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Design and Analysis of Wishbones in Double Wishbone Suspension System: Technical Note

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ABSTRACT:

This paper details the design and analysis of the wishbones in double wishbone suspension system. Initially Pugh's matrix approach is used to score the conventional materials and light weight metal matrix composites for the wishbone design. Based on the scores, an Alumina matrix composite has been found as the preferred material. Then, the designed wishbones were analysed using ANSYS finite element analysis software using AISI 1040 and metal matrix composite materials. Based on the FEA results, it has been concluded that the metal matrix composite yielded a better durability and strength than conventional metal.

KEYWORDS:

Wishbone suspension systems; Finite element analysis; Pugh's matrix; Metal matrix composites

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1. Introduction

Suspension is the system of tires, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two [1]. Suspension system serves as a dual purpose utility contributing to the vehicle's road holding/handling and braking for good active safety and ride quality that is reasonably well isolated from road noise, bumps and vibrations [2-3]. The main objective of this paper is to design and analyse the entire double wishbone suspension system for an all-terrain vehicle for improving the stability and handling of the vehicle. Double wishbone suspension system designs allow the engineer to carefully control the motion of the wheel throughout suspension travel. This multi-link suspension system has interconnected behaviour and its optimization is so complex [4-6]. Hence, finite element analysis approaches are popular in design and analysis of suspensions, e.g. 3-D model of the lower wishbone arm is assessed for modal and strength.

Proper material selection plays an important and crucial role in an effective manufacturing system for superior production quality, cost optimization and improved productivity. While choosing the proper material for a specific industrial application, there is not always a single definite selection criterion [7]. Systematic selection of materials for a given engineering application begins with the study of different material selection properties and their related costs with specific application capabilities [8-9]. Wrong selection of materials often leads to huge cost contribution. So, the designers need to identify and select proper materials with specific functionalities in order to get the desired output with minimum cost involvement. But, the selection of proper materials for engineering applications is not an easy task to perform. In this paper, a bespoke double wishbone suspension system is designed and then the lower arm is analysed using conventional metal and an alternative metal matrix composite material. The choice of material is decided by using Pugh's matrix and both the designs are statically analysed to predict the deformations and local stresses at the critical interfaces.

2. Materials

Generally, for manufacturing wishbones in double wishbone suspension system, American standard materials - AISI 1040, AISI 1018, AISI 1020, AISI 4130 are currently used. These materials have very high specific density in the range of 7.8 to 7.9 g/cc and their mechanical properties are not sufficient to withstand strident environmental conditions or performance requirements. The main draw back that is encountered while manufacturing the double wishbone suspension system is its cost of manufacturing. The mechanical properties and cost for all the existing and proposed alternative materials for a double wishbone suspension system design are given in Tables 1 and 2 respectively. Ceramic matrix composites are proposed for manufacturing wishbones in double wishbone suspension system. Proposed ceramic matrix composites are - Silicon carbide (SiC), Alumina (Al_2O_3), Zirconia (ZrO_2) and Silicon nitride (Si_3N_4) based on their availability in the market irrespective of their cost. These materials share common mechanical properties like, high heat resistance, corrosion resistance, extremely high hardness, excellent thermal conductivity, low thermal expansion and low specific density.

Table 1: Existing materials properties

Material	AISI 1018	AISI 1040	AISI 4130	AISI 1020
Cost / meter in USD	4.96	6.49	11.1	33.6
Yield strength (MPa)	317	415	460	294.4
Tensile strength (MPa)	440	620	560	294.74
Carbon content (%)	0.18	0.4	0.3	0.23
Hardness (BHN)	126	201	217	211
Density (g/cc)	7.9	7.85	7.8	7.9

Table 2: Proposed material properties

Material properties	SiC	Al_2O_3	ZrO_2	Si_3N_4
Cost/meter (USD)	36	1.90	14.95	28.13
Tensile strength (MPa)	3800	3650	1689	3293
Bending strength (MPa)	445	480	555.5	1000
Hardness (HV 0.5)	2500	1666	1389	1666.6

3. Theoretical material selection

There are so many methods available to select the best material out of the several packs of materials by using their mechanical properties, cost or some other criteria based on the required applications [9]. Pugh's matrix is used to select the best material for the wishbones of the suspension system. Pugh matrix is executed by building an analysis team, and framing up a matrix of analysed criteria versus possible manifestation. The options are compared with respect to the criteria and each option is awarded with scores using a symbolic approach (one symbol for better than, another for neutral, and another for worse than baseline). These get converted into scores and added in the matrix to obtain scores for each option. Table 1 shows the Pugh's matrix for the conventional material selection out of American standard materials - AISI 1040, AISI 1020, AISI 1018 and AISI 4130. We need a material which is having less density, high yield strength, and high tensile strength and less expensive. Adding the scores in each column and placing them in net score concluded that both AISI 1040 and AISI 4130 are the best choices based on the same score of +1. In this case, AISI 1040 is selected as the best material amongst all others. Table 2 shows the Pugh's matrix based on comparison of the properties of AISI 1040 with the properties of composite materials. Alumina (Al_2O_3) has the highest score so it is the most suitable material for manufacturing wishbones in double wishbone suspension system.

Table 3: Pugh's matrix for conventional materials

Properties	AISI 1018	AISI 1040	AISI 4130	AISI 1020
Density	-1	0	+1	-1
Tensile strength	-1	0	+1	-2
Yield strength	-1	+1	0	-2
Cost/meter	+1	0	-1	-2
Net score	-2	+1	+1	-7

Table 4: Pugh's matrix for metal matrix composites

Properties	SiC	Al_2O_3	ZrO_2	Si_3N_4
Tensile strength	+2	+2	+1	+2
Yield strength	+1	+1	+1	+2
Hardness (HV 0.5)	+2	+1	+1	+1
Cost/meter	-1	+1	-1	-2
Net score	+4	+5	+2	+3

4. Finite element simulation

Fig. 1 shows an isometric view of the wishbone suspension assembly incorporating lower and upper wishbone design using SOLIDWORKS CAD modelling software. This CAD model is then imported into ANSYS finite element analysis software and then meshed using 3D tetra type elements. The two nodes of the wishbone are applied with fixed boundary conditions. A pressure of 415 MPa is applied at the interface location. The input parameters for the finite element model are listed in Table 5. A linear static analysis is carried out then the maximum principal stress, maximum principal stain and total deformation in wishbones are assessed (see Figs. 2 to 7). Table 6 gives a comparison of the finite element analysis results for the two selected materials. The total deformation, stress and strain values of alumina (Al_2O_3) are very much less than the American standard material AISI 1040.

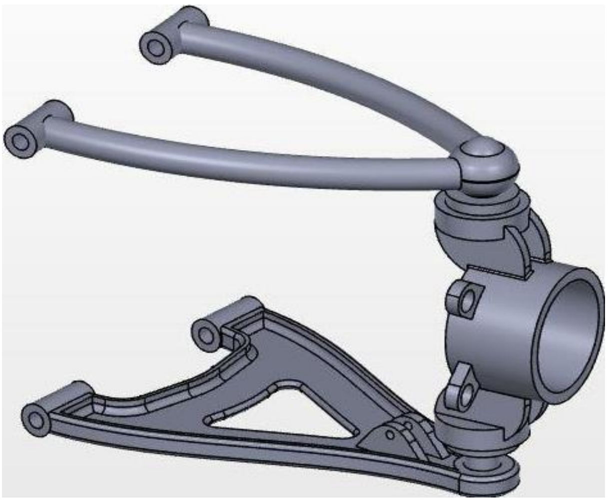

Fig. 1: Double wishbone suspension system assembly

Table 5: Input parameters

Parameters	AISI 1040	Al_2O_3
Young's modulus	200 GPa	393 GPa
Poisson's ratio	0.28	0.22
Tensile strength	620 MPa	665 MPa
Density	7.845 g/cc	3.86 g/cc

Table 6: Analysis results

Results/Materials	AISI 1040	Al_2O_3
Total deformation (mm)	2.3341	1.2102
Maximum principal elastic strain (MPa)	0.0226	0.011611
Maximum principal elastic stress (MPa)	4538	4457.9

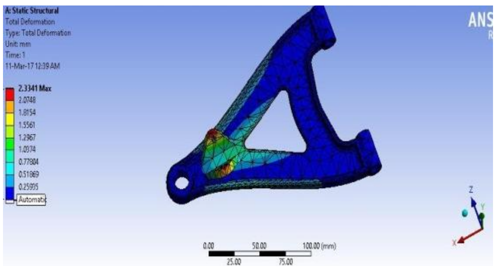

Fig. 2: AISI 1040 - Total deformation

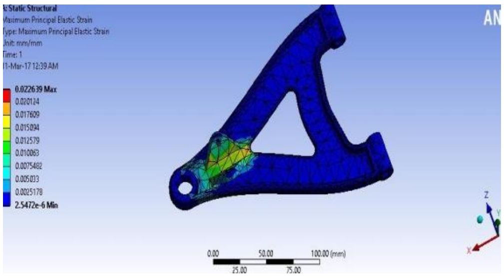

Fig. 3: AISI 1040 - Maximum principal strain

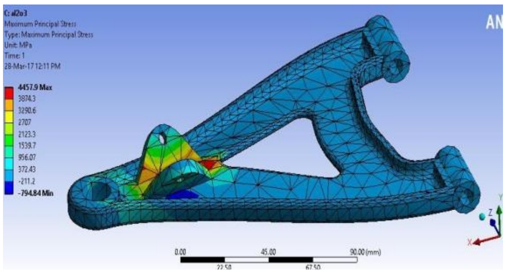

Fig. 4: AISI 1040 - Maximum principal stress

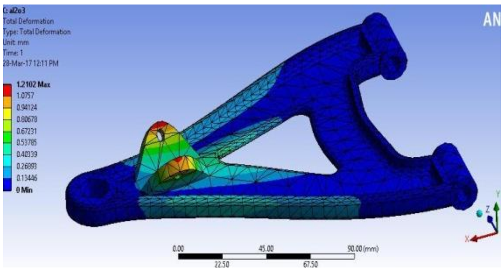

Fig. 5: Al_2O_3 - Total deformation

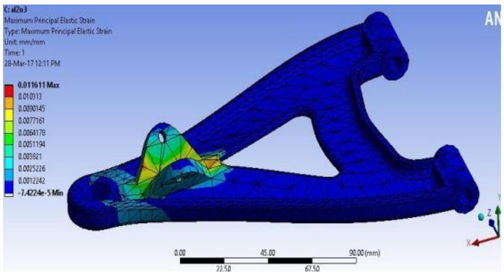

Fig. 6: Al_2O_3 – Maximum principal strain

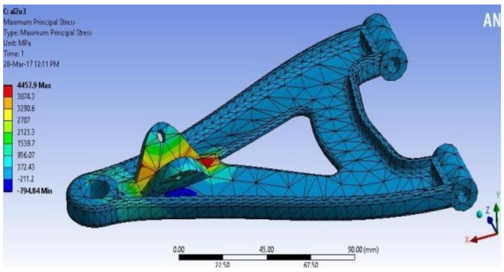

Fig. 7: Al_2O_3 - Maximum principal stress

5. Conclusion

In this technical note, Pugh's matrix was used to select the best materials amongst the conventional AISI alloys and metal matrix composite materials for wishbones of the double wishbone suspension system. Then, a linear static analysis was carried out using ANSYS. From the analysis results it can be concluded that that alumina (Al_2O_3) has better performance values than AISI 1040. Further, the cost of 1kg of alumina (Al_2O_3) is 1.90 USD which is almost 5 times lesser cost than AISI 1040 material. So, concluding that alumina (Al_2O_3) is the best material to manufacture wishbones in double wishbone suspension system to decrease the manufacturing cost and better performance characteristics than standard AISI 1040.

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