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Analysis of Load Test Fixture Acting Under Static Loading Condition

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Abstract: ***Structural items include various fabricated and machined items. Various types of fabrication processes like welding, bending, riveting etc. and machining processes like grinding, milling and turning are carried out to produce different components. When these components are assembled to have final product, lots of problems are faced. Problems like crack formation, wear of components, failure of component in service etc. arise. So to avoid this, Root-Cause Analysis of these defects is carried out and production process is modified as per the results of analysis. Root-Cause Analysis consists of why-why analysis, process sheets preparation, design of jigs and fixtures if necessary and design of inspection gauges and templates for inspection purpose. Load test fixture is used to check the sustainability of the component under given operating load. If cracks or any defects are found then root-cause analysis of those defects is carried out.***

Keywords: Root-Cause Analysis (RCA), 5-Why Analysis, Cause and Effect Diagram, Critical to Quality (CTQ).

1. Introduction

The fast changing economic conditions such as global competition, declining profit margin, customer demand for high quality product, product variety and reduced lead–time etc. induce a major impact on manufacturing industries. Components are produced using various types of fabrication processes like welding, bending, riveting etc. and machining processes like grinding, milling and turning. While doing this, problems like crack formation, wear of components, failure of component in service etc. arise. So to avoid this, Root-Cause Analysis of these defects is carried out and production process is modified as per the results of analysis. Analyzing failures is a critical process in determining the physical root causes of problems. The process is complex, draws upon many different technical disciplines, and uses a variety of observation, inspection, and laboratory techniques. Load test fixture is used to check the sustainability of the component under given operating load. If cracks or any defects are found then root-cause analysis of those defects is carried out [1].

2. Process Engineering

Process Engineering includes preparation of a sheet, a document which specifies standard practices those are needed to be followed in order to reduce non-conformities during fabrication and machining. It also specifies the critical dimensions i.e. critical to quality (CTQ) dimensions with stringent tolerances.

2.1 Jigs, Fixtures and Inspection Gauge Design

When the work piece is loaded on a machine tool, then it needs to be fixed so that accurate results are obtained. For this purpose, jigs and fixtures are to be designed to hold the work piece. Jig and fixtures are production work holding devices used to manufacture duplicate parts accurately. The correct relationship and alignment between the tool and work piece must be maintained. To do this, a jig or fixture is designed and built to hold, support and locate every part to ensure that each is machined within specified limits.

- **Jig -** A jig is a special device that holds, supports or is placed on the part to be machined. It only locates and holds the work piece but also guides the cutting tool.
- **Fixture** - A fixture is a production tool that locates, holds and supports the work securely so the required machining operations can be performed. A fixture should be securely fastened to the table of machine upon which the work is done.
- **Inspection Gauge** - Gauges are to be designed for inspection purposes to check how accurate the component is produced. Gauges are of two types, GO and NO GO gauge [2].

3. Root-Cause Analysis

Root-Cause Analysis (RCA) is a method that is used to address a problem or non-conformance. It is used for elimination of the cause and prevention of the problem from recurring. Root-Cause analysis is a completely separate process to incident management and immediate corrective action, although they are often completed in close proximity. RCA is simply the application of a series of well known, common sense techniques which can produce a systematic, qualified and documented approach to the identification, understanding and resolution of underlying causes [3].

4. Analysis of Load Test Fixture using Simple Hand Calculations

4.1 Terminology for Static Loading

σ_t = Direct Tensile Stress = to be found out
P = Static Tensile Load = 70 Tones
A_t = C/S Area of Bolt (M20) upon which Load is acting
= 272 mm^2 for Fine Grade
= 245 mm^2 for Coarse Grade

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$\sigma_{ut\ (bolt)}$ = Ultimate Tensile Strength of Bolt = 1040 Mpa
$\sigma_{y\ (bolt)}$ = Yield Strength of Bolt = 940 Mpa
$\sigma_{ut\ (beam)}$ = Ultimate Tensile Strength = 410 Mpa
$\sigma_{y\ (beam)}$ = Yield Strength of Beam = 240 Mpa
$R_A = R_B$ = Reaction at A and B = 35 Tons = 343350 N
E = Young's Modulus = 200 Gpa = 200000 Mpa

4.2 Static Loading of Bolts

$\sigma_t = {}^{P}/_{8\ x\ A_t} = {}^{343350}/_{8\ x\ 245}$ = 175.17 Mpa
$\sigma_{y\ (bolt)}$ = Yield Strength of Bolt = 940 Mpa
FOS = ${}^{Yield\ Strength}/_{Design\ Stress}$ = 940 / 175.17 = 5.36

Design is **safe**.

4.3 Static Loading of Beam

$I_x = 436118805.5\ mm^4$
Y = 254.52 m

Area of C/S of Beam = $A_1 + A_2 + \ldots + A_7 + A_8 = 23000\ mm^2$
Volume of Beam = Area of C/S of Beam x Length of Beam
= 23000 x 5780 = $132940000\ mm^3$
Mass = Density * Volume
= 7812 x 10^{-9} x 132940000 = 101879.51N

$M_{max} = {}^{WL}/_{8} = {}^{(686700 - 101879.51) x\ 5780}/_{8}$

= $(584820.49)\ x\ 5780$ = 422532804.025 N.m

${}^{\sigma}/_{y} = {}^{M}/_{I}$
σ = 248.5 Mpa

FOS = 250 / 248.5 = **1.0**

δ = ${}^{PL^3}/_{192\ EI}$
= ${}^{686700\ x\ (5780)^3}/_{192\ x\ 2\ x\ 10^5\ x\ 436118805.5}$

= 7.91 mm.

5. Simulation of Load Test Fixture

5.1 Introduction

It consists of horizontal simply supported beam with dynamic load of 70 Tons acting upwards and self-weights acting downwards. The static analysis is carried out with the help of SOLIDWORKS12. Fig. 1 shows cross section of beam.

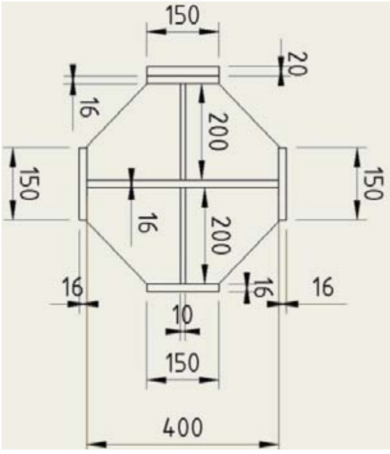

Figure 1: Cross section of Simply Supported Beam

5.2 Assumptions

These are assumptions which are required for the simulation. These assumptions depend on type of problem such as structural, thermal, static and dynamic etc [4].

Table 1: Assumption table

Study name	Study 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from Flow Simulation	Off
Solver type	FFEPlus
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off

5.3 Units

This table contains details about unit system used in analysis.

Table 2: Unit table

Unit system:	SI (MKS)
Length/Displacement	Mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

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5.4 Material Properties

This table contains material properties like yield strength, tensile strength, elastic modulus, Poisson's ratio, mass modulus, shear modulus.

Table 3: Material property table

Name	plain carbon steel
Model type	linear elastic isotropic
Default failure criteria	max von mises stress
Yield strength	2.20594e+008 n/m^2
Tensile strength	3.99826e+008 n/m^2
Elastic modulus	2.1e+011 n/m^2
Poisson's ratio	0.28
Mass density	7800 kg/m^3
Shear modulus	7.9e+010 n/m^2
Thermal expansion coefficient	1.3e-005 /Kelvin

5.5 Load

This table shows location of load and its magnitude.

Table 4: Load Location table

Load name	**Load Image**	**Load Details**
Force-1		Entities: 1 face(s) Type: Apply normal force Value: 700000 N

5.6 Contact Information

This table shows global and local coordinates for the analysis

Table 5: Global Co-ordinate Table

Contact	Contact Image	Contact Properties
Global Contact		Type: Bonded Components: component Options: Compatible mesh

5.7 Mesh Information and Details

This Table shows mesh information like element size, mesh quality, mesh type, nodes and aspect ratio.

Table 6: Mesh Information Table

Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	87.8782 mm
Tolerance	4.39391 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off
Total Nodes	32432
0Total Elements	16663
Maximum Aspect Ratio	41.368
% of elements with Aspect Ratio < 3	15.7
% of elements with Aspect Ratio > 10	15.4
% of distorted elements(Jacobian)	0

5.8 Meshing of Beam

Figure 2 shows meshing of beam. Meshing is carried out with solid mesh and 4 jacobian points.

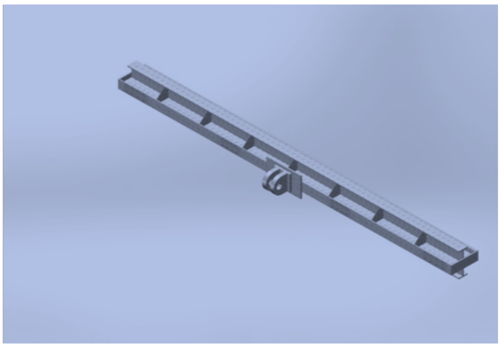

Figure 2: Meshing of Simply Supported Beam

5.9 Reaction Force

This table shows reaction due to forces acting on a beam.

Table 7: Force Value Table

Set	Sum X	Sum Y	Sum Z	Result
Model	-11.2468	-10.7156	700008	700008

5.10 Reaction Moments

This table shows moments acting on a beam.

Table 7: Moment Value Table

Selection set	Sum X	Sum Y	Sum Z	Resultant
Entire Model	0	0	0	0

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6. Results and Discussion

6.1 Stress

Stress is an internal reaction of a component generated by external force per unit area. This external force can be measured in N or KN. Blue color indicates areas with minimum stress and Red color indicated areas with maximum stress. Remaining all color indicate stress between maximum and minimum stress [5]. Fig. 3 shows stress distribution.

Table 8: Stress Distribution Table

Type	Min	Max
VON: von Mises Stress	111282 N/m^2 Node: 30677	2.21451e+009 N/m^2 Node: 12590

Figure 3: Stress Distribution of Simply Supported Beam

6.2 Strain

Strain is a ratio of change on a specific dimension to the original dimension. Strain has no unit. Fig. 4 shows strain in horizontal beam. Blue color indicates areas with minimum strain and Red color indicated areas with maximum strain. Remaining all color indicate strain between maximum and minimum strain [5].

Table 8: Strain Table

Type	Min	Max
ESTRN: Equivalent Strain	3.90333e-007 Element: 15763	0.00464886 Element: 6831

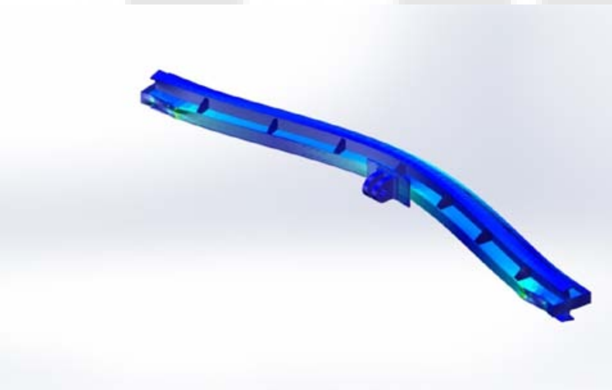

Figure 4: Strain in Simply Supported Beam

6.3 Displacement

Fig. 5 shows displacement of beam and table 9 contains value of displacement of the mid section.

Table 9: Displacement Table

Type	Min	Max
URES: Resultant Displacement	0 mm Node: 5792	9.83515 mm Node: 30120

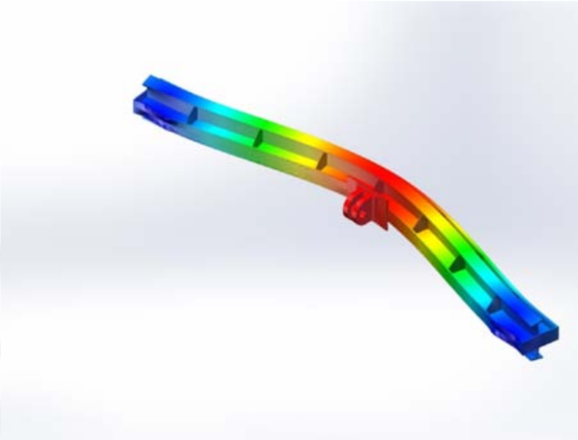

Figure 5: Displacement of Simply Supported Beam

6.4 Load Test Fixture

Load test fixture consists of two vertical columns and single horizontal beam. Two tilted supports are attached to this structure. At the centre position, a hydraulic cylinder is attached which is single acting cylinder. Using this cylinder, load is applied. Fig. 6 shows actual load test fixture used to impart load on the components.

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Figure 5: Load Test Fixture

7. Conclusion

This paper gives the idea of load test fixture used to hold the jobs or to impart pressure. As it consists of a hydraulic cylinder, it can generate a large magnitude of force. So its analysis becomes necessary because its failure may cause damage to operators as well as components. The approach presented in this paper gives an analytical methodology to perform the root cause diagnosis of product service failures. The solution offered here gives interaction of design, process parameters and machines. Blue color indicates areas with minimum values and Red color indicated areas with maximum values. Remaining all the colors indicate intermediate values. As majority of areas are showing blue color so design is safe. Stress induced in a beam is 248.5 Mpa (By analytical methods) and 221.45 Mpa (by SOLIDWORKS 2012). Also displacement of beam is 7.91 mm (By analytical methods) and 9.83 mm (by SOLIDWORKS 2012). This variation is because approximation used by FEM methods while doing simulation. This fixture can be used without fail for the load testing of components weighing less than or equal to 70 Tons [6] – [7].

8. Future Scope

This paper focuses on analysis load test fixture under static loading condition but in industries, lots of vibrations and varying loads act on the system. So Fatigue or dynamic analysis has to be carried out considering all remaining considerations like frequency and magnitude of changing load, endurance limit of beam and bolt, proof stress, Goodman's criteria etc.

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