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Safety Analysis of Two Wheeler Side Wheel Attachment for Differently Abled People

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Abstract - **In present scenario, transportation is one of the major requirements of the people for transportation of goods or self from one place to another place. For a differently abled person, transportation is a major issue and so the mobility of differently abled people is among the great concerns of the human civilization. It is really very hard to realize the problems and sorrows of a differently abled or debilitated person who is dependent on others or is confined on a wheel chair with a limited mobility. Contemporarily modified scooters used by the physically disabled people for transportation are rarely fabricated in companies or organized industries and government organizations but they are fabricated through road side garages as per customer requirements by welding and joining the wheels for stabilizing the vehicle. These general considerations are not enough for modifying the vehicle and do not provide driving safety. Hence this can be more dangerous for differently abled people. It may be very risky and uncomfortable to drive such modified scooters. A three or four wheeler scooter allows a differently abled or debilitated person with partial disability to commute themselves and perform their activities without anyone's assistance.**

Keyword: Side Wheel Attachment, Safety Analysis, Two Wheeler For disabled people, authorized modification of 2 Wheeler.

INTRODUCTION

Disability may include impairments, limitations in performing the activities, and participation constraints. Impairment is a drawback in body performance or structure. Activity limitation could be a problem encountered by a person in corporal accomplishment of a task or action. Participation restriction could be a drawback intimated by an individual involvement in life conditions. Disability is principally caused by the impairments of various subsystems of the body which can be classified in physical disability and mobility impairments. Any impairment that limits physical operation of limbs or organs can be a physical disability. Mobility impairment could be a class of disability that involves individuals with various types of disabilities. This kind of incapacity comprises of higher limb incapacity, lower limb incapacity, and incapacity in co-ordination with various organs of body. Physical disability can be additionally termed as handicap, once physically debilitated individuals encounter cultural, social or physical barriers that hinder their access to completely different system within the day to day life that are easily accessible for other common people. As such, handicap is a loss of opportunities to participate equally with others one among the areas where physically challenged individuals lose out is the transportation. Transport disability restricts physically challenged individuals from all types of movements from one place to another. It is the responsibility of us being engineers to Build and design the mobility sources for them such as vehicles which are feasible and safe for them. In this project we come with recommendations that would be useful for industry involved with fabrication of such side wheel attachments of the scooters.

RELEVANCE:

The project is carried out to verify and analyze various faults in the design, insurance, testing and standardization of the authorized and non-authorized side wheel attachments manufacturers. It may be a severe issue if the vehicles used by the differently abled people do not have the legal permission to run on the road. The issues about the insurance of the vehicle are also of the concern. For this it was required to take a survey of vehicles. Whether they are following the legal ways to run their vehicles on the road or not. The Regional Transport Officer gives a certification to such side wheel and side car attached vehicles. These certificates should be authenticated and legal as per the laws and standards. The materials used by the fabricators should be standardized. The fasteners used should be rated. Such type of survey is very important. This is done to give the safety design considerations to such fabricators because 40 percent people using such type of vehicle are fabricating their vehicles from the local non- authorized fabricators. Census has unveiled in 2011 that over 21 million people in India (around 2.23% of population) are suffering from some kind of disability. Out of the total disabled population in country, 9.3 million of them include females and 12.6 million are males. As per the different surveys, approximately 3 to 5 million of the people use the vehicles especially made for them. So for such a large population, the evaluation of the safety and legality is very important concern.

Hence for proper transportation of such people from one place to another place, the vehicles manufactured should be of the safe design and features.

OBJECTIVES

1. To carry the survey of side wheel attached vehicles & fabricators to study the design and process.
2. To carry out the safety audit and effective load analysis.
3. To recommend appropriate modifications/design process changes w.r.to side wheel attachments.

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LITERATURE SURVEY

The work done in the research is the surveying of the side wheel attached vehicles made for the differently abled people and give the recommendations to the non-authorized vehicle fabricators regarding material selection, joining process and the design considerations. Such type of work has not been done yet as we have searched various journals, research thesis, etc.

We found three reports related to the research work done for differently abled peoples' vehicles.

[1] 'Design of Scooter for Physically Handicapped with Foldable Roof' by Mr. Vishal Upadhyay, This report is about the various modifications in the vehicle used by the differently abled people. It also provides some data related to design of joining members used in the side wheel attachment. It is helpful for us in studying the types of sections used in the members used in the linkage of side wheel attachments.

[2] 'Attachment for Converting A Bicycle into A Tricycle (tricycle US2995378 A)' by Mr. Whetstone Meynard C. In this paper, the researcher has modified the bicycle to convert from two wheeler to three wheeler.

[3] 'The patent paper we found was Retractable Motorcycle Stop Support Wheels (US5029894 A)', by David M. Willman. In this paper, the retractable support wheels are assembled to the two wheeler. The side wheels can be assembled during driving and disassembled during parking.

SURVEY

VISITS: The initial work that is done to start the work is to visit various people who have such vehicles having side wheel attachments. From them it was required to get the information relating to from where they have fabricated their vehicle's attachment, the cost they spent on that, the specifications about the attachments and all. Then it was decided to visit vehicles having side wheel attachments, so that we could know how many vehicles are having the attachments fabricated from non-authorized fabricators and how many are from the authorized fabricators.

MODELS OBSERVED:

During the survey, we found so many vehicles having side wheel attachments. Following are some models which we observed during the project work. Those include the vehicles of various companies such as Honda, Suzuki, Bajaj, Hero, etc

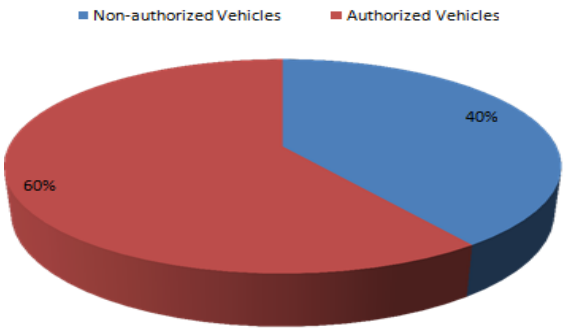

Fig.1 Survey of Authorized and Non Authorized Vehicle.

By observing various models we got a lot of differences and factors which differentiates between the authorized and non-authorized attachments which are shown in Table: 1 and model seen in rural area is shown in fig: 2 as below.

Fig.2. Side Wheel Attachment Attached on Vehicle.

From the observation of various models shown in Table 2.3, we got that the authorized fabricators do all the load analysis and follow all the design considerations. While the non- authorized workshops are not doing that. They are simply joining the members by trial and error methods as done by the craftsman design.

Although the cost of the authorized side wheel attachment is more i.e. 12000 to 15000, the maintenance of theirs is less. While the non-authorized side wheel attachments do have less cost i.e. 7000 to 8000 but more maintenance than the authorized attachments.

Certificates:

The vehicles having side wheel attachments are certified by Automotive Research Association of India (ARAI) and Regional Transport Officer (RTO). These certifications are not provided by the non-authorized local fabricators. RTO certificate which is certified to the authorized side wheel attached vehicle. Vehicle is taken to the RTO office where it is checked and the form named Form 17 is to be filled by us. This form contains all the information about the vehicle model, full name of certificate holder and the class of vehicle, etc. ARAI certificate certified to the authorized side wheel attached vehicle. This certificate is taken from the ARAI by the authorized fabricator from who the vehicle is fabricated. The performance test is carried out by the ARAI and then the certificate given.

Weld Quality:

The weld quality of the attachment done by the roadside garage mechanics is observed and ratings are given to the various parameters. The ratings are given on the basis of the observations. The hotspots and the porosities impinged on the surface are more. Simply arc welding is used for the welding process. The design for welded joints and the strength of the welds is not done anymore.

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Sr. no	Factor	Authorized	Non-Authorized
1.	Design and Load Analysis	Design and load analysis is done.	Design and load analysis is not done
2.	Material Testing	EBS, tensile testing, hardness, toughness etc. testing are done.	Material is randomly chosen but not tested.
3.	Welding Quality	Less porosity & hotspots, welding quality is good.	Porosity is more in welding, more hotspots welding quality is poor.
4.	Fasteners Rating	Rated Fasteners are used. Mainly consists of ASME & SAE ratings.	Rated but not appropriate for given load.
5.	Symbol of Life	Symbol is provided.	Symbol is not provided
6.	Insurance	There is no problem occurs re-garding to insurance	The insurance of vehicle cannot be done.
7.	Certification	ARAI Approval and RTO Certification	No Certification
8.	Cost & Mainte-nance	Cost of Authorized vehicle is more with less maintenance	Cost of non-authorized vehicles is less but it has more maintenance.

Table 1. Comparison between Authorized and Non-Authorized Vehicles manufactured for abled people.

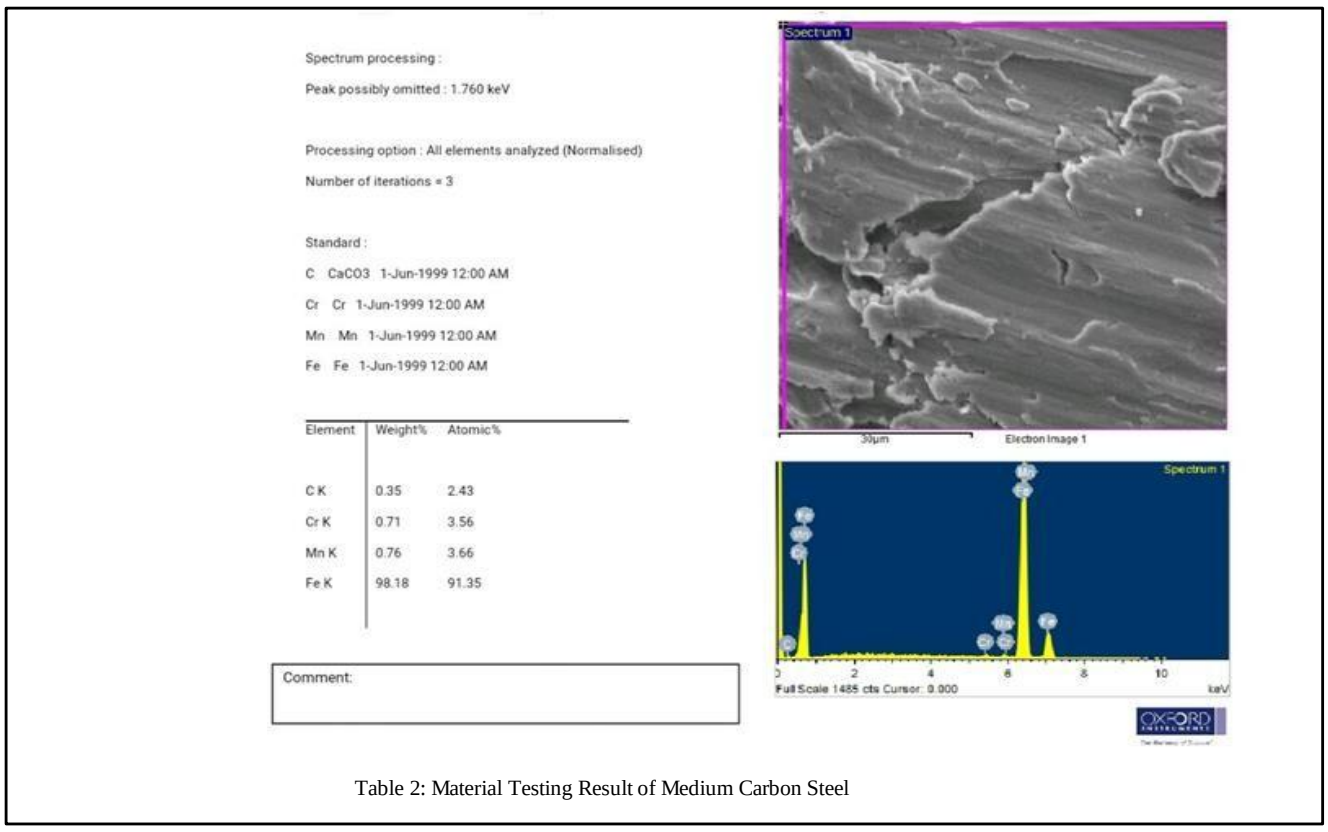

Table 2: Material Testing Result of Medium Carbon Steel

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Input Parameters		
Batch No.	:	T.Y Auto
Serial No.	:	115
Specimen Type	:	Round
Initial Diameter (mm)	:	16.000
Final Diameter (mm)	:	0.000
C/S Area (mm²)	:	201.062
Final Area (mm²)	:	0.000
Original Gauge Length	:	80.000
Final Gauge Length (mm)	:	0.000
Ext. Gauge Length (mm)	:	25.000
Pre Load (%)	:	0.100
Disp. Rate (mm/min)	:	30.000

Results			
Ultimate Load	(kN)	:	97.20
Ult.Tensile Strength	(kN/mm²)	:	0.483
Disp. At Ult. Load	(mm)	:	71.40
Maximum Displacement	(mm)	:	82.70
Proof Load 0.1 %	(kN)	:	8.042
Proof Stress 0.1 %	(kN/mm²)	:	0.036
Proof Load 0.2 %	(kN)	:	7.439
Proof Stress 0.2 %	(kN/mm²)	:	0.037
Breaking Load	(kN)	:	70.30
Breaking Stress	(kN/mm²)	:	0.350
% Elongation w.r.t. Final Gauge Len		:	Error

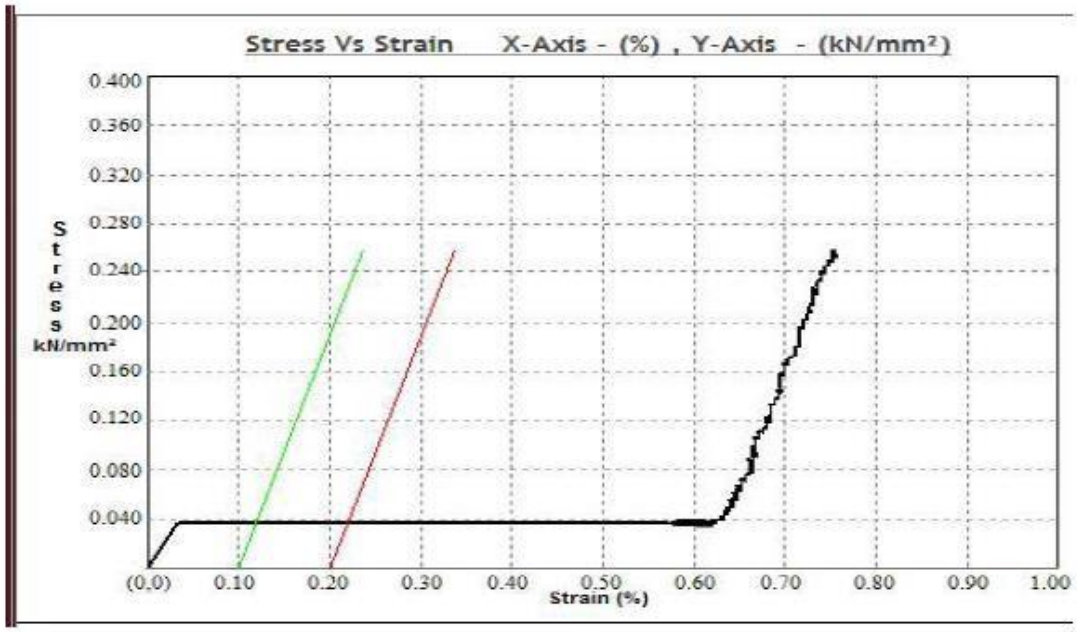

Table 2: Tensile Test of Medium Carbon Steel Material

Observations

1. Welded surface has a lot of hotspots.
2. Welding is more porous.
3. The welding electrodes used for the process are commonly used steel rod electrodes but no composite rods are used for better strength of the weld.

Fastener Rating

Fasteners are complex mechanically-engineered hardware. They are made using different materials, different thread types (i.e. coarse, fine, extra fine), various lengths, with grip or no grip (shank), different types (i.e. hex, 12 pt., carriage, etc.), different coatings (i.e. passivized cadmium, dry film lube, etc.), various classes of fit (i.e. class 3), and multiple grades (i.e. grade 5, 8, etc.). Bolts come with left or right hand threads, metric or SAE threads, different number of threads per inch (i.e. 20 or 28 for the same size fastener).

The fasteners used in the non-authorized attachments are SAE and ASME rated but they are not taken as per the loading or strength required. Only the diameter is considered while selecting the fastener but not the strength in tension and shear.

The bolts used here in the application of the side wheel attachment by the roadside mechanics are not used as per the ratings. The bolts should be used as per the load it can withstand. Here the load on the both wheels is approximately 50 kg combined. It means 50 X 9.81N = 490.5 N. Hence the bolt should have the dia. and length such that it should not fail at the given load. In short, it should have the yield strength in shear more because the bolt here will fail in shear. The bolt to be used should be having yield strength more than 490.5 MPa and as we know that the ultimate shear strength in shear of a fastener is typically about 60% of its yield strength in tension hence the yield strength in shear strength of the bolt should be more than 785 MPa. Hence the bolt used should be of Grade 5 having yield strength approx. 600 MPa. But here in some cases, bolts with no markings

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are used which has less yield strength in shear and tension both. In some cases the bolts are seen having the grades on it but the fabricator has not thought of the strength criteria rather than diameter of the bolt. He has simply chosen the bolts by considering diameter needed.

Recommendations:
The bolts with high shear strength should be used.
The bolts of Grade 5 should be used for the given load in this application.

MATERIAL TESTING

For selection of the material it is required to know the various properties of the material like composition, strength, hardness, toughness, and various mechanical properties such as yield strength, ultimate strength etc. For this, we carried out various tests such as,
EDS (Energy Dispersive X-ray Spectroscopy)
Tensile Test on UTM
Rockwell Hardness Test
EDS (Energy Dispersive X-ray Spectroscopy)
This test is done by the x-ray diffraction on the material.. The test is carried out on two materials given by the local fabricators
We tested both the materials and found the composition of the both materials. Following is the reports table no 2. From this report we got the chemical composition of the material. It has 0.35 % Carbon. It means that this is a Medium Carbon Steel. From the design data book, we got various properties of the material with given composition for the further check of design failure. In the report some terms are used such as,
Peak possibly omitted - The material under test does have some impurities and dust on its top surface. While testing, the energy emitted by such impurities is neglected. Kev- Kilo Electron Volt
Standards- The carbon, Manganese, Chromium, ferrous, etc present in the material may not present alone but along with its oxides or carbonates. ex. In the composition of the material we have tested, Carbon is not present alone but it is with calcium and oxygen (Calcium Carbonate). Hence, we are writing CaCO3.

Tensile Test on UTM
Material for the tensile test is medium carbon steel. From this report shown in table 2. We got various properties of the material such as ultimate stress, proof stress, breaking load, breaking stress etc.

Rockwell Hardness Test

The hardness testing of the material which we had selected we had got from local non-authorized fabricators (Medium Carbon Steel) was tested under Rockwell Hardness Testing machine. The Rockwell Hardness No. of the material is found to be 91 HRB. In the test, the scale selected for the testing is Black Scale and the Indenter selected for testing is Diamond Indenter Now, we have the value HRB of the material that we have tested. Convert the HRB to the HB or BHN by the formula given. Hence for HRB=91, HB =189. Now find the value of tensile strength for 189 HB. It will be nearer to 450 MPa. Now we have the relation between the yield strength in tension and the ultimate tensile strength. Hence we get yield strength in tension=approximately 400 MPa. This means the hardness is good enough for a safe design. Because in further chapter 3, we have calculated that the yield strength should be greater than 280 MPa.

Design of Members:

In this, we calculate if the members used in the design are safe in the static and dynamic conditions or not. From that calculated data, we give the recommendations to the non-authorized fabricators w.r.to the dimensions and the material selection.
Fig.3 shows the 3D model of the common linkage used for the side wheel attachments. The two wheels shown in the figure are side wheels. There are two lever members connected to the wheel hub at one end and their other ends are connected to the intermediate joining member. The joining member is a hollow section member which joins the two lever member.

Design of Lever Member:

Here we have calculated the bending failure of the lever member. The lever member is considered to be a cantilever as the load is acting on the free end and the other end is fixed by the bolt.

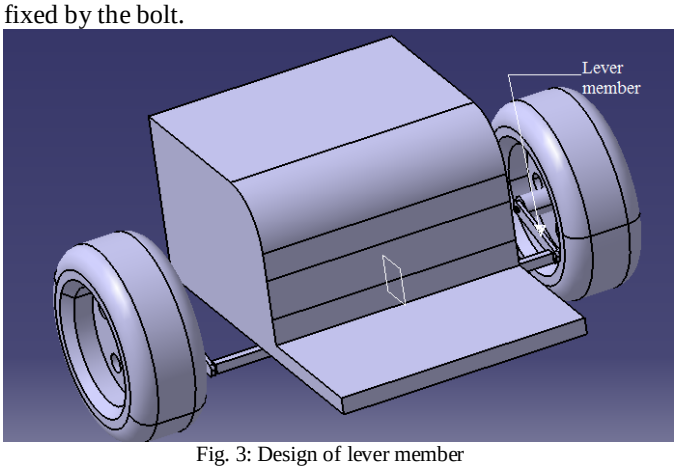

Fig. 3: Design of lever member

Fig 3 shows the 3D model of the lever member. It is a model drawn in CATIA. It is the common model used for the side wheel attachments that we have observed. For calculations of the bending stresses, the free body diagram is shown in fig. 3.11. The side view of free body diagram shows the cross section of the member i.e. solid rectangular section.
Here, consider the member as cantilever

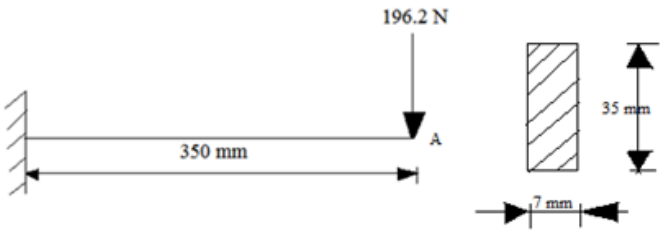

Fig. 4: Free Body Diagram

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Assume here that sum of all vertical forces is zero
Now,
$\sum W=0$
$-196.2+R_A=0$
Hence RA=196.2
Now,
$\sigma_{b\ working}= (M_b \times yI)/I$
$=196.2\times350\times(6tb2/12)$
$=196.2\times350\times(6/245)$
$=48.0482$ N/mm2
Now from the material it is known that S_{yt}= 280N/mm2
$\sigma_{b\ max}$=(Syt/ F.O.S.)
Consider F.O.S = 4
Therefore, $\sigma_{b\ max}$ = 70 N/mm2
Here, $\sigma_{b\ max} > \sigma_{b\ working}$
So design is safe.
Now, consider F.O.S=6 as there is human safety is considered.
$\sigma_{b\ max}$ =(Syt/F.O.S.) =47.66 N/mm2
& $\sigma_{b\ working}$ = 48 N/mm2
$\sigma_{b\ max} \approx \sigma_{b\ working}$
Design is not much safer here,

So for dynamic condition
For designing the joining lever under dynamic conditions we consider factor ' kb'.
Now,
$\sigma_{b\ working} = k_b \times \sigma_{b\ working} = 1.5\times48.0489$
$\sigma_{b\ working}$ = 72.07 N/mm2
And $\sigma_{b\ max}$= (Syt/F.O.S.)= 70 N/mm2
Now,
$\sigma_{b\ working} > \sigma_{b\ max}$
Hence, design is not safe.
Recommendations:
Use material with high yield strength.
Generally hardened and tempered steel with C=0.3% which has Syt=400 N/mm^2 is used.
Cold rolled annealed steel bars which have 0.2% carbon and yield strength 330 N/mm^2 is to be used.
More materials
C= 0.25 and Mn= 0.75 having Syt=330 N/mm^2
The dimensions i.e. b and t of the member should be increased which will reduce the working stress.

Design of Joining Member:

Here we are calculating the bending failure of the joining member. It is the member used to join both the wheels. It is made up of hollow circular section at middle and hollow square section at the end. But no load is action on the hollow circular section, so we are considering the cross section as Hollow Square for the calculations here as the load is acting on the hollow square section of the member.

Fig 3.12 shows the 3D model of the joining lever. It is a model drawn in CATIA. It is the common model used for the side wheel attachments that we have observed. For calculations of the bending stresses, the free body diagram is shown in fig. 3.13. The section of the member used here is hollow square section

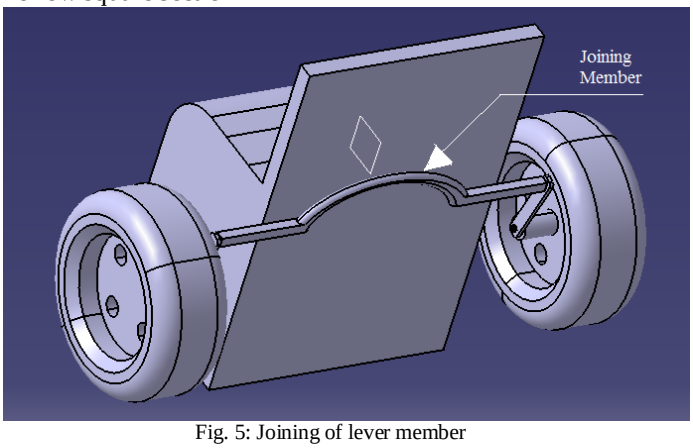

Fig. 5: Joining of lever member

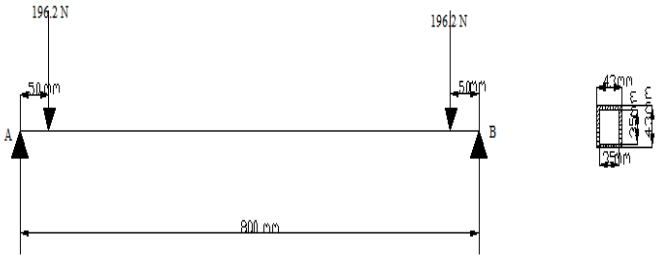

Fig. 6: Free Body Diagram joining of member

Here, assume that sum of all vertical forces are zero.
RA= 196.2× (750/80) + 196.2× (50/800)
= 196.2 N
& RB = 196.2 N
Now,
σ_b working = $Mb \times (Y/I)$
& Mb= 196.2×400-196.2×350
Mb= 9810 N/mm2
σ_b working =(9810×(4/32))
/((43*43*43/12)−(35*35*35/12))
= 69.42 N/mm2
σ_{bmax} =(Syt/F.O.S.)= 70 N/mm2
Here,
$\sigma_{bmax} < \sigma_b$ working , so design is not much safe.

Dynamic Conditions:
Design of main joining member between two wheels
Here,
We have calculated σ_b working = 69.42 N/mm2
Now for designing of dynamic loadings we have to multiply $\sigma_b$by factor Kb
Now,
σ_b working = 69.42× kb = 1.5×69.42= 104.13 N/mm2
σ_{bmax} =(Syt/F.O.S.)
= 70 N/mm2
Now,
σ_b working > σ_{bmax}
Therefore, design is not safe.
Recommendations:

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1) Here mild steel with carbon percentage 0.35 is used, which has Syt = 280N/mm2. In case of this, steel with less carbon % such as, C= 0.25% and Mn= 0.75% steel having Syt = 390 N/mm2 is used which increase maximum bending stress.
2) Dimensions rather increase the breadth and width of the bar with respect to the length of bar (member).
3) The positioning of the load if slightly moved towards the fixed ends if, then the bending will be less.

CONCLUSION

In this project work, the survey of the various models of two wheelers having side wheel attachments is carried out. The survey was carried for the authorized two wheelers having side wheel attachments and non- authorized two wheelers having side wheel attachments. The authorized two wheelers with side wheel attachments are certified by RTO and ARAI, hence they can be called safe but the side wheel attachments fabricated by the non-authorized workshops are not certified. Hence, we studied the various factors such as fastener quality, weld quality, material selection and load analysis. The tests such as EDS, tensile test, hardness test etc. were carried out for checking the properties of material used for non-authorized side wheel attachments. The calculations for checking the safety of the various members used in the design of the non-authorized fabricators were done.
From the data obtained from the above work, we could provide the following recommendations to both the transport authority and the non-authorized fabricators.
1. Recommendations to the transport authority

2. Recommendations to the non-authorized fabricators

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4. www.iron-foundry.com/BORUI CASTING INTERNATIONAL LTD

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