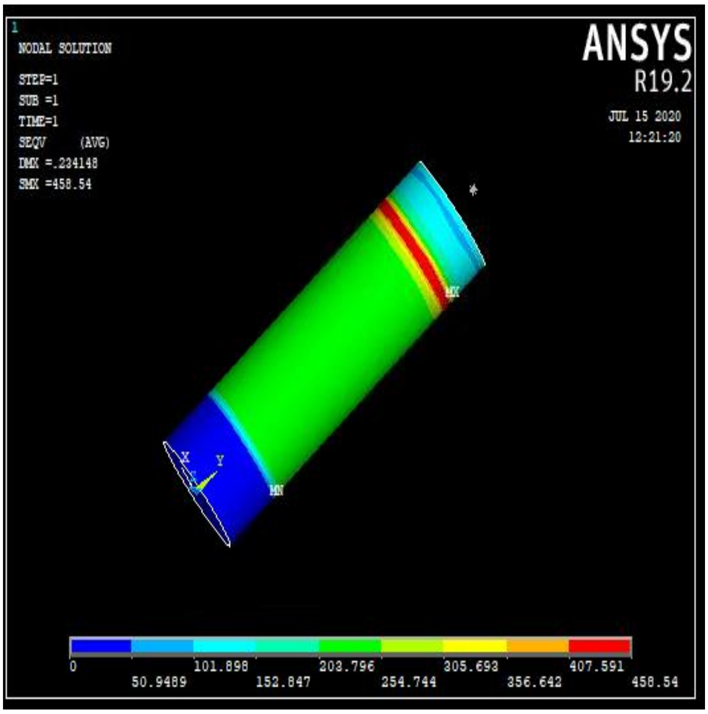


Fig 8. Stress value for pin is 458.54 MPa

Displacement

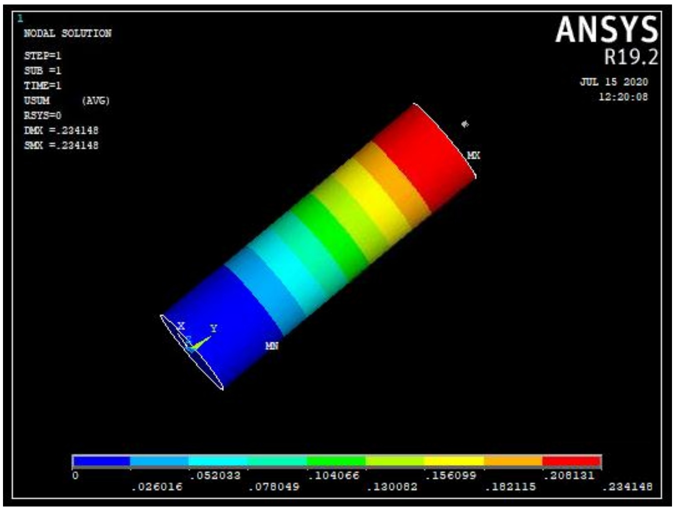


Fig 9. The maximum displacment is coming out to be 0.234 mm

7. RESULT COMPARISON TABLE

Bending Load

Sr.no.	Specification	Stress Mpa	Deformation mm
1	Existing Design .2 mm case depth	133.433 MPa	0.0410 mm
2	0.5 mm case depth	133.320 MPa	0.0409 mm
3	1.0 mm case depth	133.209 MPa	0.0409 mm
4	1.5 mm case depth	122.025 MPa	0.0375 mm

Table No. 1- Results for bending load

Tensile Loading

Sr.no.	Specification	Stress Mpa	Deformation mm
1	Existing Design .2 mm case depth	550.43 MPa	0.281 mm
2	0.5 mm case depth	519.193 MPa	0.265 mm
3	1.0 mm case depth	488.867 MPa	0.249 mm
4	1.5 mm case depth	458.540 MPa	0.234 mm

Table No. 2- Results for tensile loading

8. CONCLUSIONS

- As observed in the bending results that stress up to 1 mm are not affected much but when jumped to 1.5mm there is considerable amount of stress reduction which is 122 Mpa. Similarly deformation is lowest which is 0.0375mm.
- We have stopped the increase in case depth iteration as the core structure should not get affected to maintain flexibility and to avoid fracture due to brittleness.
- As observed in the Tensile loading results that stress reduced as we increase case depth. the lowest observed at 1.5 case depth is 458 Mpa. Similarly deformation is lowest which is 0.234 mm. which is safe as per the guideline the safe limits are Tensile strength 1030 Mpa and Max deformation 0.76 mm (Ref - Chapter "specifications of knuckle pin")
- Hence The best of all the iteration is chosen for the fabrication which is knuckle pin with 1.5 mm case depth which is having bending stress value as 122Mpa, 0.037 mm deformation and tensile stress 458 Mpa, 0.234 mm deformation.

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