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RADU CHIRIAC

DIAGRAMA INDICATĂ PENTRU MOTORUL CU ARDERE INTERNĂ



EDITURA AGIR

- The actual development of humanity is based in its major part on fossil resources consumption, among which oil is on top.

The internal combustion engine, probably one of the most improved inventions of mankind is nowadays in an almost paradoxical situation; it has an increased market demand but in the same time, it must accomplish more severe restrictions.

A more powerful, more efficient, more reliable, less pollutant and continuously cheaper engine is highly demanded, but seems to be quite an impossible thing.

- Due to the hard competition in the field of the automotive industry very sophisticated equipments for experimental investigation are used in order to ensure fuel savings and greenhouse gas emissions reductions. However behind many of the recent achievements there still is a classical investigation method, the pressure indicated diagram.

- This work intends to offer the reader a general overview on this subject, together with a detailed image on what is the instrumentation, the demands and the accuracy conditions necessary for sound results. It is mostly addressed to students, engineers and specialists from the internal combustion engines domain, but also to those who want to know more on this topic.

The book is organized in three chapters, pressure indicated diagram sampling, calculation models related to the pressure diagram and analysis, prediction and optimization techniques based on pressure diagram. It covers subjects as, piezoelectric pressure measurement system, thermodynamic, zero-dimensional and phenomenological models, cycle-by-cycle engine variability, and engine knock phenomena, rate of heat release influence on engine performance.

Cartea are la bază cursuri susținute la Universitatea Tehnică din Iași. Ea se dorește a fi și un util material de studiu individual pentru specialiștii angrenați direct în industria automobilelor, pentru experții și evaluatorii tehnici, ori pentru cei care lucrează în domenii conexe.

O motivare majoră a editării volumului II constă în detalierea unor tehnologii recente din industria autovehiculelor care vizează direct sau indirect siguranța pasagerilor.

În capitolul trei (primul capitol al prezentului volum), sunt prezentate principii și soluții tehnologice ce permit disiparea unei energii importante din impact în structuri deformabile speciale, menținând astfel în stare cât mai intactă cabina pasagerilor. Tot în acest capitol sunt tratate pentru prima dată în țară în mod detaliat sistemele pasive de securitate ce asigură și protejează pasagerii pe durata producării coliziunilor, centurile de siguranță, respectiv dispozitivele airbag.

În capitolul patru este abordat sistematic subiectul limitelor biomecanice ale corpului uman, insistându-se asupra indicilor de codificare a gravitației unor traumatisme, ca și pe definirea coridoarelor de siguranță specifice diverselor părți ale corpului afectate în impact. Tot aici sunt prezentate în detaliu familii de manechine fizice și virtuale utilizate în testările experimentale, respectiv simulările virtuale ale diverselor tipuri de coliziuni și a urmărilor acestora asupra pasagerilor.

În capitolul cinci s-a analizat în detaliu influența personalității, a comportamentului uman și a reacțiilor conducătorilor auto asupra producerii accidentelor, prin prisma neadaptării la cerințele traficului. Este analizată în detaliu corelația dintre unii indici accidentologici și anumiți factori perturbatori, printre care amintim consumul de alcool, de medicamente și de droguri, starea de sănătate sau de oboseală; totodată, au fost examineate și erorile de conducere provenite din percepția inexactă a realității.

Deosebit de util este și studiul privind managementul siguranței rutiere prezentat în al șaselea capitol, tratarea problematicii abordate după metodele actuale utilizate în CE garantând succese similare, care sunt deja vizibile și în aplicațiile recente din țara noastră.

Capitolul șapte este dedicat unei noi discipline, accidentologia rutieră, apărută și dezvoltată în lume în ultimii 35 ani, dar ale cărei influențe în reducerea numărului și gravitației accidentelor rutiere s-au făcut simțite. Se oferă accesul la metodologiile moderne, economice, sigure și eficiente, de reducere a numărului și gravitației accidentelor, a căror aplicare poate diminua rapid decalajele țării noastre față de statele CE în ceea ce privește siguranța circulației.

Ultimul capitol analizează rolul infrastructurii și logisticii rutiere asupra siguranței traficului; materialul prezintă interes prin expunerea sintetică a normativelor ce trebuie respectate la construcția și întreținerea drumerilor și podurilor, la semnalizarea și dirijarea intersecțiilor, la iluminarea și vizibilitatea obstacolelor.



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- The affiliation at International Federation of Automotive Engineers Societies and (European Automobile Engineering's Cooperation and the organization in Brasov of two FISITA Council reunions;
- The establishing of partnerships with the member societies of FISITA. A main point in this activity was the partnership with SAE International (USA), established in 1996;
- The stimulation of engineers, specialists, researchers, students to participate with papers at Internationals Congresses;
- The including of SIAR Congresses at Brasov (CONAT), Bucharest (ESFA), Pitesti (CAR), Craiova (SMAT), Cluj-Napoca (AMMA) and Timisoara (MVT) under the patronage of FISITA - EAEC;
- The organization of seminars, conferences and professional reunions for specialists in transportation, automobiles, road telematics, vehicles accident reconstruction, quality, material science, electronics and computer science, development, diagnosis, liability;

The cooperation with the Auto Test review will improve the professionalism, scientific level and distribution area and will promote the quality of the studies, research and projects of our automotive school.

*Prof. Dr. Eng. (Ph.D.) Anghel CHIRU
Dean, University of Brașov*

Privilegii pentru vehiculele din UE

Principiul liberei circulații a bunurilor semnifică, în cazul vehiculelor rutiere, faptul că un anumit vehicul deja omologat comunitar de tip pe baza unei directive cadru, aşadar cel pentru care s-a demonstrat îndeplinirea cerințelor tehnice impuse, nu mai necesită reomologare la introducerea lui în România. Procedura aplicabilă la achiziționarea unui vehicul din România trebuie să fie absolut aceeași cu cea aplicabilă în cazul în care vehiculul ar fi cumpărat din oricare alt stat membru UE.

Și, cel puțin în ceea ce privește atribuțiile RAR, vă asigurăm de respectarea deplină a celor de mai sus. Ca o consecință directă, apare ca element de noutate renunțarea la impunerea criteriului de poluare la prima înmatriculare în România a vehiculelor utilizate (vestitele norme Euro 3), dar numai pentru vehiculele care au fost ultima dată înmatriculate într-un stat membru UE. Celealte vehicule (ca incidență se remarcă cele din Statele Unite și Canada) trebuie în continuare să respecte normele de poluare europene Euro 3.

În concluzie, aderarea României la UE aduce o tratare preferențială pentru vehiculele din UE din punct de vedere al simplificării procedurilor RAR (tarife mai mici și tempi de răspuns de asemenea mai buni), în timp ce pentru vehiculele care provin din afara UE nu se modifică modul de lucru care se aplică și până acum.

Fără a comenta dezbatările generate de aplicarea taxei speciale pentru prima înmatriculare în România și mai ales rezultatul lor final, sperăm ca mentalitatea noastră să nu compromită eforturile care durează de 15 ani și prin care, deocamdată, am reușit să nu devenim ultima destinație a vehiculelor uzate ale Europei.

*Sef Departament Omologări Individuale
Cristian BUCUR*



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Lean Mixtures - a Reached Purpose

Using the Conversion of a Classical Internal Combustion Engine

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REZUMAT

Lucrarea prezintă o posibilitate interesantă de folosire a amestecurilor sărace în motoarele cu aprindere prin scânteie prin transformarea unui propulsor clasic cu ardere internă, apelând la soluții tehnice complexe. Beneficiul principal al soluției de stratificare a amestecului bazată pe injecția directă de combustibil într-o cameră de ardere divizată, fiind obținerea unui consum redus de combustibil în condițiile unui nivel de poluare acceptabil. Problema cea mai dificilă de realizat a reprezentat-o formarea amestecului carburant. Utilizând un echipament de injecție mecanic și pornind de la forma și structura jetului de combustibil injectat s-a determinat arhitectura camerei de ardere și poziționarea punctului de aprindere. Experimentele efectuate au avut ca punct de plecare atât un fundament teoretic solid, dar și simularea numerică.

The research in the field of mixture formation designed with a view to improving power, consumption and pollution performances, is mainly centered on two directions:

- improvement of engine functioning in the partial loadings, by employing lean mixtures; in these operating conditions the spark ignition engine for automotive applications is often used uneconomically;
- improvement of mixture formation based on development of auxiliary equipment.

During the burning process in the common spark ignition engine, there are two opposite phenomena. For the first period of the burning process, when the initialization of the flame nucleus is started, a reach mixture and less turbulence is necessary in the spark plug area. Otherwise in the second period of the burning process, when the flame is developed in the burning chamber, a great turbulence is necessary. To achieve those objectives there are two issues:

- stratified charge, in the manner to obtain a rich mixture only in the spark plug area;
- to separate the initialization of the flame nucleus by the flame development in the combustion chamber.

Our concept is developed around the second idea, which means to separate the initialization of the flame nucleus from the rest of burning processes. It is well known that many engine producers are using a lot of principal components of the engine like the cylinder block, the crankshaft, connecting rod, etc., for both the diesel and the gasoline engine.

The existence of originally high-pressure injection equipment and our own experience in the field have made possible for us to approach the complex aspect of direct injection. We have chosen a convertible engine (76 mm cylinder bore, 77 mm stroke) and have approached simultaneously the problem of formation and combustion of lean mixtures.

To study the latter we have chosen, on a preliminary stage an injection pump with oil under pressure for greasing the pumping unit, a pump without discharge regulator. The classic pump camshaft was changed with a camshaft with eccentric profile. We have chosen a flame jet engine quite different from previously designed engines of this type by using a divided combustion chamber and in ensuring a $\gamma = 0,47$ ratio between the volume of combustion chambers, fig. 1. At this engine, the cylinder block, the crankshaft, the connecting rods are from the gasoline engine, and the cylinder head and the camshaft from the diesel engine. The pistons were modified to obtain a convenient compression ratio. The main combustion chamber is fed by a designed electronic fuel injection, the intake manifold has no throttle, and the secondary combustion chamber is fed by means of a mechanical injection pump. The best moment for beginning of injection is 75° before TDC, in

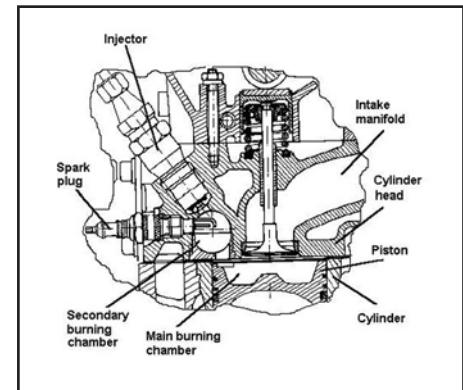


Fig. 1 The stratification solution

compression process.

One of the difficult problems was to choose the ignition point, because the procedure uses the rotation movement of the air in the secondary combustion chamber and fuel drops, which are centrifugally separated according to their mass, different proportioning, are thus obtained. The convenient modeling of the connection channel between the two burning rooms effects this movement also. At the stratified charge engines, which use the direct mechanical injection fuel, one of the problems is the form and the structure of fuel spray. To know what is happened into the secondary combustion chamber, is necessary to know rotations charging speed, the heat and mass transfer at the fuel drop level, and the modification of air parameters during the compression process. The charging speed motion in the secondary combustion chamber depend on the piston area S_p , the area of the connection channel S_c , the crankshaft angle φ_c at the beginning of the compression process, the crankshaft angle φ_x when the volume of principal combustion chamber is V_x , the piston speed w_x , the discharge coefficient μ in the connection canal, and the crankshaft speed ω . A fuel drop, in relative motion related at warm air, change the initial dimensions do according to the time from the

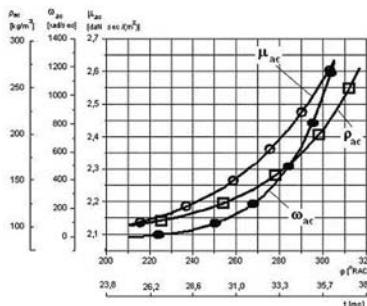


Fig. 2 The evolution of the main parameters from the secondary burning chamber

injection start and the vaporization coefficient k . The air interesting parameters during the compression process are the density ρ_{ac} and the viscosity μ_{ac} . The development of fuel spray, in the secondary burning chamber depend on the pressure and the temperature of fuel mixture during the compression process p_{ac} and T_{ac} , the air constant R_a , the compression ratio e , the air density ρ_a , the crankshaft speed n , the constructive ratio γ and the polytropic exponent n_1 .

The computer simulations presents in fig. 2, the evolution of the main parameters from the secondary burning chamber, according to the

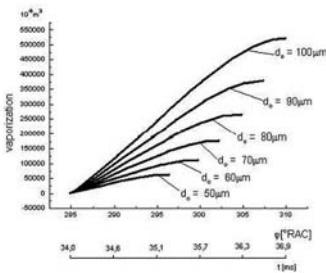


Fig. 3 The fuel drop vaporization

crankshaft movement or time. The graph from fig. 3 presents the fuel drop vaporization (with diameter between 50...100 μm), according to the crankshaft movement or time, and demonstrate that in our conditions, the air motion into the secondary burning chamber has no major influence on the trajectory of the fuel spray. The air motion works over the vaporized fuel drops from the spray. They make few complete rotations in the burning chamber, from the injection moment since the ignition time.

The experimental results, fig. 4, shows the idle running characteristic as compared to classic engine characteristic; the figure also shows volumetric efficiency, air excess coefficients and exhaust gases temperature variations.

Fig. 5 shows the load characteristic and the variation of other significant parameters, at 1600 rpm

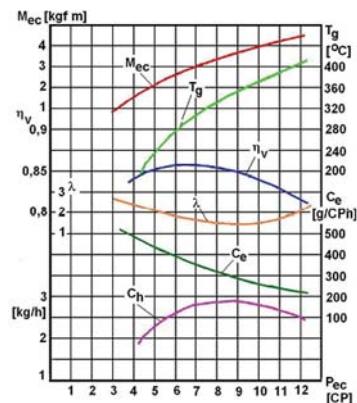


Fig. 5 The load characteristic and the variation of other significant parameters

speed of the engine. Significant results have also been obtained for partial loading as which can be used to drive the automobile at stabilized speed. So for a 22 HP effective power at 3000 rpm at 1,38 air-excess coefficient was obtained, $\eta_v = 0,79$ volumetric efficiency, 247 g/HP h effective specific consumption. For another characteristic engine operating condition for a 27 HP power, 3000 rpm, a 1,23 air-excess coefficient, $\eta_v = 0,79$ volumetric efficiency and 229 g/HP h effective specific consumption were obtained.

In conclusion, the experience stored in the field of injection equipment has made it possible to approach complex problems beginning with modification of mixture formation for existent engines and ranging to new solutions for formation and combustion of lean mixtures which is a field that can yields still unexplored possibilities. Economic advantages and increased cyclic stability plead for the use of the described procedure in the common spark ignition engine feeded by direct fuel injection. Working on a well-known engine, the obtained gain of performance contributes to the improvement of dynamic and consumption qualities of these.

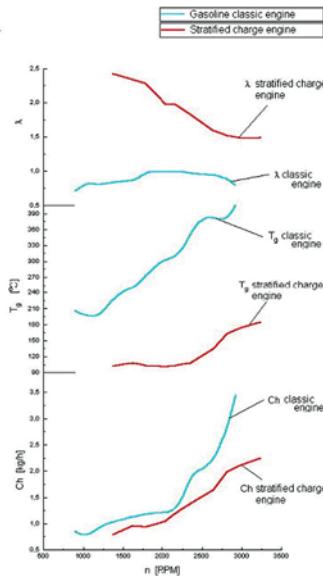


Fig. 4 The idle running characteristic

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Study of the Underhood Airflow on Aerodynamics of the Motorcars

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KEYWORDS - Aerodynamic loads, underhood airflow, underbody drag of vehicle, dimensionless characteristic indicators, optimum drag value

REZUMAT

Studiul aerodinamic al curgerii pe structura inferioară a automobilelor

Comportamentul dinamic al automobilelor în ceea ce privește stabilitatea, manevrabilitatea, sensibilitatea la rafale laterale, cu consecințe directe asupra consumului de combustibil și zgometoului generat de interacțiunea cu aerul atmosferic, este influențat decisiv de forțele aerodinamice care acționează asupra acestora. Până de curând, forma exteroară a caroseriei a reprezentat pentru inginerii proiectanți principala preocupare din punct de vedere aerodinamic, geometria structurii inferioare având un rol secundar în procesul de definire al unui automobil, sau a fost complet neglijată precum în cazul mașinilor de teren. Studii recente au arătat că pentru un automobil modern aproximativ 45% din rezistența aerodinamică se datorează formei caroseriei, 30% roțiilor și pasajelor acestora și 25% geometriei structurii inferioare. După cum se observă, îmbunătățirea caracteristicilor aerodinamice ale geometriei structurii inferioare ale autovehiculelor reprezintă un factor semnificativ în procesul de reducere rezistenței aerodinamice, implicit și a consumului de combustibil. Recent, managementul curgerii aerului pe sub vehicul a devenit una din problemele majore ale proiectării automobilelor.

În acest sens, în lucrare sunt evidențiați fac-

torii care influențează rezistența aerodinamică generată de interacțiunea aerodinamică dintre structura caroseriei inferioare a unui automobil și calea de rulare, având ca punct de plecare modelul teoretic expus în referință [3]. Studiul este însotit de un exemplu de calcul pentru un automobil SUV, a cărui geometrie a structurii inferioare a fost modelată ca tunel Venturi, fiind evidențiate astfel posibilitățile de optimizare a rezistenței aerodinamice.

The aerodynamic performances of the vehicles are characterised using specific coefficients, dimensionless, as drag and lift coefficients. Using of these as the measure of the state of the art in the vehicle aerodynamics, the continuously progress is possible in this field. In this context, because the decomposition of the aerodynamic forces into measurable components would facilitate the optimisation design process of the carriage body, in the previous study [3] was presented a theoretical method for computing of the drag due to the underhood airflow. In this sense, was proposed the decomposition of the global drag, D , into two components, D_{ext} and D_{ub} . The first one is the drag due to the flow upon the external surface of the vehicle, having the rate flow Q_{ext} . The second term represents the drag due to the flow under the body of vehicle, in the space determined by the lower surface of the vehicle and the road, treated as a convergent-divergent air nozzle with the flow rate Q_{ub} . Also, dimensionless indicators were defined to characterise the underhood airflow as following: CD_{ub} , drag coefficient of the

underbody, KD_{ub} , coefficient what represent the ratio between underbody drag and total drag and KQ_{ub} , coefficient what characterise the participation of the underbody flow rate on total flow rate Q .

In this paper are emphasised the main factors which having importance on the underbody drag and which may lead to optimising steps with respect to the aerodynamics of the vehicles. The study is illustrated by means of a numerical exemplification performed with a SUV model having the underbody geometry modelled as a Venturi tunnel. The parametric study of the underbody drag coefficient permits the plotting of a diagram of this as function of the dimensionless indicators, which reveal an optimum of CD_{ub} .

THEORETICAL CONSIDERATIONS

The total drag D of the vehicles is determined by the dynamic interaction between the vehicle, adequately shaped, in motion, and the atmospheric air from upstream, motionless. The air envelopes and flows from the leading edge (the zone of the radiator) on the lateral, upper surface and under the vehicle. It can be computed using the following Equation:

$$(1) \quad D = \frac{\tilde{n} \cdot v_\infty^2}{2} c_D A$$

where:

- \tilde{n} - is the air density;
- v_∞ - is the relative velocity between vehicle and air;
- c_D - is the drag dimensionless coefficient in body axis coordinates;

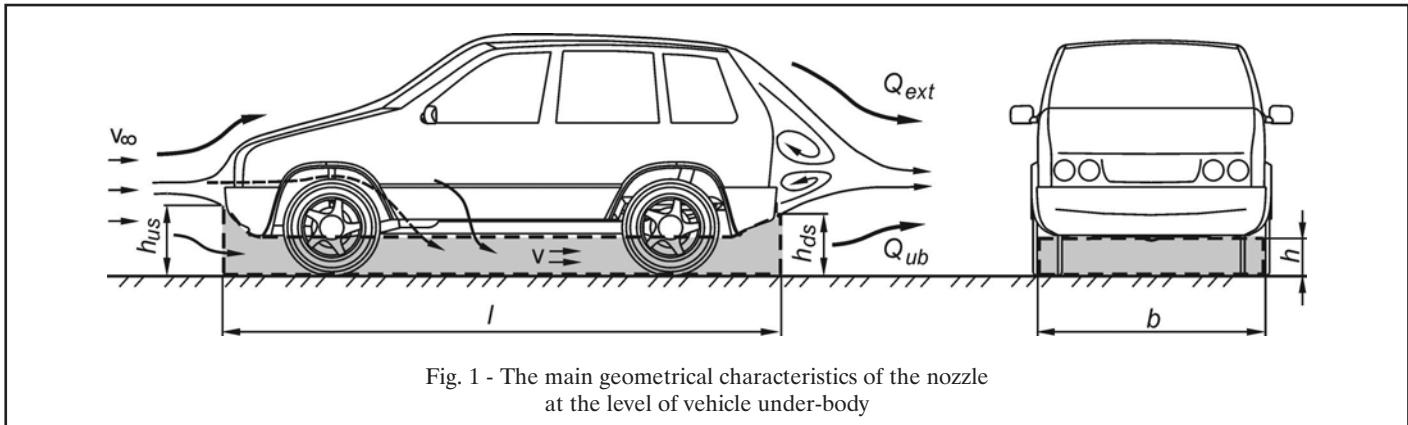


Fig. 1 - The main geometrical characteristics of the nozzle at the level of vehicle under-body

- A - is the area of the maximum cross section of vehicle.

The drag coefficient C_D has a complex determination, endowed with numerous constructive and exploiting influence factors. It is experimentally determined through tests in wind tunnels.

As the decomposition of the aerodynamic forces into measurable components would facilitate the optimisation design process of the cars' body, in the previous study [3] was presented a theoretical method for computing of the drag due to the underhood airflow. In this way, there was proposed the decomposition of the global force of road resistance, according to the Equation:

$$(2) \quad D = D_{ext} + D_{ub}$$

where:

D_{ext} - the drag due to the flow upon the external surface of the vehicle, having the rate flow Q_{ext} (see Figure 1);

D_{ub} - the drag due to the flow under the body of vehicle, in the space determined by the lower surface of the vehicle and the road, treated as a convergent-divergent air nozzle with the flow rate Q_{ub} .

The sum of two mentioned rate flows represent the volume of air what enveloping the vehicle, dislocated in time unit :

$$(3) \quad Q = Q_{ext} + Q_{ub} = v_{\infty} A$$

The main components of Q_{ub} are given by:

- the stationary air, in atmospheric conditions, motionless, upstream, "swallowed by the mobile nozzle", having the flow rate Q_1 ;

- the inferior branch of the stream generated through impact at the leading edge, which flows under the vehicle, having the flow rate Q_2 ; an important fraction of this is used, generally, for cooling in the engine compartment. For this theoretical approach the air suctioned from lateral sides by means of free ejection was neglected. Also, considering that the resultant fluid is homogeneous in the entire cross section of the nozzle $b \times h$, for the second component of the drag of vehicles, D_{ub} , were proposed the following Equation:

$$(4) \quad D_{ub} = \alpha_{en} b h \frac{\tilde{n} v^3}{2 v_{\infty}}$$

where:

α_{en} - is the coefficient of the equivalent hydraulic resistance of the nozzle;

v - is the average velocity of the air through the section of the nozzle;

Also, the following dimensionless indicators were defined to characterise the underhood airflow process:

$K_{D_{ub}}$ - is the coefficient what represent the ratio between underbody drag and global drag defined as product of three dimensionless factors, Equation (5);

$K_{Q_{ub}}$ - is the coefficient what characterise the participation of the underbody flow rate on total flow rate, Equation (6);

$$(5) \quad K_{D_{ub}} = \frac{D_{ub}}{D} = \frac{\alpha_{en} b h \left(\frac{v}{v_{\infty}} \right)^3}{C_D A}$$

where:

$\frac{\alpha_{en}}{C_D}$ - is the relative drag;

$\frac{b h}{A}$ - is the relative area;

$\left(\frac{v}{v_{\infty}} \right)^3$ - is the relative velocity.

$$(6) \quad K_{Q_{ub}} = \frac{Q_{ub}}{Q}$$

In this way, the underbody drag coefficient $C_{D_{ub}}$ can be expressed with the Equation:

$$(7) \quad C_{D_{ub}} = K_{D_{ub}} \cdot C_D = \alpha_{en} \frac{b h \left(\frac{v}{v_{\infty}} \right)^3}{A}$$

NUMERICAL APPLICATION

There are considered the following dates as for experimental model ARO 26 of ARO SA, Romanian Automotive Company: $A=2.6 \text{ m}^2$, $b=1.7 \text{ m}$, $l=4.1 \text{ m}$, $h=0.42 \text{ m}$, $h_{us}=h_{ds}=0.54 \text{ m}$, $c_x=0.443$ (experimental). For the air was considered a density as for standard atmosphere: $\rho=1.205 \text{ kg/m}^3$. The calculus for the coefficient of the equivalent hydraulic resistance of the nozzle (a quick one, on the first stage) was made according with [2. 237] for $I_0=3.75 \text{ m}$: $\zeta_{en}=3.345$.

Results concerning the variation of $K_{D_{ub}}$ and $C_{D_{ub}}$ with $K_{Q_{ub}}$ are presented in Figure 2 considering $Q_2=(0.5 - 8.0)\%Q$ as parameter.

Figure 3 depict the underbody drag variation with the reference velocity. The computations were made for 5 speeds, as following:

CONCLUSIONS

As can be observed in previous Figures, the increasing of the flow rate under the vehicle has a negative impact on underbody drag of vehicle, also for total drag.

As an optimising measure is necessary to limit, much as possible, the flow rate Q_{ub} under the vehicle through the control of its components. Concerning the flow rate Q_1 (swallowed by the mobile nozzle) this can be easily decreased using auxiliary structural ele-

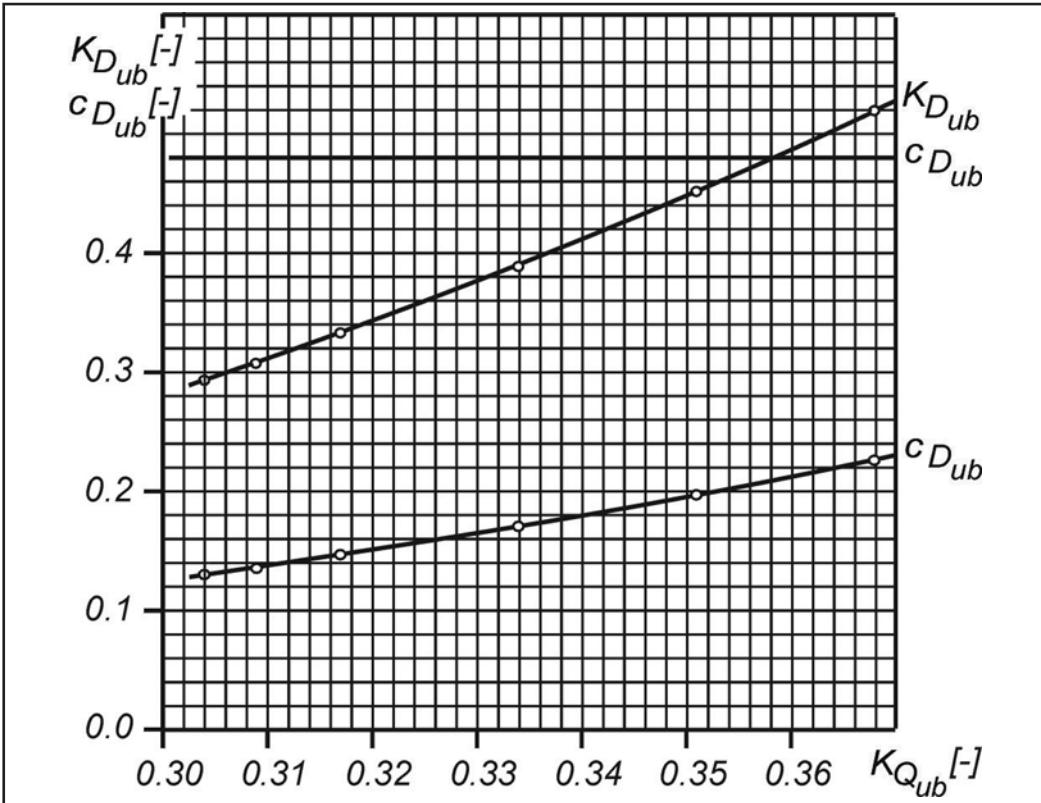


Fig. 2 - Variations of $K_{D_{ub}}$ and $C_{D_{ub}}$ with $K_{Q_{ub}}$

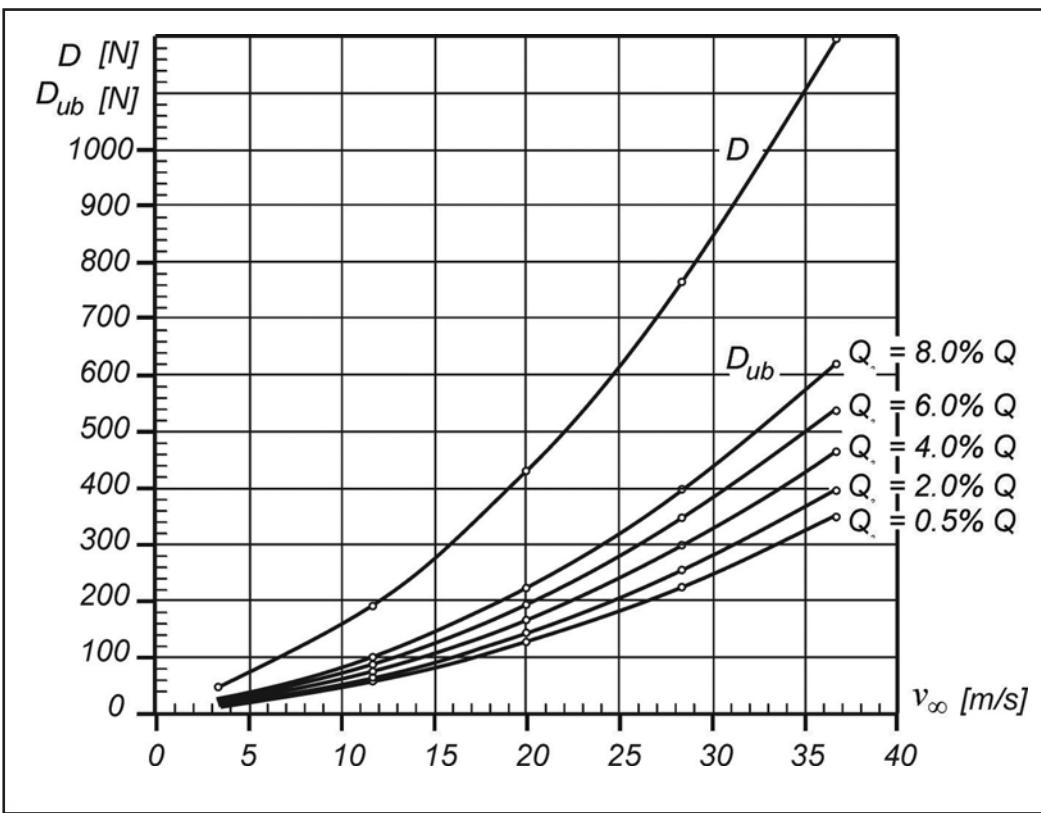


Fig. 3 - Variations of D and D_{ub} with v_{∞} and $Q_2 v_{\infty}$

ments, as a special profiled aerodynamic radiator shell.

The second component of the Q_{ub} , respectively flow rate due to the stream generated through impact in the leading edge of the car, can be reduced using a solution with lateral apertures to exhaust the air from engine compartment. Also, this method can be used to manage of the airflow on lateral side of the car, in order to avoid the detachment of the flow from these areas.

Obviously the decreasing of Q_{ub} can be obtained through the diminution of the ground clearance of the vehicle, as for the recent automobiles which have variable ground clearance with speed. In this way, diagrams of aerodynamic coefficients can be plotted, as one shown in Figure 4, where is depicted the variation of $C_{D_{ub}}$ versus $K_{Q_{ub}}$ as function of ground clearance in range (65% - 100%)h (ground clearance in basic configuration).

As can be observed, depending on flow under vehicle, decreasing of ground clearance is not always a proper solution for the reduction of drag. In studied case, for a smaller ground clearance from usual configuration in amount of 35%, the drag coefficients $C_{D_{ub}}$ and implicit C_D are increasing. Thus, for $Q_2=0.08Q$ and $h=65\%$, the value of C_D is increasing to $C_D=0.45$ (see Table 1). For an optimum situation from aerodynamic point of view, ground clearance must be decreased simultaneously with the flow rate under the vehicle. Also, experimental measurements [4] performed on a 1:6 scale model having the underbody reproducing a Venturi configuration tunnel show an improving of the aerodynamic characteristics of the car, empha-

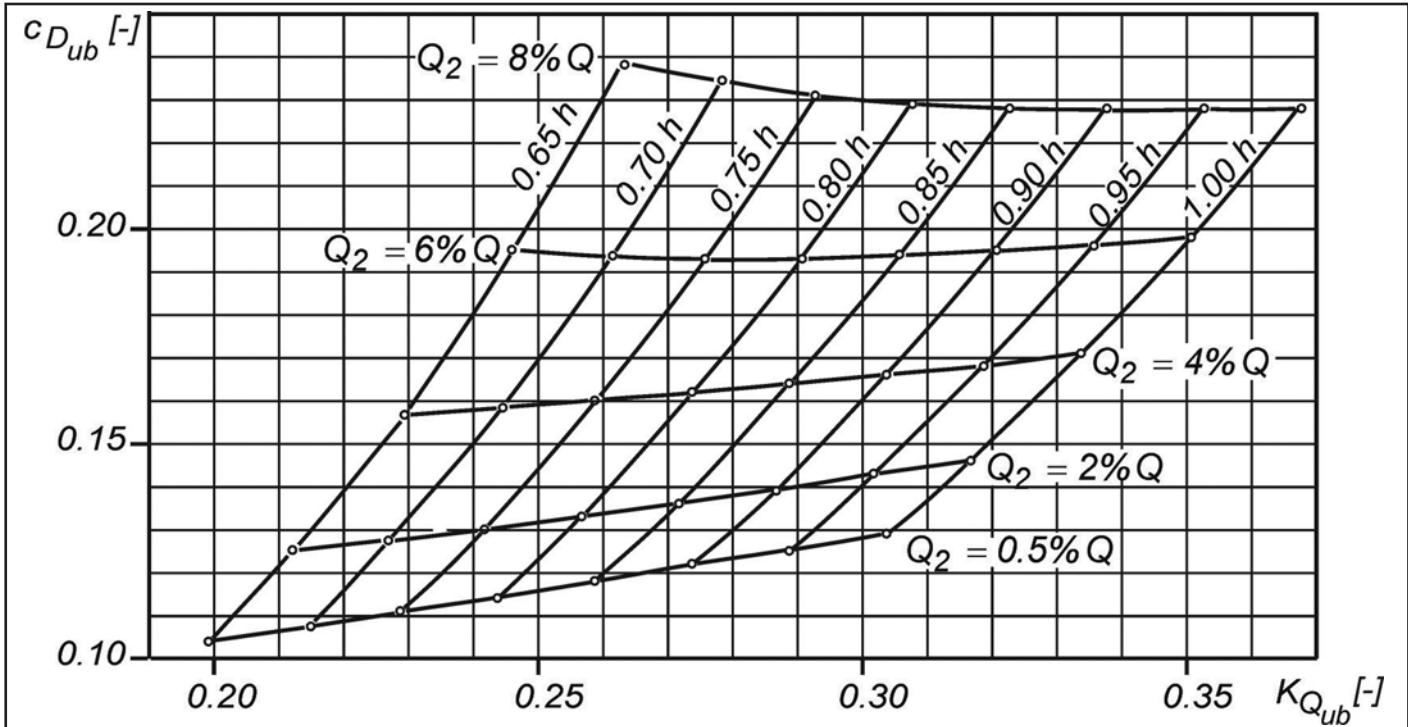


Fig. 4 - Parametric variation of $C_{D_{ub}}$ versus $K_{Q_{ub}}$

sised mainly by the lift coefficient.

To this end we mention that the presented method for the aerodynamic underhood evaluation can be used for optimising of the flow around vehicles even in a

very early design stage. Also, in order to have best results concerning the dynamic behaviour of the cars there is necessary an active control of their ground clearance according with the speed and underbody flow.

Informații suplimentare puteți obține scriind la următoarea adresă:
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Table 1		$Q_2=0.5\%$	$Q_2=2\%Q$	$Q_2=4\%Q$	$Q_2=6\%Q$	$Q_2=8\%Q$
$h=95\%$	$K_{Q_{ub}}$	0.298	0.302	0.319	0.336	0.353
	$C_{D_{ub}}$	0.125	0.143	0.168	0.196	0.228
	CD	0.436	0.437	0.437	0.438	0.440
$h=85\%$	$K_{Q_{ub}}$	0.259	0.272	0.289	0.306	0.323
	$C_{D_{ub}}$	0.118	0.136	0.164	0.195	0.228
	CD	0.429	0.430	0.433	0.436	0.440
$h=75\%$	$K_{Q_{ub}}$	0.229	0.242	0.259	0.276	0.293
	$C_{D_{ub}}$	0.111	0.130	0.160	0.193	0.231
	CD	0.422	0.424	0.429	0.435	0.443
$h=65\%$	$K_{Q_{ub}}$	0.199	0.212	0.229	0.246	0.263
	$C_{D_{ub}}$	0.104	0.125	0.157	0.195	0.238
	CD	0.415	0.419	0.426	0.437	0.450

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Etude par simulation numérique de l'influence des moments de changement des vitesses sur les performances dynamiques et d'économie

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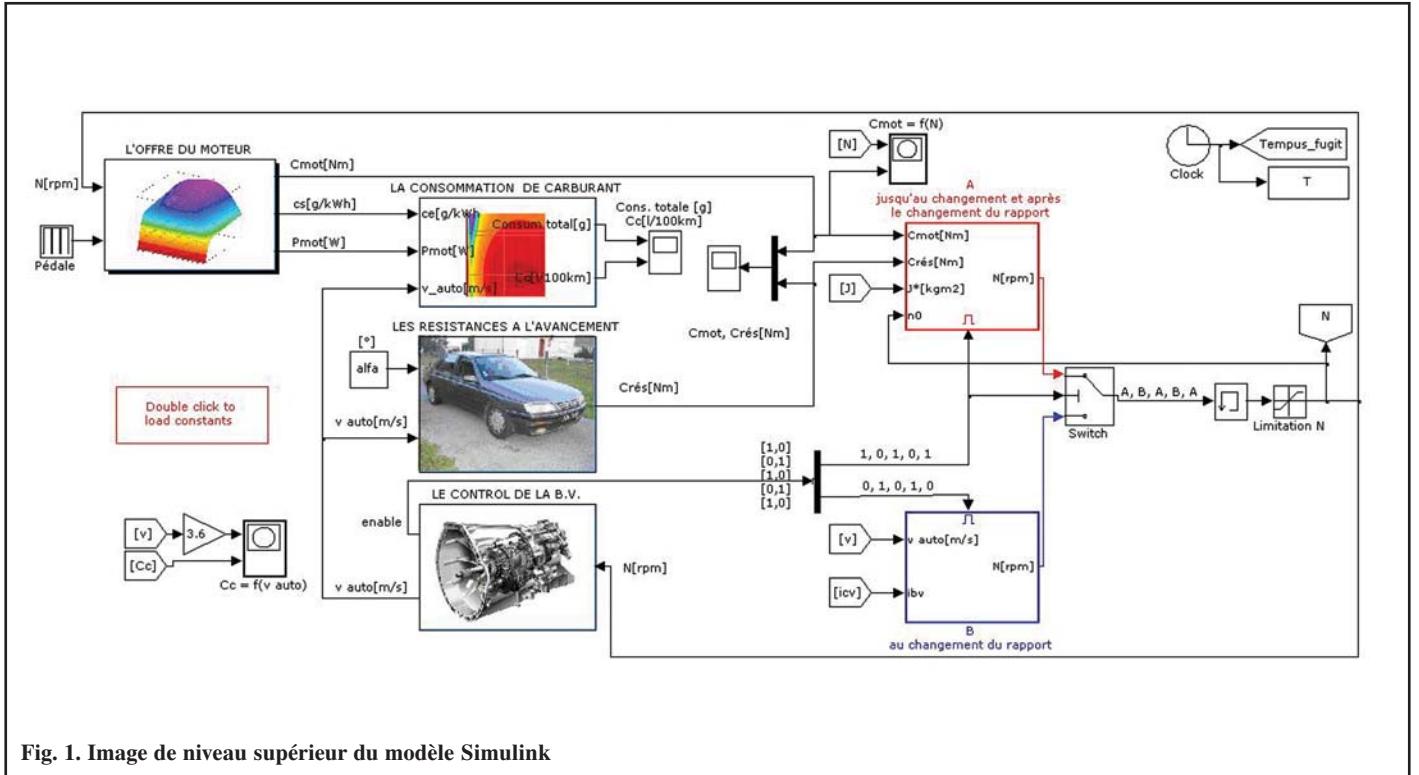


Fig. 1. Image de niveau supérieur du modèle Simulink

1. Introduction

Conception, intérieurs, moteurs, bruits, vibrations, éclairage, la simulation est partout. La voiture 100 % numérique, entièrement simulée, n'est pas encore d'actualité, mais les ordinateurs et les logiciels progressent tellement vite que rien ne semble impossible (par exemple, dans les dernières 15 années, la fréquence des microprocesseurs utilisés pour les ordinateurs habituels est passée de 16 MHz à 2 - 3 GHz). Virtuel, réel, la frontière est de plus en plus mince. Aujourd'hui, grâce aux progrès de l'informatique, le monde virtuel est devenu une réalité. La conception et la modélisation d'objets se font désormais quasiment toujours sur ordinateur. Les progrès réalisés dans la simulation en temps réel, per-

mettent de proposer des logiciels capables de tout créer.

L'industrie des automobiles est aujourd'hui sous pression avec des processus de développement de plus en plus courts. Pour cette raison, un intérêt majeur de la simulation est qu'elle doit permettre de trouver les solutions de plus en plus tôt, pour obtenir les meilleurs produits.

L'un des principaux avantages de la simulation numérique de l'automobile c'est la possibilité de reproduire exactement certains paramètres comme la vitesse du véhicule, l'accélération ou les conditions de roulement. Les résultats du calcul offrent une bonne vue des phénomènes passés dans une session de simulation. Ces résultats peuvent couvrir une plage plus large

de l'influence des paramètres, avec des coûts sensiblement petits, en comparaison avec les essais et les mesurages effectués sur la route, sur banc d'essai ou sur les pistes d'essais spécialement aménagés (un véritable test sur banc d'essai peut durer plusieurs mois, alors qu'une simulation de 200000 km est réalisée en quelques jours, /20/). Ils peuvent soutenir les logiciels spécifiques d'essai des automobiles et aussi de compléter des bases des données déjà existantes.

Le tout numérique dans la construction automobile n'est pas pour demain, mais cette utopie ne semble plus en être une, des grandes compagnies, proposant des programmes de simulation numérique de plus en plus évolués, /17, 22, 23/.

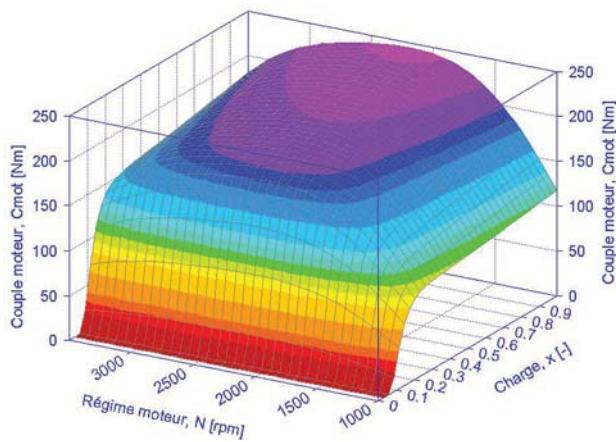
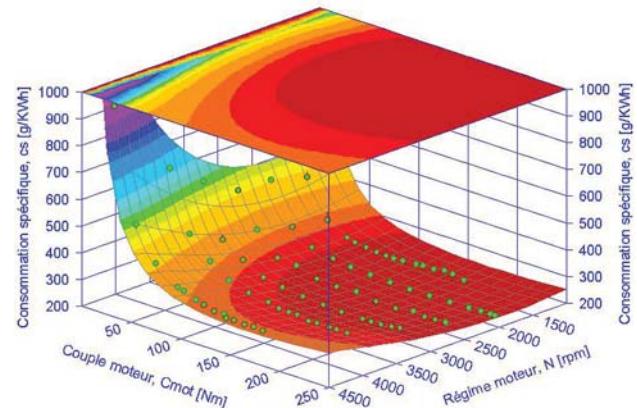


Fig. 2. Surface générée du champ d'offre du moteur XUD 11 ATE, $R^2 = 0,997$

Fig. 3. Fonction ce = f(N, c_{mot}), $R^2=0.991$



2. La modélisation dynamique du véhicule

Cette approche de modélisation du véhicule est basée sur les essais effectués sur un banc moteur à volant d'inertie, /11, 12, 18/. En conséquence, pour que la validation du modèle soit possible, le raisonnement a été fait au niveau du volant du moteur. Autrement dit, la masse en translation du véhicule a été réduite au niveau du volant du moteur en utilisant une masse en rotation (un volant) avec une inertie équivalente identique.

Le but de cette étude a été de réaliser un modèle de simulation apte à effectuer d'accélérations avec le changement des rapports des vitesses. Pour la validation on a utilisé les essais d'accélération effectués sur le banc moteur à volant d'inertie du CNAM de Paris, /8, 9, 12, 18/.

L'image de niveau supérieur du modèle Simulink réalisé est illustrée dans la figure 1, /18, 19/. Dans la structure du modèle on peut observer les modules spécifiques des cartographies du moteur et de la consommation de carburant, des résistances à l'avancement, du système de contrôle de la transmission, et dernièrement, le module additionnel de calcul du régime moteur en concordance avec le processus de changement des rapports.

On observe qu'un modèle Simulink est, en effet, une collection d'objets (modules) interconnectés, avec une signification physique bien déterminée. Une telle démarche impose une attention spéciale pour s'assurer d'une *relation causale correcte* entre les objets du

modèle; son non respect risque de provoquer l'apparition de *boucles causales*, qui vont compromettre le modèle de simulation. Ils sont, finalement, l'expression d'un modèle de simulation non conforme implémenté ou autrement dit, qui ne décrit pas en conformité le phénomène physique modélisé.

On n'insiste pas dans cet article sur la description du modèle de simulation car il a été bien présenté dans les ouvrages /18, 19/. Néanmoins, on souligne le fait que l'obtention de résultats corrects dans une telle étude est conditionnée – premièrement – par l'existence d'un modèle fiable de la source d'énergie (i.e. le moteur thermique). De ce point de vue, l'approche globale dans la modélisation du moteur consiste à raisonner en „boîte noire“: à l'entrée il y a les signaux de régime et de charge (l'enfoncement de la pédale d'accélération) tandis qu'à la sortie il y a le couple moteur et la consommation spécifique. Les fonctions de transfert entre l'entrée et la sortie sont basées sur les résultats expérimentaux effectués sur le banc moteur à volant d'inertie. En fait, on a utilisé une approche mixte qui consiste dans la combinaison des résultats stationnaires et non stationnaires, /18/.

Ce type de modélisation du moteur est plutôt utile pour l'étude de l'influence des caractéristiques de la transmission et/ou de l'automobile sur les performances dynamiques et/ou d'économie et pollution.

En ce qui concerne les fonctions de transfert mentionnés ci-dessus, dans la figure 2 on

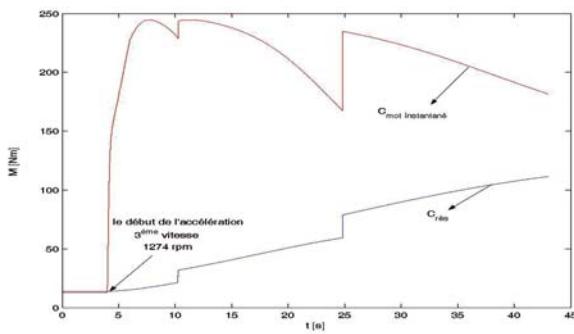
présente la fonction analytique qui approxime au mieux la surface déterminée par les points expérimentaux de couple moteur, /13, 18/. Aussi la figure 3 constitue la représentation graphique de la variation de la consommation spécifique effective. Pour la détermination des fonctions analytiques on a utilisé le logiciel JANDEL, /21/, spécialisé dans la résolution des tels opérations, par l'utilisation de la méthode des moindres carrés.

3. Resultats et discussions

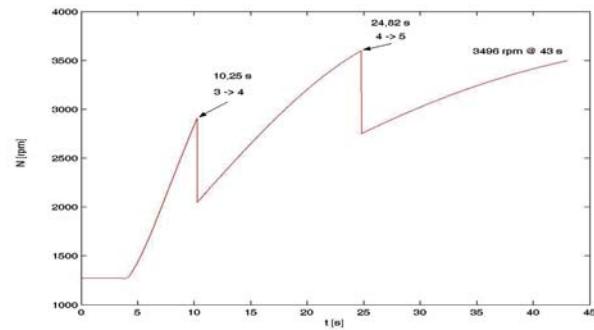
La cause du processus d'accélération est l'enfoncement de la pédale d'accélération dont son scénario est le suivant: sur les premiers 4 secondes est imposé le fonctionnement stabilisé, et dans les 2 suivants secondes est sollicité le niveau maximum de charge, qui sera maintenu jusqu'au fin de la simulation.

La simulation du processus d'accélération avec le changement des vitesses se fait en partant de 3^{ème} vitesse, /12, 15, 18/. Par conséquent, l'enfoncement brusque de la pédale d'accélération détermine une augmentation rapide du couple moteur en rapport avec le couple résistant (graphe a, figure 4). Dans le graphe b, on observe les moments du changement des vitesses, qui sont choisies fonction du régime moteur. En concordance avec ces moments, dans les graphes c et d, sont présentés les valeurs des rapports de transmission, respectifs des moments massiques d'inertie équivalente.

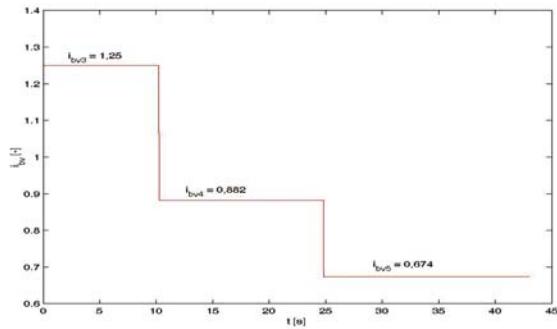
La variation du couple moteur avec le régime est représentée dans le graphe e, où on peut



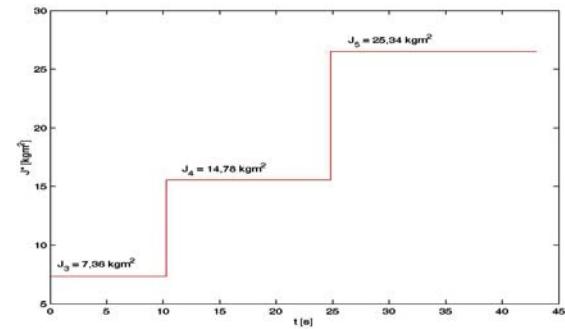
a. $C_{mot \text{ instantané}}$ et C_{res} vs. temps de simulation



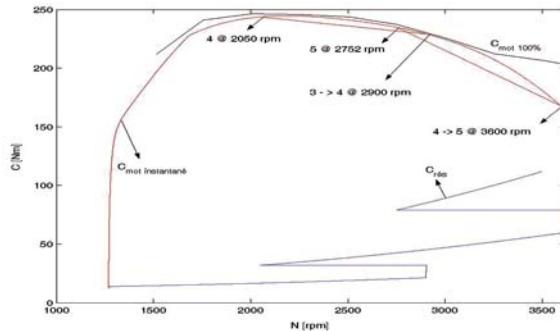
b. N vs. temps de simulation



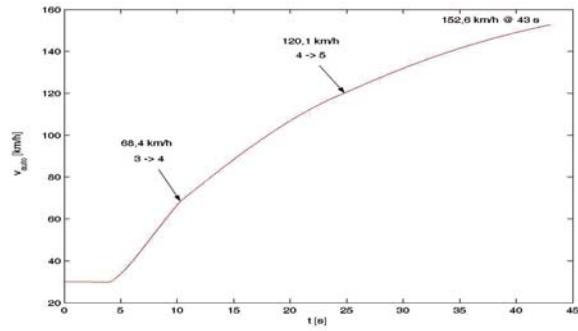
c. i_{bv} vs. temps de simulation



d. J^* vs. temps de simulation



e. $C_{mot \text{ (100\%)}}$, $C_{mot \text{ instantané}}$ et C_{res} vs. N



f. v_{auto} vs. temps de simulation

Fig. 4. Performances dynamiques sur l'essai d'accélération avec le changement des vitesses

remarquer, également, l'allure croissante du couple résistant, qui impose un fonctionnement du moteur aux charges de plus en plus grandes. Donc, le fonctionnement du moteur se translate sur les zones des rendements plus élevés (fig. 5).

En ce qui concerne la variation de la vitesse, dans le graphe f on observe le fait que le parcours de l'intervalle (30 . 152,6) km/h s'effectue en 39 s.

De point de vue performances d'économie,

dans la figure 6 on remarque l'évolution de la consommation totale de carburant.

L'avantage principal du modèle de simulation réalisé consiste dans la possibilité d'effectuer des études comparatives sur l'influence des moments de changement des vitesses sur les performances dynamiques et de consommation de carburant.

Dans la figure 7 on présente les résultats d'une telle étude:

- en analysant la figure 4, a, on a constaté que

le passage dans la 4^{ème} vitesse s'effectue après l'atteinte de la valeur maximale du couple moteur, motif pour lequel, dans un premier cas, on a désiré simuler le processus d'accélération dans les conditions quand ce changement se réalise dans le moment du couple maximum (N = 2180 tours/min - changement précoce),

- le 2^{ème} cas simule représente le passage dans la 4^{ème} au régime moteur N = 3250 tours/min (changement tardive).

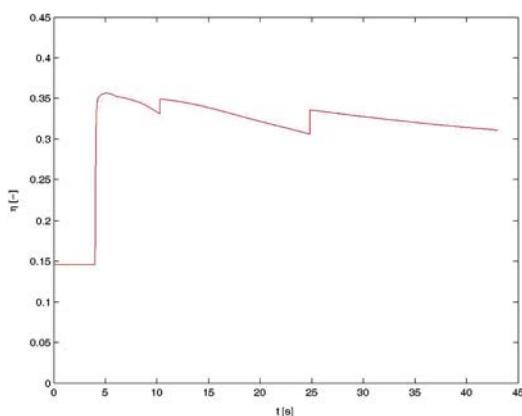
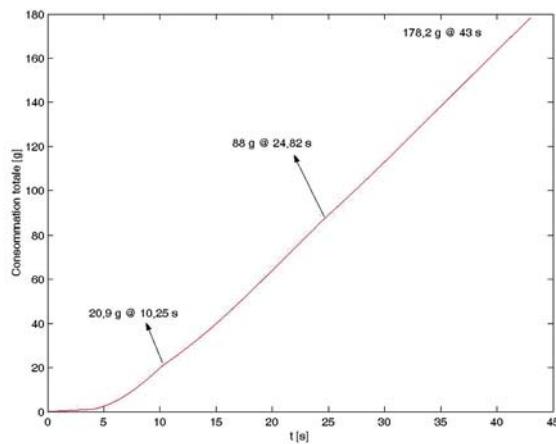


Fig. 5.
Rendement effectif vs. temps

Fig. 6. Evolution de la consommation de carburant



Ainsi, comme on peut observer en figure 7, se confirme la contradiction entre la manière de conduite économique et la conduite sportive. Dans le premier cas, on poursuit une consommation réduite de carburant comptant sur *le passage précoce* dans les vitesses supérieures, tandis que pour le deuxième cas, on vise une croissance rapide du régime moteur par le changement tardive des vitesses.

Pour des raisons de clarté des graphes, en figure 7, on n'a pas superposé les évolutions temporelles des paramètres enregistrés dans le 3^{ème} cas analyse: changement précoce aussi en 4^{ème} qu'en 5^{ème} vitesse ($N_{3>4}=2180$ tr/min, $N_{4>5}=3200$ tr/min). Les résultats de cette simulation ne font que soutenir l'affirmation antérieure, puisque le changement précoce des deux rapports a déterminé une vitesse maximale et une consommation totale de carburant légèrement inférieures à celles obtenues dans la première situation analysée (150,4 km/h, respectif 168,4 g).

Tous ces faits étant présentés, on considère important de souligner que le changement d'un rapport ne doit pas, dans aucun cas, se produire sur l'allure ascendante de la courbe du couple moteur, parce que le régime moteur, résulte suite à la sélection du nouveau rapport, ne fait que déplacer le point de fonctionnement du moteur dans une zone caractérisé par des valeurs même plus petites du couple moteur (v. figure 7, a . 1^{er} cas). En ce qui regarde la manière de conduite sportive, il est important que le choix du moment de changement de la vitesse soit fait ainsi que celle-ci ne génère pas un régime moteur trop petit pour reprendre l'accélération dans le nouveau rapport engagé.

4. Conclusions

Grâce à l'utilisation du banc moteur à volant d'inertie, pour réaliser la simulation du véhicule automobile on a pris en considération une stratégie apte à reproduire le fonctionnement de ce banc. En ce qui concerne la

modélisation du champ d'offre du moteur, on a essayé d'utiliser des fonctions analytiques, qui approximent la surface caractérisée par les points prélevés expérimentalement.

Un modèle virtuel Simulink a été aussi réalisé pour effectuer une analyse en transitoire des essais d'accélération avec le changement des vitesses dont les résultats ont été validés à l'aide d'expérimentations menées sur le banc à volant d'inertie.

Quel est l'avantage du modèle? Il offre la possibilité d'effectuer des études comparatives, en ce qui concerne les performances dynamiques et de consommation de carburant, sur l'influence des moments de changement des vitesses ou bien de valeurs de rapports de transmission etc.

En tenant compte de la nécessité actuelle de limiter les émissions de CO₂ responsables en grande partie de l'effet de serre, il se révèle particulièrement important que, pour un moteur donné, des études comparatives par simulation numérique puissent être menées sur l'influence des caractéristiques de la transmission sur la consommation de carburant.

Bien entendu, si le choix de la transmission est primordial sur la consommation de carburant, ce choix a aussi une influence primordial sur l'agrement de conduite, paramètre très subjectif qui peut malgré tout lui aussi être pris en compte dans les programmes de simulation.

REZUMAT

Concurența, atât de prezentă în industria de automobile, legislația de protecție a mediului încunjurător, cerințele și gusturile cumpărătorilor de automobile, au impus, în ultimii 20 de ani, reducerea timpului dedicat dezvoltării unui nou model de automobil.

Această nouă tendință a impuls cedarea parțială a locului cercetării experimentale, în favoarea ingineriei conceptuale și a studiului validării virtuale, realizată prin simularea pe calculator.

Încercările de accelerare efectuate pe standul motor cu volant de inertie al CNAM Paris au furnizat o importantă bază de date, necesară concepției unui program de simulare a funcționării automobilului.

Așadar, lucrarea prezintă un model de simulare a automobilului, capabil să reproducă funcționarea standului motor cu volant de inertie dar și efectuarea unor studii comparative legate de influența parametrilor transmisiei asupra performanțelor globale ale unui automobil pe perioada accelerărilor.

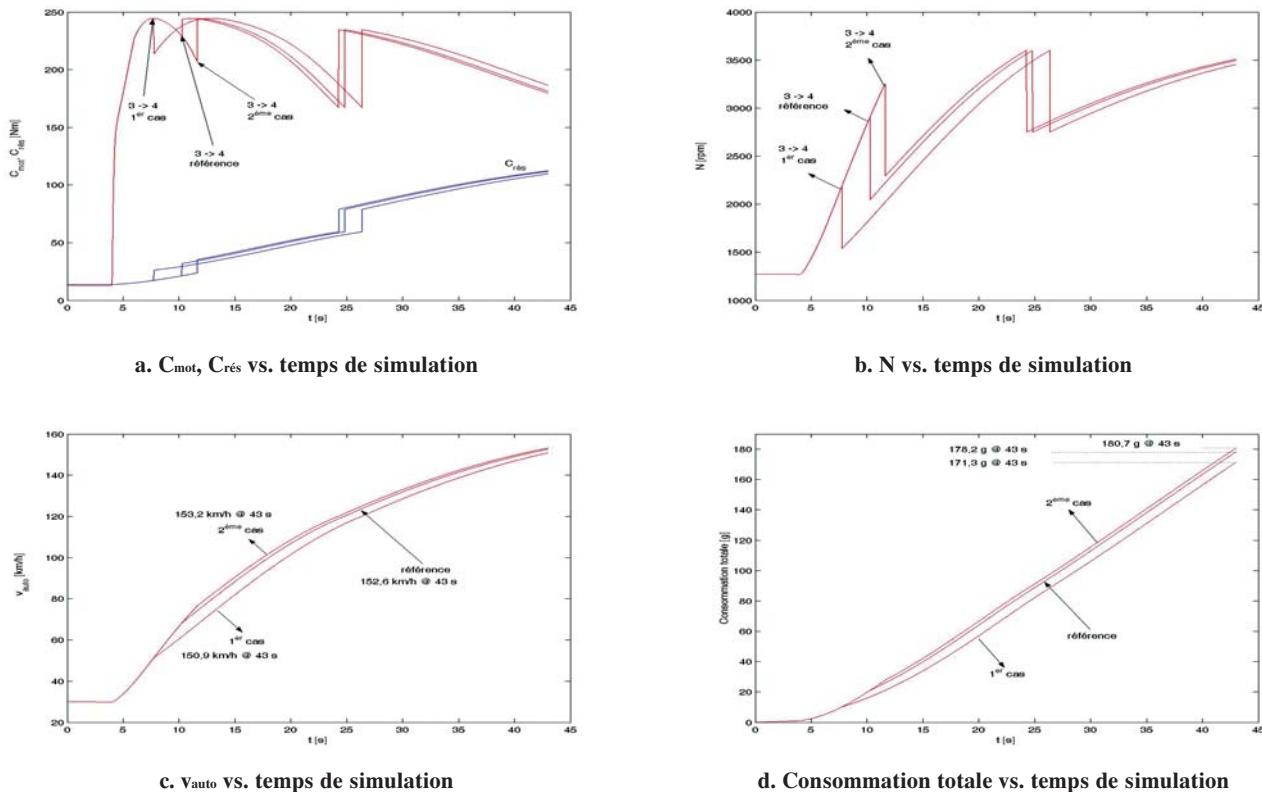


Fig. 7. Analyse de l'influence des moments de changement des vitesses sur les performances dynamiques et d'économie

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On exprime les plus sincères remerciements à Monsieur Michel FEIDT, professeur à l'Université Henri Poincaré de Nancy et à l'ADEME, Agence de l'Environnement et de la Maîtrise de l'Energie de France d'avoir financé la réalisation de ce travail entre les années 2003-2006, grâce à une politique de coopération scientifique et universitaire avec les Pays de l'Europe Centrale et Orientale.

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Automobile Electrification Trends

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Rezumat:

Electrificarea automobilului: articolul de față oferă o imagine panoramică, bogat ilustrată a principalelor obiective și soluții, cu rezultate la zi, cu privire la utilizarea tot mai pronunțată a energiei electrice pe automobil, în vederea reducerii consumului de combustibil și a poluării în traficul urban, în condiții de siguranță și confort ușor mărite, la prețuri de investiție în echipamente electrice/electronice de putere moderată.

A. Scope and targets

The scope of this paper is to describe electric power conversion and its power electronics digital control for new functions on board of automobile for energy saving, low pollution and more safety and comfort.

What is it?

$\%E = \text{peak electric power} \times 100 / (\text{peak electric power} + \text{peak ICE power}) = P_{el} \times 100 / (P_{el} + P_{ICE})$

$\%E = (5-10\%)$ for ICE vehicle with ISA (integrated starter alternator) at 14Vdc or 42Vdc

$\%E = (10-15\%)$ for Mild EHV at 42 Vdc

$\%E = (30-50\%)$ for Full EHV at 500 Vdc and 42 Vdc

$\%E = 100\%$ EV

Why %E?

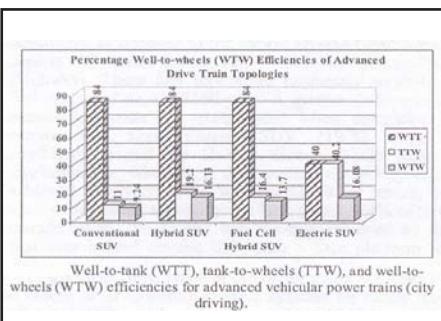
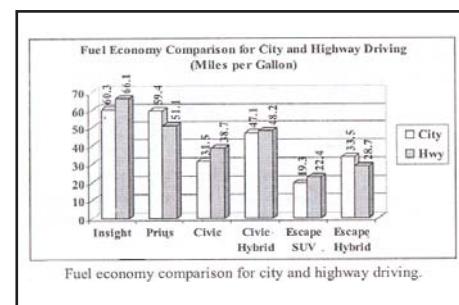
Because of:

- energy savings and less pollution (up to 50% less)
- increased safety and comfort
- Targets of automobile electrifications are such as in Fig. 1:
- 42Vdc power bus and converters
- electric power steering assist
- electric steering by wire
- electric braking by wire
- electric throttle and valve control
- electric active suspension damping
- direct fuel injection
- integrated Starter/Alternators in HEV and EV (with mixed: ICE and electric power trains)

B. Hybrid electric vehicles (HEV), fuel economy so far

As seen in Fig. 2 the first commercial HEVs such Honda Insight, Honda Civic, Toyota Prius and Ford Escape SUV provide significant fuel savings at the European fuel costs, around 33% per year, for strong HEV (66% electrification ratio). But the city driving advantages are much better.

Figure 2 Automobile electrification results



Conv. Vehicle MPG	Annual Fuel Cost	HEV 30% MPG Increase	Annual Savings	HEV 60% MPG Increase	Annual Savings
10.0	\$6000	13.0	\$1385	16.0	\$2250
15.0	\$4000	19.5	\$923	24.0	\$1500
20.0	\$3000	26.0	\$692	32.0	\$1125
25.0	\$2400	32.5	\$554	40.0	\$900
30.0	\$2000	39.0	\$462	48.0	\$750
35.0	\$1714	45.5	\$395	56.0	\$643
40.0	\$1500	52.0	\$346	64.0	\$562

ANNUAL FUEL (GASOLINE) SAVINGS ACHIEVED BY HEVS @ \$5.00/GALLON.

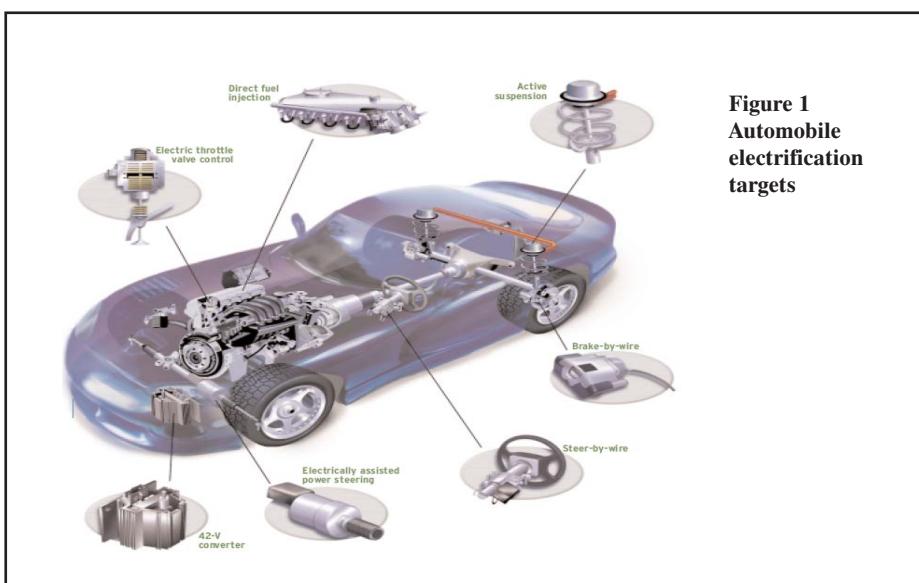
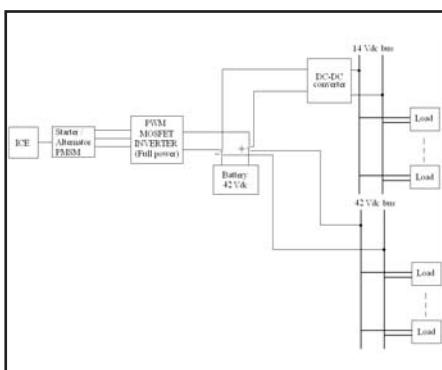


Figure 1
Automobile
electrification
targets

C. Target 1: The 42Vdc/14Vdc power bus

The key to electrification is power electronics digital control of various functions on automobile by electric motors. To make it more economical the 42Vdc bus was selected recently as a compromise for drivers safety. An advanced 42Vdc power bus (commercial only on Toyota Crown Royal mild HEV) should contain an integrator starter/alternator with full power electronics control that not only produces electric power on board, but, also through a belt transmission, starts the ICE in a few tens of seconds after automatic ICE shutdown (to save energy), and then it contributes to fast acceleration and finally yields a 15% fuel savings.

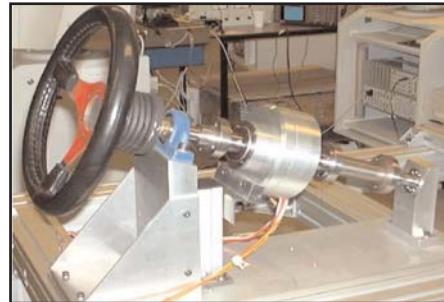
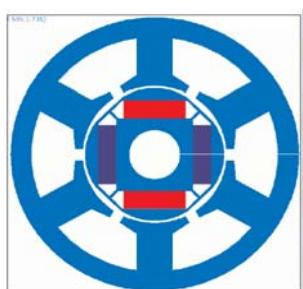
Figure 3 Future 42 Vdc bus with ISA (integrated starter alternator)



D. Target 2: Electric power steering assist

Using a low volume, high efficiency, fast and low storage pulsation permanent magnet brushless motor (PMSM) with position triggered power electronics control is the way to go for power steering assist and most major automobile manufacture have installed one on one of their very recently models still at the existing 14Vdc bus. It may be used for front or rear drive trains.

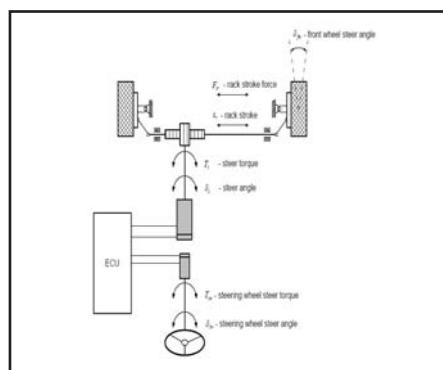
Figure 4 Electric power steering assist (with PMSM)



E. Target 3: Steering by wire

Mechanical decoupling between the driver's wheel (Fig. 5) and the vehicle steering system is common on aircraft and vessel drive-trains but is still in the laboratories for automobile, due to safety precautions.

Figure 5 Steering by wire



Steering by wire includes the electric power steering assist for driving feeling preservation but it adds the main electric drive that does steering; both electric motors are controlled concurrently based on road-wheel and turn-wheel measured (and estimated for redundancy) positions.

It is supposed to increase safety and reduce energy consumption.

F. Target 4 Electric braking by wire

Control of electric brakes based on online vehicle dynamic evolution, with the driver still activating the brake pedal but with CPU deciding, based on numerous vehicle state variable estimators, deciding what to do including the steering of vehicle after the driver lost conscience, is the ultimate goal of electric braking by wire (Fig. 6).

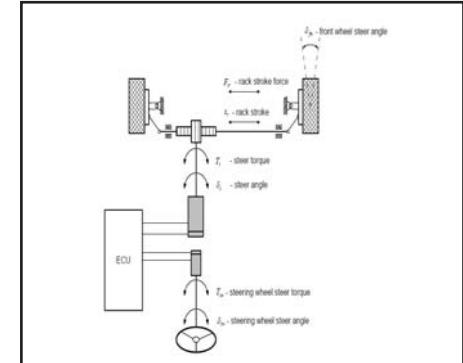


Figure 6 Electric braking by wire

G. Target 5 Electromagnetic valves

The 16 typical valves on a 4 cylinder, 1.6 liter ICE are standardly activated by a common cam shaft and they consume at best 1.5kW (average).

Fuel savings of (10-15)% can be obtained by independent (and eventually gradual) valves driving with electric motor at variable speed: rotary motors (Fig. 7a) or linear motors (Fig. 7b), all with permanent magnets to cut volume and electric losses. A 3 millisecond average drive cycle shows the extraordinary demands from the electric drives.

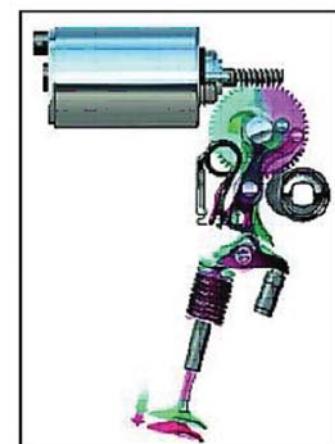


Figure 7 Electromagnetic valves with rotary PMSM

Despite worldwide efforts the electromagnetic valves are still not commercial, mainly due to their too large peak power (average input power is already ok) which, for peak power shaving, needs super-capacitors that are still very expensive.

However this is one more reason to try fur

ther, especially for multi-cylinders ICE for large cars, lorries or city buses.

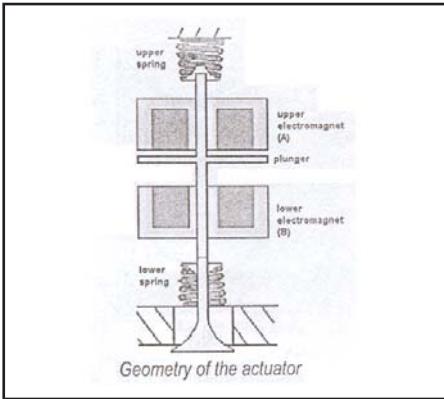


Figure 7 Electromagnetic valves with linear motors

H. Target 6 Electric active suspension

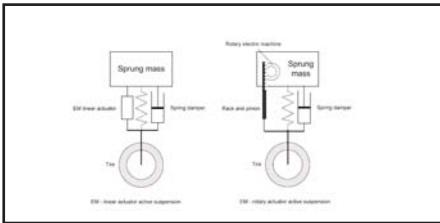


Figure 8 Active electric damping with (a) linear actuator (b) rotary actuator

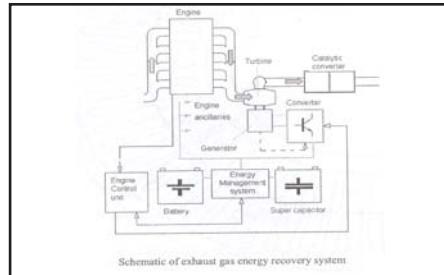
To damp low frequency car-cabin oscillations, an electric damping system using rotary or linear electric motors (Fig. 8), controlled by individual power electronics converters connected to the common 42Vdc, have been proposed already in early nineties with a few already apparently commercial embodiments (Toyota's Lexus).

The fact that the active electric damping allows for bidirectional fast power flow between vehicle corners, makes the average power absorbed from the power bus small; its

peaks however have to be "shaved" by supercapacitors, which are still expensive.

I. Target 7 Exhaust- gas electric energy recovery

Mounting a hyper speed (80,000 rpm) turbine (of up to 6 kW(peak) on the exhaust trajectory



(Fig. 9)) that drives an electric motor/generator will not only save energy, but it may give away with the alternator completely.

J. Target 8 The integrator starter/alternator on HEV

Combined ICE and electric traction, especially in urban driving, saves up to 50% of the fuel consumption (4.8l /100 km for Toyota Prius 4 for 3000 USD additional equipment).

There are quite a few topologies for HEV (parallel, series, combined) and Fig. 10a shows a belt integrated starter/alternator for a parallel HEV (in parallel hybrids the ICE is de-rated, which explains some of the fuel savings also). Fig. 10b illustrates the motor and generator torque requirements versus speed.

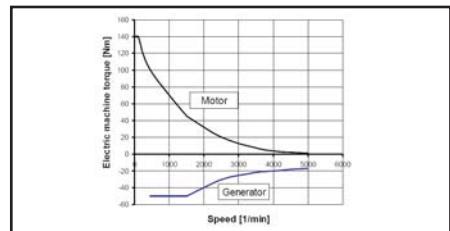
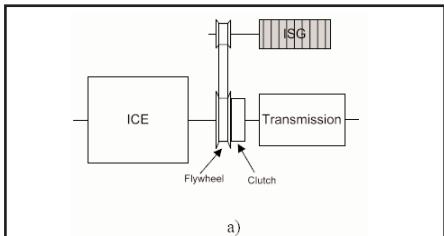


Figure 10 (a) Belt integrated starter/alternator on parallel HEV (b) typical torque/speed limit curves for a small car

Finally, a review of HEV based on Toyota Prius and Ford Escape is shown in Fig. 11.



Figure 11 HEV review

Note on electric vehicles

The ultimate goal is the battery or fuel-cell electric (automobile) but, 100 years after Ford's first electric automobile, the limited range and the high costs of fuel-cells still hampers the electric vehicle mass utilization.

K. Conclusions

Automobile electrification:

- serves to save fuel (energy), reduce pollution, increase safety and comfort;
- it is already well under way and here to stay
- there are still many challenges ahead
- a most likely 2020 automobile hybridization is shown below in the table:

	14-V	42-V	Micro	Mild	Full
	HEV	HEV	HEV	HEV	HEV
Baseline	0%	33%	58%	6%	3%
Easy Street	0%	32%	57%	7%	4%
Rough Ride	0%	5%	37%	46%	11%

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Comisia de Terminologie pentru Științele Exacte a Academiei României și-a propus ca unul din principalele sale obiective să fie editarea de dicționare multilingve, care să contribuie la stabilirea unei terminologii corecte în domeniul științelor exacte. Având în vedere dimensiunile unei astfel de lucrări s-a decis realizarea ei în etape și pe diferite domenii, începându-se cu domeniul științelor tehnice.

Dicționarul Explicativ pentru Știință și Tehnologie - Transporturi Rutiere a apărut într-un prim volum (literele A-K) ce se referă la terminologia domeniului autovehiculelor rutiere și este realizat pe baza fondului terminologic standardizat pe plan mondial. La elaborarea acestuia s-au avut în vedere câteva principii de bază: s-a dat o deosebită importanță definițiilor conceptelor, astfel încât acestea să fie clare și exacte; s-a urmărit ca relațiile dintre concepe să corespundă unei ie-rarhizări, având la bază tezaurizarea terminologiei din domeniul respectiv; atât la stabilirea termenilor, cât și la elaborarea definițiilor s-au avut în vedere cele mai reprezentative și recente documentații elaborate de organisme naționale și internaționale competente în respectivele domenii.

Întrucât, aşa după cum s-a arătat mai sus, prezenta lucrare se încadrează într-o serie de dicționare elaborate pe diferite domenii, s-a considerat ca, pentru evitarea unor suprapunerii, să fie prezentate termenii specifici autovehiculelor rutiere, iar dintre cei aparținând științelor fundamentale (matematică, fizică, chimie) sau celor tehnice generale (rezistența materialelor, organe de mașini, electrotehnica, electronică, termotehnică, informatică) să fie abordați doar cei mai importanți și intim legați de ingineria autovehiculelor.

Dicționarul se adresează specialiștilor din mai multe domenii aferente ingineriei autovehiculelor: cercetare, dezvoltare și realizare de autovehicule, menenanță, asigurări, organizarea traficului și transportului rutier, definirea regulației tehnice privind automobilul și urmărirea respectării lor, învățământ tehnic mediu și superior.

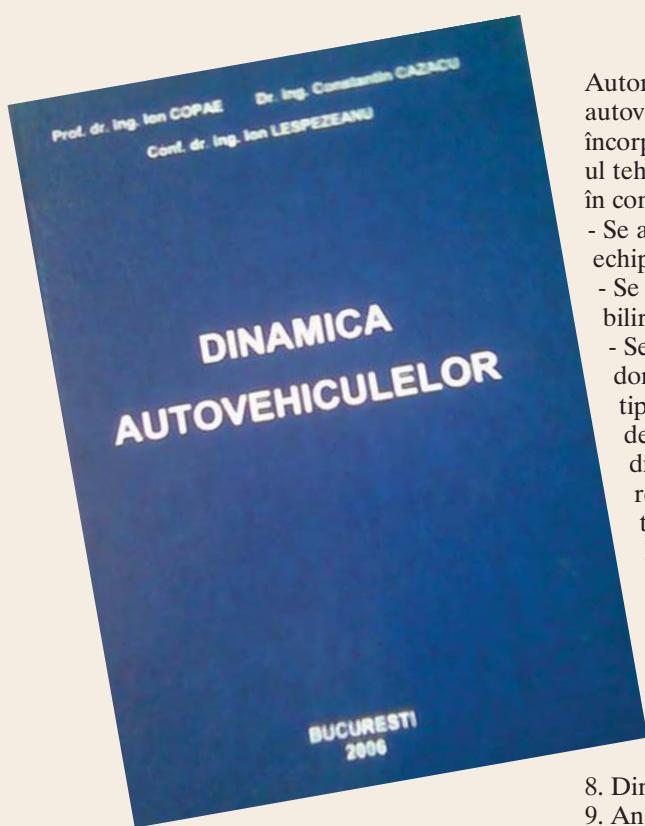


Autorii lucrării au pus accentul pe cercetările experimentale în studiul dinamicii autovehiculelor, profitând de existența traductoarelor și elementelor de execuție încorporate, a calculatorului de bord și a unui soft, Matlab, ideal pentru domeniul tehnico-ingineresc, realizând o tratare sistemică, interdisciplinară, luându-se în considerare atât influența terenului, cât și acțiunea conducătorului auto.

- Se abordează în mod unitar dinamica autovehiculelor cu roți și cu senile, echipate cu motoare cu aprindere cu scânteie și cu aprindere prin comprimare
- Se utilizează concepe și algoritmi specifici identificării sistemelor, pentru stabilirea modelelor matematice pornind de la datele experimentale
- Se tratează probleme care nu sunt abordate în literatura de specialitate din domeniul autovehiculelor, dar care aparțin de dinamica sistemelor de orice tip: analiza dispersională, analiza de sensibilitate, analiza de corelație, analiza de coerență, analiza în frecvență bispectrală, analiza în timp-frecvență, eco-dinamicitatea autovehiculelor, analiza robustă, dinamica spectrală, regresii, rețele neuronale, algoritmi genetici, mulțimi fuzzy, algoritmi neuro-fuzzy, tehnici bootstrap, statistică bayesiană, curbe principale.

Lucrarea este organizată pe următoarele capitole:

1. Elemente de bază din teoria sistemelor
2. Cercetări experimentale
3. Analiza în timp a datelor experimentale
4. Analiza în frecvență a datelor experimentale
5. Analiza în timp-frecvență a datelor experimentale
6. Dinamica liniară a autovehiculelor
7. Dinamica neliniară a autovehiculelor
8. Dinamica și economicitatea autovehiculelor
9. Analiza robustă a dinamicii autovehiculelor



REGISTRUL AUTO ROMÂN



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