TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 58, Issue III, September, 2015

THE EVALUATION OF NORMAL LOAD REDISTRIBUTION ON THE STATIC AXLES AND ON THE WHEELS, WHEN THE VEHICLE IS IN MOTION

Adrian TODORUŢ, Nicolae CORDOŞ, Mihai-Dan BURDEA, Monica BĂLCĂU

Abstract: *The knowledge of the normal reaction to the car axles is required to determine its grip and for the study of braking and stability issues during his movement. The size of the reaction is influenced by the conditions of movement and constructive parameters of the the vehicle. The vehicle dynamic axles loads are studied because they have influences on the grip forces and for the study of braking problems and stability during the movement. During the vehicle exploitation, the wheels grip forces with greater dynamic load will increase and those with lower dynamic load will decrease, having direct influence on their stability.*

For the assessment of the normal static axle load redistribution, when the vehicle is in motion, in various situations of exploitation, resort to: conducting the experimental measurements concerning the determination of the normal static axle load for different situations of the vehicle load; determining the center of gravity for considered loading situations; development of a numerical calculation model in MathCad that gives the results with graphic interpretation of dynamic loads of the vehicle axles, maximum grip force, dynamic change coefficients of the normal reaction of vehicle axle that takes into account the constructive parameters of the vehicle, various travel modes (start, stop, cornering), geometry, nature and condition of the road, etc.

Key words: *vehicle, wheel, axle, dynamic load, numerical calculation*

1. INTRODUCTION

The normal reaction to the vehicle axle refers to the sum of the normal reaction at the respective wheels axles. For the stoping vehicles, the normal reactions to the axles are influenced by static weight distribution of the vehicle axle, the center of gravity and by the inclination of the road. When driving, there is a redistribution of the normal static axle and wheels load because of the additional forces and moments that arise [3, 12, 13]. Redistribution of the normal load on the axles is influenced by the vehicle regime of movement, loading status, the driving axle position, the construction characteristics of the vehicle and the road characteristics [2, 3, 4, 5, 6, 9].

The tangential reactions at the wheels are limited by the grip, so the normal reactions to the axles can not exceed certain limits [2, 9, 11].

In the case of a vehicle with two axles, to whom *the rear axle is the driving axle and the front axle is non-driving* axle the coefficients of dynamic change of the normal reaction to the front axle m_{d1} and rear axle m_{d2} has subunit values respectively above par values ($m_{d1} < 1$ and $m_{d2} > 1$), which shows that during the movement of such a vehicle, there is a unloaded of the front axle and a load of rear axle, compared to their static loads. At such vehicles, for the normal movement conditions, the rear axle is loaded additionally with about 10…30% as compared to static load [3, 4, 11, 12]. For a vehicle with rear-wheel drive, at starting, with the center of gravity remoteness towards the front axle, the grip coefficient increases because of the rear axle dynamic loading [8]. Results on the variation of the dynamic load coefficient m_{d2} in the ratio between the height of the center of gravity h_g and wheelbase A to a level road were obtained in [13]. For the vehicle, the dynamic load at rear driving axle can exceed the static load by about 20% [13], for a road with good grip. On buses, the maximum gain is approx. 26%, while at the trucks it can be as high as approx. 36% [13].

In the case of a car with two axle, to whom *the front axle is the driving axle and the rear axle is non-driving axle*, $m_{d1} < 1$ and $m_{d2} > 1$ which shows that during the movement of the vehicle with the engine in front axle, there is a unload on front axle and a loading of the rear axle, compared to their static loads [4, 11]. Results on the variation of the change coefficient for the normal reaction m_{d1} at the front axle, according to the wheelbase and the grip coefficient was obtained in [4].

Under normal circumstances (A = 2.5…4.5 m), the changing coefficient of the reaction to the front axle is m_{d1} = 0.8…0.9 which means that at the movement of the car, the rear axle is loaded additionally with about 10…20% [3, 11]. Results regarding on the variation coefficient m_{d1} according to the report h_g/A were obtained in [13] and results regarding on the center of gravity position on the grip influence for driving front axle vehicle were obtained in [8]. With the increasing of the ratio between the distance beetwen the center of gravity and the front axle *a* and wheelbase *A*, the grip to the front axle decreases, because this axle is dynamically unloaded and rear axle is loading.

In the case of a vehicle with two axles, to which *both axles are driving axles*, $m_{d1} < 1$ and $m_{d2} > 1$ [3, 11, 12], which shows that there is a unloaded during the vehicle movement at the front axle and a loading at rear axle compared to their static loads.

Results regarding the variation of m_{d1} coefficient depending on the distance of the center of gravity to the rear axle *b* and the coefficient m_{d2} depending on the distance of the center of gravity at the front axle *a*, for the same data as in cases above were obtained in [4, 11]. Under normal circumstances (a = b = 1…3 m), the coefficient m_{d1} =0.4…0.8 and the coefficient m_{d2} = 1.2…1.6, which means that dynamic changing of the normal reaction at the vehicle with two axles is much more intensive than single-axle vehicle. This is because the maximum traction force is much greater at the vehicle with both driving axles [3, 4, 11, 12].

In the case of the vehicle startup, whether the vehicle has driven axle to the front, rear driving axle or both driving axles, the coefficient of dynamic change of the normal reaction at the front axle will be subunit value and at rear axle will be above par value, which means that front axle will unloaded dynamic, while the rear axle is loaded dynamically.

In comparison with previous cases, car axle weight distribution and therefore the normal reactions to the two axles *during braking*, is changing. Results regarding the influence of the center of gravity on the grip coefficient for a braked vehicle with two axles, were obtained in [8]. During the vehicle braking, the value of the coefficient of dynamic change for the front axle will be greater than one ($m_{f1} > 1$) and for the rear axle will be subunit ($m_{f2} < 1$), which means that in this case the front axle will be dynamically load, while the rear axle will be dynamically unloaded by approximately 25% compared to their static loads [3, 12].

During *the cornering*, through the centrifugal force, there will be some unloaded of the wheel inside the curve and a dynamic loading of the wheels outside the curve [7].

Thus the dynamic reactions on the transversely plan to the front of the wheels outside of the curve, increased by a certain value beside the static reactions and the wheels inside curve is unloaded with the same amount [7].

Due to this redistribution of the normal load while steering, the wheels inside the curve will have less grip and the exterior wheels will have an increased grip [1].

Results regarding the influence of centripetal acceleration on the normal load redistribution for the wheels inside and outside of the curve have been obtained in [1]. With increasing of the centripetal acceleration, the normal load of the wheel inside the curve will decrease, while the load on the outer wheel will increase.

In Table 1 [10, 13] are surprised the average values for the parameters of the mass center of cars.

Table 1

Average values for the parameters of the mass center of the vehicle

The parameter of the mass center	Load status of the car	Values
$\frac{a}{A}$	empty	0.450…0.540
	loaded	0.490…0.550
$\frac{h_g}{A}$	empty	0.160…0.260
	loaded	0.165…0.260

2. EXPERIMENTAL MEASUREMENTS

The static distribution of axle masses, depending on the additional masses (Fig. 1) for the vehicle in the study (Volkswagen Polo 1.7 SDI 6N1) has been experimentally loaded and it was weighed on the installation for road vehicles axle weighing PCA200, from the RAR - Romanian Automotive Register Salaj. The measurements were carried out for the six different cases of the vehicle load (Fig. 1), at a constant tyre pressure by 0.22 MPa. The results obtained from the measurements are captured in Table 2. The dimensional parameters of the vehicle were taken [15] from its technical data (Length, 3.715 m; Width, 1.655 m; Height, 1.420 m; Wheelbase, 2.400 m; Track front, 1.351 m; Track rear, 1.384 m; Tires, 175/65 R13).

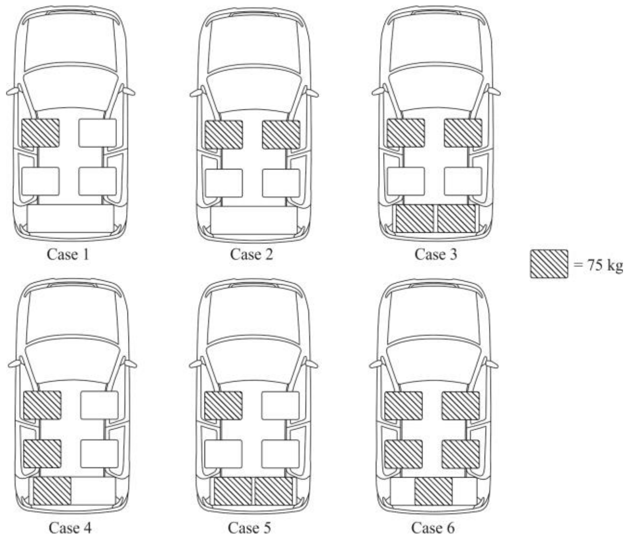

Fig. 1. The loading of the vehicle.

Table 2

Results regarding the normal static axle load distribution

Loading case	Mass on front axle, [kg]			Mass on rear axle, [kg]			Total mass, [kg]
	Left	Right	Total	Left	Right	Total	
The case 1	358	351	709	224	195	419	1128
The case 2	365	376	741	229	215	444	1185
The case 3	359	368	727	286	269	555	1282
The case 4	372	342	714	293	225	518	1232
The case 5	359	343	702	281	247	528	1230
The case 6	369	377	746	301	287	588	1334

3. NOTATIONS USED IN THE NUMERICAL CALCULATION MODEL

Numerical computation algorithm, developed in MathCAD, take into account the constructive parameters of the vehicle, the various regimes of travel (start, stop, cornering), geometry, nature and condition of the road, etc. and is based on the results on the normal static axle load distribution, obtained experimentally in different load situations of the vehicle (see Table 2).

Thus, the main notations used are found in Table 3.

4. METHOD OF NUMERICAL EVALUATION

4.1. Evaluation of the center of gravity

Based on the results obtained by weighing, the calculation model developed allows to determine the center of gravity of the vehicle for each loading case (Fig. 2), depending on the weight distribution of the vehicle on its wheels.

It may be noted that the center of gravity varies depending on how the car is loading.

Table 3

The main notations used in the calculation algorithm

The size	Notation	M.U.
❑ tangential reactions to the front and rear axle	X_1, X_2	N
❑ tangential reactions to the front and rear axle	Z_1, Z_2	N
❑ the amount of dynamic reaction forces at the left and right wheels of the vehicle	Z_s, Z_d	N
❑ the drag	F_a	N
❑ resistance force to start	F_d	N
❑ vehicle weight	G_a	N
❑ static axle loads when the vehicle is at rest on level road	G_1, G_2	N
❑ distance from center of gravity to the front axle and rear axle	a, b	m
❑ height of center of pressure it is considered applied drag force	h_a	m
❑ height of center of gravity	h_g	m
❑ wheelbase of the vehicle	A	m
❑ rolling rays (dynamic) of the wheel to the front axle and rear axle	r_1, r_2 (r_d)	m
❑ maximum grip force	X_{max}	N
❑ maximum grip force when braking	$X_{max\ f}$	N
❑ the wheels lateral reactions	Y_1, Y_2	N
❑ gravitational acceleration	g	m/s^2
❑ distances from the center of gravity to the left wheels or right side of of the vehicle	c, d	m
❑ the gauge of the vehicle	E	m
❑ turning radius	R	m
❑ speed of the of the vehicle	v	km/h
❑ steering angle of the steering wheel compared to the rear axle	θ	deg
❑ the longitudinal inclination of the road	α	deg
❑ transverse tilt of the road	β	deg
❑ angular speed of the car been in cornering	ω	rad/s
❑ coefficients of dynamic change of the normal reaction to the front and rear axles when driving	m_{d1}, m_{d2}	-
❑ coefficients of dynamic change of the normal reaction to the front and rear axles when breaking	m_{f1}, m_{f2}	-
❑ rolling resistance coefficient	f	-
❑ grip coefficient	φ	-

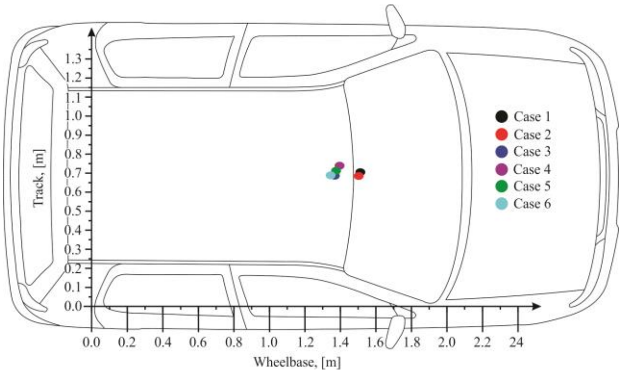

Fig. 2. Position of center of gravity for the six load cases.

4.2. Evaluation of the dynamic load on the longitudinal plane of vehicle axles

In developing of the numerical model calculation for determining the normal reaction to vehicle axles, are using some hypotheses [2]:

– the vehicle is considered as a rigid, neglecting the oscillations caused by the suspension;
– the tyre rolling rays are the same for all wheels;
– the rolling resistance coefficients and the grip are the same for all wheels;
– the loading of the vehicle is considered symmetrical towards the longitudinal plane of symmetry of the vehicle.

Taking into account the vehicle taking in the study, the numerical calculation model is developed for driving front axle (Fig. 3). Given the vehicle weight and center of gravity, has been determinedthe dynamic reactions, maximum grip and dynamic change coefficients for different situations of the road longitudinal inclination (α = 0°, 3°, 6°), and for different states and nature of the road (asphalt or concrete road in good condition, earth road, road with trodden snow).

From the moments equation in relation to A (see Fig. 3) and taking into account that the center of gravity height h_g is considered approximately equal to the height of the pressure center h_a and at the speed at which the maximum traction force is performed, the drag can be neglected and it obtain the calculation for the relationship Z_2 [2, 3, 4, 6, 9]:

$$Z_{2(m)}(j,k,n) = \frac{a_{(m)} + f_{(j,k)} \cdot r_d + \varphi_{(j,k)} \cdot h_g}{A + (\varphi_{(j,k)} + f_{(j,k)}) \cdot h_g} \cdot G_{a(m)} \cdot \cos\alpha_{(n)}, \quad (1)$$

and from the equation of the moment in relation to point B (Fig. 3) results Z_1 [2, 3, 4, 6, 9]:

$$Z_{1(m)}(j,k,n)=\frac{b_{(m)}+f_{(j,k)}\cdot(h_g-r_d)}{A+(\varphi_{(j,k)}+f_{(j,k)})\cdot h_g}\cdot G_{a(m)}\cdot\cos\alpha_{(n)} .\quad(2)$$

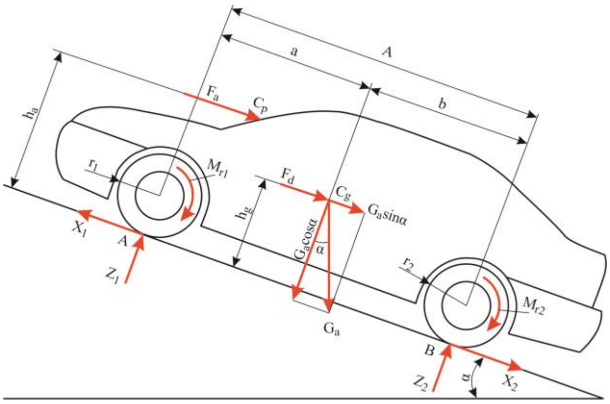

Fig. 3. Scheme of forces, moments and reaction forces acting on a moving car (M_{r1}, M_{r2} - the moments of rolling resistance for front and rear axle).

Since the vehicle has driven front axle, the maximum grip force will be [2, 3, 4, 6, 9]:

$$X_{max\,1}=\varphi\cdot Z_1 . \quad(3)$$

In the developed calculation model, $Z_{1(m)}$ refers to the reaction of the front axle for the loading case *m* (see Fig. 1) and the significance of the three variables *(j,k,n)* is: *j* takes on values from 1 to 3 and refers to the three states and nature of the road (1 - concrete or asphalt driveway in good condition, 2 - earth road, 3 - snow beaten path), *k* takes values from 0 to 20 and refers to the number of values in which is divided the interval between the minimum and maximum for a specific states and condition of the road, and *n* has values from 1 to 3 and relate to the three longitudinal inclination of the road (0°, 3°, 6°).

The coefficient of dynamic change of the normal reaction to front axle m_{d1} and rear axle m_{d2} are given by the ratio between the dynamic normal reaction and static load of a axle [2, 3, 12]:

$$m_{d1}=\frac{Z_1}{G_1}=\frac{Z_1}{G_a}\cdot\frac{A}{b}, \quad(4)$$

$$m_{d2}=\frac{Z_2}{G_2}=\frac{Z_2}{G_a}\cdot\frac{A}{a}. \quad(5)$$

Results on the variation of the dynamic reaction forces, of the maximum grip force and of the coefficient of dynamic change according to the nature and geometry of the road, for case 1 of loading (see Fig. 1), are captured in Figures 4, 5 and 6.

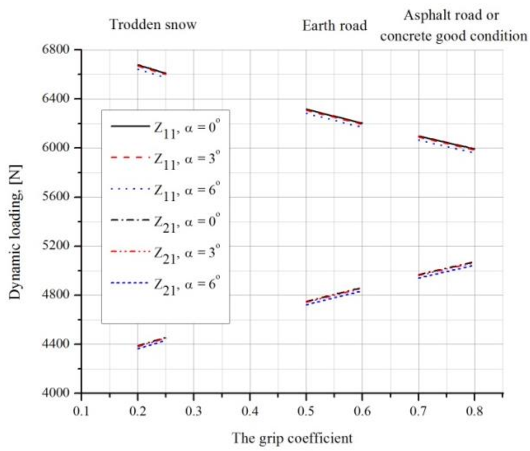

Fig. 4. The variation of the dynamic loading depending on the nature of the road, in *case 1* of loading.

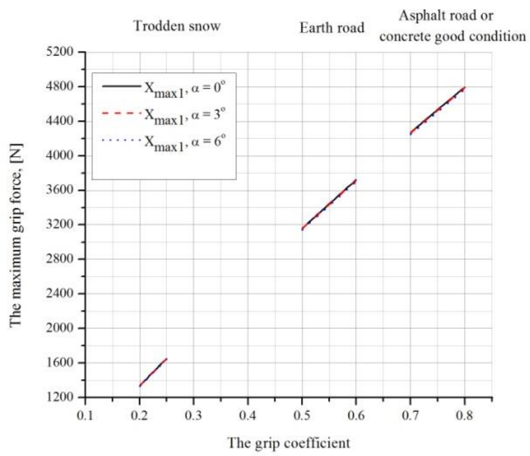

Fig. 5. The variation of the maximum grip force according to the nature of the road, in *case 1* of loading.

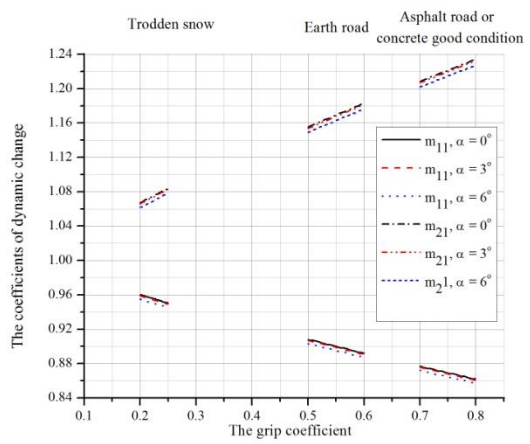

Fig. 6. The variation of the coefficient of dynamic change according to the nature of the road, in *case 1* of loading.

From Figure 4 it is found that the higher grip coefficient is, regardless of the nature and condition of the road, dynamic load on the front axle will decrease, while the dynamic loading will increase the rear axle for a motor vehicle with front axle during startup. Another influence on the dynamic loads has the longitudinal inclination angle α of the road.

The results from the Figure 5 shows that with increase the grip coefficient will increase the maximum grip force, but if the longitudinal inclination α of the road will increases, the maximum grip force will have a lower value because the dynamic reaction of the driven front axle will decrease.

The results captured in Figure 6 shows that the value of dynamic change coefficient for front axle is subunit, and the coefficient of dynamic change coefficient for rear axle is higher than one, which means that, at vehicle starting, once the grip increased, the front axle will have a dynamic charge more pronounced, while the rear axle will have a more pronounced dynamic loading. The longitudinal angle of inclination α has also influence on the results.

For each of the six loading cases (see Fig. 1) during the vehicle startup on a road covered with asphalt or concrete in good condition, there is a redistribution of the static normal loads (see Fig. 7) so that the front axle will have a dinamicaly unloaded around 13%, while the rear axle will be dynamically loaded by approximately 17%.

In figure 8 it can be noticed the way in which it changes the dynamic reactions for the two axles compared to the dynamic reactions obtained according in loading *case 1* for situations where the studied vehicle is loaded as *cases* 2, 3, 4, 5 and 6 (see Fig. 1). The results were obtained when the vehicle is traveling on a level road, covered with asphalt or concrete in good condition.

The way in which shall be modify the maximum grip force for the studied the loaded vehicle, according to *cases* 2, 3, 4, 5, and 6 (see Fig. 1) as against to the maximum grip force obtained for loading *case 1* (see Fig. 1), can follow in Figure 9. The results were obtained for a level road covered with asphalt or concrete in good condition.

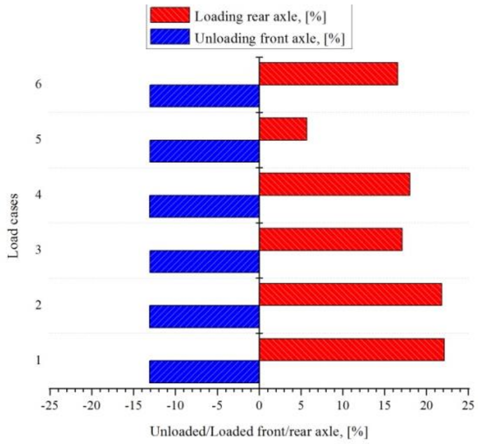

Fig. 7. Unloaded/loaded front/rear axle.

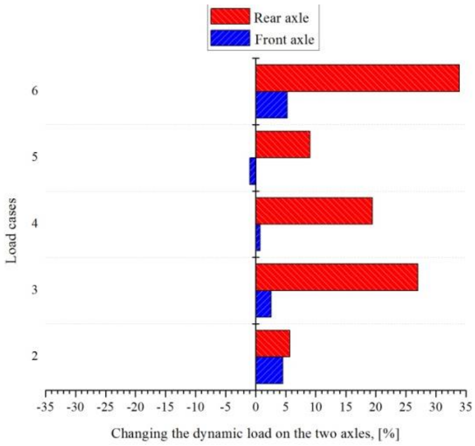

Fig. 8. Changing the dynamic load to the two axles compared to *case 1* of loading.

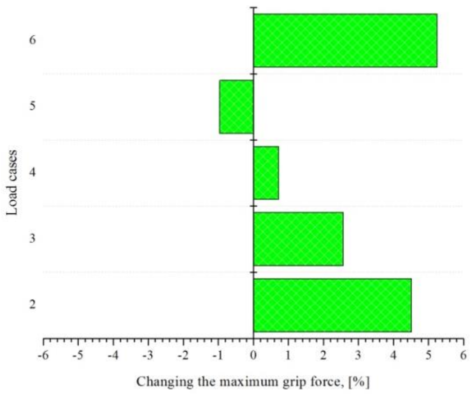

Fig. 9. Changing the maximum grip force than *case 1* of loading.

4.3. Evaluation the dynamic loading of vehicle axles, when is braking

The dynamic reactions in this case, is determined from the equations of moments towards to the points A and B (Fig. 10) [2, 3, 4, 6, 9]:

$$Z_{2(m)f}(j,k,n) = \frac{a_{(m)} + f_{(j,k)} \cdot r_d - \varphi_{(j,k)} \cdot h_g}{A} \cdot G_{a(m)} \cdot \cos\alpha_{(n)}, \quad (6)$$

$$Z_{1(m)f}(j,k,n) = \frac{b_{(m)} + \varphi_{(j,k)} \cdot h_g - f_{(j,k)} \cdot r_d}{A} \cdot G_{a(m)} \cdot \cos\alpha_{(n)} \cdot \quad (7)$$

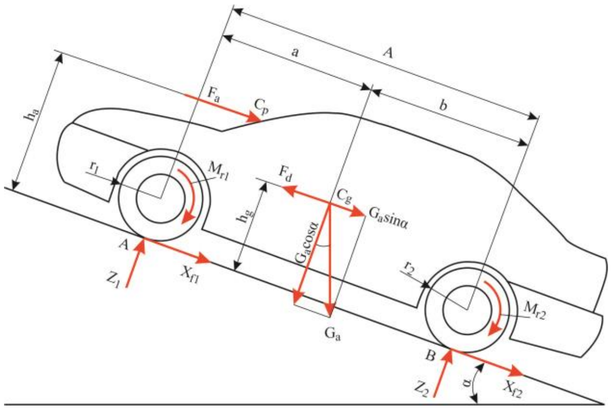

Fig. 10. The scheme of forces, moments and reaction forces which acts on of the vehicle with two axles during braking.

When braking, the dynamic changing coefficients of the normal reaction to the two axles are given by relations [3, 12]:

$$m_{f1} = \frac{b + \varphi \cdot h_g}{b} \cdot \cos\alpha\,, \quad (8)$$

$$m_{f2} = \frac{a - \varphi \cdot h_g}{a} \cdot \cos\alpha\,. \quad (9)$$

The maximum grip force when braking will be of the form [2, 3, 4, 6, 9]:

$$X_{\max f} = \varphi \cdot (Z_1 + Z_2). \quad (10)$$

In this situation too, the relationship calculation are written as $Z_{1(m)f}(j,k,n)$, where f relates to braked, for the rest are the same meanings as in the relations (1) and (2).

When the vehicle is braking, the results regarding at the variation of dynamic reactions on maximum grip force and for the changing dynamic coefficients depending on the nature and geometry of the road for loading *case 1* (see Fig. 1) are captured in Figures 11, 12 and 13.

In the case of a braked vehicle with both axles, with increasing the grip coefficient, increases too the dynamically loading on the front axle, while the rear axle reduces the dynamic loading (see Fig. 11), and maximum grip force increases with increasing the grip coefficient (see Fig. 12). In such cases, the coefficient of dynamic change for the front axle is greater than one, and the coefficient of dynamic change to the rear axle is subunit (see Fig. 13), which means that during the braking, the front axle is loaded dynamically, while rear axle is dynamic unloaded.

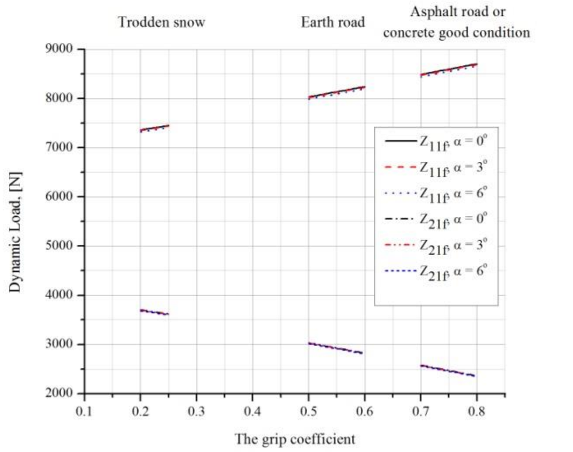

Fig. 11. The variation of the dynamic loads, when braking, depending on the nature of the road, in *case 1* of loading.

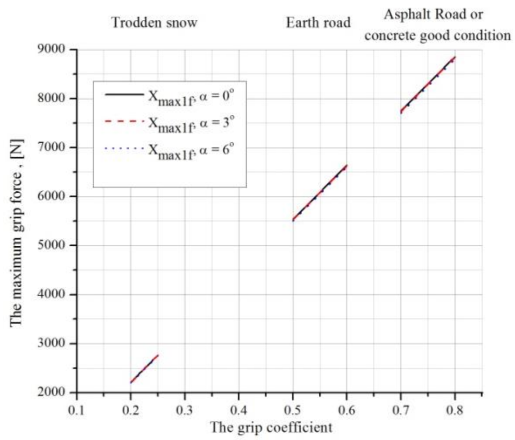

Fig. 12. The variation of the the maximum grip force in the case of braking, depending on the nature of the road, in *case 1* of loading.

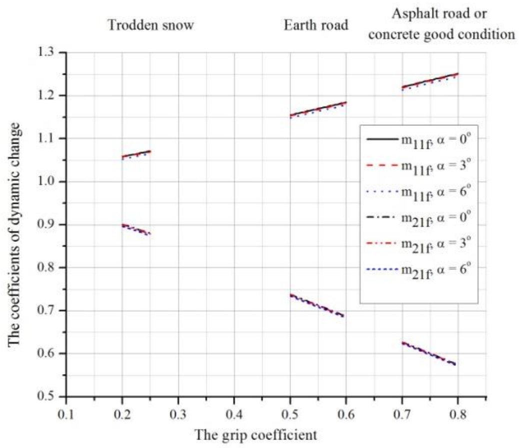

Fig. 13. The variation of the dynamic change coefficient in the case of braking, depending on the nature of the road, in *case 1* of loading.

Figure 14 captures as a percentage for each of the six loading cases (see Fig. 1), the dynamically loading of the axle front respectively the dynamic unloaded of the rear axle when the vehicle is braking. During the braking of the vehicle, there is a unload of the rear axle by approximately 36%, while the front axle is loading by about 25% (see Fig. 14). Results were obtained for a level road covered with asphalt or concrete in good condition.

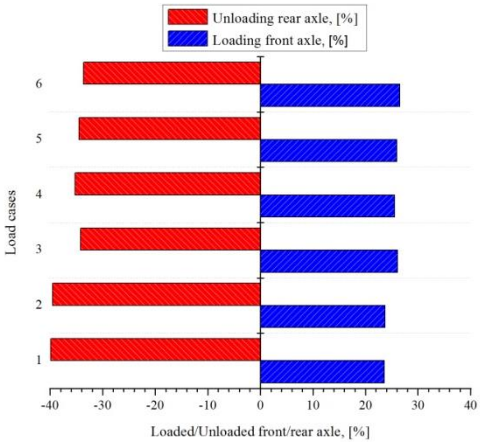

Fig. 14. Loading / unloading to the front /rear axle when braking.

The way that it's changes the dynamic loads on the two axles of the braked vehicle on both axles, loaded as in *the cases* 2, 3, 4, 5 and 6 (see Fig. 1), compared to dynamic loads obtained for loading *case 1* (see Fig. 1), one can follow in Figure 15. The results were obtained for a level road covered with asphalt or concrete in good condition.

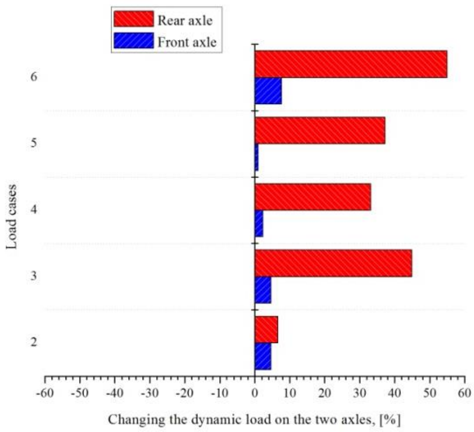

Fig. 15. The dynamic load modification at two axles, in the case of braking, compared to loading *case 1*.

In the figure 16 is surprised how it changes the maximum grip force on both axles of the braked vehicle, loaded according to *the cases* 2, 3, 4, 5 and 6 (see Fig. 1), compared to the maximum grip force obtained for the loading *case 1* (see Fig. 1). Results were obtained for a level road covered with asphalt or concrete in good condition.

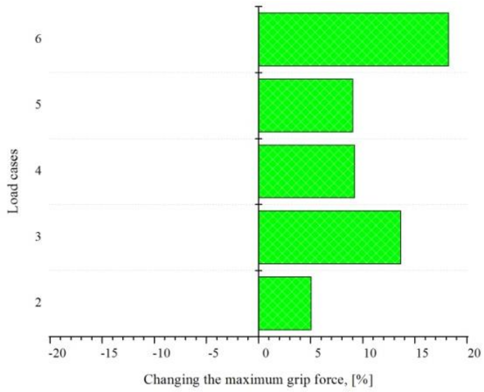

Fig. 16. Changing the maximum grip braking force compared to loading *case 1*.

It can be seen that as against the loading *case 1*, in all other loading cases considered (see Fig. 1), dynamic loads (Fig. 15) and maximum grip strength (Fig. 16) shows an increase.

4.4. Evaluation of dynamic loading of the vehicle wheels in transverse plane, on the sloping road and in cornering

The determination of the dynamic reaction on the transverse plane is made when the vehicle is moving on a road with transverse tilt *β* while it executing a right turn. The forces and moments that acting on the vehicle are located in the corner are shown in Figure 17 [6, 10, 14].

The normal reaction on the left or right of the vehicle is determined by the equations of moments in relation to points C and D (Fig. 18) [6, 9, 10, 14]:

$$Z_s = \frac{(F_{iy} \cdot \cos\beta - G_a \cdot \sin\beta) \cdot h_g + (F_{iy} \cdot \sin\beta + G_a \cdot \cos\beta) \cdot d}{E}, \quad (11)$$

$$Z_d = \frac{(F_{iy} \cdot \sin\beta + G_a \cdot \cos\beta) \cdot c - (F_{iy} \cdot \cos\beta - G_a \cdot \sin\beta) \cdot h_g}{E}. \quad (12)$$

in which, for v = ct. and R = ct., inertial force F_{iy}, is given by [10]:

$$F_{iy} = \frac{G_a \cdot v^2}{g \cdot R}. \quad (13)$$

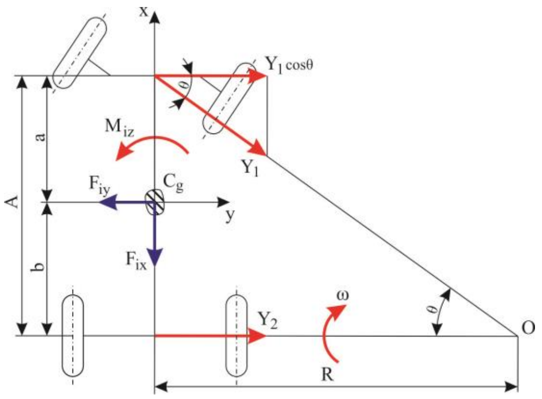

Fig. 17. Forces and the moments which acts on of the vehicle when driving in cornering. C_g - center of gravity; F_{iy} - transversal inertial force; F_{ix} - longitudinal inertia force; M_{iz} - resistance moment of turning; Y_1 and Y_2 - the lateral reactions of the wheels; R - turning radius; θ - the steering angle of the steering wheel compared to the rear axle; ω - angular speed of the vehicle found in the cornering.

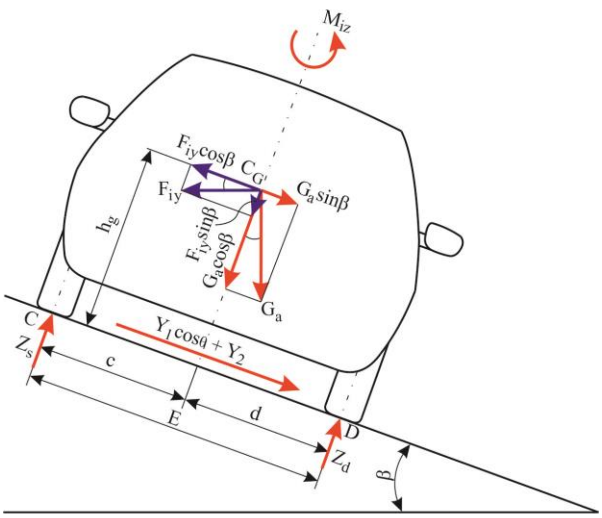

Fig. 18. Moments and forces which acts on of the vehicle when driving on a cornering road with transverse tilt.

In the calculation of the developed model, the calculation are written in the form $Z_{s(m)}(hv,lr,nt)$, in which *s* means the reaction on the left wheel, m refers to the m loading case (see Fig. 1) and the variables *(hv,lr,nt)* have the following specifications: *hv* take values from 1 to 6 and it relate to the speed of the vehicle 1 - correspond to the speed of 30 km /h, and 6 - the speed of 80 km/h, the speed increases from 10 to 10 km/h; *lr* take values from 1 to 5 and relate to the curve radius which increases from 40 to 200 m from 40 to 40 m, and the *nt* values from 1 to 3 and refers to the angle of inclination β of the road cross; 1 - corresponds to the angle of 0°, 2 - for β = 2.5° and 3 - to β = 5°.

For the *case 1* of loading (see Fig. 1), in figures 19 and 20, are captured the variation of the dynamic load to left wheels respectively to right wheels of the vehicle, depending on its speed, to the movement in turn for different curve radius, and for different angles of the road. In the figures 21 and 22 are captured the dynamic load variations of the left wheels and right wheels of the vehicle, depending on the radius of the curve, as it moves in cornering, for different speeds, and for different transversal angles of the road.

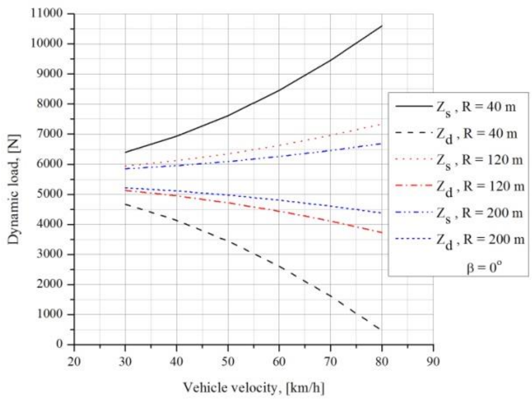

Fig. 19. The variation of the the dynamic loading depending on the vehicle speed, in the case of different curve radius, for *case 1* of loading.

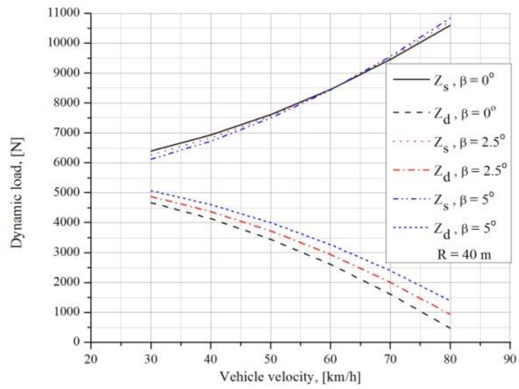

Fig. 20. The variation of the dynamic loads depending on the vehicle speed, on different transversal angles of the road for *case 1* of loading.

In the figure 19 it can be follow the variation of dynamic loads depending on vehicle speed to a different road level and curve radius. It is observed that with increasing the radius of the curve, the dynamic loading on the left wheels respectively the dynamic unloaded of the right wheel is not so pronounced.

In the figure 20 is surprised the variation of dynamic loading depending on the vehicle speed for a constant curve radius for different transversal angles of the road.

The variation of the dynamic loads on the radius of the curve for a horizontal road and different speeds of the vehicle, is captured in Figure 21.

In the figure 22 it can be follow the variation of dynamic loads depending on the radius of the curve for a constant speed of the vehicle and different transversal angles of the road.

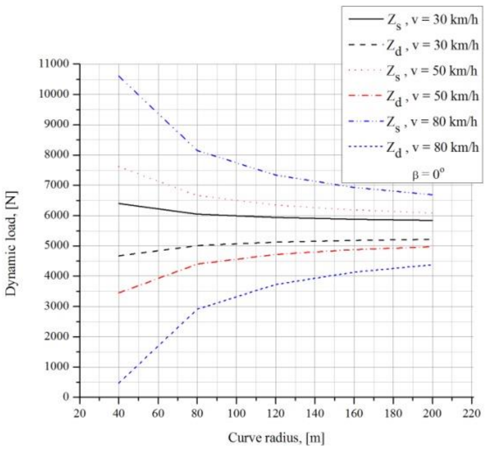

Fig. 21. The variation of the dynamic loads depending on the radius of the curve when the different speeds of the vehicle, for *case 1* of loading.

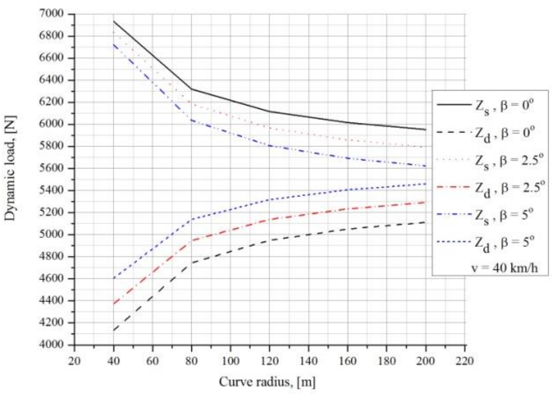

Fig. 22. The variation of the dynamic loads depending on the radius of the curve when various transversal angles of the road for *case 1* of loading.

In the Figure 23 it is shown as a percentage the dynamic load of the left wheel respectively right wheel of the vehicle for each of the six load cases considered (see Fig. 1). The results obtained for the situation where the vehicle moves uniformly accelerated on a right turn with a curve radius R = 40 m, shows that the wheels from inside the curve are dynamically unloaded with about 47% while the outer wheels are dynamic load around 45% for each of the six load cases considered (see Fig. 1).

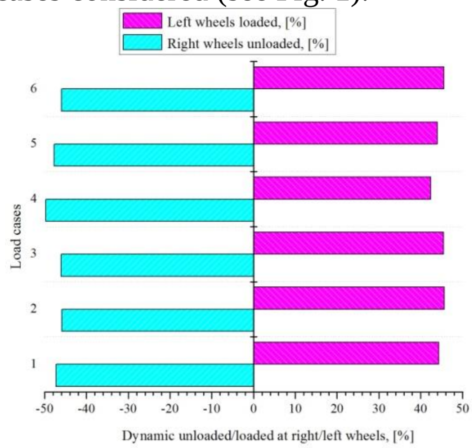

Fig. 23. Dynamic unloading / loading at right /left wheels when cornering.

In the Figure 24 it is shown how it's modify the dynamic reactions on the left wheels and on the right wheels for a loaded vehicle in accordance with *the cases* 2, 3, 4, 5 and 6 (see Fig. 1), compared to the dynamic reactions obtained for *case 1* of loading (see Fig. 1). The results were obtained for a situation where the vehicle moves uniformly accelerated in a right turn on a road with a curve radius R = 40 m.

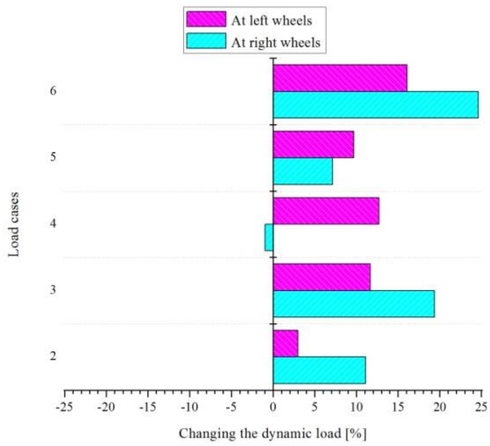

Fig. 24. Changing the dynamic loading, in transversely plan compared to *case 1*.

5. CONCLUSIONS

Studies, the researches and the experimental measurements taken during the preparation of this paper, allowed the possibility of issuing final conclusions regarding the proposed theme:

- the redistributing of the static normal load when the car is in motion is influenced by technical parameters of the vehicle (wheelbase, track width, center of gravity, etc.), how is the loading mode, the nature and condition of the road, and the longitudinal and transverse inclination of the road;
- the dynamic axles loads/wheels are also influenced by the mode of operation of the vehicle (starting, braking or cornering movement), the position and number of axles;
- the maximum grip force is influenced by the position and number of axle / brake, dynamic loading, or to the nature and condition of the road;
- the safe vehicle movement is conditioned by its stability during exploitation so it is necessary to determine the boundary conditions that may lose stability and its behavior for different modes of travel;
- the calculation model developed can be adapted for the other types of passenger cars and for other load cases or other operating conditions of each vehicle;
- the use of computer simulation programs it is necessary to analyze the vehicle behavior in various situations of exploitation and determine the boundary conditions of stability, due to the advantages that they offer (reduced working time, achieving results very close to actual costs relatively low, etc.).

6. REFERENCES

[1] Abe, M., *Vehicle Handling Dynamics, Theory and Application.* Oxford, Butterworth-Heinemann, Published by Elsevier Ltd., 2009.

[2] Andreescu, C., *Dinamica autovehiculelor pe roți*. Vol.1. București, Editura Politehnica Press, 2010.

[3] Câmpian, V.; ș.a., *Automobile*. Brașov, Editura Universității Transilvania din Brașov, 1989.

[4] Ghiulai, C.; Vasiliu, C., *Dinamica autovehiculelor*. Bucuresti, Editura Didactică și Pedagogică, 1975.

[5] Gillespie, T.D., *Fundamentals of Vehicle Dynamics.* Warrendale, PA: Society of Automotive Engineers, 1992.

[6] Macarie, T.N., *Automobile. Dinamica*. Piteşti, Editura Universităţii din Piteşti, 2003.

[7] Pacejka, H.B., *Tyre and Vehicle Dynamics. Second Edition*. Oxford, Marea Britanie, Editura Elsevier Ltd., 2006.

[8] Reza, N.J., *Vehicle Dynamics: Theory and Applications,* New York, Statele Unite ale Americii, Editura Springers Science+Business Media, LLC, 2008.

[9] Tabacu, Şt.; ş.a., *Dinamica autovehiculelor. Îndrumar de proiectare*. Piteşti, Editura Universităţii din Piteşti, 2004.

[10] Todoruț, A., *Bazele dinamicii autovehiculelor*. *Algoritmi de calcul, teste, aplicații*. Cluj-Napoca, Editura Sincron. 2005.

[11] Untaru, M.; ș.a., *Automobile*. București, Editura Didactică și Pedagogică, 1968.

[12] Untaru, M.; ș.a., *Automobile*. București, Editura Didactică și Pedagogică, 1975.

[13] Untaru, M.; ș.a., *Dinamica autovehiculelor pe roți*. București, Editura Didactică și Pedagogică, 1981.

[14] Untaru, M.; ș.a., *Dinamica autovehiculelor*. Braşov, Universitatea Transilvania din Braşov, sectorul Reprografie U02, 1988.

[15] *** *Cars specifications,* http://carsspecifications.com/auto/volkswagen/polo/polo-6n1-1-7-sdi.htm, (accesat la 30/05/2014).

EVALUAREA REDISTRIBUIRII SARCINII NORMALE STATICE PE PUNȚI ȘI ROȚI, ATUNCI CÂND AUTOTURISMUL SE AFLĂ ÎN MIȘCARE

Rezumat: Cunoaşterea reacţiunilor normale la punţile autoturismului este necesară pentru determinarea aderenţei acestuia şi pentru studiul problemelor legate de frânarea şi stabilitatea lui în timpul deplasării. Mărimea acestor reacţiuni este influenţată de condiţiile de deplasare şi de parametrii constructivi ai autoturismului. Încărcările dinamice ale punților autoturismelor se studiază datorită influențelor pe care acestea le au asupra forțelor de aderență și pentru studiul problemelor legate de frânarea și stabilitatea acestora în timpul deplasării. În timpul exploatării autoturismelor, forțele de

aderență la roțile cu încărcare dinamică mai mare vor crește, iar la cele cu încărcare dinamică mai redusă vor scădea, având influență directă asupra stabilității lor.

Pentru evaluarea redistribuirii sarcinii normale statice pe punți, atunci când autoturismul se află în mișcare, în diferite situații de exploatare, se recurge la: efectuarea unor măsurători experimentale cu privire la determinarea sarcinilor normale statice pe punți, pentru diferite situații de încărcare ale autoturismului; determinarea poziției centrului de greutate pentru situațiile de încărcare luate în considerare; elaborarea unui model de calcul numeric în MathCad care să permită obținerea de rezultate cu interpretare grafică a încărcărilor dinamice ale punților autoturismului, forța maximă de aderență, coeficienţii de schimbare dinamică a reacţiunilor normale pe punţile autoturismului și care să țină seama de parametrii constructivi ai autoturismului, diferitele regimuri de deplasare (demaraj, frânare, viraj), geometria, natura și starea drumului etc.

Adrian TODORUȚ, PhD. Eng., Associate Professor, Technical University of Cluj-Napoca, Faculty of Mechanical Engineering, Department of Automotive Engineering and Transports, Romania, adrian.todorut@auto.utcluj.ro, Office Phone 0264 401 674.

Nicolae CORDOȘ, PhD. Eng., Lecturer, Technical University of Cluj-Napoca, Faculty of Mechanical Engineering, Department of Automotive Engineering and Transports, Romania, Nicolae.Cordos@auto.utcluj.ro, Office Phone 0264 202 790.

Mihai-Dan BURDEA, Eng., Automotive Engineering - Road Vehicles, & Student of Master - Vehicle and Environment, Technical University of Cluj-Napoca, Faculty of Mechanical Engineering, Department of Automotive Engineering and Transports, Romania, burdea.mihai@gmail.com.

Monica BĂLCĂU, PhD. Eng., Lecturer, Technical University of Cluj-Napoca, Faculty of Mechanical Engineering, Department of Automotive Engineering and Transports, Romania, monica.balcau@auto.utcluj.ro, Office Phone 0264 401 610.