Optimization of Truck Tyre Performance Using FEA Approach

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Abstract- The work done in the paper involves the analysis of automotive (truck) tyres using FEA software (ANSYS). Tyres with the three different types of tread patterns, that is, symmetrical, asymmetrical and directional tread patterns are modelled in CAD software CATIA and are then subjected to static structural and transient structural analysis in ANSYS software. Parameters like the total deformation, Von-Mises stress and strain, strain energy are determined under standard loading conditions in static and dynamic settings. Along with the tread pattern the tyre material (major material of the tyre composition) is also varied. The work done in the paper looks to find alternate materials for manufacturing tyres which can help improve the reliability, life span and performance of tyres which in turn help reduce the problem of waste tyre disposal which has had a severe environmental impact around the world.

Keywords – Tyres, Tyre Tread, Tread Patterns, FEA Analysis, Alternate Materials,Perfromance Enhancement, Waste Reduction

I. INTRODUCTION

Tyres are a vital component of any vehicle. Different types of tyre tread patterns available are symmetric, asymmetric and directional. Symmetric tyre tread pattern are generally the most economic type in terms of cost, they are good for dry weather conditions but struggle to perform as well in winter or wet weather conditions. Directional tyre tread patterns are used to counter hydroplaning in wet weather conditions, they perform well in dry weather conditions as well. Asymmetric tyres are high performance tyres which are excellent in all weather conditions.

For the manufacture of tyres natural rubber made from the latex of the Hevea brasiliensis tree is used along with other chemicals and reagents. Finding a viable better performing alternate material to natural rubber would lead to increased life span, reliability and performance of tyres which will be extremely beneficial for the automotive industry as well as the consumers. The increased life span of tyres if such an alternate is found will also aid in a critical environmental issue which is the disposal of waste tyres. As less waste will be generated. Tyres being non-biodegradable lead to soil pollution.

Thus, this project aims to assess various alternate materials combining them with various tread patterns and compare the results of the analysis of various materials with that of natural rubber to suggest some alternates based on the FEA analysis. The analysis results are validated by the experimental test carried out on the various materials.

The methods of subjecting vehicle tyres to impulse loads and testing them was discussed by Baranowski [4].The correlation between tyre life increase and the positive impact on the environment in terms of reduction in waste tyre generation was studied byEdmo da Cunha Rodovalho [2].The measurement of the deformation in truck tyres subjected to working loads, in-depth methodology to analyze the deformation to predict tyre failure was studied by Yi Xiong [7].Static analysis of a tyre made of natural rubber was performed by Chukwutoo Christopher Ihueze [1].Dynamic analysis of passenger vehicle tyres, aimed at studying the tyre degradation over a period of time was done by Baranowski [3] and also by Wang Qingchao [6] and Shingo Ozaki [5].

II. METHODOLOGY

The methodology used is as follows: Literature Survey,design of the tyre models using CATIA Student V5-6R2017,generic symmetric ,asymmetric and directional tread pattern tyres are modelled.The tyre properties and dimensions for light trucks which are commonly used in India are considered,Diameter Overall= 553mm, Load Index =88 (Load of 560 kg per tyre), Section Width= 185mm, Speed Symbol= K (110 KPH).ANSYS 18.2 Student Version is used for FEA.Different materials with suitable properties for being used to make tyres are evaluated,static structural analysis is carried out on the tyre model made of different materials and varying tread pattern combinations.This is followed by the transient structural analysis of the tyre models using different material and tread combinations.The results are tabulated for the various material and tread pattern combinations and they are compared with each other.An experimental test is used to validate the analysis result. A suitable alternate to rubber is selected and its economic and environmental viability are studied. Its manufacturability and sustainability are studied as well.Based on these studies a suggestion for an alternate to rubber is made. The experimental test involves a load of 100N being applied on the sample using a mechanized computer controlled plunger. The samples are10cm X 10cm of all the 5 materials.The sample is placed in the holder of the deformation testing machine and the load is applied.The deformation caused in the sample due to the application of the load through the plunger is recorded.The results are tabulated and studied.

III. EXPERIMENT AND RESULT

The tyres are modelled in CATIA Student V5-6R2017, static structural and tranisent analysis are carried out in ANSYS 18.2 Student Version and the experimental deformation test involves subjecting 10cm x 10cm samples of the five materials to a load of 100 N and measuring the deformation produced.

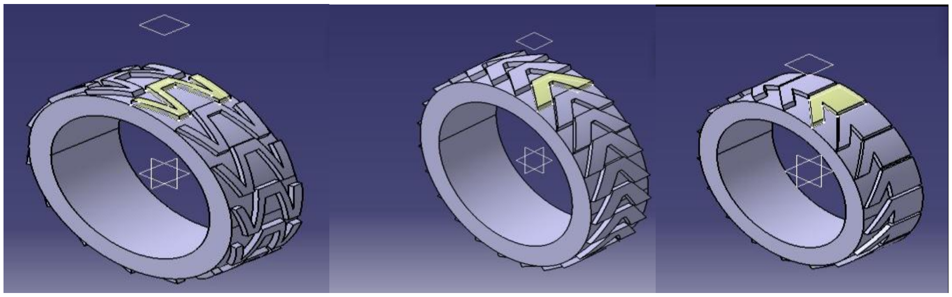

Fig.1:From left to right : Symmetric,Directional and Asymmetric Tyre Models in CATIA

Directional Tyre- Polyurethane- Static Structural

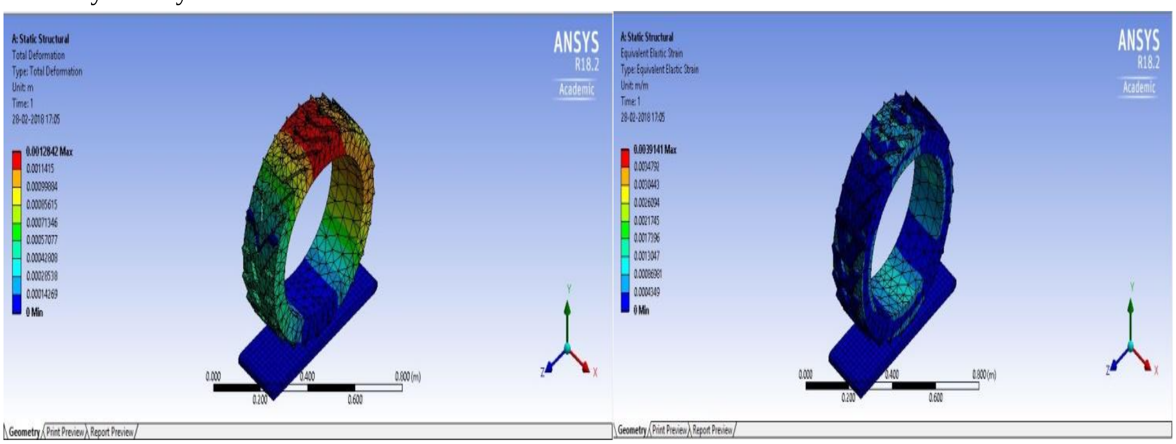

Fig. 2:From Left to Right : Total Deformation, Von-Mises Strain

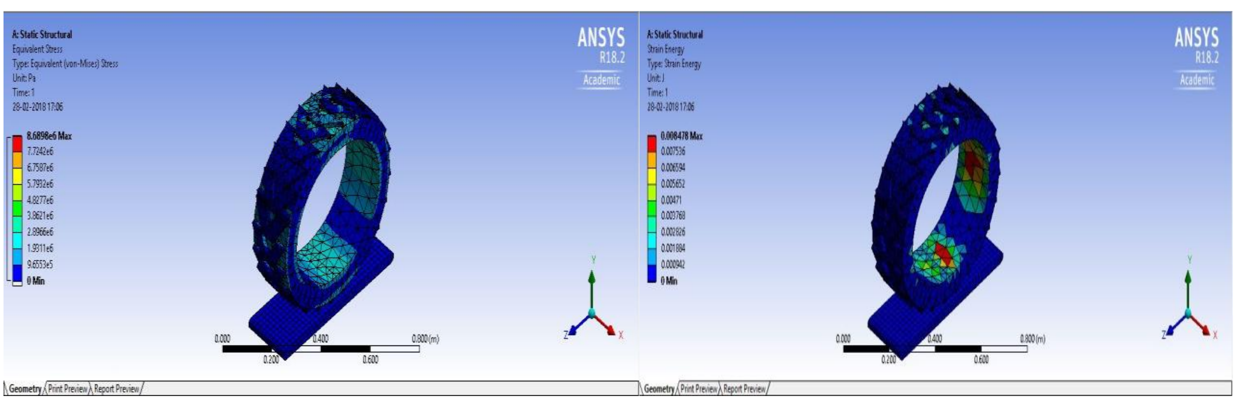

Fig. 3:From Left to Right : Von-Mises Stress, Strain Energy

Asymmetric Tyre- Neoprene- Transient Structural Analysis

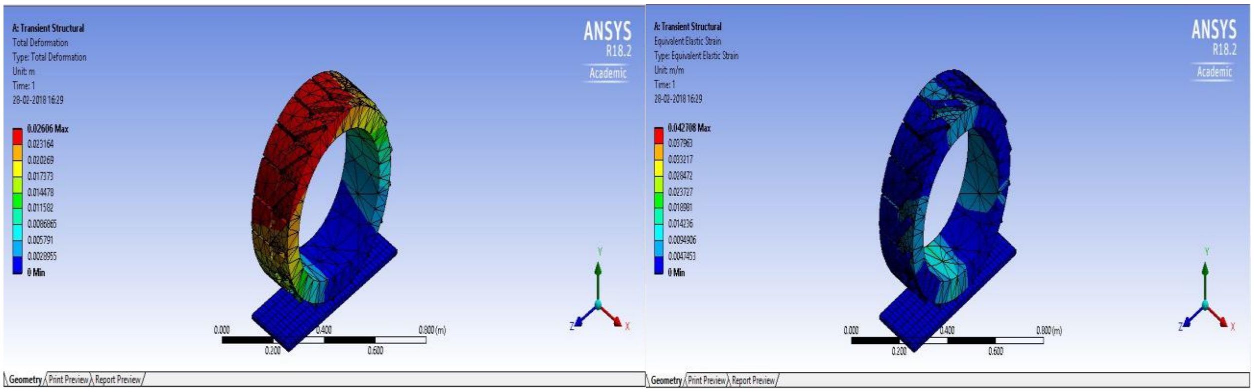

Fig.4:From Left to Right : Total Deformation, Von-Mises Strain

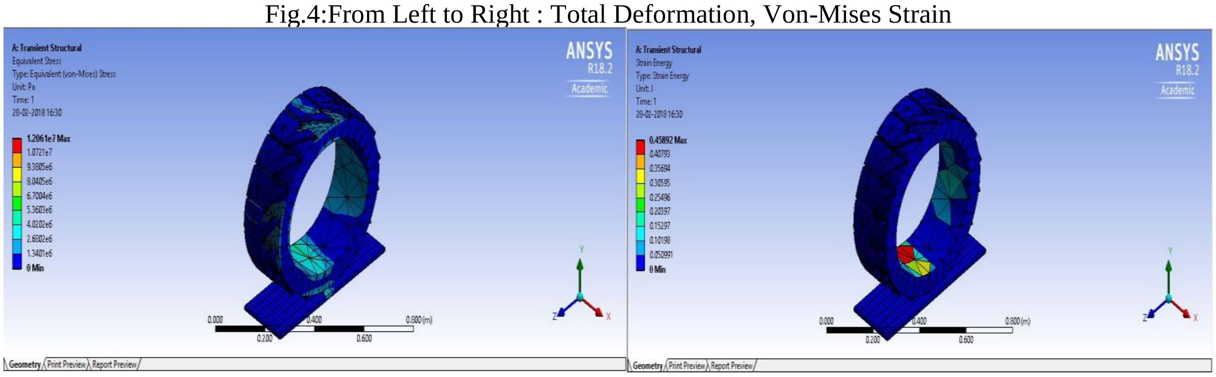

Fig.5:From Left to Right : Von-Mises Stress, Strain Energy

Fig.6:A sample used for the deformation test

Experimental Deformation Test Results

S.No.	Material	Total Deformation (m)
1.	Rubber	0.0255
2.	Neoprene	0.0085
3.	Adiprene	0.0056
4.	Polyurethane	0.0011
5.	Polytetrafluoroethylene	0.0056

Static Structural Analysis Results

S.No.	Tread Pattern	Material	Total Deformation (m)(Max.)	Von-Mises Stress(N/m2) (Max.)	Strain (Max.)	Strain Energy (Nm or J) (Max.)
1.	Symmetric	Rubber	0.085105	1.0287e7	0.1096	0.63232
2.	Symmetric	Neoprene	0.011363	8.1442e6	0.030507	0.08616
3.	Symmetric	Adiprene	0.0070355	7.032e6	0.016127	0.053453
4.	Symmetric	Polyurethane	0.0014147	6.8215e6	0.0031284	0.010734
5.	Symmetric	Polytetrafluoroethylene	0.0070355	7.032e6	0.016127	0.053453
6.	Asymmetric	Rubber	0.036761	6.506e6	0.067088	0.73844
7.	Asymmetric	Neoprene	0.012195	7.0463e6	0.024812	0.17383
8.	Asymmetric	Adiprene	0.0073258	6.7505e6	0.015153	0.11286
9.	Asymmetric	Polyurethane	0.001466	6.7455e6	0.0030306	0.022572
10.	Asymmetric	Polytetrafluoroethylene	0.0073258	6.7505e6	0.015153	0.11286
11.	Directional	Rubber	0.032043	9.705e6	0.11273	0.22519
12.	Directional	Neoprene	0.010678	1.0023e7	0.038743	0.075302
13.	Directional	Adiprene	0.0064196	8.6975e6	0.019588	0.042383
14.	Directional	Polyurethane	0.0012842	8.6896e6	0.0039141	0.008478
15.	Directional	Polytetrafluoroethylene	0.0064196	8.6975e6	0.019588	0.042383

Transient Structural Analysis Results

S.No.	Tread Pattern	Material	Total Deformation (m)(Max.)	Von-Mises Stress(N/m2) (Max.)	Strain (Max.)	Strain Energy (Nm or J) (Max.)
1.	Symmetric	Rubber	0.14032	1.7241e7	0.17727	1.266
2.	Symmetric	Neoprene	0.046083	1.6982e7	0.058199	0.4128
3.	Symmetric	Adiprene	0.02729	1.6757e7	0.034455	0.24291
4.	Symmetric	Polyurethane	0.006238	1.9177e7	0.0078903	0.058984
5.	Symmetric	Polytetrafluoroethylene	0.041216	2.5396e7	0.052293	0.45493
6.	Asymmetric	Rubber	0.080861	1.1485e7	0.11918	1.8548
7.	Asymmetric	Neoprene	0.02606	1.2061e7	0.042708	0.45892
8.	Asymmetric	Adiprene	0.0153	1.1886e7	0.025249	0.26768
9.	Asymmetric	Polyurethane	0.0037867	1.3639e7	0.0057971	0.071383
10.	Asymmetric	Polytetrafluoroethylene	0.028645	1.8372e7	0.039113	0.65593
11.	Directional	Rubber	0.051247	8.2617e6	0.091908	0.53935
12.	Directional	Neoprene	0.016542	8.0954e6	0.030009	0.17262
13.	Directional	Adiprene	0.0096575	7.9552e6	0.017691	0.10002
14.	Directional	Polyurethane	0.0025249	9.3124e6	0.0041723	0.027551
15.	Directional	Polytetrafluoroethylene	0.021098	1.3106e7	0.029916	0.27403

IV.CONCLUSION

For static structural analysis from the above results it is noted that in the case of all the three types of tyre treads polyurethane is the material which undergoes the least deformation when subjected to the maximum rated load (5600N) followed by adiprene,polytetrafluoroethylene, neoprene and then rubber. In terms of stress polyurethane has the least maximum stress except for the asymmetric tyre where it has almost the same value as rubber. The strain produced in polyurethane tyres is also the least followed by adiprene,polytetrafluoroethylene,neoprene and then rubber. The strain energy produced for all the three tread patterns again is the least when polyurethane is the material used.Thus, from the static analysis conducted polyurethane is a favourable alternate in terms of its properties. In the transient structural analysis results it is noted that polyurethane tyres regardless of the type of tread undergo the least deformation under load. Adiprene is the second best material in terms of the deformation undergone under load. Adiprene tyres develop the least amount of Von-Mises stress under load. The strain developed and the strain energy produced are the least in polyurethane tyres. Rubber has the maximum deformation, strain developed as well as strain energy produced amongst the five materials used in the analysis. Thus, from the transient analysis conducted polyurethane is a favourable alternate in terms of its properties. The experimental deformation test which involved subjected 10cm X 10cm samples of the five materials to a load of a 100N using an industrial testing setup produced results showing that polyurethane undergoes the least deformation under load followed by adiprene and tetrafluoroethylene (similar deformation values), neoprene and rubber. The results of the experiment validate the analysis results. The cost of all the four materials are higher than that of rubber. This remains a major drawback in terms of the use of these materials as potential substitutes or alternates for natural rubber in the near future in the tyre manufacturing industry. Rubber costs anywhere between Rs.125-160/kg whereas these other materials costs range between Rs.300-700/kg. Polyurethane whose properties were found to be favourable through the analysis costs between Rs. 300-400/kg. Polyurethane has been scientifically found to be biodegradable under the action of certain species of fungus in landfills under aerobic and anaerobic conditions. Based on the results of the structural and transient analysis performed and the experimental deformation test Polyurethane can be considered as a potential alternate to natural rubber in the tyre making process.

V. REFERENCES

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