The effect of tire treads shape to stick – slip phenomenon in frictional contact

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Abstract

The mechanics of a tire in contact with a frictional flat or curved surface is importance to the understanding of road/vehicle load transfer characteristics. Such contact takes place between the road and the tread blocks of tires. It is necessary to understand the responses of these blocks to contact forces. According to [2], that described about the method of finding stick and slip regions by using the F_t and $F_{t\,Cal.}$ curves that is good agreement. This work considers the tire tread model as rectangular block with a gap at the mid region of tire tread block. There are contacts with a frictional flat surface on the top face. The contact pressure is calculated for wide range of coefficient of friction as the same as [2]. The stick - slip phenomenon are predicted as a function of coefficient of friction too.

Keywords: Contact pressure, Tire tread, Rubber block, Stick-slip phenomenon

1. Introduction

Stick-slip phenomena occurred in the tire tread when it has contacted by the ground. It can be predicted as the function of friction coefficient as shown in [2]. The stick and the slip are important phenomena which occur at the contact region. The classification of stick and slip phenomenon is purposed in [2] will also be considered in this work. The procedure of this study are the same as [2], it difference only in the model of tire tread, that is rectangular block with a gap at the mid region of tire tread as shown in figure 1. The tire material is modeled as the Mooney-Rivlin model.

2. Finite element model

Finite element method is widely used in solving engineering problems. Contacting between tire and the road at static situation can be modeled by contacting between tread of tire and frictional flat plate. The dimensions of the tread block are 1.0, 0.8, and 0.3 inch in the X, Y and Z directions, respectively. For this study the problem is divided in two parts, the first one is the deformable part (rubber block), and the second one is the frictional rigid flat plate as shown in figure 2.

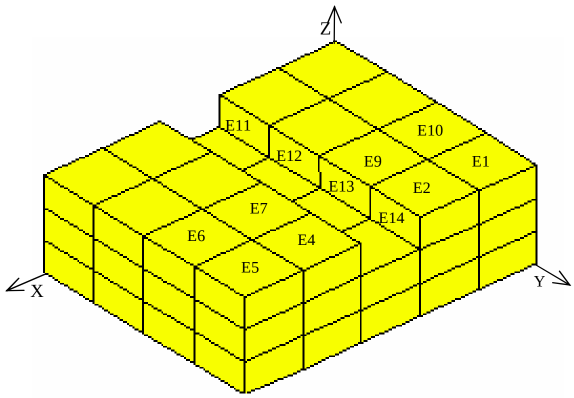


Figure 1. The surface element consideration on the rubber block with a gap

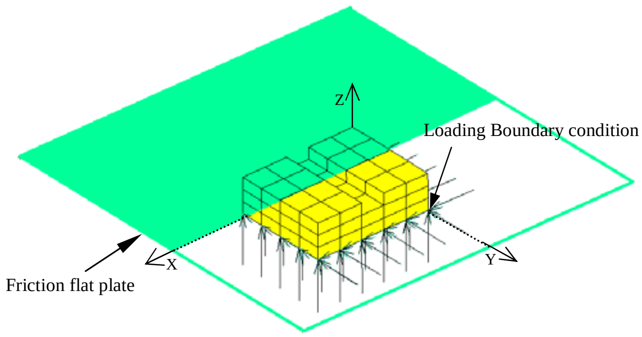


Figure 2. Finite element model rubber block with a gap

Element type number 84 is taken to be used with 60 elements. It is three dimensional brick element, first-order isoparametric element (arbitrarily distorted brick) with mixed formulation [6]. The rubber block is compressed in the Z direction from the bottom surface nodes by the displacement loading curve by 5%,10%,15% and 20% compressive strain as shown the figure 3. The boundary conditions are divided in two parts. For the first one, the rubber block is fixed in the Z direction on the top face and the second one, the bottom face of block is fixed in the X and Y directions as shown in the figure 2.

Coulomb friction law, to be used for this work, that is the same as previous work [2].

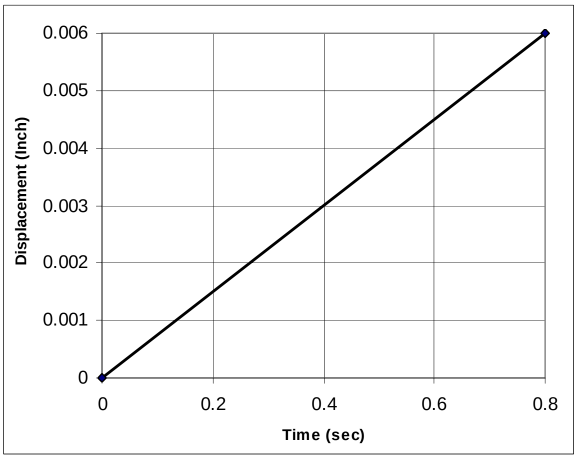


Figure3. Displacement loading curve

3. Material properties

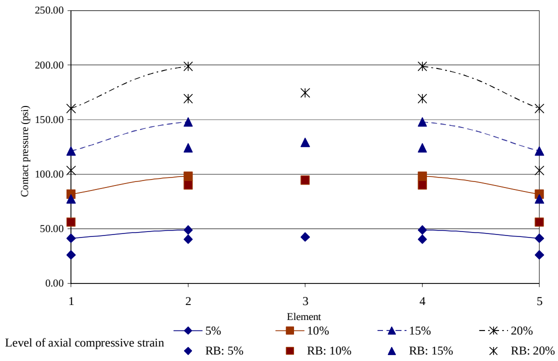
The Mooney-Rivlin material model is modeled for this work as $C_{10} = 100\ psi$, $C_{01} = 20\ psi$, and $K = 30{,}000\ psi$ [1].

The contact stress at the contacting surface can be calculated by averaging the nodal normal stresses at the four corner of individual surface element face.

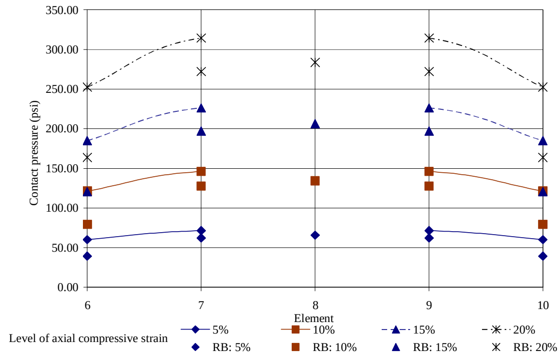
4. Finite element results

Due to symmetry, the finite element model used for the present work is considered only half of the surface elements as shown in figure 1. Two important points for this study are contact pressure distribution and the effect of friction on the contact status (stick or slip phenomena) on the rubber block face. The notation of original rubber block are assigned alphabet RB at the front of all value that refer to and the rubber block with a gap is not.

For the frictionless condition, the contact stress distributions increases with increasing of the level of axial compressive strain are as shown in figure 4. (a) and (b). It can be seen that the contact pressure increases as one move toward the center of the contacting surface. The magnitude of contact stress of rubber block with a gap is higher than original rubber block for the same compressive strain as shown in figure 4 (a) and (b). It is reasonable because of the decreasing of contact area.

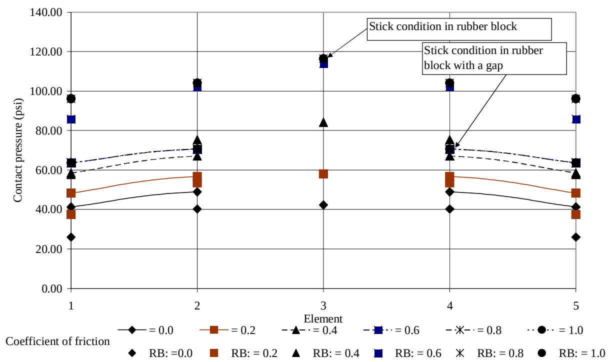


(a) For element 1 to 5

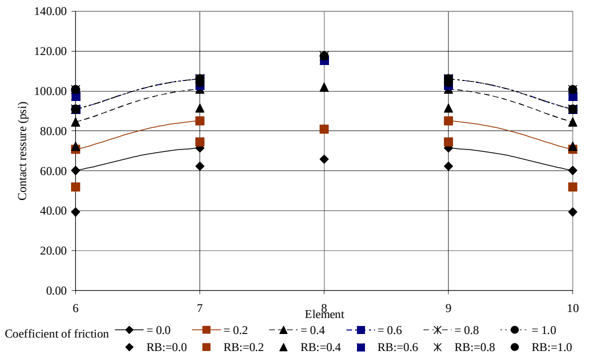


(b) For element 6 to 10

Figure 4. Frictionless contact pressure at various compressive strain

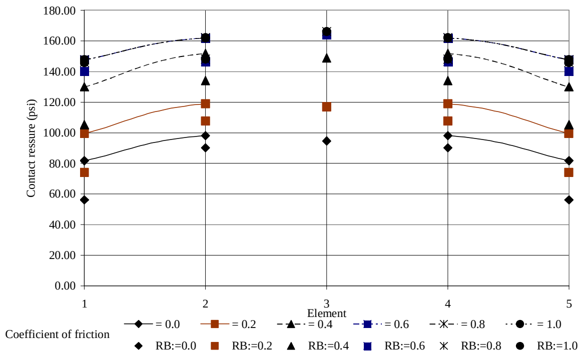


(a) For element 1 to 5

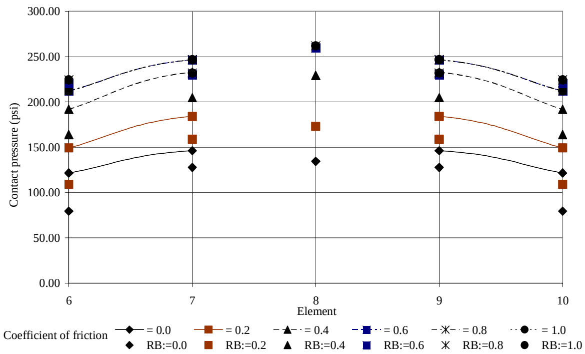


(b) For element 6 to 10

Figure 5. Contact pressure at various coefficients of friction at 5% compression



(a) For element 1 to 5



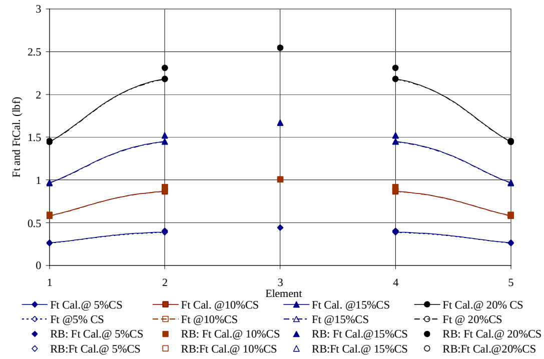
(b) For element 6 to 10

Figure 6. Contact pressure at various coefficients of friction at 10% compression

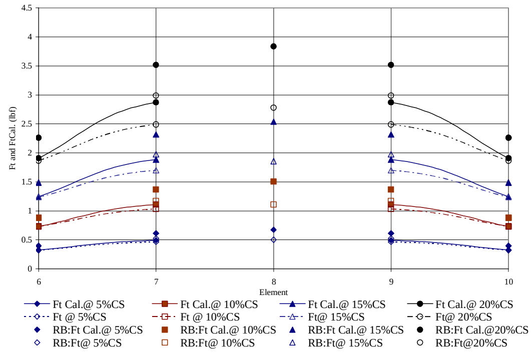
The effects of friction on contact pressure at axial compressive strain of 5% and 10% are as shown in figures 5.and 6., respectively. The contact pressure increases with increasing of friction coefficient up to a value of $\mu = 0.6$. The magnitudes of the contact pressures remain unchanged with $\mu \geq 0.6$ for the present loading condition. This implies that, at this coefficient of friction and above, the contact is maintained without any slippage during the course of increasing compressive strain. The effects of friction on the contact stress in the rubber block with a gap are the same trend for all compressive strain. When we analyst in detail respect to the original rubber block, the magnitude of contact stress in the rubber block with a gap are higher than the original rubber block for friction coefficients less than 0.6 as shown in figure 5-6 (a) and (b).

According to the classification of contact status in [2], the stick and slip conditions can be classified by comparison of the F_t curve and the $F_{t\,Cal.}$ curve which the F_t curve must be lined in lower level than the $F_{t\,Cal.}$ contact condition is stick, and the F_t curve and the $F_{t\,Cal.}$ curve, that is coincides for the same axial compressive strain, the contact status is slip.

According to figure 7 (a) at friction coefficient equal to $\mu = 0.2$, the tangential stress of rubber block with a gap is less than the original rubber block for all compressive strain. The F_t curve and the $F_{t\,Cal.}$ curve are the same trend as the original rubber block that coincides for slip and, that $F_{t\,Cal.}$ curve lining lower the F_t curve is the sign of stick.

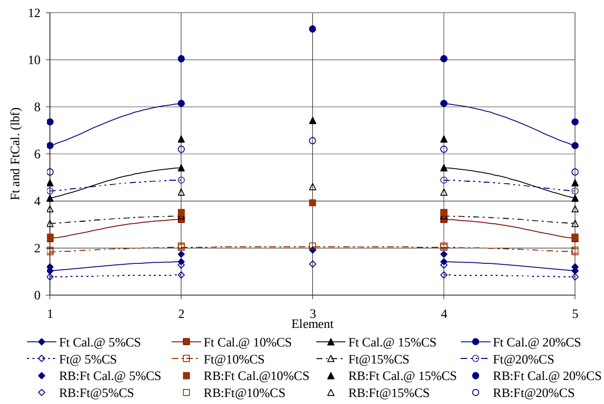


(a) For element 1 to 5



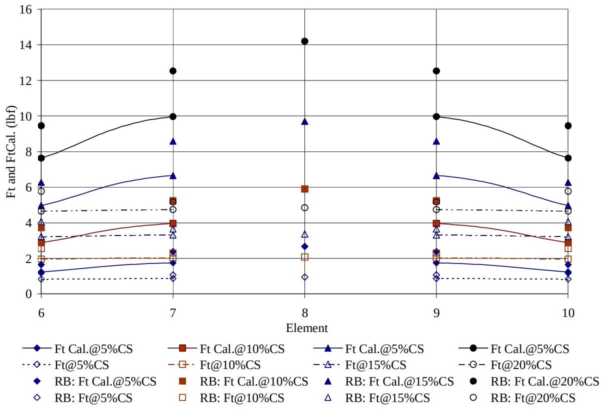
(b) For element 6 to 10

Figure 7. The comparison of contact friction forces with respect to the calculated Coulumb contact friction force with $\mu = 0.2$



(a) For element 1 to 5

Figure 8. The comparison of contact friction forces with respect to the calculated Coulumb contact friction force with $\mu = 0.6$



(b) For element 6 to 10

Figure 8. The comparison of contact friction forces with respect to the calculated Coulumb contact friction force with μ = 0.6

5. Discussions and conclusions

According to figure 4.(a) and (b), the magnitude of contact pressure in rubber block with a gap is higher than in the original rubber block, that effect from decreasing of contact area.

The friction in normally is effect to the tangential stress. The stick and slip are two phenomena that important to be designed the tire tread. The friction law is the high light this work that classified stick and slip phenomenon. According to compressive stain equal to 5% as shown in figure 5-6 (a) and (b), the stick point of friction coefficient is the same for both rubber block (μ = 0.6)but the magnitude of contact pressure of rubber block with a gap (60-70 psi) is lower than the original rubber block (85- 115 psi).

The tangential stress according to the previous work procedure [2], the magnitude of tangential stress decrease for the all of compressive strain as shown in figure 7-8 (a) and (b) at the same time the surface stress at the element 11, 12, 13 and 14 as show in figure1. are higher than the contact region about 2 – 5 times. That element is applied by is the axial stress, as the short column the magnitude so be high.

Results from the FEM simulations can be summarized as follow :

5.1 The contact pressure gradient increases with increasing level of the compressive strain.

5.2 The coefficient of friction is the cause of changing of the stick and slip phenomenon. The state of slip phenomenon can be changed to the state of stick by increasing of the coefficient of friction.

5.3 At the friction coefficient of μ = 0.6 is the starting point of perfect stick.

5.4 The stick and slip conditions can be classified by comparison of the F_t curve and the $F_{t\,Cal.}$ curve as the previous work.

5.5 The stick phenomenon occurs at the inner part of contact region and the slip occurs at the outer part of contact region at various friction coefficients except at μ = 0.0.

5.6 The rubber block with a gap under axial compressive load effect to the maximum contact pressure and the tangential forces as follow:

5.6.1 Contact pressure increase for all of compressive strain and the same time of the tangential forces is decrease.

5.6.2 The maximum stress occurs at the side surface of rubber block.

5.6.3 Increasing of the friction coefficient effect to the maximum contact pressure increase and the tangential force decrease.

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7. References

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