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USE OF HIGH STRENGTH SHEET METALS FOR PASSENGER CAR BODIES

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1. INTRODUCTON

Requirements of the society concerning the automobile performances and functions are becoming increasingly stringent, as a result of the need for rational use of raw materials and energy, as well as the need for lower environmental pollution, higher comfort, greater safety etc. (Fig. 1). Reduction of body weight, modification of supporting structure and replacement of the conventional body materials with the lighter ones are some of the possible ways for meeting the above requirements. The lighter materials used for manufacturing the automobile

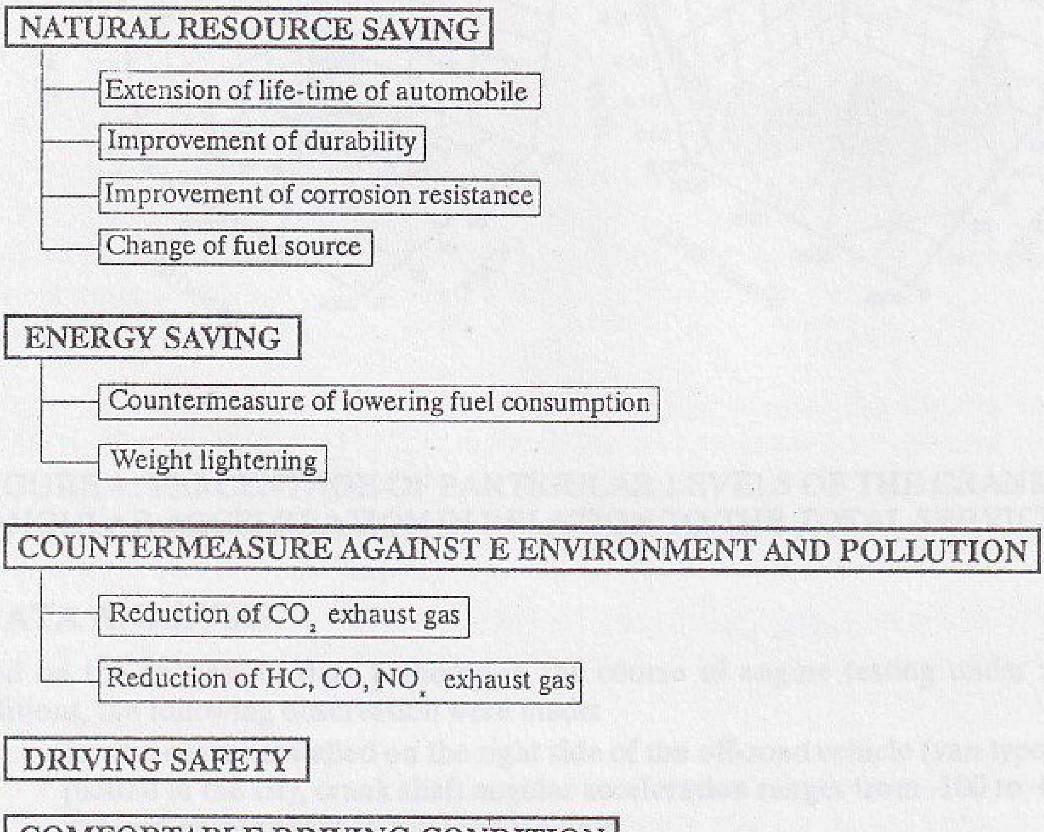

FIGURE 1.: SOCIAL AND GLOBAL ENVIRONMENTAL REQUIREMENTS CONCERNING THE AUTOMOBILE PRODUCTION /1/

bodies are as follows: high strength steel sheet metals (HsS), sheet metals made of aluminum alloys, titan and its alloys, "sandwich" sheet metals, composites etc. Fig. 2 shows the basic concept of the standard selection of the materials used for automobile bodies /1/.

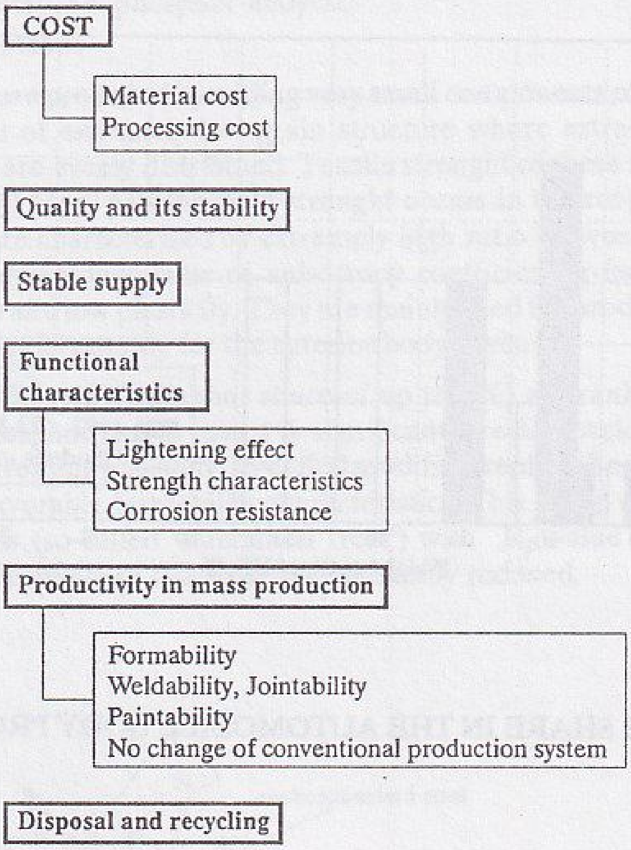

FIGURE 2.: STANDARD SELECTION OF THE MATERIALS USED FOR AUTOMOBILE BODIES/1/

From the formability standpoint, there are numerous problems in manufacturing body parts using light materials. In general, formability of tight materials is lower compared to low-carbon steels. In this case, in addition to material destruction, there are also problems in the form of wrinkles, surface deflections and springback. The dominant characteristics related to outer pressed parts are stiffness, shape fixability and surface quality, while the important features of the inner components are the stiffness of certain pressed parts and the complete structure, as well as the fatigue strength.

2. HIGH STRENGTH SHEET METALS

2.1. Application trends

High strength sheet metals are most frequently used in machine construction industry, because of its high stiffness and low weight (contributing to lower total weight of the specific design). HSS enable production of automobile bodies with higher stiffness and lower weight, showing satisfactory performances (energy accummulation upon accidents, oscillatory comfort etc.). The initial use of HSS began in the '70s, as a response to the energy crisis, and its application continuously rised (Fig. 3), especially in the Japanese car factories. It is estimated that (according to /2/) the present share of HSS, which is equal to around 20%, will be increased in the future to almost 43%. Simultaneously, the body weight will be reduced by 10-20%.

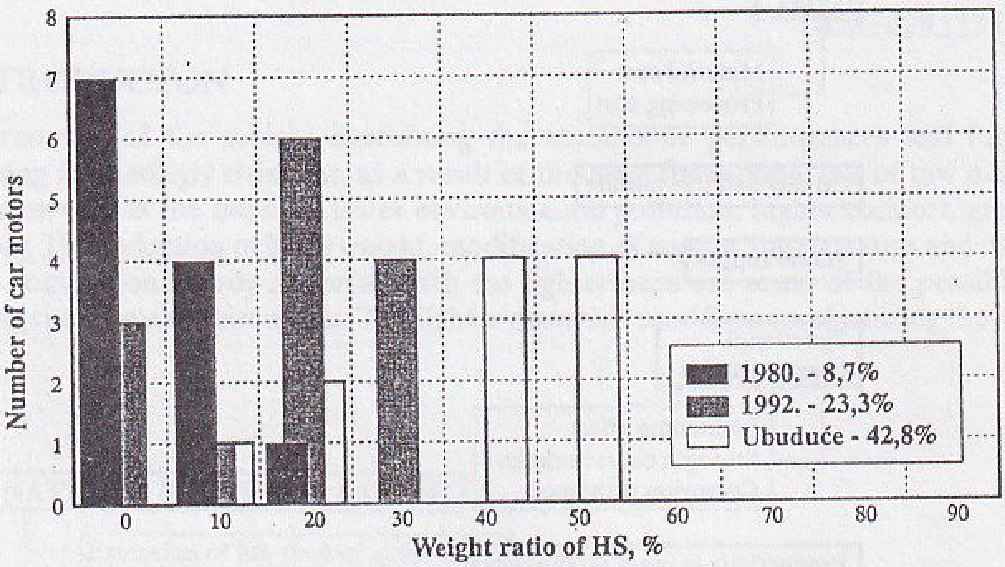

FIGURE 3.: HSS SHARE IN THE AUTOMOBILE BODY PRODUCTION /2/

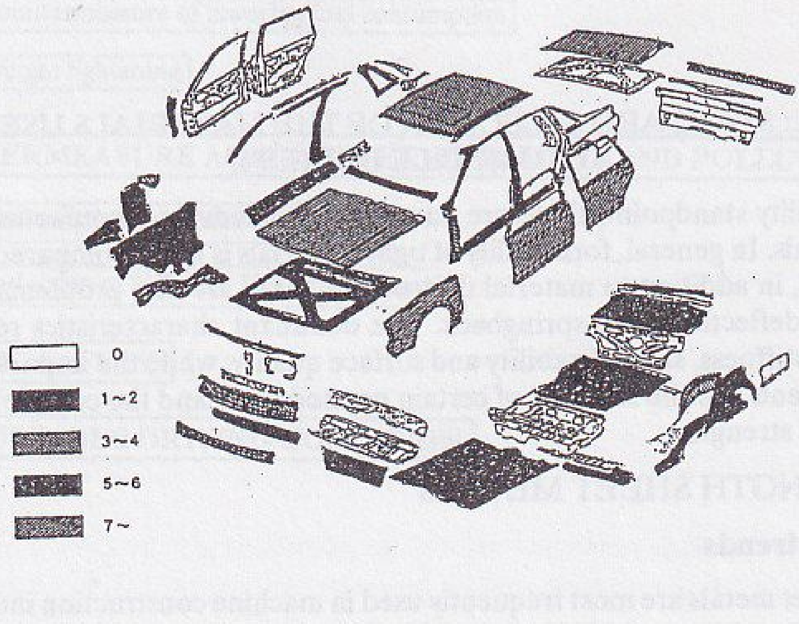

FIGURE 4.: LOCATIONS OF HSS USE IN AUTOMOBILE BODY PRODUCTION

Compared to conventional low-carbon sheet metals for deep drawing, these sheet metals have unfavorable processability characteristics and higher price for the same weight. They are used for manufacturing body parts that do not require high degree of deformations (Fig. 4).

2.2. Basic propeflies of high strength steels

Basic classification of these steels is as follows:

- conventional micro-alloyed ones,
- rephosphoreted, i.e. phosphor-alloyed,
- two-phased steels.

Micro-alloyed steels are produced by adding very small components of alloy elements Nb amd Ti, enabling creation of extremely low grain structure where extracted grains of carbides, nitrides, sulfides etc. are evenly distributed. Tensile strenght of these materials is found in the wide range of 380-800 Mpa, and the yield strenght occurs in the range of 280-500 Mpa. The steels in this group are characterized by extremely high ratio between the yield strenght and tensile strength, relatively low value of anisotropy coefficient (r-factor), insufficient strain mardening (n-factor) and low plasticity. They are mainly used for production of the supporting body elements and less frequently for the exterior body parts.

Phosphor-alloyed steels (with phosphor share of up to 1%) are ranked among new types of materials. Higher phosphor shares than 1% significantly reduce weldability. By lowering the yield strenght and increasing plasticity, so-called modified-rephosphoreted steels are obtained, having much more favorable formability characteristics. This group covers other steels based on the hard solutions (so-called "interstitial freet') with R_p value equal to approximately 150MPa. The shape tixability of this steel is significantly reduced.

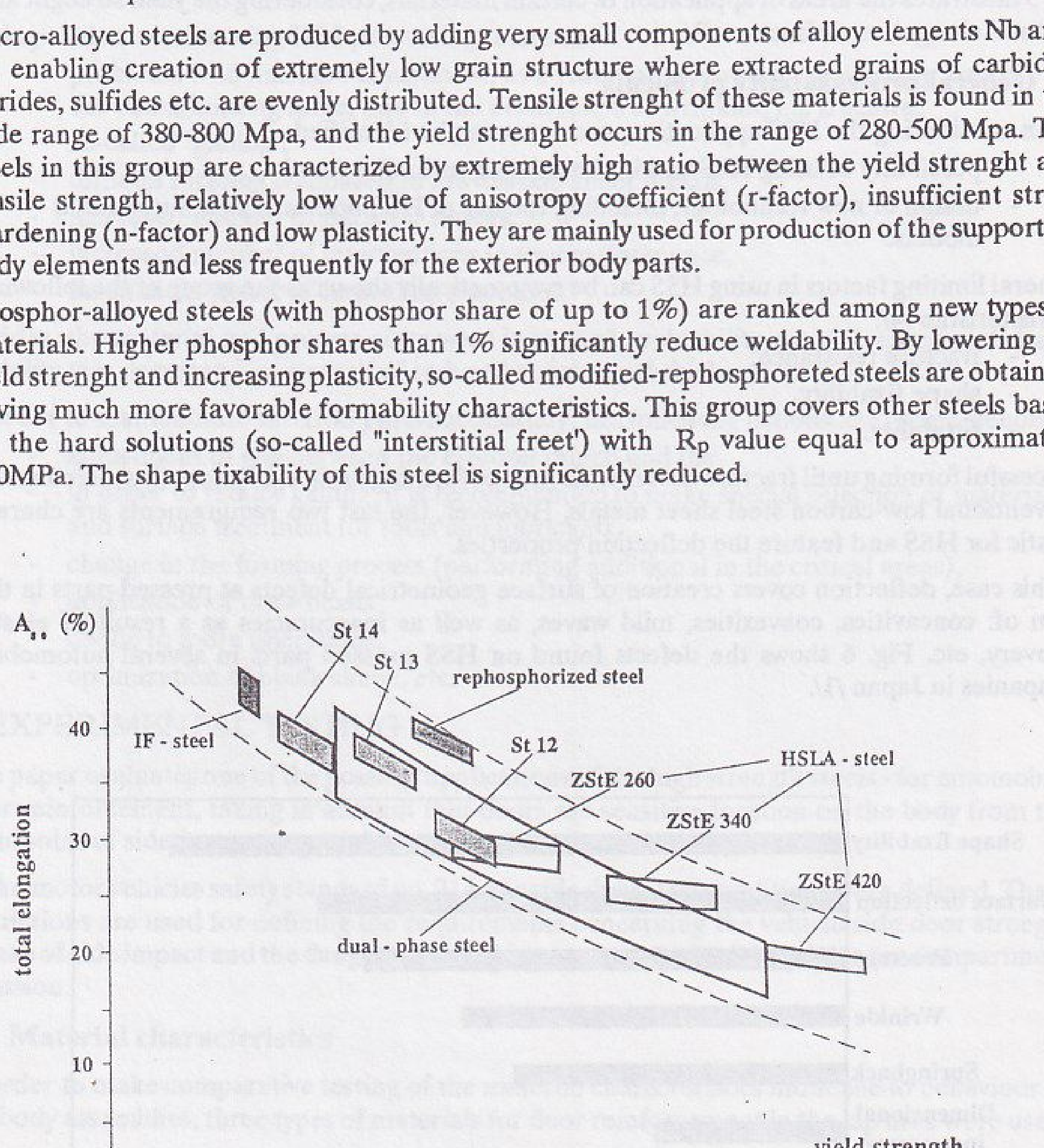

FIGURE 5.: CHARACTERISTICS OF SHEET METALS USED FOR AUTOMOBILE BODIES /3/

Two-phased HSSs have the structure that contains around 80-90% of ferrite and about 10-20% of martensite and oustanding austenite mixture. They have extraordinary deformation reinforcement properties and very high subsequent aging capacity. Their shortcoming relates to low r-factor and low concavity resistance.

Two-phased and rephosphoreted steels exhibit intensive aging already at the temperature of 200°C, which enables additional, so-called, "bake-hardening" of the body parts which occurs after pressing operation in the painting and baking phase. This serves as the means for partial compensation of the basic shortcoming of these steels - low yield strenght, i.e. shape fixability.

Fig. 5 illustrates the areas of application of certain materials, considering the yield strenght and the total elongation at fracture /3/.

2.3. General processability problems

Upon considering the HSS application, two cases can be identified:

- possibility of using HSS within the existing technology and
- design of new technology, including the use of HSS bodies in new automobile models.

General limiting factors in using HSS can be systematically shown as the group of the following characteristics /4/:

- fracture resistance,
- shape fixability,
- fittability.

Successful forming until fracture covers wide area of forming limit, exceptionally studied at the conventional low-carbon steel sheet metals. However, the last two requirements are characteristic for HSS and feature the deflection properties.

In this case, deflection covers creation of surface geometrical defects at pressed parts in the form of: concavities, convexities, mild waves, as well as inaccuracies as a result of elastic recovery, etc. Fig. 6 shows the defects found on HSS pressed parts in several automobile companies in Japan /1/.

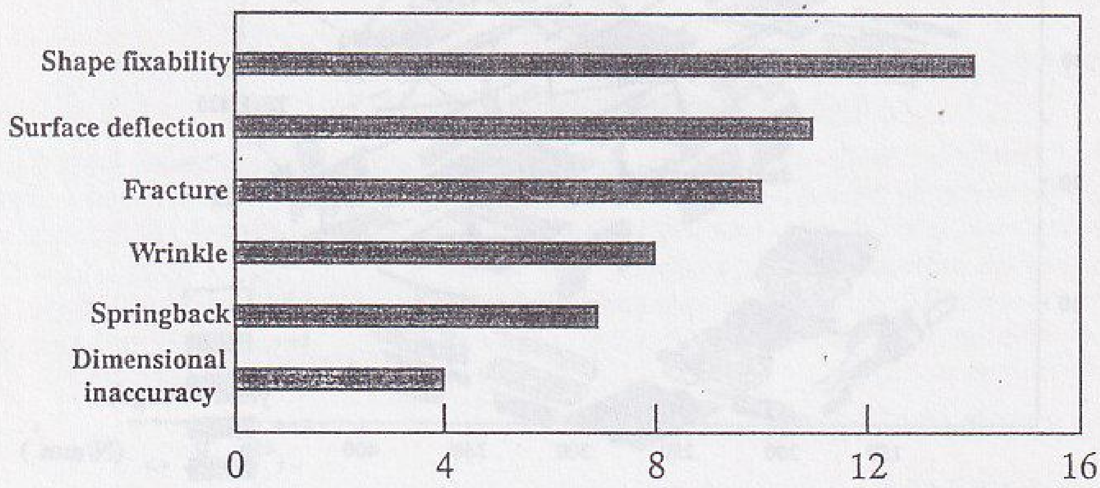

FIGURE 6.: PROBLEMS OF HSS IN FORMING PROCESSES

Shape fixability refer to the material capability to keep the shape and dimensions it had upon processing after shape forming and removal from the tool. Fixability refers to the material capability to keep contact with the tool contact surfaces during processing.

Deflection properties are most frequently tested in the laboratory conditions on the models, which are used for simulating non-homogenous strain-stress condition in certain segments of the part being pressed. Conventional testing in this area is so-called "Yoshida-test", which includes the tensile test of the square (diagonal) or triangle test piece (on the longest side). Height of the wrinkle formed in the direction of tensile testing illustrates the deflection trend /5/.

Basic problems concerning HSS processing relate to:

- problems with machine adjustment, as a result of narrowing the working area of the blank holding force, due to the occurrence of wrinkles, i.e. fracture,
- so-called "galling",
- difficult forming compared to low-carbon sheet metals,
- increased number of parts for rework,
- increased number of interventions in tool maintenance,
- insufficient power of individual machines.

Besides, the material and process costs were increased, weldability was decreased and shape fixability was decreased, as a result of reduced sheet metal thickness.

In order to manufacture the HSS parts successfully, the following actions are recommended:

- adjustment of gap between the ejection punch and die,
- in order to reduce galling, it is recommended to make special selection of materials and surface treatment for tools and lubricants,
- change in the forming process (performing additional in the critical areas),
- application of draw beads
- divide to more operations,
- optimization of blank shape, etc.

3. EXPERIMENTAL TESTING

The paper evaluates one of the possible applications of the high strength steels - for automobile door reinforcement, taking in account that doors are sensitive location on the body from the standpoint of side impact, especially in the lap area.

In the motor vehicles safety standard no. 214, the side doors test conditions were defined. These regulations are used for defining the requirements concerning the vehicle side door strength in case of side impact and the danger that would occur as a result of the passenger compartment intrusion.

3.1. Material characteristics

In order to make comparative testing of the material characteristics influence to behaviour of the body assemblies, three types of materials for door reinforcement in the lap area were used:

- Version 1 (standard material - low-carbon steel sheet metal Č.0146b with thickness of 1.6 mm),
- Version 2 (the same class of material, but with thickness of 2mm), and
- Version 3 (micro-alloyed sheet metal with increased strength x42). Due to the low plasticity properties, this material (domestic production) was used for making reinforcements, where bending forming was dominant.

In addition to the basic characteristics, defined by the standards, the strenghtening curves with the appropriate approximations were given, as a special indicator of the tested materials strength, as shown in Fig. 7.

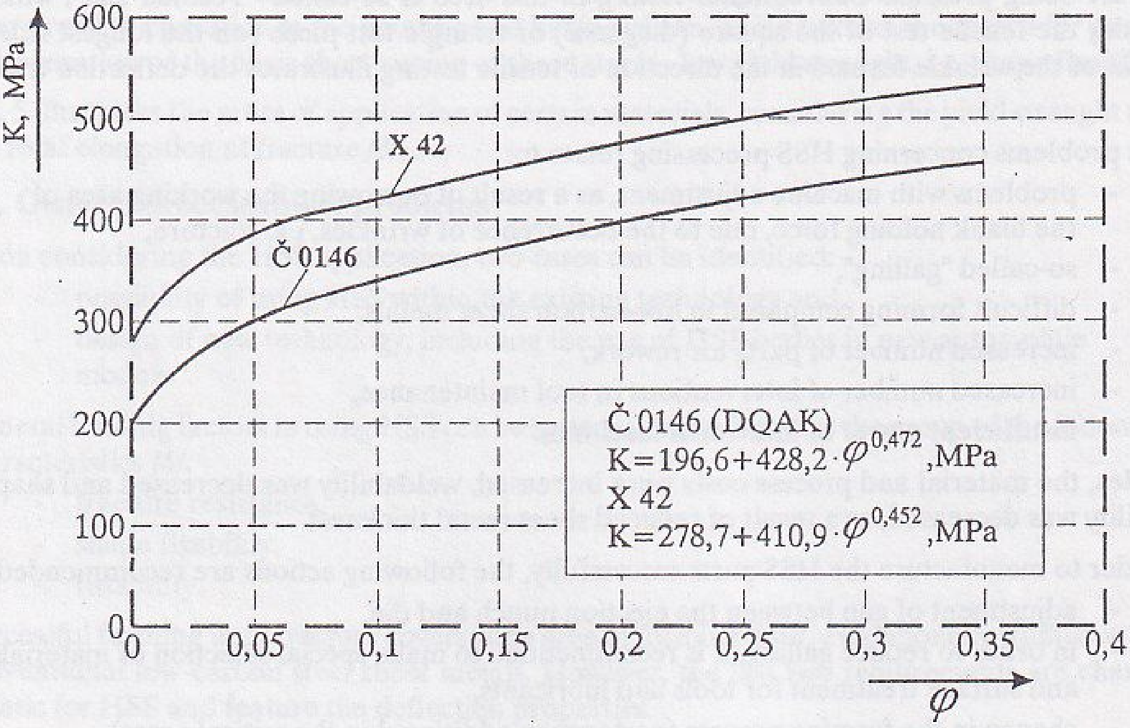

FIGURE 7.: THE STRENGHTENING CURVES FOR TESTED MATERIALS

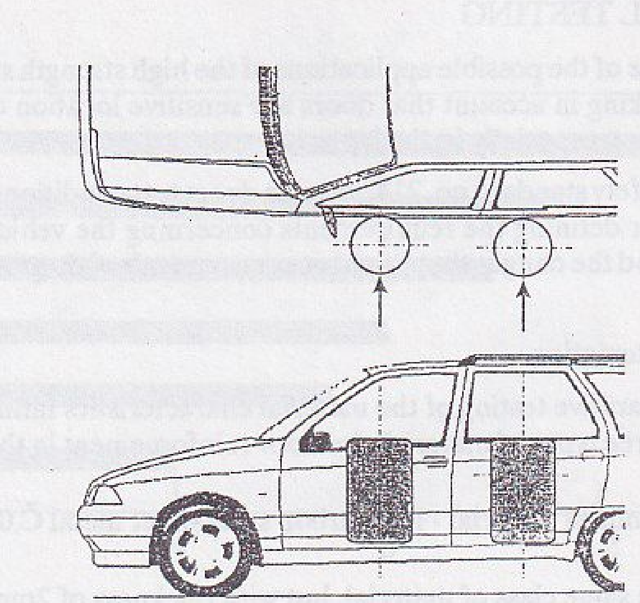

FIGURE 8.: THE TESTED DOORS ATTACHMENT CONDITIONS

The cross-section of the reinforcements is shown in Fig. 8. The door reinforcement behaviour was analyzed for two reasons: the requirements relating to the body are becoming increasingly strict concerning the existing and the near future demands regarding the vehicle impact, as well as the relatively simple shape of the mounting support that is currently being installed to the vehicle. In order to satisfy the regulations concerning the side impact, it is necessary to reinforce the doors in the lap area. Previous design concepts of the door structural frame, used on the tested side doors, required only the door reinforcement in the lap area with the support having the open cross-section. Analyzed versions of the door reinforcements made by application of new materials were possible through the use of the existing tools, in order to obtain the recommendations for the design solutions in the serial production.

3.2. Influence of the reinforcement to the side door behaviour

3.2.1. Test conditions

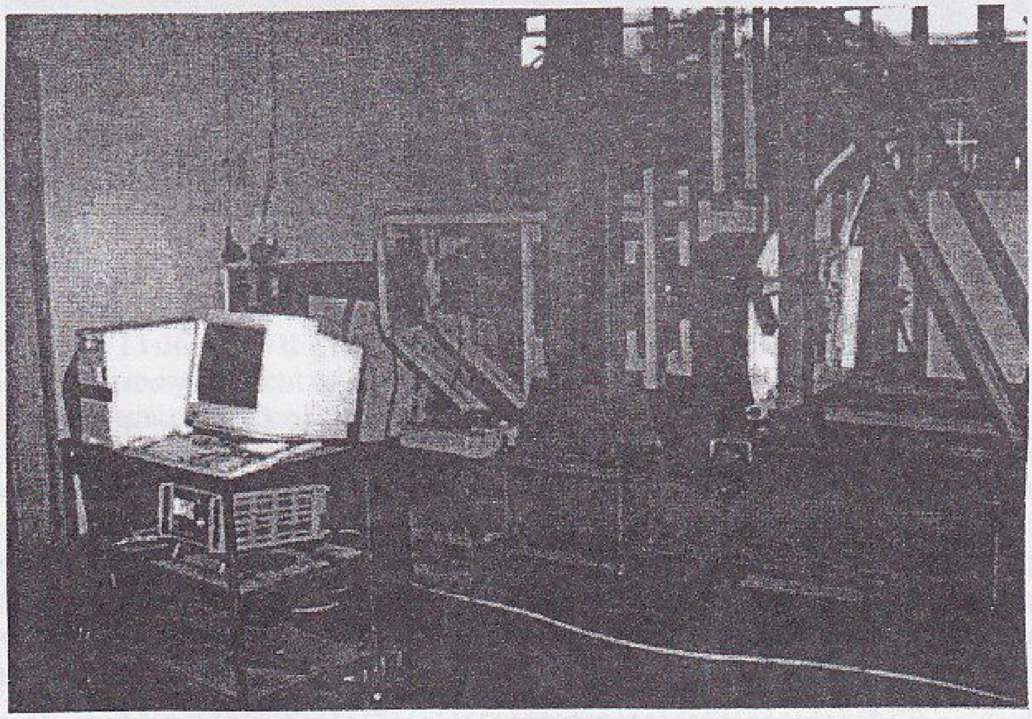

FIGURE 9.: POSITION AND APPLICATION METHOD OF THE TEST DEVICE

The test conditions were partially adapted to the test conditions defined in the regulations, Fig. 9. The load was imposed perpendicularly to the longitudinal vehicle plane, on the point defined in the regulation, at the height of 5 inches from the bottom door edge. The load can be imposed with the defined force, deformation velocity or the imposed displacement. Within this experiment, the load was imposed using the constant velocity. The experiment was interrupted at the moment when contact was made between the door reinforcement and the inner door panel, in order to avoid this influence. The test device is shown in Fig. 10.

The test device was supposed to enable easy door replacement, where this influence was measured, and at the same time to simulate the conditions of attaching the doors to the automobile body through the doors mounting system. The same doors attachment locations were kept (lock and hinges), as shown in Fig. 11 The doors were in contact with the structural frame used for attaching them to the test bench in the lap area. The loading means position was adapted to the regulation requirements, and the contact was made at the door circumfer-

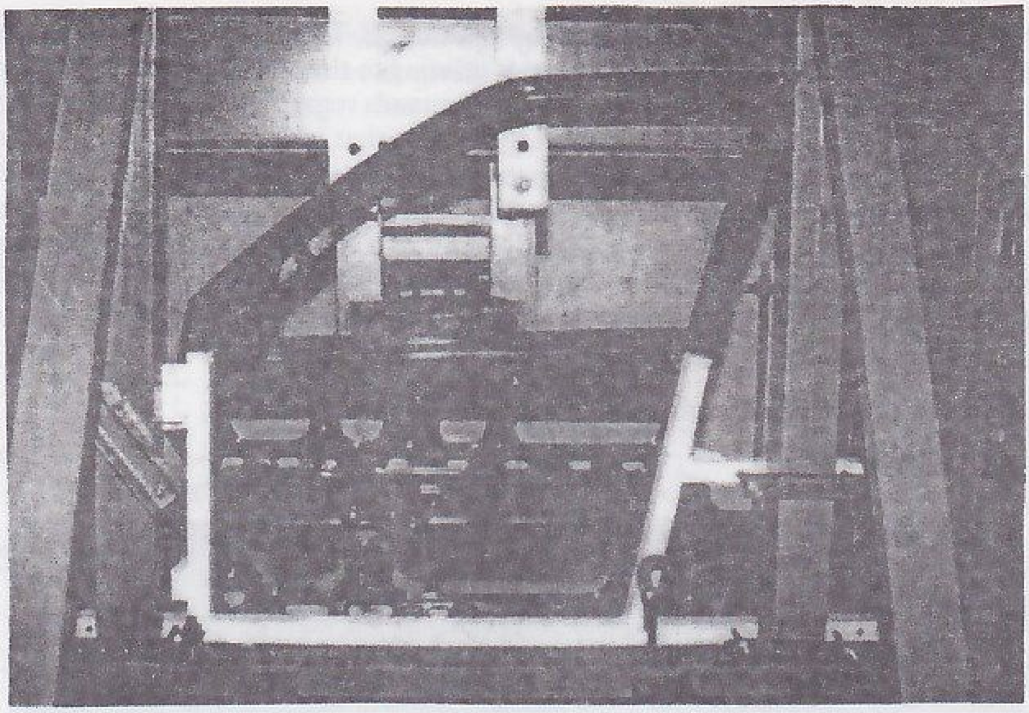

FIGURE 10.: THE TEST DEVICE LAYOUT

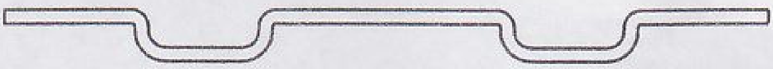

FIGURE 11.: THE DOOR REINFORCEMENT CROSS-SECTION LAYOUT

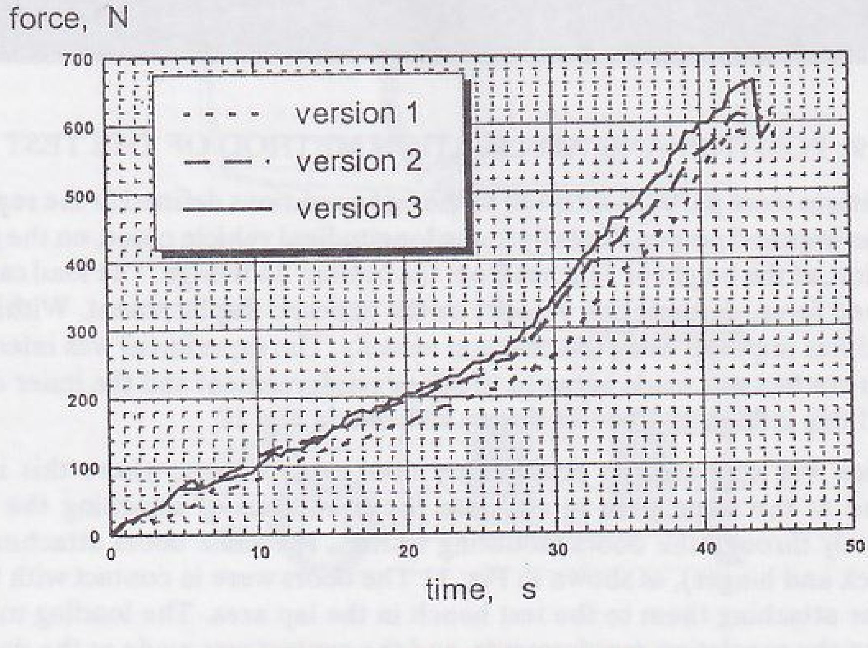

FIGURE 12. TEST RESULTS:

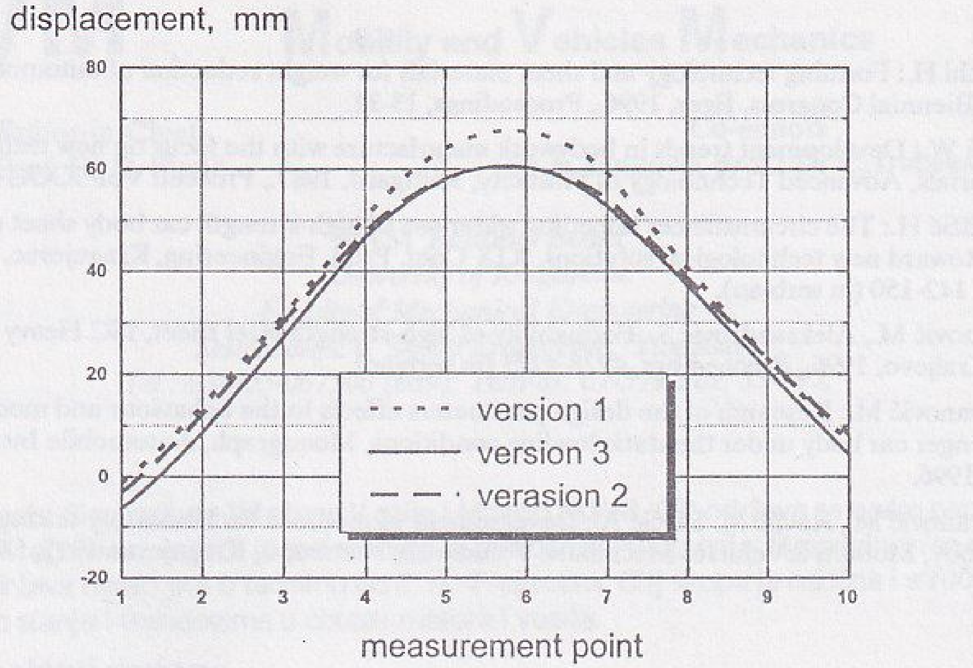

FIGURE 13.: SHAPE OF DOOR DEFORMATION AT THE SUPPORT AXIS

ential rim at the point of installation of the rubber seal moulding (only at the lower door area). The load was imposed at the vehicle longitudinal plane.

Figures 12 and 13 illustrate the test results concerning the reinforcement influence to the door behaviour. The measurement of reinforcement influence n the door behaviour was performed without any effects of the door structural frame, because the experiment was interrupted at the moment when contact was made between the reinforcement and the structural frame. In Fig. 12, it can be seen that the highest force was achieved in the version 3 of the reinforcement. The door behaviour was similar for all three cases of the used reinforcements. Fig. 13 illustrates the shape of the final deformation of the outer door panel at the reinforcement axis plane. The influence similar to the one shown in Fig. 12 was shown. The highest deformation occurred at the door with the standard door reinforcement (version 1). The best door behaviour occurred with the version 3.

The experimental results indicate that certain improvement in behaviour of the side doors was accomplished through use of the new material. The total influence of the new material use in such a redesign is negligible.

4. CONCLUSIONS

The automobile industry is faced with the increasing number of requirements concerning the regulations that have to be met. One of the ways to meet them is the use of new materials, not only for the body itself, but also for the interior and exterior components. However, in order fulfill the set goals and to satisfy certain requirements through use of the new materials, it is necessary to find the appropriate application locations. The experimental results given in the paper indicate that through change of the material thickness only, the expected results are not obtained In the supporting structure elements, use of the new materials should also be combined with the part shape forming application.

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