THE INFLUENCE OF THE ROAD SURFACE FOR THE WHEEL CAR

Cristian MINCA

Timisoara, Romania

Abstract: *In temperate climatic conditions the water depths on wet roads are generally low, typically less than 1 mm. In this paper I examine the various types of road surface and the manner in which they can be classified in terms of macro and micro texture. I propose a simplified representation of the tire road interface in which the tire footprint is divided into 2 zones, a dry zone in which dry road friction levels are obtained and an initial wet zone in which there is a water layer between the tire and road and which gives no retardation.*

Keywords: *road surface, macro and micro texture, footprint, dry zone, wet zone, layer*

INTRODUCTION

In temperate climates roads are wet for considerable periods of time after rainfall due to poor drying conditions. This paper examines the influence of road surface type and tire tread on locked wheel retardation for such conditions, firstly examining the mechanics of the tire-road interaction under wet conditions and proposing a general model for the effective dry tire to road footprint under wet conditions and its variation with speed after examination of the experimental data a simple physical model for tire to road contact is proposed.

1. RAINFALL AND WATER DEPTHS ON ROADS

The water depth on a road surface is defined as the height of water above the level of the top of the large scale roughness. This large scale roughness is defined as the macro-texture. In temperate climates and with the typical range of cross-section of modern roads it has been shown (1) that the water depth for rainfall intensities normally encountered rarely exceeds 2 mm and is more typically 1 mm or less. When the rain stops a significant time can elapse before the road surface becomes fully dry. In this paper the data for water depths from the just wet condition to less than 2 mm has been analyzed.

ROAD SURFACE CLASSIFICATION

The skidding resistance of a road surface is influenced by two characteristics of the surface itself.

These are what have become commonly referred to as the macro-texture and the micro-texture of the road surface.

Figure 1 illustrates the nature of the different road surface.

The macro-structure is the large scale roughness of the surface and in bituminous road surfacing it is formed by the aggregate.

Similarly concrete surface is provided with macro-texture by transverse brushing or grooving while the material is still plastic or by sawing grooves into the hardened surface.

Therefore the macro-texture of the road surface can be readily identified.

The major influences of macro-texture on skidding resistance are that it provides drainage paths to allow water to be removed rapidly from the tire to road interface and gives asperities of suitable magnitude to cause hysteresis losses in the tire material as it deforms around the asperities.

The term Rough is used to denote a surface which has good macro-texture.

The term smooth is used to denote a surface which has no macro-texture.

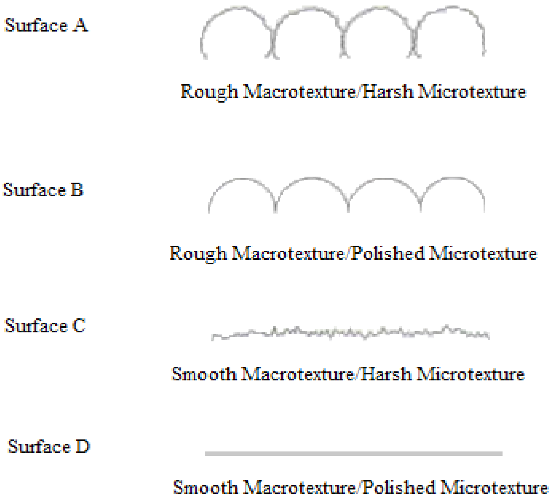

Fig. 1:Terms used to describe road surface texture

The micro-structure is the finer element of the road surface and constitutes the tiny asperities in the surface. For a bituminous surface the micro-texture is found on the aggregate particles with a secondary contribution from the sand sized particles in the exposed bitumen binder or asphalt mortar. In a concrete surfacing the micro-texture derives almost totally from the sand in the mortar. It has been shown that the micro-texture can be assessed by drawing a finger nail across the macro-texture or the exposed bitumen binder. The term Harsh refers to a surface with good micro-texture. The term Polished refers to a surface with no micro-texture.

As there are two states for macro-texture i.e. Rough and Smooth and micro-texture i.e. Harsh and Polished we can combine these to give four distinct types of road surface. These are given in table 1.

Table 1

Type	**Macro**	**Micro**
A	Rough	Harsh
B	Rough	Polished
C	Smooth	Harsh
D	Smooth	Polished

CAR BRAKING UNDER WET CONDITIONS

When emergency braking is applied under wet road conditions the frictional force at the tires increases rapidly to a peak value.

At this stage the wheels are still rotating and therefore directional control of the vehicle is in the hands of the driver. ABS braking system essentially operate to maintain the braking force at the peak level so that locking of the wheels does not occur during emergency brake applications. ABS does this by rapid on/off cycling of the braking system to prevent locking of the wheels thus leaving it possible for the driver to use a steering input as an avoidance measure as well as emergency braking. However where ABS is not fitted, it is virtually impossible for the normal average driver to maintain this peak value and there is a rapid and significant drop in the friction force level available. The wheels are now sliding along the road surface i.e. locked wheel braking conditions exist, and the driver cannot steer the vehicle. This paper deals specifically with the locked wheel braking condition. However the theoretical models can also be applied to rotating tires.

It is the lubricating action of the water on the road surface which reduces the skidding resistance on wet road surfaces. Two requirements must be met for effective braking force coefficients to remain available under emergency braking conditions:

1. The water film on the surface must be broken through to provide dry contact between the tire and the road surface.
2. The surface with which the tire comes into contact should not be polished.

In relation to Condition 1 the rupture of the water film is achieved by providing adequate drainage to permit the water to be expelled from between the tire and road surface. This can be provided for by having good tread depth on the tire or by having suitable road surface macro-texture or indeed a combination of both.

In relation to condition 2 the grip at the tire/road contact will depend on the state of non polish i.e. the micro-structure of the surface with which the tire footprint comes into contact. Ideally the surface at the points of contact should have very fine scale sharp edges which will enable the remaining water film to be penetrated.

TIRE-ROAD CONTACT

Moore (2) proposed the existence of three characteristic zones of contact under a rolling or sliding tire in wet road condition, fig. 2

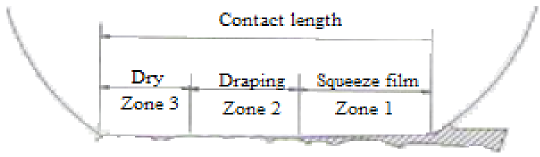

Fig 2: Characteristic zones of contact under a rolling or sliding tire in wet road conditions

The three zones which comprise the tire contact area are as follows:

(1)A squeeze film zone which is at the forward part of tire contact area in the direction of motion. This zone is where the individual tread elements of the tire tread squeeze out the water film under the action of inflation pressure.

(2)A transition zone which is where partial breakdown of the water film is occurring. This zone is where the tire elements having penetrated the squeeze film commence to drape or conform to about the macro-texture of the road surface and to make contact with the macro-texture of the road surface.

(3)A traction or braking zone where the water film has been completely displaced or removed and there is dry contact between the tire and the road surface i.e. almost all wet road skid resistance or tractive capability is developed in this region of contact.

Purushothaman (3) has demonstrated that high value of braking force coefficient, in the same order as those achieved on dry surfaces, occur at very low speeds i.e. when close to to being stopped. This occurs because at this low speed there is extensive breakthrough of the water film between the tire and road surface i.e. zone (3) above is close to maximum. At soon as the speed increases the lubricating action of the water begins to determine the level of the braking force coefficient. The effect of an increase in the speed of rolling or sliding can be explained in terms of the resultant increase in the proportion of contact occupied by the water supported zone in relation to the total contact area. The contact duration time, even at low speed, between the tire and the road is only of the order of a few milliseconds.

In the case of sliding tire this is the time for which any point of the ground is within the tire to ground contact region. Therefore as the speed of the vehicle increases the total contact duration reduces and there is insufficient time for the tire the maximum contact area that is possible in zone (3) thus reducing the braking force coefficient below what would be expected at lower speed. Of course the rate of reduction in braking force coefficient with increasing speed will primarily depend on the macro-texture and micro-texture of the road surface in conjuction with the tire tread pattern.

HYDRODYNAMIC MODEL

It has been shown that the braking force coefficient reduces in value as the speed of the vehicle increases. This decrease is due to the hydrodynamic pressure which builds up in the contact area between the tire and the road. Consider a plane rectangular hard body which slides at some speed over a stationary plane hard surface and allow the body to have the freedom to rotate around horizontal axis, the body pivots and a wedge shaped of liquid builds up between the plane surfaces. This effect is the basis of sliding bearing lubrication. It has been shown that the minimum film thickness i.e. the minimum clearance between the two surfaces is proportional to the square root of the relative sliding speed. It has also been shown that this proportionality holds for a soft elastomer sliding over a hard surface.

Shallamach&Grosch (4) made use of the hydrodynamic theory of lubrication and they assumed that the frictional force, F, is proportional to the effective dry contact area, A_d, so that and that the roughness, micro or otherwise, could be represented as spheres of equal radius r.

$$F=const.A_d \tag{1}$$

If the lubricating film thickness is h at the sliding velocity v, and h is smaller than r, then the dry area protruding through the film i.e. the dry contact area, A_d is:

$$A_d=2\pi Nr^2(1-h/x) \tag{2}$$

where

N is the number of spheres in the contact area. As hydrodynamic research has shown that film height, h, is proportional to the square root of V substitution into equation (3) can be expressed as follows:

$$\mu = \mu_0(1 - bV^{0.5}) \quad (3)$$

where

μ_0 is the dry friction coefficient.

The Shallamach and Grosch model is based on the concept that the upper portion of the spheres protrude through the water film over the entire tire to road footprint area. This model does not accord with the experimental evidence of an initial wet contact area followed by mixed and dry contact areas.

PROPOSED GENERALISED MODEL

In this paper a simpler model is proposed to represent the tire contact area and only two zones of contact are considered, wet and dry. In the wet zone there is not retardation forces available and it is only in the dry zone of the tire footprint that retardation forces are developed. The relationship between the effective retardation forces and the ratio of the wet contact zone and the total tire foot print is derived below:

$$F_v = P.A_c \quad (4)$$

where F_v=the total vertical force at the tire road interface; P=tire pressure;

A_c=the total area of nominal tire foot print

However A_c can be also written as

$$A_c = A_{wet} + A_{dry} \quad (5)$$

As it is the area of dry contact within the total tire/road contact area which gives rise to the frictional forces at the tire/road interface then

$$F_H = \mu_0 F_{v(dry)} \quad (6)$$

where F_H=friction force at tire/road interface

$F_{v(dry)}$=effective vertical force in the dry zone of contact area; μ_0=braking force coefficient between tire and road in dry contact conditions

However $F_{v(dry)} = P.\ A_{dry}$ (7)

Therefore $F_H = \mu_0 P.\ A_{dry}$ (8)

and re-arranging equation 5 gives

$$A_{dry} = A_c(1 - A_{wet}/A_c) \quad (9)$$

Therefore substituting equation 9 and 4 into equation 8 gives

$$F_H = \mu_0 F_v(1 - A_{wet}/A_c) \quad (10)$$

Dividing across by F_v gives the retardation coefficient i.e.

$$\mu = F_H/F_v \quad (11)$$

finally after substitution and re-arranging the final equation which represents the proposed model is obtained

$$\mu = \mu_0(1 - A_{wet}/A_c) \quad (12)$$

The time of contact t_c is equal to the length of the contact patch divided by the speed V. This means that when the tire is stationary the contact time is infinite. Consequently the ratio of the wet zone of the contact area, A_{wet}, to the total contact area, A_c, is equal to zero. Therefore the full dry value of friction is available when the tire is stationary.

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