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Simulation based Sensitivity Study of Tread Pattern and Materials on Cooling Efficiency of M1 Vehicle Tyres

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ABSTRACT:

Tread wear of tyres is one of the serious issues in automobiles. Higher amount of heat is generated due to lesser availability of air in the tread region when the vehicle is travelling at high speeds. The existing M1 vehicle tyre has some specific standards of tread angle. In this paper, flow simulation and drop tests of M1 vehicle tyre are carried out using Solidworks. The objective of the work is to improve the cooling efficiency of tyre for vehicle speeds as 40 kmph, 80 kmph and 120 kmph. Various tread patterns for tyres made with hard rubber, Nylon66 and Nylon6 materials were simulated to predict the temperature distribution. Based on the temperature distribution and drop test results from the simulation, improved designs of M1 vehicle tyre are presented.

KEYWORDS:

Vehicle tyre; Tread wear; Cooling efficiency; Tread pattern; Flow simulation; Drop test

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1. Introduction

As tyres are used, the tread is worn off, limiting its effectiveness in providing traction. A worn tyre can often be re-treaded. The tread patterns are designed to provide good traction during ride and prevent skids influenced by hydroplaning. The proportion of rubber to air space on the road surface directly affects its traction. Tyre tread pattern design has an effect upon noise, especially at freeway speeds. The depth of tread should be at least 1.6mm. The techniques used for the determination of tyre temperatures shows that many attempts have been taken to simulate the tyre temperature distribution with axi-symmetric geometry through a simple thermo mechanical behaviour.

The proposed simulation method involves new tyre design with different tread pattern and materials. The M1 type of commercial vehicle tyre is selected based upon the standard norms and considerations. The analysis is carried out by using Solidworks flow simulation for the new tyre design involving various tread patterns. Drop test simulation is also carried out for the designed new tyre. In order to find the suitable tyre with maximum cooling efficiency, a comparison is carried out for the designed tyres with the existing commercial tyre.

2. Materials and methods

In M1 type of vehicle, high heat is generated at the tyre when it is travelling at high speeds. Low heat dissipation leads to tyre failure resulting in frequent replacement of tyre, loss of steering control and finally reduces the overall cooling efficiency of the tyre. Hence, the tyre material and tread pattern can be varied to maximize the cooling efficiency of the tyre [5]. The process flow for the simulation driven sensitivity study for M1 vehicle tyre to maximize the cooling efficiency is shown in Fig. 1. The load capacity, aspect ratio, nominal width, speed rating, rim diameter, type of ply is selected based on the standard norms. 3D models for the existing commercial tyre tread pattern of the standard size and dimensions are created using Solidworks.

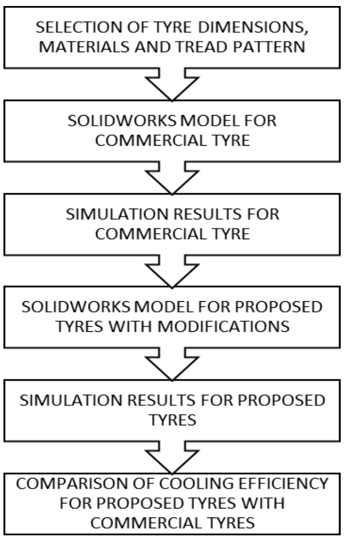

Fig. 1: Process flow

The cooling efficiency of the tyre surface is analysed using "Flow Simulation" computational fluid dynamics (CFD), [2], module in Solidworks 2013

Premium. "Flow simulation" enables quick and efficient simulation of fluid flow and heat transfer. The boundary conditions like inlet velocity and outlet pressure of air are defined. Initial temperature and initial pressure as are set as 28 ºC (room temperature) and 1 atm respectively. The materials used in the CFD analysis are hard rubber, Nylon66 and Nylon6. Natural rubber is commonly used as a material in commercial tyres. Natural rubber normally absorbs large amount of heat. Therefore outer surface of the tyre will be torn out or tyre burst happens. To overcome this, heat generated at the outer surface is reduced by changing the tyre material. Ultimate tensile strength (UTS) and density of these three tyre materials considered in the simulation are given in Table 1.

Table 1: Mechanical properties

Material	UTS (MPa)	Density (g/cc)
Hard rubber	39	1.13 to 1.18
Nylon66	60 to 80	1.13 to 1.15
Nylon6	55.2	1.16

3. Results and discussion

3.1. CFD analysis results

After applying the material, it is necessary to provide the boundary conditions. The flow simulation works only at a closed region, for that there is a need to create a computational domain and a fluid sub domain to activate it. Then the inlet velocity and initial pressure will be given. Simulations were conducted at vehicle speeds of 40 kmph, 80 kmph and 120 kmph. These speeds were considered as inlet velocity at opposite direction of vehicle movement for compensating the stationary tyre. If the tyre is rotating in practical manner, then the inlet velocity as in the same direction [3]. Simulations were conducted using commercial tyre made with natural rubber material. The temperature distribution fringe plots and corresponding temperature over the tyre circumferential length were shown in Figs. 2(a) to (c) for 40 kmph, 80 kmph and 120 kmph vehicle speeds respectively. At low speeds, the temperature over length is uniform, whereas at high speeds this variation is too steep. Maximum temperature in the order of 43 °C is observed for the commercial tyre.

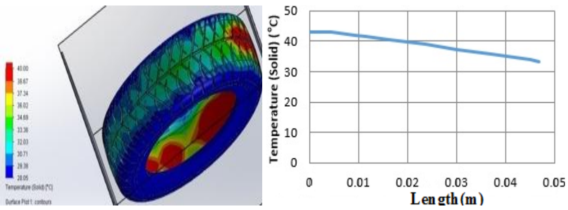

Fig. 2(a): Temperature distribution fringe and Temp. vs. Length at 40 kmph for commercial tyre

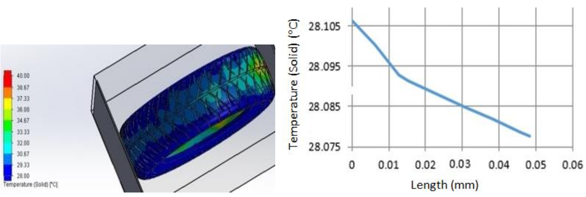

Fig. 2(b): Temperature distribution fringe and Temp. vs. Length at 80 kmph for commercial tyre

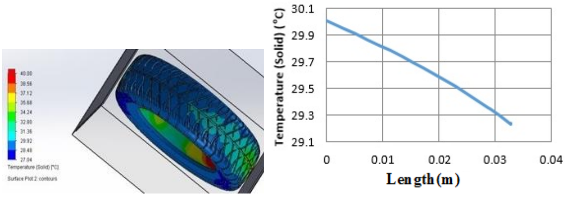

Fig. 2(c): Temperature distribution fringe and Temp. vs. Length at 120 kmph for commercial tyre

The following five designs of tread pattern were considered in the simulation with a view to achieve best cooling efficiency design:

- Design 1 (Unidirectional type)P 205/75 R 15 84 H
- Design 2 (Asymmetric type) P 205/75 R 15 84 H
- Design 3 (Unidirectional type) P 215/85 R 15 90 H
- Design 4 (Asymmetric type) P 205/75 R 15 84 H
- Design 5 (Asymmetric type) P 205/75 R 15 84 H

Simulations were carried out by changing the material to hard rubber and the CFD analysis was carried out for 40 kmph, 80 kmph and 120 kmph. The temperature distribution fringe plot and temperature vs. Length graphs are presented in Fig. 3 to Fig. 7 for tyre Designs 1 to 5 respectively. With the same boundary conditions, simulations were repeated for the designs with Nylon66 and Nylon6 materials.

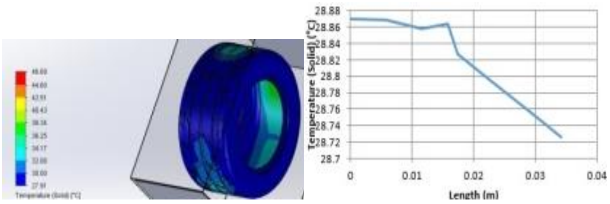

Fig. 3(a): Temperature distribution at 40 kmph for tyre Design 1

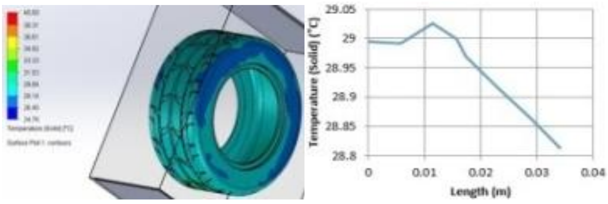

Fig. 3(a): Temperature distribution at 80 kmph for tyre Design 1

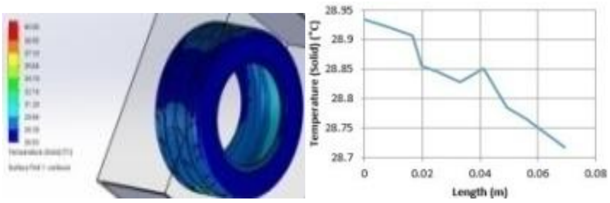

Fig. 3(c): Temperature distribution at 120 kmph for tyre Design 1

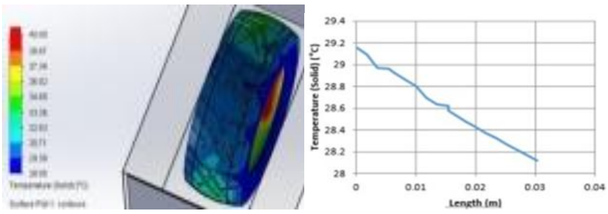

Fig. 4(a): Temperature distribution at 40 kmph for tyre Design 2

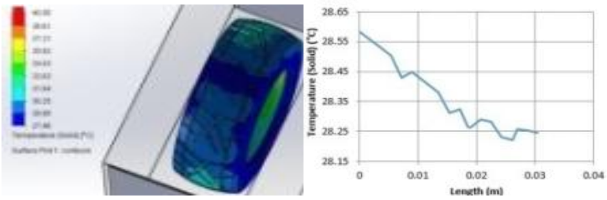

Fig. 4(b): Temperature distribution at 80 kmph for tyre Design 2

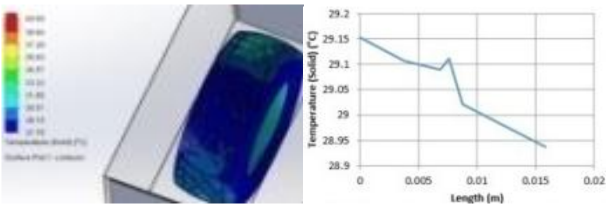

Fig. 4(c): Temperature distribution at 120 kmph for tyre Design 2

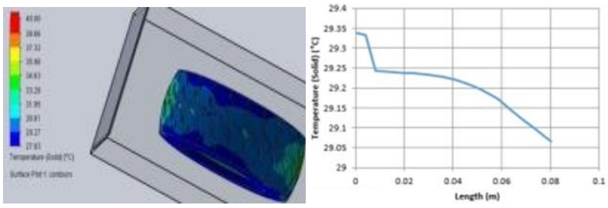

Fig. 5(a): Temperature distribution at 40 kmph for tyre Design 3

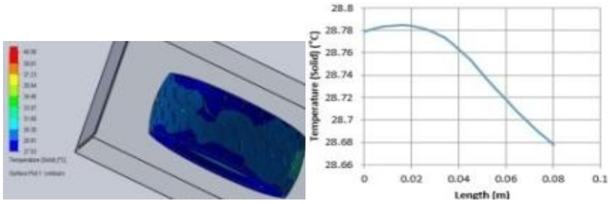

Fig. 5(b): Temperature distribution at 80 kmph for tyre Design 3

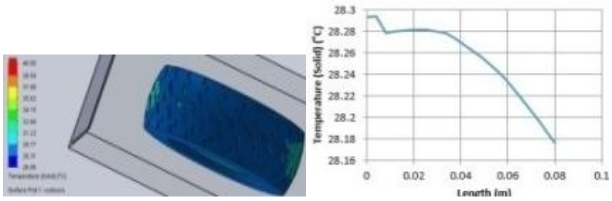

Fig. 5(c): Temperature distribution at 120 kmph for tyre Design 3

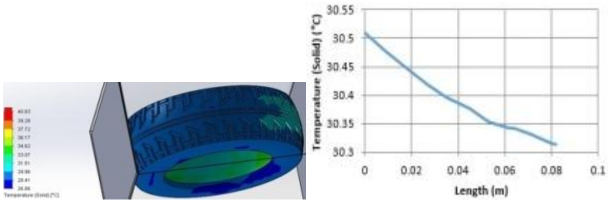

Fig. 6(a): Temperature distribution at 40 kmph for tyre Design 4

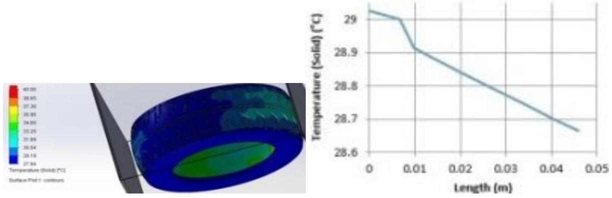

Fig. 6(b): Temperature distribution at 80 kmph for tyre Design 4

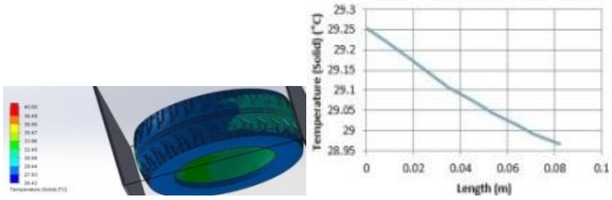

Fig. 6(c): Temperature distribution at 120 kmph for tyre Design 4

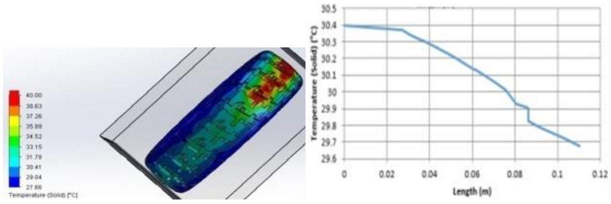

Fig. 7(a): Temperature distribution at 40 kmph for tyre Design 5

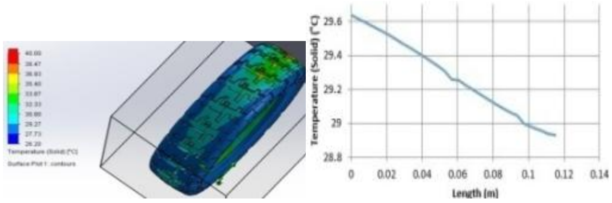

Fig. 7(b): Temperature distribution at 80 kmph for tyre Design 5

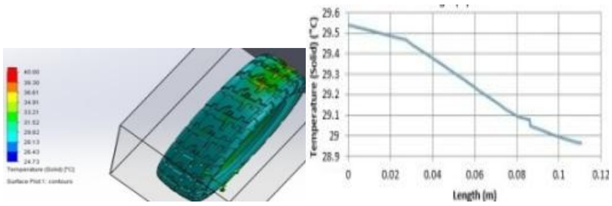

Fig. 7(c): Temperature distribution at 120 kmph for tyre Design 5

Cooling efficiency means that the % of cooling of tyre surface after inlet velocity is applied to the tyre tread. These values give the percentage of temperature reduction at the tyre surface. Table 2 summarises the cooling percentage for designed tread patterns along with the change of material and speed. Average cooling efficiency of five simulated designs using hard rubber, Nylon66 and Nylon6 materials are compared in Fig. 8. Based on the highest cooling efficiency, preference is given for Design 3 with hard rubber, Design 1 with Nylon66 and Design 3 for Nylon 6.

Table 2: Comparison of cooling efficiency (in %) for designed tyres

Material	Hard rubber				Nylon66				Nylon6			
Speed (kmph)	40	120	80	Average	40	120	80	Average	40	120	80	Average
Commercial tyre	8.88	8.88	5.73	7.83	6.61	9.06	6.72	7.46	2.73	7.73	7.93	6.13
Design 1 tyre	12.49	7.43	4.37	8.1	10.4	15.16	15.99	13.85	5.67	6.01	10.68	7.45
Design 2 tyre	8.4	2.98	12.65	8.01	7.71	3.14	5.12	5.32	3.37	7.45	8.75	6.52
Design 3 tyre	8.01	15.35	3.93	9.1	1.96	9.19	17.29	9.48	4.89	12.45	16.9	11.41
Design 4 tyre	9.1	7.91	6.58	7.86	6.16	8.5	10.71	8.46	5.17	6.45	3.92	5.18
Design 5 tyre	5.16	5.21	11.75	7.37	3.28	1.55	17.73	7.52	6.34	10.01	8.14	8.16

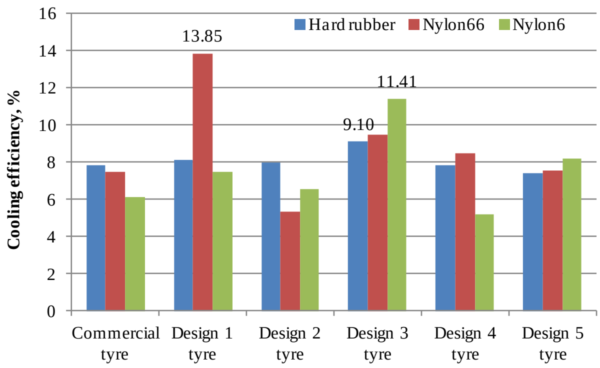

Fig. 8: Comparison of average cooling percentages

3.2. Drop test simulation results

The maximum load withstanding capability of the tyre can be established by drop test simulation [1]. Drop test analysis of the designed tyres is carried out using Solidworks. The maximum "g force" experienced by individual components is one of the primary unknowns before a drop test. The test result gives the time varying stresses and deformations due to an initial impact of the tyre with the floor. As the tyre deforms, secondary internal and external impacts were simulated to identify the critical failure points based on peak stresses and displacements [4]. The drop test simulation is carried out on the preferred tyre designs - Design 3 with hard rubber (Fig. 9), Design 3 with Nylon6 (Fig. 10) and Design 1 with Nylon66 (Fig. 11). The result contains time history graph and Vonmises stress (N/m^2) for the selected tread pattern and tyre materials.

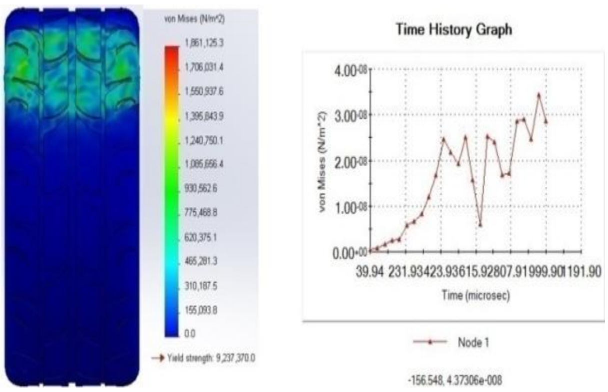

Fig. 9: Vonmises stress & time history for Design 3 (Hard rubber)

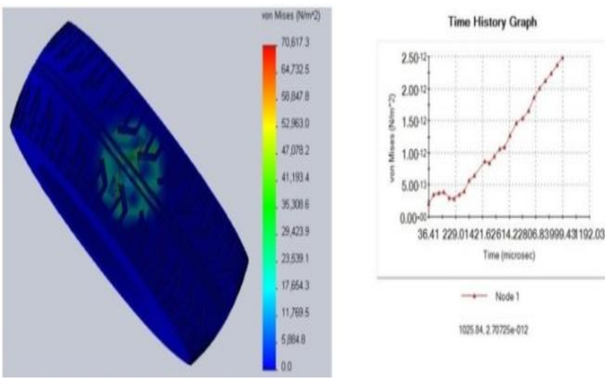

Fig. 10: Vonmises stress and time history for Design1 (Nylon66)

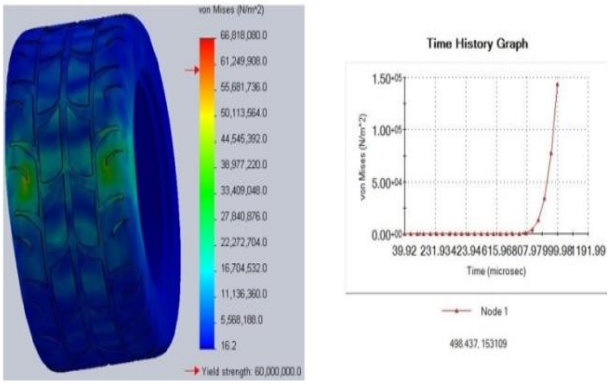

Fig. 11: Vonmises stress and time history for Design 3 (Nylon6)

4. Conclusion

In this paper, commercial tyre and five tread designs were evaluated to improve the cooling efficiency by employing CFD and drop test simulations using Solidworks. Maximum cooling efficiency was obtained for Design 3 with hard rubber, Design 1 with Nylon66 and Design 3 with Nylon6. Drop test results are better for Design 3. Hence this design is preferred for the detailed design. The analysis can be extended by varying the tread angle. As the material is changed only at the tyre surface, further studies can be looked into the layers of the tyre as a composite material.

REFERENCES:

[1] A.L. Browne and D. Whicker. 1977. Design of tire tread elements for optimum thin film wet traction, *SAE Tech. Paper 770278*. http://dx.doi.org/10.4271/770278.

[2] K.V. Narasimha Rao, R.K. Kumar, P.C. Bohara and R. Mukhopadhyay. 2006. A finite element algorithm for the prediction of steady-state temperatures of rolling tires, *Tire Science and Technology*, 34 (3), 195-214.

[3] S. Brenner and J.L. Turner. 1975. Tread wear rate properties, *American society for Testing and Materials*, 65-78.

[4] D.F. Standy, K.J. Granat, N.J. Durisek, K.T. Tandy, J.M. Baldwin and R.J. Pascarella. 2007. Vehicle response comparison to tire tread separations induced by circumferentially cut and distressed tires, *SAE Tech. Paper 2007-01-0733*. http://dx.doi.org/10.4271/2007-01-0733.

[5] K. Singh. 2011. *Automobile Engineering (Volume -2)*, Standard Publishes-Distributors.