International Refereed Journal of Engineering and Science (IRJES)
ISSN (Online) 2319-183X, (Print) 2319-1821
Volume 1, Issue 4(December 2012), PP.49-55
www.irjes.com

Aquaplaning - Study Regarding The Adherence Of The Vehicles

Danut Ciubotaru[1], Vasile Neculaiasa[2]
[1] *Ministry of Domestic Affairs and Administration,*
Community Public Service, Driving License and Vehicle Matriculation Officet, Botosani, Romania
[2] *"Gheorghe Asachi" Technical University, Iasi, Romania*

ABSTRACT: *The authors present in this study the useful criteria in conceiving, building and exploiting vehicle tires in hydroplaning, that reduce the number of traffic accidents. The analytical expressions presented here enable us mathematical determination of tire reaction on a wet road.*
Keywords – *Adherence, Hydroplaning, Road, Tire.*

I INTRODUCTION

According to the EU yearly report regarding road fatal crashes in EU, presented by the European commissioner for transport in Romania, death rate in 2011 [1] was 94 per mil. inhabitants, which ranks our country in the 3rd position with most victims in road accidents after Poland (109 deaths per mil inhabitants) and Greece (97 deaths per mil inhabitants).

Excessive speeding and driving disregarding weather traffic conditions is the second cause in rank in the road accidents caused by drivers.

To know the hydroplaning phenomenon when the vehicle tire separates from a wet road at a high speed is of great practical importance because it influences road safety while driving. No rarely do experts have to face situations when it is absolutely necessary to clarify the causes that led to an accident and ask for the particular conditions when the car crash took place.

The characteristics of the driving surface are determined by the nature and ruggedness of the shallow layer, humidity and cleanliness level of the tire rolling surface.

A suggestive analysis of the adhering quotient variation may be performed in the initial and final rain interval fig. (1) [2]. During the initial rain interval the mud pellicle on the driven surface together with the water creates a viscosity layer leading to a small adhering quotient; after the interval when the rain falls, the adhering quotient rises to a value corresponding to a wet surface and when the rain stops the quotient reaches the value of a dry surface.

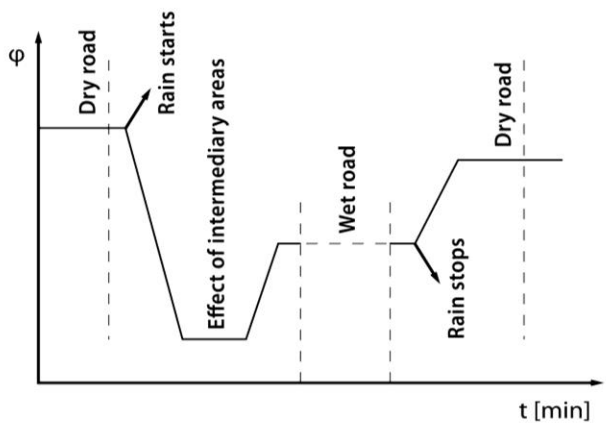

Fig. 1 - Influence of the road humidity on the adhering quotient

The hydroplaning phenomenon is presented in graph (2) [3]. When driving slowly, water is completely eliminated from the contact surface graph (2a); at an increasing speed a new wedge? of water is formed fig. (2b) between the tire and the road and at a critical speed (Vcr) the water pellicle becomes equal to the contact surface length, point at which the tire separation appears fig. (2c).

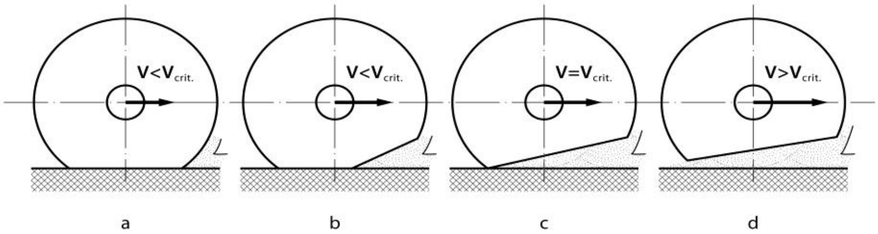

Fig. 2 - The driving process on a wet road

In fig. (2d), at a speed higher than the critical speed the tire floats on the water and the contact between the tire and the road is exclusively realized through water.

II MATERIALS AND METHODS

Areas of tire contact with the rolled surface in case of hydroplaning

Regarding the number of characteristic areas of the contact surface between the tire and the road most authors take into consideration the existence of three distinct areas.

In paper [1], the author shows that the geometrical place/point of passing from one area to the other, from one nervure to the other, the space is not straight but a certain curve, form of which is experimentally determined and dependent on the tire pressure in contact with the road.

Paper [4] explains the theory of the three areas, the decrease of the adhering quotient depending on the speed both of the rolling tire and of the blocked one. The water pellicle under the tire extends proportionally with the speed and the tire is completely supported by water at a critical speed graphs (1c) and (1d). At the sliding tire the adhering quotient decreases considerably and proportionally with the speed increase on a rugged surface. The presence of nervures, of blocks and bars in the exterior surface of the tire makes it easier going through the water pellicle, situation in which water is eliminated from plans with smaller surfaces and it has evacuation points through the profile canals of the tire.

In paper [5], Desmond F. Moore proposes the theory of four areas of the tire when rolling, one of which being inclined.

In the study of hydroplaning, Veith proposes in paper [6], physical models similar to those in hydrodynamic greasing or limited greasing, stressing the fact that in the case of a tire the penetration of the liquid is of elastic-hydro dynamic nature.

Hydroplanation Calculus

The method of calculation is presented in paper [7] under two different aspects: when in the contact surface coexist both dry contact and liquid area and when the tire is in no contact with the road.

In the former case the author uses the hypothesis with three areas: 1-water, 2-semidry, 3-dry (graph 3). The area No 2 is neglected due to its small size compared with the other 2 areas.

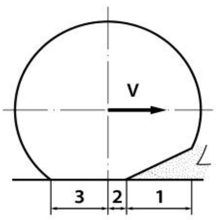

Fig. 3 - Display of the areas in the contact surface between the tire-wet rolled surface in case $V<V_{crt}$

Starting from the impulse theorem of the liquid wedge (graph 4) which is formed through the deviation angle & of the water layer having the thickness ha of the tire rolling at a speed V

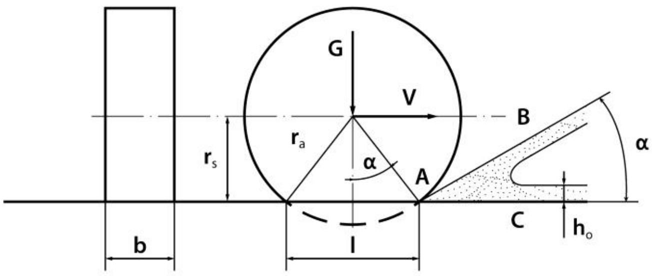

Fig. 4 - Calculation formulae when in the contact surface there are both dry contact and liquid area

Knowing the free ray of the wheel, the rolling ray Rr and the width of the contact surface between the tire and the road b the general relation

$P \cdot Q(V_2 - V_1) = EF$ according to fig. (5) comes:

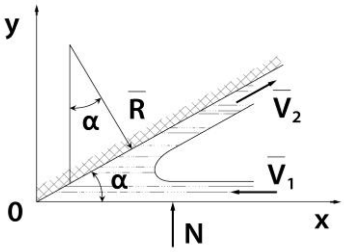

Fig. 5 - Choice of the coordinating axes when in the contact surface there are both dry contact and liquid area

$$Q \cdot V(\cos\alpha + 1) = R \cdot \sin\alpha$$
$$Q \cdot V \cdot \sin\alpha = N - R \cdot \cos\alpha$$

From paper [8] results the formula of vertical component Fv which tries to separate the tire from the road:

$$F_v = p \cdot Q \cdot V \frac{1+\cos\alpha}{tg\alpha}$$

For small angles the relation becomes:

$F_v = 2 \cdot p \cdot Q \cdot V \frac{1}{\alpha}$ where $Q = b \cdot h_a \cdot V$

The aforementioned relation becomes:

$$F_v = 2 \cdot q \cdot b \cdot h_a \cdot \frac{V^2}{\alpha} \qquad (1)$$

To establish the adherence quotient on a wet road f wet depending on the dry adherence quotient and the driving speed, results:

$$f_{wet} = \frac{F_{wet}}{G}; \; f_{dry} = \frac{F_{dry}}{G}$$

On a wet road the adherence is realized on the third section fig. (3) where there is dry area, the contact force on this segment is (G - F_v) and creates the adherence force.

$$F_{wet} = f_{wet}(G - F_v)$$

The adherence quotient on a wet road will be:

$$f_{wet} = \frac{F_{wet}}{G} = \frac{f_{dry}(G - F_v)}{G} = f_{dry}\left(1 - \frac{F_v}{G}\right) \quad (2)$$

By replacing formula (1) in (2)

$$f_{wet} = f_{dry}\left(1 - \frac{2 \cdot q \cdot b \cdot h_o}{G \cdot \alpha} \cdot V^2\right) \quad (3)$$

The expression (3) interprets correctly the experimented data in research studies.

To determine the hydroplaning critical speed when the adherence quotient is 0, we shall equalize expression (3) with 0:

$1 - \frac{2 \cdot q \cdot b \cdot h_o \cdot V^2}{\alpha \cdot G} = 0$ it results:

$$V_{crit} = \sqrt{\frac{\alpha \cdot G}{2 \cdot q \cdot b \cdot h_o}} \quad (4)$$

The study performed [7] implies minute attention regarding the normal average pressure between the tire and the road:

$$Pm = \frac{G}{St}\left[daN / cm^2\right] \quad (5)$$

$$Pm = \frac{G}{b \cdot l}$$

Considering the tire perfectly elastic Pm = Pi, (Pi = air internal pressure in tire) it comes out that relation (5) can be written as such:

$$V_{crit} = \sqrt{\frac{\alpha \cdot p \cdot l}{2 \cdot q \cdot h_o}} = \sqrt{\frac{\alpha \cdot l}{2 \cdot q \cdot h_o}} \cdot \sqrt{p} \quad (6)$$

The relation (6) stresses the influence of the water layer thickness ha on the critical speed as well as the shape change of the loaded tire. By the help of density q we may introduce the driving conditions on a dirty road: mud, oil, etc.

In order to calculate hydro planning when the tire is completely off the rolling surface, paper [8] presents the model from which results that the lift force becomes infinite thus making it clear that the moment of separation cannot be described by both of them.

Dynamic Hydroplaning

In paper [5] Moore shows that the complete separation of the tire from the road when it becomes flooded which is called dynamic hydroplaning.

In fig. (6) [2], the tire is presented in partial hydroplaning conditions, situation in which three areas can be distinguished. Front section A where the tire attacks the road forming a continuous water pellicle, acting as a wedge over the tire with the effect of raising it from the road. B area presents discontinuities alternating with the adherence area between the tire and the road.

C -area which may not appear in case of total hydroplaning is a firm contact area between the two areas being the only section able to ensure the car stability.

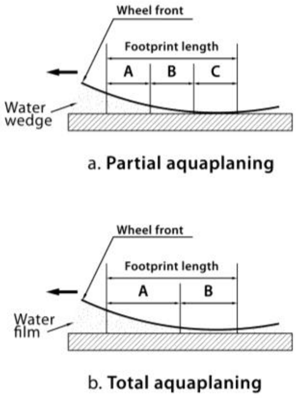

Fig. 6 - Partial and total hydroplaning supposes forming a wedge and a pellicle of water which raises the tire from the road

Fig. 7 [3] - Visualization of the real phenomenon of a tire while hydroplaning, photographed through a window glass

From the analysis undergone it came out that the necessary force to remove water from the road depends on the tire type, tire load, internal air pressure in tire, thickness of the water layer, of the tire and the vehicle speed.

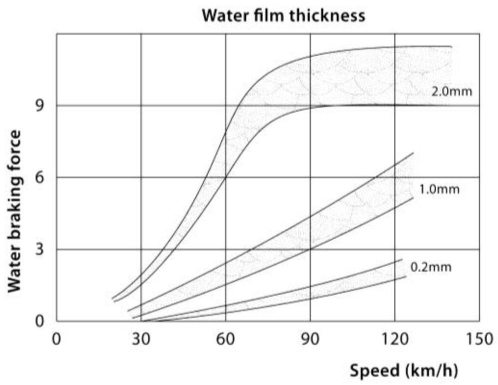

Fig. 8 - Variation of the traction force according to the sliding speed (radial tire)

Fig. (8) stresses the fact that the traction force for a radial tire increases not linear with the sliding speed for heights of the liquid layer from 0.2 to 2mm, according to the relation:

$$F_p = k \cdot b \cdot V^n \tag{7}$$

Where:

K - constant
N - greater than the unity
b - tire width
V - driving speed
n - value starts to decrease at higher speeds and for a 2 mm height of water layer, the exponent becomes zero as if it were floating on the water pellicle

Hydroplaning

These conditions appear when extremely thin water pellicles on top of ruggedness in the area of contact surface prevent the direct contact between the profile surface of the tire and the road. These pellicles may be at least 0.01 mm and because of the viscosity effects they are very difficult to be removed.

The calculation of the viscous hydroplaning consists in determining the necessary time in which a certain tire profile expels the liquid layer on the road.

Paper [5] suggests how to calculate the time of expelling the liquid from under the tire by the help of relation:

$$T_1 = \frac{K_1 \cdot \mu \cdot A_1^2 \cdot h_v^2}{W \cdot \Phi\left(\frac{\varepsilon}{h}\right)} \left[1 - \left(\frac{h_v}{h_o}\right)^2\right] \tag{8}$$

Where:

μ - of the fluid pellicle
A_1 - surface of an individual element of the tire rolled surface
W - load applied
h_o - initial thickness of the not penetrated water layer
h_v - final thickness of the viscous water pellicle
K_1 - shape quotient for the element of tire rolling surface
Φ - polynomial written in the terms of ruggedness
$\frac{\varepsilon}{h}$ - ruggedness height of the rolled surface

Most studies on viscous hydroplaning were limited to thin pellicles.

III RESULTS AND DISCUSSION

The results presented in chart (1) were realized within the Romanian Vehicle Department using a car, Logan make, according to the ECE ONU 13/06 amendment 09.

In conclusion driving at different speeds on a wet road, with two sets of tires-one new and the other one used (slicks) demonstrated that worn tires have a much better adherence on a dry road and that this decreases direct proportionally with the thickness of the water layer on the road.

Table 1

Friction quotient values at different speeds

Vehicle Speed(*km/h*)	Tire condition	Road conditions				
		Dry	Wet	Rain (water<1*cm*)	Havy rain (water<2*cm*)	Ice
Coefficient of static friction						
50 *km/h*	New	0.85	0.65	0.55	0.52	<0.1
	Used	1.1	0.53	0.41	0.25	
90 *km/h*	New	0.82	0.62	0.32	0.06	
	Used	0.95	0.21	0.11	0.06	
130 *km/h*	New	0.75	0.43	0.23	0	
	Used	0.9	0.22	0.11	0	

To increase adherence on a wet road, water accumulated under the tire should be eliminated and this can be done by means of canals built in the profile of the tire.

IV CONCLUSION

Dynamic hydroplaning is determined by the force produced by the water jet deviated and by the resulting force given by the dynamic pressure and it has as a feature the total separation of the tire from the road. Viscous hydroplaning is produced only by the viscosity of the fluid.

The analysis presented in this paper offers criteria to compare levels of adherence on a wet rolled surface for the great diversity of tire profiles found in the car industry.

REFERENCES

[1] B. J. ALBERT, *Tire Reaction While Rubbing on a Wet Road* (Rubber Chemistry and Technology, issue 4, 2010) pp. 753 – 779

[2] M. FIERBINTEANU, *Car crashes in traffic* (Little Star Publishing Company, Bucharest, 2010) pp. 151 – 190

[3] Gh. GAIGINSCHI, *Traffic Safe Driving* (Technical Publishing Company, Bucharest, 2004)

[4] G.& C. MOYEACK, *Resistance in Tire Sliding on Wet Surfaces* (Rubber Chemistry and Technology, issue 4, 1968)

[5] D. F. MOORE, *The Friction of Pneumatic tires* (American Elesevier Publishing Company, Inc New York, 1975)

[6] V. NECULAIASA, *Wheel Vehicle Dynamics* (The Polirom Publishing, Bucharest, 1996) pp. 79 – 83

[7] Gh. POTINCU, *Theoretical Calculus of Adherence Quotient When Driving on a Wet Road* (Bulletin II, Pitesti, 1979)

[8] M. & C. UNTARU, *Wheel Vehicle Dynamics* (The Didactic and Pedagogical Publishing, Bucharest, 1981) pp. 32 – 40

[9] Statistical Data, Ministry of Domestic Affairs, DR, 2012

[10] A. VEITH, *Measuring the Natural Force of Tires When Driving on a Wet Surface* (Goodrinch Company Research Center, Ohio, USA, 1983)