Fig 8. The fineblanking process

CONCLUSIONS

The analysis of the character of the change of the component stresses σ_x, σ_y in different sections in the region between the wedge-shaped rib and the cutting surface, gives possibilities for defining the optimal parameters of fine blanking process. These are:

- The relative distance from the top of the impressed wedge-shaped rib to the cutting surface (a/s, where: s- thickness of the material, a- distance from the top of the rib to the cutting surface);
- The relative depth of impressing the wedge-shaped rib (h/s) into the material (h- high of the rib).

The optimal value of those parameters are the geometrical relationship in the region between the wedge-shaped rib and the cutting surface, which would insure high quality of the cutting surface during the lowest pressures on the surface of the tool as well as a longest usage of the tool. With FEA, the values of the parameters are: $a/s > 0.69$ and $h/s < 0.3045$, and from the theoretical researches[2] $a/h=0.7$ and $h/s=0.3$.

REFERENCES

1. A.Kocov. Solving the problem of the limit of the plastic zone in the process of fine blanking. Proc. of the 11th Danubia-Adria Sympozium on Experimental Methods in Solid Mechanics,Baden/Vienna, Austria, 1994. 61-63
2. R.Hill. The Mathematical Theory Of The Plasticity. Oxford: University Press 1971
3. S.Kobayayashi. Metal Forming And The Finite Element Method. Oxford: Univresity Press 1982

NEW SHEET MATERIALS FOR AUTOMOTIVE PANELS AND THEIR FORMABILITY

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In the last few decades the automobile industry has passed through an intensive development, integrating the latest conceptions from different areas of science and technology. The development and usage of new materials for autobodies is being coordinated with general social demands, regarding economic resources, energy saving, ecology, driving safety etc. In this paper problems of application of high strength steel sheets and aluminium alloys sheets in car manufacturing industry are considered, sheets categories are enumerated, restrictions (especially deflection problems)are analyzed, and tests for formability evaluation are presented. For a particular type of these sheets experimental results are presented, which contain standard and special parameters of formability, forming limit indicators, etc.

KEYWORDS: autobody sheets, high strength steel sheets, aluminium alloy sheets, formability, deflection

1. INTRODUCTION

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. Social demands towards a car have been changing and adjusting to the social environment. Summary survey of the car production development in the function of social changes and development of technology in Japan in the last four decades, is illustrated in fig. 1 /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 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. For a car manufacturer, five demanding areas can be distinguished: costs, production, styling and space optimization, physical characteristics and quality, and environmental impact. (fig. 2, /2/.

From the formability standpoint, there are numerous problems in manufacturing body parts using light materials. In general, formability of light 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 /3/.

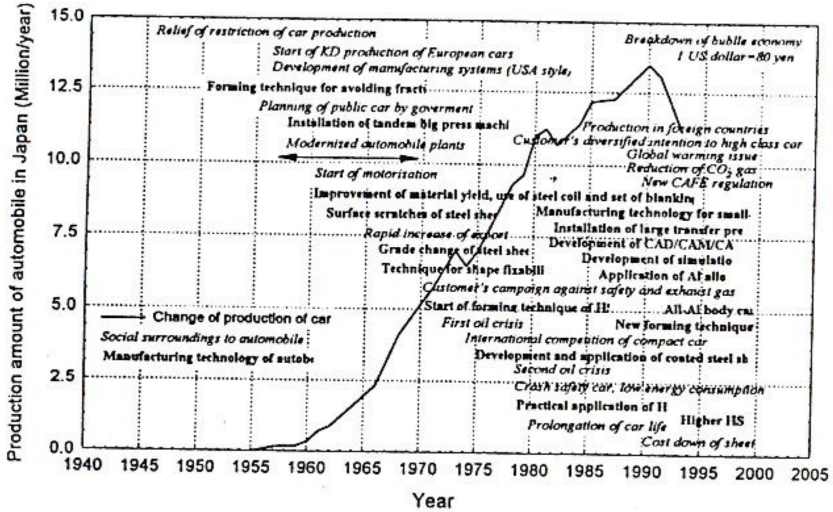

Fig. 1 Change of car production in Japan, social surroundings related to automobile and manufacturing technology of autobody parts /1/

2. SHEET MATERIALS FOR WEIGHT REDUCTION OF AUTOBODY

2.1. High strength steel sheets

High strength sheet metals are most frequently used in machine construction industry, because of their 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 is continuously rising especially in the Japanese car factories. It is estimated that (according to / /) 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%.

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

Basic classification of these steels is as follows:

- conventional micro-alloyed ones (HSLA),
- rephosphorized, i.e. phosphor-alloyed steels,
- dual-phase steels.

Fig. 3 illustrates the development of high-strength, cold-rolled steels for auto-body applications /2/.

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.

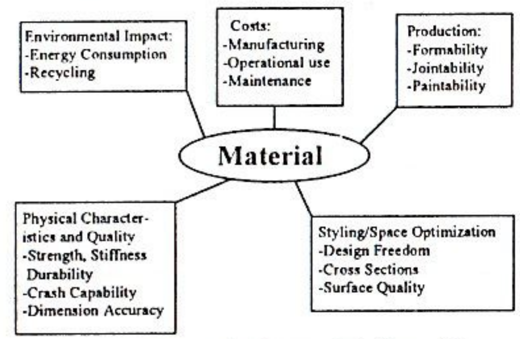

Fig. 2 Relevant car body material challenges /2/

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, was exceptionally studied at the conventional low-carbon steel sheet metals. However, the last two requirements are characteristic of 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.

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

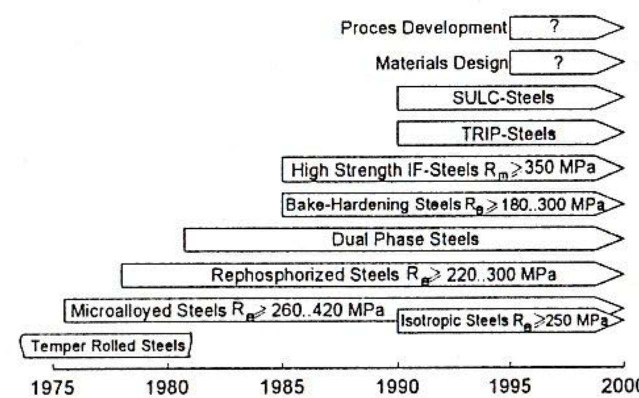

Fig. 3 The development of high strength steels /2/

Deflection properties are most frequently tested in the laboratory conditions on the models, which are used for simulating nonhomogeneous stress-strain 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.

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" and difficult forming compared to low-carbon sheet metals,

-increased number of parts for rework and 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 punch and die,

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

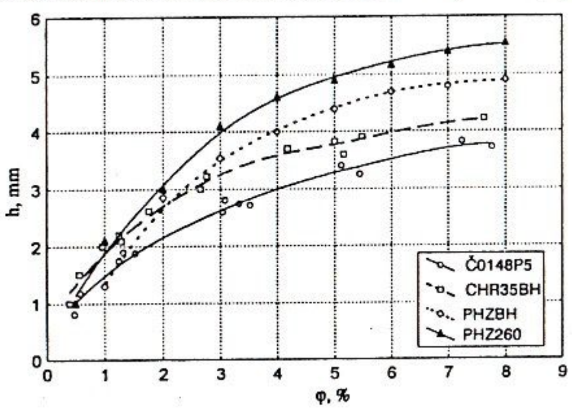

Fig. 4 Wrinkle height dependence on the degree of strain

Further on, some results of deflection investigation for four steel sheet metals categories are given. PHZ materials refer to sheet metals alloyed by phosphorus. The following materials have been used:

a) classic annealing, t=685 °C, lasting 20+22 h (material PHZ 260),

b) annealing above PSK line, t=722°C, lasting 20+22 h (material PHZ BH),

c) classic low-carbon steel sheet killed by aluminium C0148P5,

d) BH sheet metal of foreign producer marked CHR35B.

Mechanical characteristics of these materials are quoted in Tab. 1.

TAB. 1

Order	Material	R_P MPa	R_M MPa	A_{80} %	n -	r -	s mm
1	PHZ260	256	363	37	0.2	1.75	0.7
2	PHZBH	207	340	36	0.2	1.85	0.7
3	C0148P5	177	313	36.3	0.235	1.51	0.7
4	CHR35BH	222	349	33	0.2	1.81	0.7

The change of qualities of BH sheet metals was determined in laboratory, by heating specimens at temperature of 170°C, in period of 20 minutes, which corresponds to the condition of paint baking on autobody. In course of that the following characteristics were obtained:

PKZBH: R_P=288.3 MPa, R_M=353 MPa,

CHR35BH: R_P=299.3 MPa, R_M=387 MPa.

Tendency to deflection in laboratory conditions is most often examined by different kinds of modelling, which simulates strain relations in real forming. The basic examination of this kind is so called

YOSHIDA-test of single-axis tension of square specimen. In course of that, unhomogenous stress-strain field is realized in specimen and wrinkle is formed along main diagonal. Wrinkle height is the basic measuring value and indicator of tendency to deflection.Fig.4 show the results of deflection investigation for particular materials /5/.

The increase of the amount of deflection along with the increase of the yield strength is obvious. Such general evaluation is not sufficient, but has to be supplemented with results of deep drawing in real conditions. Work piece geometry, tool construction, tribological conditions, etc, are extremely important then.

The value of elastic straightening (the angle of springback) in model investigation by bending (fig. 5) can also serve as indicator of shape fixability after exiting out of a tool.

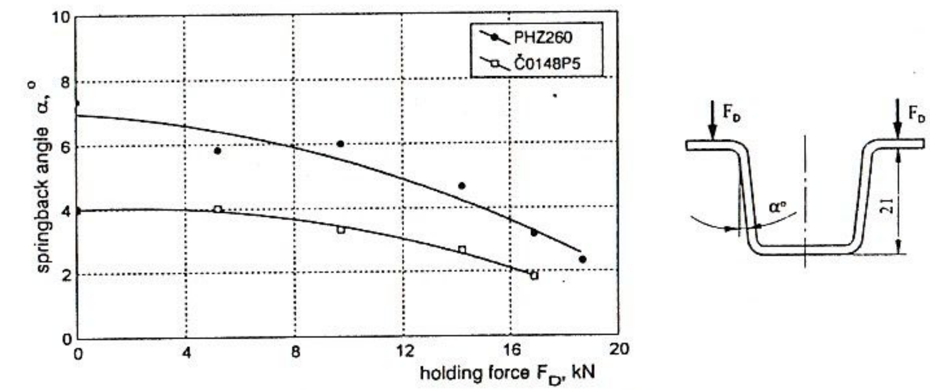

Fig. 5 Elastic straightening in two angle bending

2.2 Aluminium alloy sheet

The application of aluminium for some autobody parts manufacturing began by using Al-Mg-Zn alloy in the eighties (hood, doors, mudgards etc.). According to the researches of the Japanese association for light metals from 1990 , the share of alluminium alloys in total car mass was 8.3%. In the market, there already are some cars with whole autobody made of these alloys. According to the anticipations, the share of aluminium alloys in total car mass is expected to be about 15% for special passenger cars and 25% for high performance cars /6/.

By the application of the classic approach in car design, constant demands for the improvement of car safety, comfort, better performances and universality had as a consequence the increase of car mass. The adjusment of engine power to these demands in the sence of greater speed, implies the need for better chassis which leads to the increase of mass. In order to make a car fit for traversing long distances, the size of the tankmust be increased and, as final but not the last fact, the autobody stiffness must be increased as well. In that way, the weight spiral is formed, fig. 6 /7/.

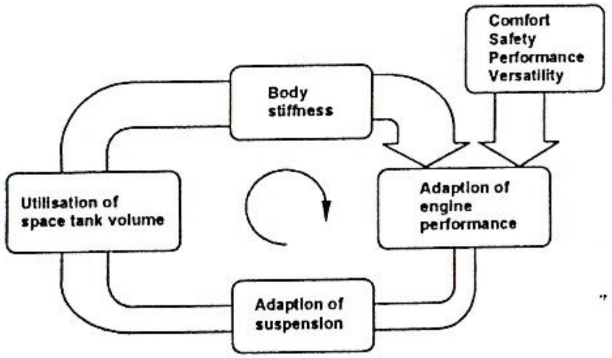

Fig. 6 Weight spiral /7/

Researches proportional to the previous observations led car manufacturers into developing a new approach to the autobody construction in which the whole autobody is made of aluminim. The example of that new approach is the philosophy developed by AUDI and can be expressed as the following slogan-"progress through technology". As far back as 1993, AUDI has been making the whole autobody of aluminium alloy (model A8). The usage of aluminium for autobody only, not including other parts, leads to significant decrease of mass, thus making the first step towards turning the weight spiral in the opposite direction (fig. 7).

In the following step, some parts can be redesigned of lighter material. These first two steps lead to additional expenses. If the performance is held constant, it becomes possible to use engine and gear box of smaller size. The reduction of autobody and engine weight leads to the decrease of forces acting upon the chassis which makes possible the lessening of chassis as well. If the maximal distance the car can traverse is held constant, then the tank volume can be reduced. The last three steps lead to the reduction of expenses.

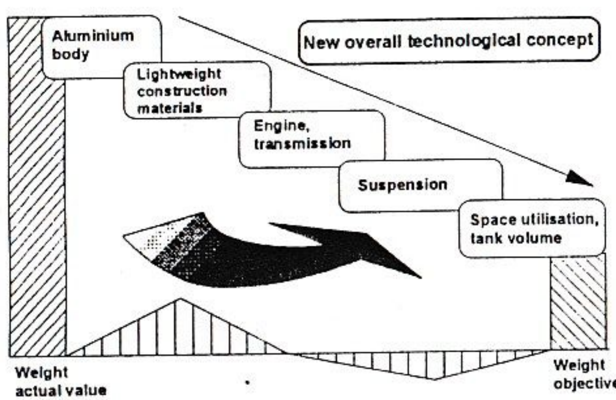

Fig. 7 Reversal of the weight spiral /7/

In the initial stage of using aluminium for autobody parts, the simple replacement of steel sheet metals by aluminium sheet metals was carried out, whilw keeping the same sheet metal thickness. This led to the reduction of mass for 66%, but the sufficient stiffness was not achieved and certain functional problems appeared. Local strengthenings may help in solving some of these problems, but it stil continues to be the classic concept used in application of steel sheet metals. The solution is the new conception in which the whole autobody is made of aluminium. Sheet metals of Al alloys and work pieces of Al obtained by extrusion and casting are used for such autobodies.

For autobody parts three groups of Al alloys are more often used: Al-Cu (series 2000), Al-Mg-Si (series 6000) and Al-Mg (series 5000). Main mechanical characteristics of these alloys are:

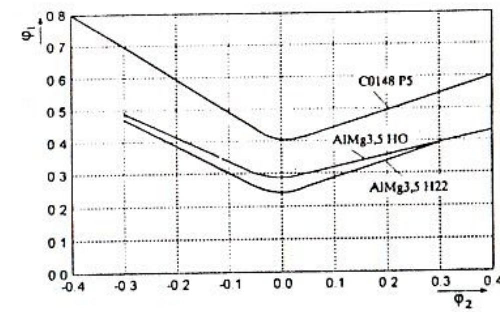

Fig. 8 FLD for various materials

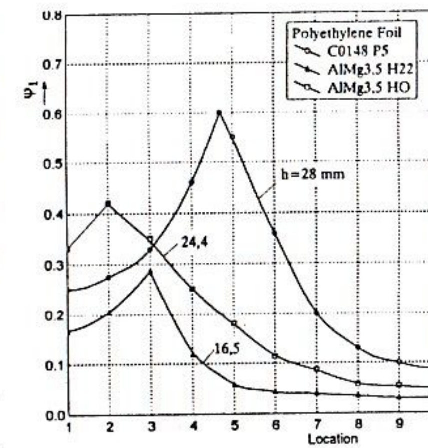

Fig. 9 Strain distributions in stretching

-yield point and tensile strength are lower than in steel sheet metals,

-elasticity module has three times less value than steel,

-elongation (especialy local) is small and nonhomogeneous forming is present,

-normal anisotropy coefficient is small (below 1),

-its hardness is relatively small and surface is easily demaged.

One of specific qualities of aluminium alloys, in comparison to steel, is that they can be obtained in great number of conditions, considering the achived strain degree or thermal treatment, which can influence the satisfying of different demands.

Some results of investigation of parameters of Al-sheet metals formability by deep drawing intended for plastic forming are given here. The investigated material is sheet metal of alloy AlMg3,5 (0.8 mm thick). Two conditions of this alloy were used: soft (H0) with hardness 48 HV and "half-hard" (H22) with hardness 69 HV. Main characteristics of these materials are given in tab. 2.

TAB. 2

Material	R_P, MP	R_M, MPa	A_{80}, %	n	r
AlMg3,5 H0	124.6	240.1	23.5	0.26	0.557
AlMg3,5 H22	185.6	265.9	14.8	0.16	0.618

Tab. 2 shows that the increase of alloy hardness reduces elongation and strain strengthening exponent n, while strength characteristics are increased.

Methodology developed for researching classic steel sheet metals formability can be used for Al-sheet metals (test of pure deep drawing, streching, forming limit diagrams (FLD), deflection tests).

Fig. 8 shows FLD for investigated materials. Diagrams were determined by using semi-spherical punch (50 mm diameter) and specimens of various width (Nakazima procedure). Determining of strains was realized by measuring circle grid before and after forming. A grid with 3.3 mm diameter was deposited onto the sheet metal surface by electro-chemical procedure. Upper lines of FLD are shown and they correspond to the appearance of the destruction of specimens.

The position of curves in FLD for AlMg3,5 alloy is lower in comparison to steel C0148P5, but the realized strains for alloys in soft state are greater in comparison to half-solid state. The cause of this is the smaller value of r factor in AlMg3,5 alloy.

Fig. 9 shows parallel main strains distributions realized in stretching of circular specimen with 120 mm diameter, and in conditions described in the paper /6/.

4. CONCLUSION

High strength steel sheet metals have exceptional application in car industry which is constantly growing, especially in developed industrial countries. Because of reduced formability qualities they are used for obtaining parts with low degree of drawing and simple geometry.

The basic advantages of using HSS are: reduction of autobody weight, increase of passive safety, improvement of sagging resistance, etc. Its disadvantages are: the appearance of deflection, change of tribological conditions, insufficient holding force, etc.

Generally speaking, Al-alloys sheet metals have lower formability in comparison to steel sheets. In manufacturing of autobody parts the following problems appear:

-the formability elements cannot be exactly controled, which makes it very difficult to make the right choice of material for some pressing parts, firstly because of small r factor value and low limit of permissible bending due to the small value of local strain,

-blank holding force range is smaller related to steel,

-demages on the work piece surface (saggings, scars) appear easily,

-Al-alloys tie themselves adhesively for the tool which leads to the work piece destruction,

-ability to maintain the shape is worse due to the small value of the elasticity module,

-Al-alloys are not magnetic which makes difficult the classic manner of manipulation of work pieces.

REFERENCES

/1/ Hayashi H., Forming technology and sheet materials for weight reduction of automobile , 19th IDDRG Biennial Congress, Eger, 1996, Proceedings, pp. 13-31.

/2/ Bleck W., Cold-Rolled High-Strength Sheet Steels for Auto Applications, JOM, 7, 1996, pp. 26-30.

/3/ Milovanovic M., Radisavljevic M., Stefanovic M., Jevtic R., Some aspects of the New Materials for application on Vehicles, MOTOAUTO 98, Sofia, 1998, Proceed., pp. 188-193.

/4/ Stefanovic M., Aleksandrovic., Formability of high strength steel sheet, ISC Heavy Machinery, Kraljevo, 1996, Proceed., pp. 4228-4233 (in serbian).

/5/ Stefanovic M., Aleksandrovic S., Milovanovic M., Jevtic R., High Strenght Steel for Automotive Panels snd their Formability, Metallurgy and New Materials Researches, 1998, Vol. VI., No.4, pp. 29-42.

/6/ Kitora K., Recent technical development in the Japanese aluminium industry, 1990, Aluminium, 66, 7/8, pp. 755-772.

/7/ Nagler M., Hummel S., Kaiser M., Zengen K.H., 1997., The Aluminium Audi A8, Aluminium Conference 97, Essen, Proceed., pp. 5/1-5/4.