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Design Improvement of the Handle bar Assembly of an Automobile Using FEA

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Abstracts

Designing the handle bar assembly of a two wheeler holds many challenges together with valuation of the structural strength of the mating components. While the handle bar is subjected to buckling, the housing and the other frame experiences tensile, compressive and shear stress. The situations during braking and the forces generated due to road bumps and pot holes can increases the problem. This work shall focus on conducting linear stress analysis while evaluating and rationalizing the loads. Finite element analysis of handle bar assembly is carried out using Altair solver code RADIOSS. In this study the handle bar assembly is excited with acceleration obtained from road load data to evaluate the strength of mountings on handle-bar. Model is prepared using Catia V5R20, Pre processer Hyper Mesh and Post processing is done using Hyper View. The Finite element analysis outcomes are also well allied by the experimental results in which failure site and pattern is accurately matched. Further modifications have been made in design to come across the strength requirement.

Keywords: Handle bar, Housing, Frame. Etc.

Introduction

Today's, analytical tools in the form of computer simulation have been developed to such a level that one can reliably calculate performance. The handle bar assembly is more susceptible to the failures as it experiences numerous forces such as forces due to bumps, braking, engine vibrations, rider force, road excitations etc. To simulate vehicle operating condition, Finite element analysis facilitates to analyses the strength of structural mountings within assembly for the excitation frequency range on the vehicle. For this planned work, the Die Cast housing of the handle bar along with the mating parts would be the centre of the study. A study is being originated by the sponsoring company for identifying the source of this failure and its location.

Problem statement: Different bike components containing handle bar have been recollected, because they fail in the course of use. These recalls are expensive for manufactures and unsafe to rider, to avoid structural failure of the component which could be reason to serious injury. This study was started to support in improvement of design and product qualification of handle bar assembly.

Objective of project: Strength analysis and Design modification aimed at strength requirement of handle bar assembly. 2) To device method that find out the point on handle bar cross section that experience the maximum stress. When handle bar exposed to load applied by rider hands, that varies accidentally in both magnitude and direction. 3) To find out loading state to be used to design and test handle bar.

Scope of work:

- Study the problem to find out the causes of failure
- Prepare a 3D model for the variant of the Handle Bar by using any drafting software
- Categorise the different components with material and specifications
- Prepare the model aimed at analysis using pre-processor/ meshing
- Conduct the iterations over the 3D (virtual) model
- View the outcomes over post-processor
- Carry out Experimental Test over a physical setup
- Match the Analytical and the Experimental results

- Offer the Design substitute for the Handle bar assembly. (In terms of change in Material or Geometry or Boundary conditions)

Literature survey

Harale Shivraj N., [1]Gyanendra Roy, “Vibration Analysis of 2 Wheeler Handle-Bar Assembly”, Mahindra 2 Wheelers Ltd. carryout strength analysis for the mountings of handlebar assemblies and concluded that the FEA and experimental tests is a noble way of new product development, FEM method can be used to decrease design cycle time, quantity of prototypes and more essentially, testing period and its associated expenses. **Above mentioned paper based on project carried out at Mahindra 2 Wheelers Ltd. This gives guide line to proposed project work.**

Cal Stone., [2] and Maury L. Hul, “Rider & bicycle Interaction Loads During Standing Treadmill Cycling” journal of applied biomechanics, in their paper they made available measurements of rider prompted loads during stand-up cycling. Double strain gauge dynamometers were employed to measure these loads on a large motorized treadmill, the cycling condition simulated hill climbing while stand-up cycling. Comparing the results to those previously published for seated cycling revealed that the loading for standing cycling differed fundamentally from that for seated cycling in certain key respects. One respect was that the maximum magnitude normal pedal force reached substantially higher values, exceeding the weight of the subject, and the phase occurred later in the crank cycle. Another respect was that the direction of the handlebar forces alternated indicating that the arms dragged up and back during the power stroke of the corresponding leg and pushed down and forward during the upstroke. **This paper will help to understand loading conditions during cycling.**

David Lopez, [4] Jovan Mayfield & Pierre Marc Paras “Stress Analysis of a Bicycle” Polytechnic institute of New York University, found that separating the bicycle into smaller segments of beams with stresses and moments to be the most effective way in constructing and designing the bicycle. All of the calculations were aimed to observe all the stresses that could potentially affect the bicycle design when a load Applied by rider of 250 lbs and acceleration of 15 m/s2. Although the bicycle could clearly be separated into smaller members much more, the five designs in this project cover enough information of the needed parts when looking at and construction of bicycle. Also, in this project friction was not factored considered upon designing this project, we found the importance of yield, maximum, principle, and shear stresses. These maximum stress values are necessary especially when provided with a factor safety in confirming a small possibility of failure. It is necessary to recognise that all parts are closely related with each other. **By the study of above report I found that, the type of material selected creates an enormous influence on the design activity.**

Finite element analysis

Drawings of handle bar (Existing)

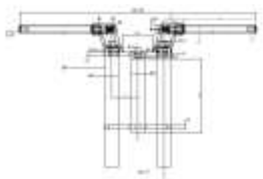


Figure: 1.1. Front view of handle bar assembly

Material & properties:

Table 1.1 Material & properties of existing handle bar assembly (C35)

Sr. No.	Compo -nent	Material	Modules N/mm^2	Poisson’s ratio	Density Ton/mm^3
1	Handle Bar	Steel (C35)	$2.1*10^5$	0.3	$2.7*10^{-9}$
2	Housing	Steel (C35)	$2.1*10^5$	0.3	$2.7*10^{-9}$
3	Frame	Steel (C35)	$2.1*10^5$	0.3	$2.7*10^{-9}$

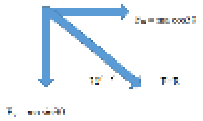
Preparation for analysis:

Loading condition: Following figure shows the load applied by rider’s hand over handle bar of a bike.

Figure: 1.2.Load acting over handle bar

While braking, the rider in motion is try’s to change the speed of the combined mass *m* of rider plus bike. This creates a negative acceleration “a” in the line of travel, the acceleration “a” causes an inertial forward force *F* on mass m (F=ma). Considering Motorist of wt.

120 kg traveling at speed of 90 km/h, suddenly apply the break and come to rest in 5 sec.



$R^2 = F^2 = Fx^2 + Fy^2$ Where, m = Mass of rider (kg), a = Acceleration (m/s^2), F = 400 N Inclined, 750 N Vertical.

FEA model development: The handlebar assembly components such as handle-bar, Housing and Frame are made of stainless steel of grades C35. FE model has been developed by with pre- processing software Hyper Mesh. Handle bar modelled with shell elements CQUAD, Housing modelled with CTRIA by extracting mid surfaces. The connections between housing, handle bar, frame modelled with RBE2 elements. The weld between each component is modelled with shell elements of average of thickness.

Analysis using solver RADIOSS: In this analysis stress pattern and displacement of different parts of handle bar assembly has been observed, with variation in geometry, material & loading conditions.

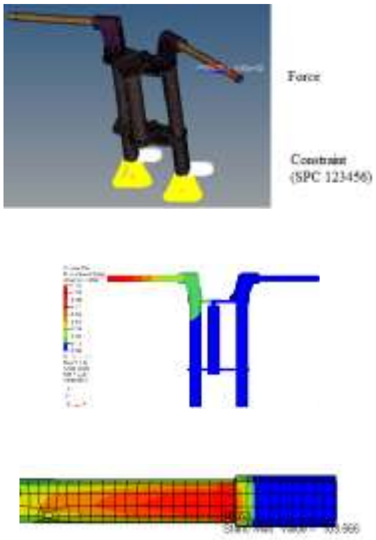


Figure: 1.3. Stress & displacement pattern in handle bar assembly

Results & discussions

Results obtained by FEA analysis tabulated below

Table 1.2.Results of FEA analysis thickness 2.5 mm, 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm2)	Displacement (mm)
01	Handle bar (C35)	131.08	1.04
02	Housing (C35)	21.52	0.26
03	Frame (C35)	34.11	0.18

Table 1.3.Results of FEA analysis thickness 2.5 mm, 750 N vertical load

Sr.no	Component	Max. stress (N/mm2)	Displacement (mm)
01	Handle bar (C35)	258.51	2.01
02	Housing (C35)	82.03	0.22
03	Frame (C35)	43.84	0.12

Table 1.4.Results of FEA analysis thickness 2 mm (Existing), 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	171.4	1.2
02	Housing (C35)	21.52	0.26
03	Frame (C35)	34.91	0.11

Table 1.5 .Results of FEA analysis thickness 2 mm (Existing), 750 N vertical load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	318.51	2.56
02	Housing (C35)	22.03	0.22
03	Frame (C35)	43.84	0.12

Table 1.6.Results of FEA analysis thickness 3 mm, 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	87.35	0.93
02	Housing (C35)	21.52	0.26
03	Frame (C35)	34.91	0.18

Table 1.7.Results of FEA analysis thickness 3 mm, 750 N vertical load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	218.73	1.8
02	Housing (C35)	82.3	0.22
03	Frame (C35)	43.84	0.12

Table 1.8.Results of FEA analysis thickness 2.5 mm, 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	103.56	1.16
02	Housing (AlSi132)	16.35	0.25
03	Frame (C35)	35.04	0.18

Table 1.9.Results of FEA analysis thickness 2.5 mm, 750 N, vertical load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	258.82	2.25
02	Housing (AlSi132)	52.64	0.26
03	Frame (C35)	43.55	0.12

Table 1.10.Results of FEA analysis thickness 2 mm (Existing), 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	318.91	2.74
02	Housing (AlSi132)	52.84	0.28
03	Frame (C35)	43.54	0.12

Table 1.11.Results of FEA analysis thickness 2 mm (Existing), 750 N, vertical load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	127.96	1.32
02	Housing (AlSi132)	16.35	0.28
03	Frame (C35)	35.03	0.18

Table 1.12.Results of FEA analysis thickness 3 mm, 400 N, 30^0 inclined load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	87.35	1.05
02	Housing (AlSi132)	16.35	0.28
03	Frame (C35)	35.03	0.18

Table 1.13.Results of FEA analysis thickness 3 mm, 750 N, vertical load

Sr.no	Component	Max. stress (N/mm^2)	Displacement (mm)
01	Handle bar (C35)	208.73	1.98
02	Housing (AlSi132)	52.64	0.26
03	Frame (C35)	43.54	0.12

The stresses in each component of handle bar assembly considering housing material AlSi132 found to be lesser than the acceptable stresses (keeping factor of safety more than two) due to well-designed geometry. By means of Finite element analysis and comparisons with existing handle bar assembly, prototype (virtual) considering housing material AlSi132 with 2.5 mm handle bar thickness were shown to be better in all rigidity aspects.

Table 1.14. Comparison between C35 & AlSi132

Sr.no.	Properties	C 35	Al Si 132
01	Chemical composition	Si-12.5%, Fe-1%,cu-2.2% Mn0.5%, Mg, Cr, Ni, Zn, Pb Ti	C-0.39%,Si0.4%,Mn-0.8%,Cr-0.4%, Mo-0.1%, Ni-0.4%
02	Modulus	2.1e5 N/mm^2	7.6e4N/mm^2
03	Density	7.9e-9 Ton/mm^3	2.7e-9 Ton/mm^3
04	Cost	0.6 $/kg	1.2 $/kg
05	Application	Carbon steel for mechanical engineering and automotive components	Aluminium-silicon casting alloys are used extensively in many industrial applications.

Mass reduction in handle bar assembly:
For 2.5 mm thickness

- Mass of assembly for steel(C 35) material = 12.05 kg
- Mass of assembly in Aluminum material (Al Si 132) = 10.76 kg
- % Reduction in mass = 10.71 %

Mathematical formulation

Considering handle bar as cantilever beam

Case 1:- Force of 400 N making an angle of 30^0 acting at free end of handle bar.

Bending stress calculation:

i) Bending stress induced in handle bar given by following equation

$$\frac{M}{I}=\frac{\sigma}{y}=\frac{G\theta}{l}$$

Where, M = bending moment (N-M), I = Moment of inertia (m^4), σ = Bending stress (N/mm^2), G = Modulus of rigidity (N/mm^2), θ =Angular twist (rad/sec), l = Length of beam (M)

D_0= 22.5 mm, D_i= 17.5 mm, t= 2.5 mm, L=235.7 (from given geometry), Material C35, E= $2.1*10^5$ N/mm^2, μ= 0.3, ρ= $7.9*10^{-9}$ ton/mm3. Bending stress in above condition is given by.

$$\sigma=\frac{My}{I}\ N/mm^2 \qquad \text{here } y= D_0/2$$

$I=\frac{\pi}{64}(D_0^4- D_i^4)=\frac{\pi}{64}(22.5^4-17.5^4)$, I= 7676.700 mm^4

M= F*L= 400*235.7, M= 94280 N-mm, y= $D_0/2$ = 11.25 mm

We get

$$\sigma=\frac{94280*11.25}{7676.700}=\underline{128.16483}\ N/mm^2$$

Deflection of beam:

Deflection of beam given by formula

$$\delta=\frac{WL^3}{3EI}=\frac{400*235.7^3}{3*2.1*10^5*7676.700}=\underline{1.082}\ mm$$

Results obtained by Mathematical Formulation for different load, material & dimension variation tabulated below.

Sr. no.	Compo-nent	Max. Stress (N/mm2)	Displacement (mm)	Specification
01	Handle bar	128.164	1.08	D_o= 22.5 mm, D_i = 17.5 mm Material C35,400 N inclined load
02		249.315	1.95	D_o= 22.5 mm, D_i = 17.5 mm Material C35,750 N vertical load
03		155.276	1.21	D_o= 22.5 mm, D_i = 18.5 mm Material C35,400 N inclined load
04		291.143	2.28	D_o= 22.5 mm, D_i = 18.5 mm Material C35,750 N vertical load
05		118.611	0.92	D_o= 22.5 mm, D_i = 16.5 mm Material C35,400 N inclined load
06		222.397	1.74	D_o= 22.5 mm, D_i = 16.5 mm Material C35,750 N vertical load
07		113.56	1.21	D_o= 22.5 mm, D_i = 17.5 mm Material AlSi132,400 N inclined load
08		268.82	2.31	D_o= 22.5 mm, D_i = 17.5 mm Material AlSi132,750 N vertical load
09		139.96	1.29	D_o= 22.5 mm, D_i = 18.5 mm Material AlSi132,400 N inclined load
10		327.91	2.62	D_o= 22.5 mm, D_i = 18.5 mm Material AlSi132,750 N vertical load
11		98.35	1.14	D_o= 22.5 mm, D_i = 16.5 mm Material AlSi132,400 N inclined load
12		238.73	1.98	D_o= 22.5 mm, D_i = 16.5 mm Material AlSi132,750 N vertical load

Experimentation

The Handle-bar assembly is tested on UTM table test rig by mounting on fixture at the steering frame with loading condition as discussed above, over the operational loading range. Instrument used strain gauge with data logger. Strain data loggers used for monitoring and recording data from external strain gauges, load cells, pressure transducers, and other low-level voltage sources. Test conducted found align with values observed through Finite element analysis.

Figure: 1.4. Experimental set up over UTM

Conclusion

As, the FEA and experimental tests are good methods for novel product development. FEA methodology can be used to decrease design cycle time, quantity of prototypes and more importantly testing time and its related charges. The Aim of this project was to improve a design and a prototype for a handle bar assembly of two wheeler which come across strength requirement. The ultimate design specifications were based on benchmarking with recent handle bar assembly, and data obtained from sponsoring company. In this paper, RADIOSS has been used to find the performance of the Handle-Bar Assembly for operative loading condition. Along with this Taguchi method approach is used to determine the effect of three parameters: Handle bar thickness (A), Load magnitude (B), Material of housing(C) on the maximum stress induced in Handle bar assembly. Factor "B" makes largest contribution to total sum of squares (74 %). The factor "A" makes next largest contribution (25 %). Whereas factor C make only 1 % contribution. The larger the contribution of a particular factor to the total sum of squares, larger the ability of the factor to influence η. referring above conclusion it is clear that Max. Stress induced in handle bar largely depend on magnitude of load & almost remain same with varying material conditions. The handle bar assembly with AlSi132 housing material seen to meeting more concerned safety, Reliability and low weight as compared with housing material C35. The results are analogous closely with the experimental test, theoretical analysis and necessary design modifications have been made from analysis and iterations.

The effort engaged for this project is in the introductory phases of current work and it is necessary to say here that these positive results will intensely needs more in depth analysis for forthcoming projects.

Scope for the future work

The instant work that essential to be completed in the upcoming stage should include Modal frequency response analysis. Modal frequency response analysis permits to examine the strength of structural parts in the excitation frequency range on the vehicle. Handle-Bar Assembly modes are important for vehicle functionality. A standard modes analysis should be implemented to see that the frequencies of system does not match with the frequencies of functional frequency. The modal analysis is useful to find out the mode shape of assembly through which further enhancement in structures can be made. The natural frequency and mode shapes need to be determined and compared with engine excitation frequency to avoid occurrence of resonance.

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