TITLE: ROTARY COUPLING BRACKET DESIGN

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ABSTRACT

The project includes the process of Re-designing the 'Rotary Coupling Stop Bracket' which restricts the undesired rotation of Rotary Coupling, to prevent the Hydraulic hose from getting damaged of an Excavator Machine. The process of redesigning starts with following the standard steps of Basic model of Design and end on prototype testing. Actual Definition of Problem was decided by use of the'8-D Report'and'Why-Why Analysis reports'.These type of analysis Reports due to their effectiveness now a days are very famous in industries, In bracket design the use of Why-Why Analysis as a theoretical Analysis was the major concern to find the root cause and to Find the alternative designs solution of the bracket .The steps of Basic Design Model are carried and are compared to find the actual design of bracket based on the different physical conditions and criteria's of production and assembling methods. By referring above steps the Standard Design Prototype model is made and the results are then compared with analytical results. Catia V5 is used for modeling the assembly and Ansys is used for the prototype cad analysis. The results are compared to decide the bests safer design selection

Keyword: - *Basic Design steps, Hydraulic Rotary joint, Jcb Excavators, Mechanical Bracket Design, Rotary coupling stop Bracket, Standard Material selection*.

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1. INTRODUCTION

Introduction

The project selection done with the aim of learning the actual process that is being followed for the [2] product design and modifications for raised issues from previous industrial Products or by the new requirements. We are thankful to JCB India Ltd [7]. For providing the opportunity to work with the deemed team which incorporates service issues and processes further to change improve design quality with best solutions. The project includes the designing of the 'Rotary Coupling Stop Bracket.' which restricts the impact of Rotary Coupling top /head Motion and prevents the Hydraulic hose from damages and reduce the important breakdown time of an Excavator Machine. The Main Objectives of Project are:

- To understand what is meant by Product Design Cycle, its stages, factors affecting it and use in industry.
- To work on live Project issues and find the decision making process.
- To learn use of different Standards in Design and manufacturing Technology.
- To learn the use of different techniques and knowledge for the different Criteria's that a Design Engineer should look for rigid and feasible solutions.

1.1 Excavator Machine and its Parts

Introduction [6]Excavators are used as a Earthmovers for Digging of trenches, holes, foundations Material handling Brush cutting with hydraulic attachments Forestry work Forestry mulching Demolition General grading/landscaping. Modern, hydraulic excavators come in a wide variety of sizes depending on bucket fitted. As shown in fig below.Fig.1.

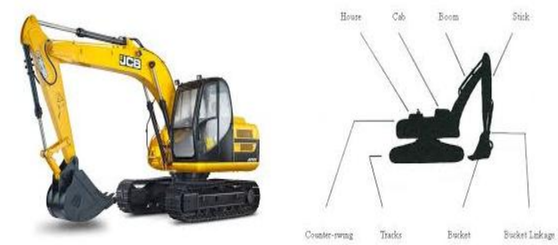

Fig -1: Jcb excavator and its parts

[5][6].The major parts in Excavator includes Tracks on Lower body Frame , ppr Frame with Engine and hydraulic system ,Boom Assembly, Arm Bucket links, Bucket assembly, Hydraulics System like Cylinders ,Rotary Coupling ,Controlling valves, Hose Assemblies, Counterweight etc.

1.2 Stop Bracket

In Excavator Machine the Rotary coupling is placed into the ‘A frame’ in between upper frame and the lover frame of Machine. The top part of Rotary Coupling is fixed with the upper frame by using the stop Bracket, which restricts the damages of Hydraulic Hoses and the Rotary Coupling unit due to uncontrolled rotation of coupling in the field work.

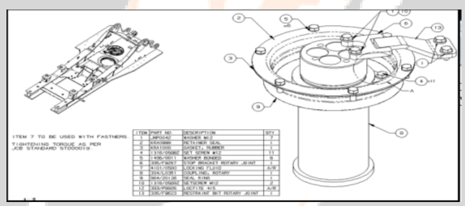

Fig -2: Rotary valve with stopping bracket

2. DESIGN OF STOP BRACKET.

There are two ways in which vessels are designed:

- Design by Rule.
- Design by Analysis.

Design by rule is used to calculate basic thickness, stresses and keeping stresses below allowable values. FE analysis is carried out to validate the design that is made by Design by rule method. Finally the results obtained from these methods are compared with Design with Analysis.

2.1 Problem Definition

The Practical Analytical Methods such as 8D Report and Why-Why Analysis Reports are Used to Find The Root Causes of Failures caused in Bracket and the possible solutions we can get to reduce the failure.
2.1.1 8-D Report :

Fig -3: 8-D report for stopping bracket assembly

2.2 Why-Why analysis Report-1:

Table-1: Why-Why Analysis 1

COMPLAINT	ROTARY COUPLING STOP BRACKET FAILURE .
PART NAME	STOP BRACKET
PROBLEM 1:LOOSNESS OF BOLT AT HEAD OF ROTARY COUPLING WHICH HOLDS BRACKET	
WHY 1	BRACKET FAILS AT FORK END
WHY 2	FORK END CROSS SECTION AREA DOES NOT TAKES LOAD
WHY 3	CROSS SECTIONAL AREA LESS AT FORK END
WHY 4	CROSS SECTIONAL AREA IS LESS SPACE DUE TO LESS SPACE AVAILABLE

2.3 Why-Why analysis Report-2:

Table-2: Why-why Analysis 2.

COMPLAINT	ROTARY COUPLING STOP BRACKET FAILURE.
PART NAME	STOP BRACKET
PROBLEM 1:LOOSNESS OF BOLT AT HEAD OF ROTARY COUPLING WHICH HOLDS BRACKET	
WHY 1	BOLTS MAY LOOSED DUE TO VIBRATION
WHY 2	VIBRATION OCCURRED DUE TO CLEARANCE BETWEEN BOLTS AND BRACKET
WHY 3	CLEARANCE FOUND DUE TO BOLT MAY NOT TIGHTENED WITH FULL TORQUE DURING ASSEMBLYTENED
WHY 4	THE BOLT MAY NOT TIGHTENED WITH PROPER TOOL
WHY 5	TOOL NOT EFFECTIVELY USED DUE TO LESS ACCESSIBLE SPACE AVAILBLE FOR TOOL USE .

2.4 Findings for Why-Why-1:

- Inaccessible space leads to limit the cross-sectional Area.
- Due to limited Access Weak cross-sectional area formed.

2.5 Findings for Why-Why-2:

- Inaccessible space to tighten the bolt leads to change of Assembly Procedure.
- Change of Assembly Procedure may lead to change of shape and layout of Bracket.
- Change of Design leads to change of Material.

2.6 Possible Solutions

Solutions should satisfy the following Criteria:

- Minimum Change in Physical Assembly Procedure.
- Minimum or Less Manufacturing Cost.
- Withstand with Loading.

2.7 Possible Solutions for Why-Why-1:

- The Weaker cross sectional area can be increased to withstand the loads.
- To increase the cross sectional area in limited space, the thickness may be increased.

2.8 Possible Solutions for Why-Why-2:

- For Appling required torque the Bracket should be bolted to Rotary Coupling first and then Coupling should fit with upper Frame.
- For Fixing the Bracket in Rotary Coupling before Coupling Fixing in Frame can be achieved by dividing the Bracket length into two parts.
- For Proper Fixing the Bracket in Frame Bolting can be used.
- Material can be changed to withstand the total torque as bracket is divided in two parts.

3 DESIGNS BY RULE

This stage includes the Design of Bracket [1] with available loading data and to find the Geometrical dimensions with Material selection.

3.1 Material Selection:

The Material for the bracket selected should satisfy the following Criteria.

- Minimum or Less Manufacturing Cost.
- Withstand with Loading.
- Easily available.

With Above Criteria the material Selected by team is Sheet steel-5000/0101.

3.2 Material Properties

Sheet steel 5000/0101 is a Mild Steel plate EN10025 S275-hot rolled with Pickled and oiled intended primarily for use of fabricators in welded frames which are designed for use in heavy loaded Earth moving Equipments. All material properties are given below.

Table-3: Properties of Sheet Steel 5000/0101

MIN YIELD	245-275 N/mm^2
UTS	410-560 N/mm^2
DENSITY	7769 Kg/m^3

3.3 Loading condition

Typical operating conditions are given as follows:

Table-4: Loading conditions

OPERATING TORQUE AT ROTARY COUPLING	445X103 N.mm
BOLT PCD ON TOP OF ROTARY COUPLING CASING	25mm
THE FORCE EXERTED ON BRACKET FORKS	17.8kN
OLD FOS VALUE	1.6

3.4 Analytical Calculations for old Bracket.

All input specifications are converted to SI unit. Henceforth, this paper follows SI units for all Calculations.

Table-5: Input specifications of old Bracket

PARAMETERS	QTY / SI UNIT
FORK END DIAMETER(D)	21 mm.
THICKNESS OF BRACKET	12 mm.
DENSITY	7769Kg/m³.
USS:ULTIMATE SHEAR STRENGTH (APP	245 N/mm².
SYS:SHEAR YIELD STRESS	145 N/mm².
ALLOWABLE STRESS(S)	90 N/mm².

3.5: Parameters Calculation:

The various parameters have been calculated using the standard formulae available in the literature and there values have been presented as follows:

Table - 6: Various Parameters Calculated

PARAMETERS	VALUE
MIN.AREA OF FORK END IN SHEARING	102 mm²
LAOD AT EACH FORK END	8900 N
SHEAR STRESS INDUCED	90 N/mm².
FOS	1.6

3.6 Design of New Bracket Thickness:

Minimum Bracket thickness is calculated by increasing the FOS Twice and using the oldData.
The Shear stress induced is calculated using following formula.
F.O.S = SYS/τ (1)
τ = 145/3.2
τ = 45.31 N/mm²

3.7: Design of New Bracket Thickness by using Direct Shear stress:

Minimum Bracket thickness is calculated using following Eq.
Shear Stress (τ) = P / A. (2)
Where, (Area) A= 2 x t x b (3)
And t =25 mm
Comparing old bracket thickness,
We find Safer Design which increases load bearing in Shear loading.

3.8 Design of Bracket as per The Why-Why report-2:

For Fixing the Bracket in Rotary Coupling before Coupling Fixing in Frame can be achieved by dividing the Bracket length into two parts. as shown in fig Part1 and Part2.

The Bracket is crosschecked with Loading at different locations at section A-A. and section-B-B in Part 1 ,similarly section C-C and section D-D in Part 2 respectively to find safer design.

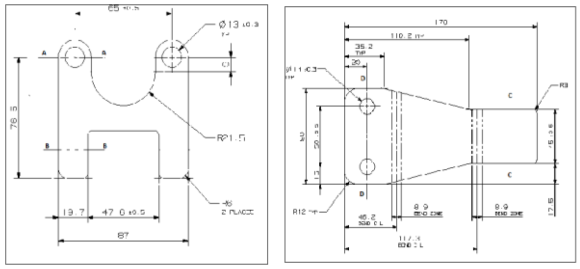

Fig-5: New Bracket part 1 and part 2.

3.9 Selection of locking bolt at Section D – D

The Selection Criteria for fixing bolt:

- Easily Availability.
- Low in cost.
- Depth for Penetration Available.
- Loading condition.

Table-7: Std.chart for Mechanical Properties

MECHANICAL PROPERTIES

Mechanical properties		Property class					
		4.8	6.8	8.8		10.9	12.9
Thread Diameter		-	-	d ≤ 16mm 1)	d > 16mm 1)	-	-
Minimum tensile strength Rm N/mm²	min.	420	600	800	830	1040	1220
Vickers hardness HV	min.	130	190	250	255	320	385
F≥98N	max.	220	250	320	335	380	435
Surface hardness HV 0.3	max.	-	-	2)			
Lower yield stress ReL N/mm²	min.	340	480	-	-	-	-
Stress at 0.2% non proportional elongation Rp0.2 N/mm²	min.	-	-	640	660	940	1100
Stress under proof load Sp	N/mm²	310	440	580	600	830	970
Breaking torque MB	N/m min.	-	-	See ISO 898/7			
Elongation after fracture, A	% min.	-	-	12	12	9	8
Reduction of area after fracture, Z	% min.	-	-	52	52	48	44
Minimum height of non-decarburized thread zone, E		-	-	1/2 H1	1/2 H1	2/3 H1	3/4 H1
Maximum depth of complete decarburization, G	mm.	-	-	0.015	0.015	0.015	0.015
Hardness after retempering		-	-	Reduction of hardness 20HV maximum			
Surface integrity		In accordance with ISO 6157-1 or ISO 6157-3 as appropriate					

With above chart of ISO 898 -1 standards and following the Criteria's,
We have,
Torque (T) =500 x 103 N.mm
and at section D – D r = 212
at section D – D Load (P) = 2358.5 N.
Hex Bolt size- M12,
With the penetrating depth of 35mm.
For Grade -10.9,
Min. Tensile Strength -1040 N/ mm² and proof load stress 830 N/ mm²

4. MODEL PREPARATION

Rotary Coupling Bracket can be modeled for the easy pictorial representation of old and new assemblies and actual pictorial Using Cad software Catia-V5 As it easiest way for modeling in Catia v5 as compared to other cad software's. With the physical geometric dimensions gained from design and the designed values the both assemblies of old and new Bracket are modeled. As shown in Fig.6.
The ANSYS is used for the analysis of Bracket design with different loading values at its weaker area.

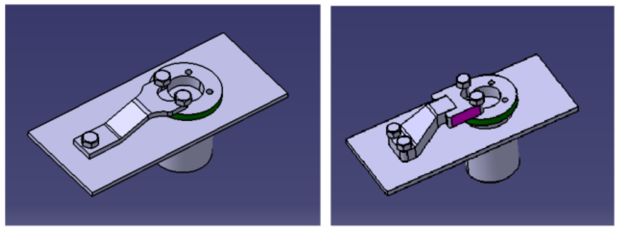

Fig-6: Assembly models of an old and new bracket

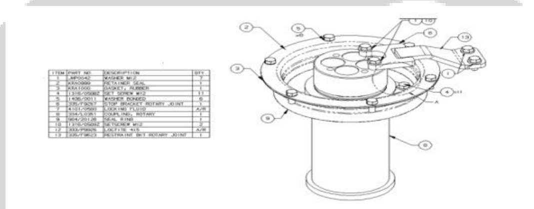

Fig-7: Assembly models of new designs with its part details.

4.1 Axi-Symmetric Approach

Axi-symmetry approach simplifies the model and also reduces the computational time. This approach can be used if the geometry is revolved about a particular axis.

In ANSYS axi-symmetry is used about Y-axis. One needs to create a model and mesh with PLANE elements of ANSYS. In all cases axi-symmetry approach is used in this thesis to represent shell, head and complete model for structural, thermal and coupled field analysis.

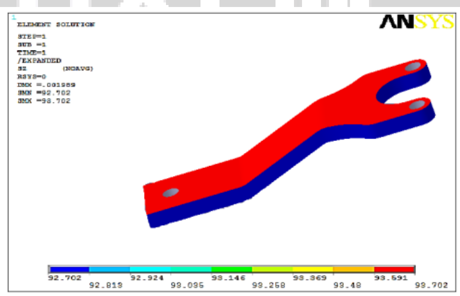

Fig-9: Structural analysis of rotary coupling old bracket.

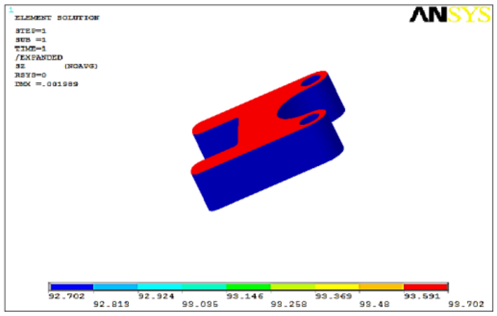

Fig-10: Structural analysis of rotary coupling new bracket.

5. COMPARISION OF RESULTS

Complete Bracket Assembly is modeled and analyzed in ANSYS using axi-symmetric analysis and results of various analyses are presented in Table No. 8.Various stress results are below allowable limits of shell as per the guidelines of ASME. Results of FE analysis are within 15% error limit when compared to analytical results. Error in FE and analytical results occurs because of various reasons such as assumptions in analytical formulation, approximations in FE formulations, choice of element in FE analysis, etc. Hence, similar procedure can be used for analysis of whole assembly.

Various stress values obtained are lesser than allowable limits of material and hence Bracket is safe and this design can be used to manufacture .The analysis has been done in ANSYS for the pressure vessel taking different instances into consideration.

Table No-8: Comparison

BRACKET BODY	DESIGNED VALUE	ANALISED WITH ANSYS	ERROR
STRESS DUE TO TWISTING SHEAR LOADING	45 Mpa	38.3 Mpa	15%
STRESS DUE TO DIRECT SHEAR LOADING	90 Mpa	79.4 Mpa	12%

5.1 Results of Bracket Analysis

Additional observation in complete Bracket assembly analysis is that junction of Bolts at the Part-1 of New bracket and rotary coupling top head is subjected to high stresses This is typically because of sudden change in loadings during Field operations. Hence, it important to select appropriate head type for given rotary Coupling.

6. CONCLUSION AND SCOPE

Both old and New Bracket Assemblies are modeled and analyzed and compared for easiest way of assembly Technique and Decided to go with the new assembly technique, as very less time is required for assembly.

6.1 Changes in Design:

- Design Change to Increase Cross-sectional Area:

The Bracket cross section area at each fork end is not equal at each side of hole, as shown in fig.8 below so it can be changed to equal side by shifting the hole by 1 mm.

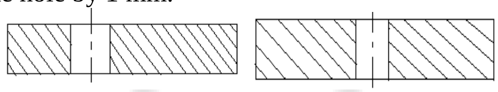

Fig-8: Comparison of old cross section area with new modified.

6.2. Design Change Due to change in Assembly Procedure:

The Fitment of bolt can be done with required torque if only its assembly done before Rotary Coupling is being fitted in upper Frame. To provide this, the total length of Bracket is divided in to two halves, as shown in fig. below. New Bracket is **divided** in two Parts

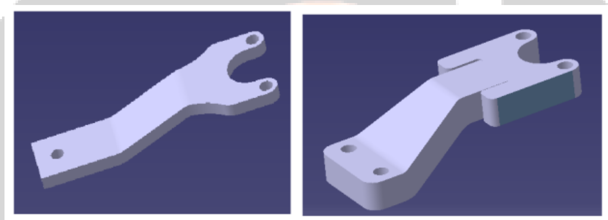

Fig-9: Old Bracket model and New model design.

6.3. Scope for Future Work:

The topic is challenging and involves lot of scope for future work. Following list outlines scope for future work:
1. The Position of bolt holding the Restriction Bracket may changed to axially , as the cross section area taking load will increase.
2. The strength of Materials for Bracket can be increased by using Composites which can lead to reduce the overall dimensions of Bracket in Assembly.

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