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Study on Stress Distribution along the Contact Patch of Tire with Road Surface for Variation in Live Load Using ANSYS

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Abstract: This work deals with the objective of determining the stress distribution along the contact patch of tire with the road surface. The literature review provided an insight into the relationship between the surfaces of the road especially the terrain the major contributor for the stress concentration. The work encapsulates the changes in designs of tread pattern, variation in live load and tire inflation pressure. The tire was modelled and test specimen was made as per the standards and the results are obtained in ANSYS. The results shows the variation in the stress distribution on the patch of contact region for different live load variation. There are scope for improvement with inclusion of different reinforcement material to study the variation in stress distribution.

Keywords: Terrain, Tread pattern, Live load, Inflation pressure and reinforcement material.

I. INTRODUCTION

The present day automotive industry owes its growth to J.B. Dunlop who made the first practical pneumatic (bicycle) tyre during 1888. But Scottish inventor R.W. Thomson was the pioneer in introducing the pneumatic tyre to the world and was patented, but never went into production. The term tyre or tire both conveys the same meaning in different language, the former is British English while the latter is American English. It is a ring shaped polymer component comprising of more than 200 raw materials. It surrounds a wheels rim to transfer the load of the vehicle to the ground in contact thus providing traction on the surface travelled over. The characteristics of tyre were not easy to be predicted. It carries the load, absorbs the shocks from the waviness of the road, to overcome this power production was made high; finally it steers and stops the vehicle then and there.

Everything started when the invention of wheel began long back ago. Initially the tires were made up of leather [1], then iron, later steel surrounding the wooden wheels used on carts and wagons. J.B.Dunlop was credited for bringing rubber into limelight by stating that it could withstand wear and tear by retaining its resilience. they went on to introduce vulcanization of natural rubber using sulphur, later they developed clincher rim for holding the tire in place. Then during 1920's came synthetic rubber from the laboratories of Bayer. During 1946, Michelin developed the radial tire method of construction and showed its superiority in handling and fuel economy. This technology was later adopted in USA by Ford Motor company in the early 1970s.

With the technological development, the need for fuel economy became a major factor which gets affected with the stress distribution. The region of contact was not more than a humans palm area but that is responsible for the vehicles stability and safety of the passenger. This gets affected when the stress concentration is more in particular region and leading to failure of the material. Tire which is made up of more than 200 materials has natural rubber, synthetic butadiene rubber, carbon black and other materials as major ingredients are mostly elastic in nature. When this material is subjected to load it absorbs the energy provided by it and utilize the same to regain its original position once it is removed. All the force magnitude is not fully converted into energy for restoring the deformed portion to normal one. There is slight deformation in the component even after the removal of the load. There are numerous research work on getting the relationship between the pavement and the contact area of the tire, but still the stress concentration or distribution along its patch of contact was not predicted

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much better. This was evident from the literature collected so far are listed below for further understanding of the concept beyond the factors influencing the distribution of stress.

II. Literature Survey

Jiasheng Yang, Ghim Ping Ong, Tien Fang Fwa, Chye Heng Chew [2], on their Modeling the Effect of Rolling Conditions on Stress Development at Tire – Pavement contact patch, described the non uniform distribution of interfacial pressure between tire and pavement over its contact area. The traditional design and analysis concentrate on the parameters of type of tire, its inflation pressure, the load acting on it, tread pattern on the tire surface and the vehicle rolling characteristics. The numerical model developed for describing the contact stress distributions exhibited a very good result. The simulated results were validated with the theoretical development of the finite element based simulation model. The simulation was carried under three different rolling conditions like free rolling, driving condition and braking condition. The model was very effective in predicting the variation in contact stress distributions for the three different rolling conditions.

W.J.vd M. Steyn and Ilse M [3] found in their work titled Evaluation of tire / surfacing / base contact stresses and texture depth that the fuel economy mostly depends on the tire rolling resistance as there is a loss of energy due to interaction between the two. This interaction was difficult to identify as it was governed by various parameters like vehicle speed, its weight, material, inflation pressure and also the road chamber. They investigated the relationship between pavement surface texture depth and tire contact stress and area with variation in inflated pressure of the tire and for different pavement surfaces. The pavement conditions was defined on the basis of surface texture, thus by varying the texture the pavement conditions was varied for different inflated pressures. The loading condition was depicted through tire / surface contact stress. It was inferred that the underinflated conditions of tire had larger contact area as compared with the overinflated conditions. The shape of the tire / surface contact stress and its intensity indicated the shift from semi rectangular area to approximated circular in shape from underinflated conditions to over inflated conditions. The cumulative distribution of contact stresses on the single seal surfacing having 1.9 mm texture depth reveals that the stress distribution is narrower especially for the upper contact stresses. The general inference is that the total rolling resistance depends upon the rolling resistance of tire and also surface factor.

Wang Yang, Sun Tiecheng, Lu Yongjie and Si Chundis [4] work on Prediction for tire pavement contact stress under steady state conditions based on 3D Finite Element Method shows that the mechanical response of pavement structure was influenced by tire force one of the important factor among various factors. This force is easily measured when the speed of rolling was low but under high speed rolling condition it is difficult to measure because of the complications associated with the spatial distribution. They provided an equivalent representation form to analysis the tire force pavement interactions on mechanical aspects. This was done by establishing an interaction model of rolling tire and rigid surface. The prototype chosen for the analysis in this case is 11.00R20 tire and steady state transport analysis was conducted using a mixed Eulerian / Lagrangian approach. The Euler model described the rigid body rotation while the deformation was depicted by Lagrangian approach. The operation of tire was influenced by numerous parameters and was explored by analysing the simulation results of tire contact stress under different working conditions.

III. Experimental Work

In this paper, the tire modelled was R20 using Solid works. The modelled tire was taken for analysis of stress distribution for different road surface conditions. The model considers the present scenarios tire tread pattern. The behaviour of the material was tested for varying live load. Basically the loads were of three different types like dead, live and wind load. The dead load was around 110 kg or 1079 N for Hero Honda Passion Pro which is under consideration for experimentation. With the assumption that the load due to the wind has no major influence on the concept of stress distribution over the patch of interaction between the two.

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Fig. 1 Tyre modelled using Solid works for analysis

The inputs were provided into ANSYS and evaluated the behaviour under the different loading conditions.

IV. Results and Discussion

The force acting per unit area of contact patch of tire seems to vary in a non-uniform manner. This variation is because of the factors like rolling resistance, tire tread pattern, tire inflation pressure, variation in the load acting on the vehicle was understood from the literature survey. The stress acting normal to the contact patch is equal to the inflation pressure of the tire exactly on the same patch was the fundamental assumptions in any kind of analysis. But the results shows that the stress distribution is not equal to the tire inflation pressure as assumed and it distribution varies from one end of the contact patch to the other as shown in Fig 2 for a static load of 1170N.

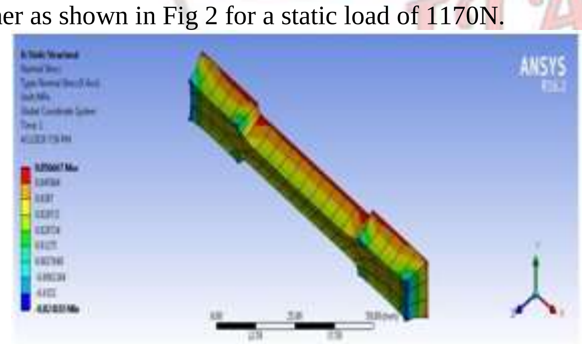

Fig 2. Stress (Vertical) distribution for a load of 1170 N

The longitudinal stress acting on the contact patch distribution for the same static load of 1170 N, operating at a speed of 50 km / hr is shown below

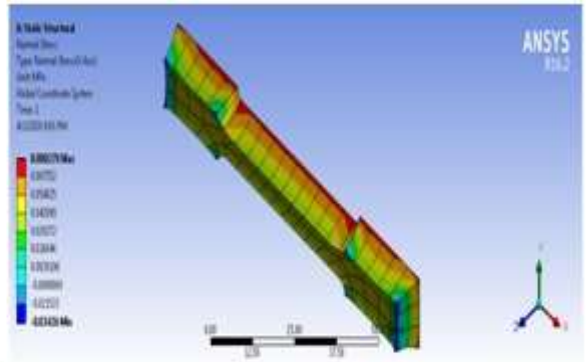

Fig 3. Stress (Longitudinal) distribution for a load of 1170 N

The lateral stress acting on the patch having contact with the road surface when the load acting on the vehicle is 1170 N while the speed of the vehicle is 50 km /hr is represented below:

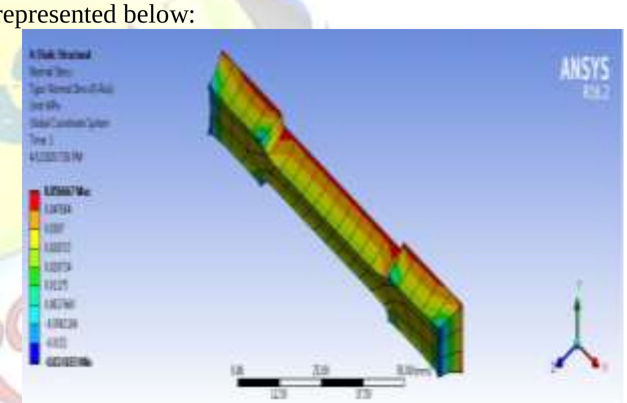

Fig 4. Stress (Lateral or Transverse) distribution for a load of 1170 N

V. Conclusion

This paper deals with the stress distribution along the contact patch of tire with surface of the road. The entire vehicle is controlled by this small patch of contact region with which the stability of the system is maintained. Thus the proposed system of changing the tire tread pattern the contact patch varies thus the stresses induced on the region of contact will differ and reduces to an extent. The simulated results are validated with the results obtained analytically through finite element formulation based on Isoparametric shell elements. This work provides scope for further design changes in the tire tread pattern along with increase in reinforcement fillers.

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