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Research Article

Cost effective solutions by Design and Analysis of Links used in Anti Rolling Device in bogies for a Mass Production

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Abstract

A Link is a component which connects opposite (left/right) wheels together by a torsion spring. to an Anti-roll bar. It is a part of many automobile suspensions that helps reduce the body roll of a vehicle during fast cornering or over road irregularities. Anti-roll bar is intended to force each side of the vehicle to lower, or rise, to similar heights, to reduce the sideways tilting (roll) of the vehicle on curves, sharp corners, or large bumps. With the bar removed, a vehicle's wheels can tilt away by much larger distances. Links are made up of Alloy special steel(34CrNiMo6).In this paper we design an Cost-effective solution of the link by minimizing the material without getting a change in the factor of safety. The changes are made in the link by reducing the material in the middle part which doesn't effect and damage the link and stresses distribution are analyzed by taking the total weight of the locomotive into the consideration. This type of cost effective design helps to reduce the production costs which will play an major role in Mass production.

Keywords: *Link, cost-effective solution, anti Rolling Bar, harmonic analysis*

1. Introduction

An **anti-roll bar** (**anti-**sway bar, sway bar, stabilizer bar) is a part of many automobile, Railway suspensions that helps reduce the body roll of a vehicle during fast cornering or over road irregularities. It connects opposite (left/right) wheels together through short lever arms linked by a torsion spring.

The anti-roll bar, as being a suspension component, is used to improve the vehicle performance with respect to these three aspects. The anti-roll bar is a rod or tube that connects the right and left suspension members. It can be used in front suspension, rear suspension or in both suspensions, no matter the suspensions are rigid axle type or independent type. Typically an Anti-roll bar is a component of Secondary suspension (Mohammad Durali, *et al* , 2002).

A sway bar is usually a torsion spring that resists body roll motions. It is usually constructed out of a cylindrical steel bar, formed into a "U" shape that connects to the body at two points, and at the left and right sides of the suspension. If the left and right wheels move together, the bar rotates about its mounting points. If the wheels move relative to each other, the bar is subjected to torsion and forced to twist. Each end of the bar is connected to an *end link* through a flexible joint. The sway bar end link connects in turn to a spot near a wheel or axle, transferring forces from a heavily-loaded axle to the opposite side (Kelvin Hubert, *et al* , 2005).

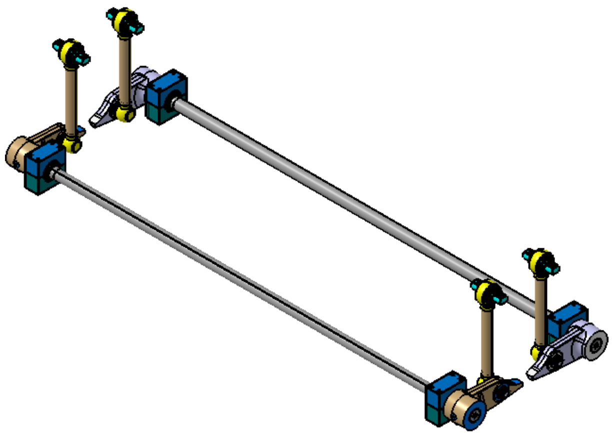

Figure 1 Link used in Anti Rolling Bar

Forces are therefore transferred

1) from the heavily-loaded axle
2) to the connected end link via a bushing
3) to the anti-sway (torsion) bar via a flexible joint
4) to the connected end link on the opposite side of the vehicle and
5) To the opposite axle. (J. E. Shigley, et al , 1989)

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2. Material Properties considered for Link

Table 1 Chemical Composition of material EN 10277

C	0.3-0.38
Si	Max 0.4
Mn	0.5-0.8
Ni	1.3-1.7
P	Max 0.025
S	Max 0.035
Cr	1.3-1.7
Mo	0.15-0.3

Table 2 Material used for links

Grade :	34CrNiMo6
Number:	1.6582
Classification:	Alloy special steel
Standard:	EN 10277-5: 2008 Bright steel products. Technical delivery conditions. Steels for quenching and tempering
	EN 10083-3: 2006 Steels for quenching and tempering. Technical delivery conditions for alloy steels
	EN 10269: 1999 Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties
	EN 10263-4: 2001 Steel rod, bars and wire for cold heading and cold extrusion. Technical delivery conditions for steels for quenching and tempering
	EN 10250-3: 2000 Open steel die forgings for general engineering purposes. Alloy special steels

3. Design and Analysis of Links for Cost effective solutions

3.1 Design of solid model

Instead of creating the solid models within ANSYS, we can create them in our favourite CAD system and then import them into ANSYS for analysis. Here in order to perform this CATIA V5 R19 version has been used to create the product as per the Boolean operation, assembling the component and creating the manufacturing drawing sheet suitable for production, by saving them in the STP file format or in a file format supported by an ANSYS Connection product. Creating a model using a CAD package has the following advantages:

- To avoid a duplication of effort by using existing CAD models to generate solid models for analysis.
- Usage of more familiar tools to create models.

However, models imported from CAD systems may require extensive repair if they are not of suitable quality for meshing. (Somnay, *et al,* 1999)

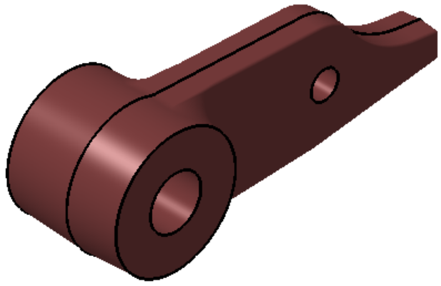

Figure 2 Design created using catia

3.2. Design Analysis using Ansys

The forces considered for performing analysis and optimization are centrifugal forces. In Newtonian mechanics, the centrifugal force is an inertial force (also called a 'fictitious' or 'pseudo' force) directed away from the axis of rotation that appears to act on all objects when viewed in a rotating reference frame. The concept of the centrifugal force can be applied in rotating devices, such as centrifuges, pumps, centrifugal, and centrifugal clutches, and in centrifugal railways, planetary orbits, banked curves, etc. when they are analyzed in a rotating coordinate system. The term has sometimes also been used for the force that is a reaction to a centripetal force. Since the anti rolling device comes into action when the locomotive drives down a circular path, due to its heavy load and velocity it undergoes centrifugal force which tries to push outwards. (Darling J, Hickson LR, *et al,* 1998)

3.3 Vertical curves

As a train negotiates a curve, the force it exerts on the track changes.(Jeripotula Sandeep Kumar ,et al ,2016) Too tight a 'crest' curve could result in the train leaving the track as it drops away beneath it; too tight a 'trough' and the train will plough downwards into the rails and damage them. More precisely, the support force R exerted by the track on a train as a function of the curve radius r, the train mass m, and the speed v, is given by

$$R = mg \pm \frac{mv^2}{r}$$

with the second term positive for troughs, negative for crests. For passenger comfort the ratio of the gravitational acceleration g to the centripetal acceleration v2/r needs to be kept as small as possible, else passengers will feel large 'changes' in their weight. These forces act as input for the analysis of Anti rolling device link. Therefore, inputs available. Below are the values of the approx weights that make up a locomotive.

Table 3 Total weight of the locomotive

Device	Weight Kgs
Bogie Assembly	11550

Underframe Structure	30256
Transformer	12000
Battery	6500
Miscellaneous	375
Loco Body Structure	6250
Power converter	3500
Oil cooler Blower	1515
H Filter	550
Traction Motor Blower 6 Quantity	2424
Auxillary Cubicle 2 Quantity	500
Communication Cubicle 2 Quantity	700
Auxillary Converter 2 Quantity	5000
Control Room Blower 2 Quantity	9000
Boxes & misc	5000
Pantograph Hatch	1100
Converter hatch	500
Pantograph	200
Main circuit breaker	500
Roof equipment	896
Ventilation	300
MR Floor	6800
Ballast plates 8 Quantity	2400
Other misc	6000

Weight of the locomotive = 112000 Kg approx
Weight of the bogie =11000kgs
Centrifugal force, $F= mv^2/r$
M= mass of locomotive
V=velocity of the locomotive
R- banking radius of the rail

Minimum curve radii for railroads are governed by the speed operated and by the mechanical ability of the rolling stock to adjust to the curvature. Equipment for unlimited interchange between railroad companies are built to accommodate 350-foot (106.7 m) radius, but normally 410-foot (125.0 m) radius is used as a minimum, as some freight cars are handled by special agreement between railroads that cannot take the sharper curvature. For handling of long freight trains, a minimum 717-foot (218.5 m) radius is preferred (embadi Koushik Varma , *et al* , 2016).

Hence

R=218.5 m

M= 112000kgs

V= 120km/Hr (since the design is for lower speeds for freight locomotive)

F= 112000*120*120/218.5

= 7266135.6 N

The equivalent stresses and deformation for the above values are checked and for the best optimised material within the range stress values are considered. Therefore multiple models with different of material optimizations are modelled and checked for the same forces and for the given stress values are observed. (P. M. Bora, *et al,* 2014)

Boundary Conditions for Analysis

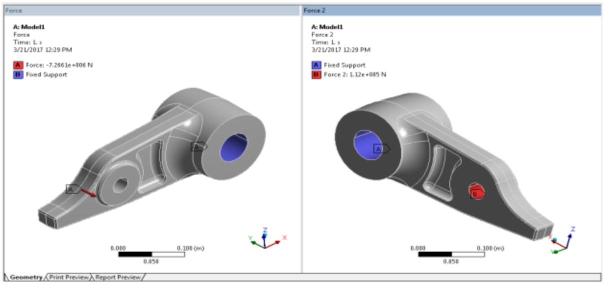

Figure 3 Design after applying the boundary Conditions

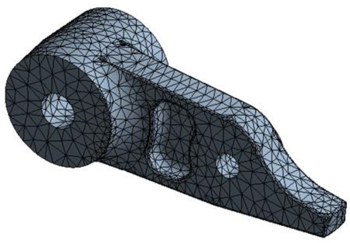

Figure 4 Finite element model of the design

A finite element model is created using Output after processing the Boundary conditions. The following are the different types of models created to design an optimium desgin which have less weight and also desired safety of factor (Nadaf prof. a. m. naniwadekar, *et al,* 2015)

Model-1

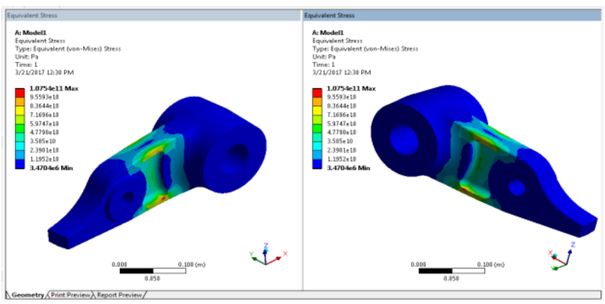

Figure 5 Model 1 designed using Ansys

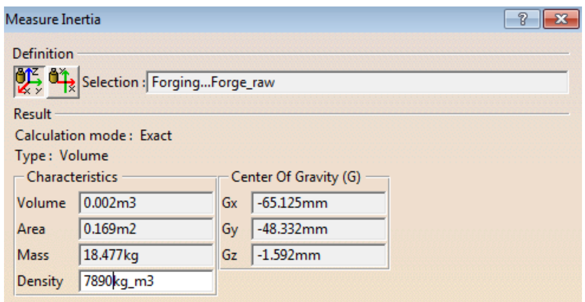

Figure 6 Measure inertia for the model 1

As it can be observed for the above model the stress are too high at few zones of the model due to the improper stress distribution along the model. Hence the design tends to create Stress concentration zone and thus may lead to fatigue under repeated loading conditions.

Model-2

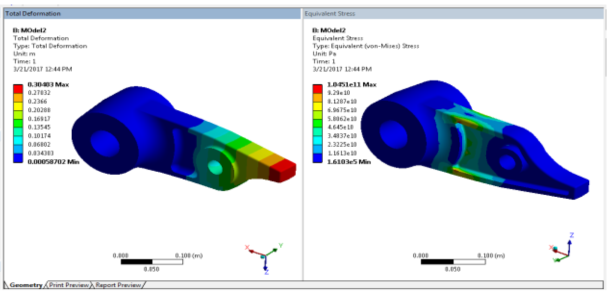

Figure 7 Model 2 designed using Ansys

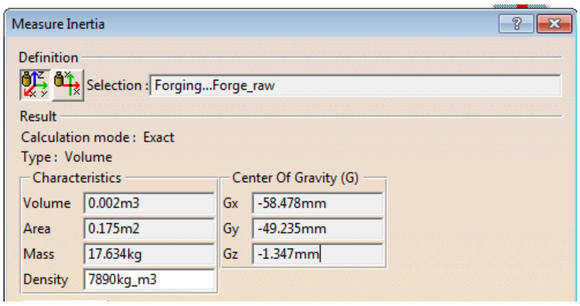

Figure 8 Measure inertia for the model 2

For the above model though the weight seems to considerably low the stress are too high as the geometry has too sharp corners and thus leading to stressful zones. The cuts have been provided on the both sides for Lever arm to reduce weight which does not seems to be good design solution. Even the stress values tend to be closer to Von mises stress. (Dariuszbojczuk, *et al,* 2014)

Model-3

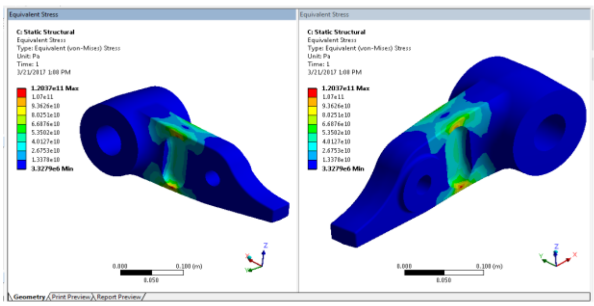

Figure 9 Model 3 designed using Ansys

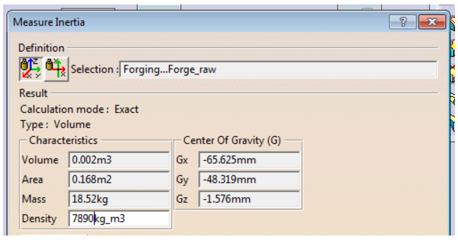

Figure 10 Measure inertia for the model 3

In this concept a oblong slot is provided on both sides of the lever and the weight seems to reduced considerably but not much achievement is seen towards reduction of equivalent stress. Due to the eccentic location of the Lever Arm the stresses seems to be too high for providing cuts on both the sides.

Model-4

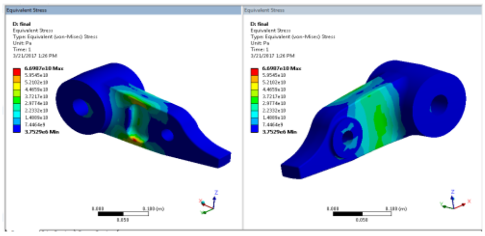

Figure 11 Model 4 designed using Ansys

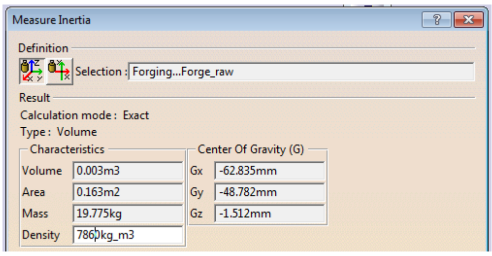

Figure 12 Measure inertia for the model 2

The above model provides a perfect insight for stress distribution. As it is visible by the equivalent stress are under much lower that than all the previous models though the weight has been little above than the other models. Here the optimization zone has been focussed only on side and thus good results have been achieved.

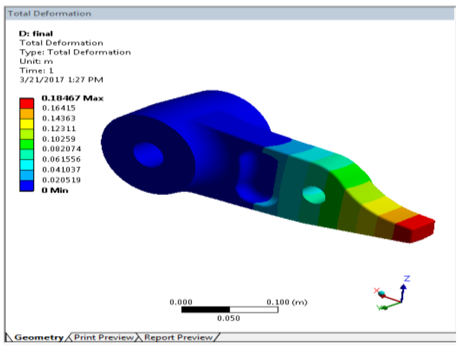

Figure 13 Stress distribution in Model-4

The below results show the Modal and harmonic analysis for the Model-4.

Table 4 Harmonic analysis of Model - 4

Object Name	Solution (A6)
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

The following bar chart indicates the frequency at each calculated mode.

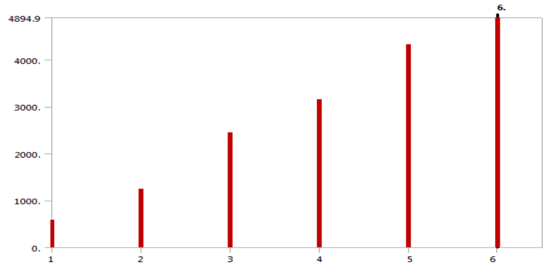

Figure 13 Frequency at each node

Table 5 Frequency at each node values

Mode	Frequency [Hz]
1.	589.53
2.	1239.5
3.	2441.
4.	3153.1
5.	4330.9
6.	4894.9

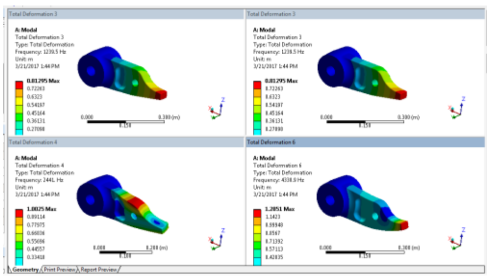

Figure 13 Harmonic Analysis Report

Initial Design

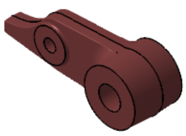

Figure 14 Initial Design of the link

Final Design

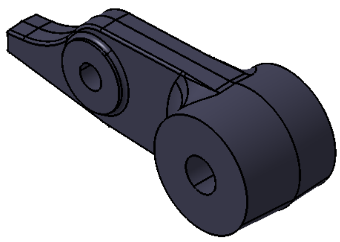

Figure 15 Final Design of the link

After machining at The contact places the final product for release

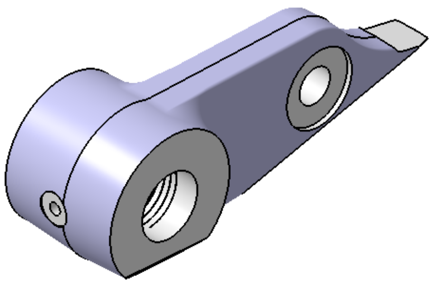

Figure 16 Final Machined product

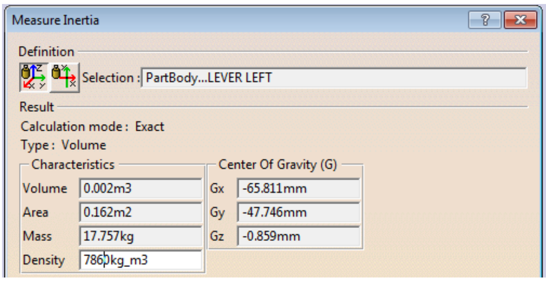

Figure 17 Measure inertia of final Machined product

Here after machining the final product weight is around 17.757Kgs approximately.

Cost Estimation

For a specific project an estimated 520 locomotives are to be built which are of Bo-Bo bogies. Hence each bogie consists of A pair of Anti Rolling Devices as shown in above pictures. Each Rolling bar comprises of 2 Links or Levers. Perhaps each bogie requires a total of 4 levers at different orientation.

Therefore total no of Bogies = 1040 nos.

Each Bogie requires 4 Levers= 1040 X 4= 4160 Units of Levers

With the previous and present design changes the overall weight in each unit is upto 3.2Kgs.

Thus overall weight reduction over a bulk order 4160x3.2 = 13,312 kgs of savings

Estimated Cost of the 34CrNiMo6+QT material as per the current market price is 120/ Per kg

Hence the overall cost to the project savings= 13,312x120= 1,597,440/-

Conclusion

By removing the material from the link there will be a reduction in the weight of the link up to 3.2kgs. In the mass production, it gets useful in saving a huge amount of money. As there is no change in the factor of safety the product can withstand its weight without any damage and effect.

Acknowledgement

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