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APPLICATION OF TAILORED BLANKS IN THE AUTOMOTIVE INDUSTRY

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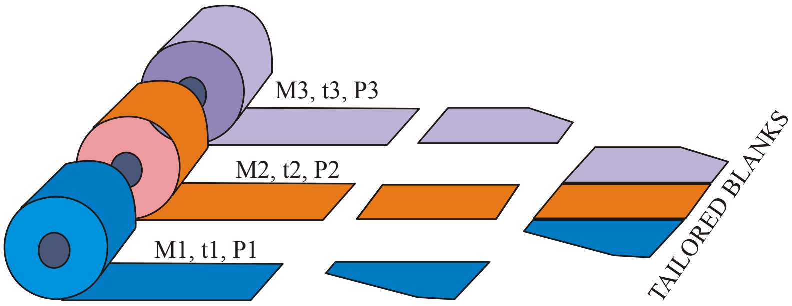
ABSTRACT

Weight reduction, increase of structural stiffness and passive safety are major challenges for achieving the new concept of automobile and truck bodies. In past few years, it led to wide use of tailored blank made of steel and aluminum alloys thanks to actual state of laser welding technique which enables high welding speed, narrow area of heat influence, system of automatic control and detection of defects. Examples of use, tool problems and introduction in new conceptions for tool production are given in this paper.

1. INTRODUCTION

More than a one third of a whole world steel and aluminum production has been processed in sheet metal semifinished products. Big consumer of sheet metal products is the automotive industry.

There have been significant changes in car production during last two decades. Permanent yearly growth of car population and energy crisis put a demand on decrease of average fuel consumption [6]. Aiming at this, developed countries have issued new standards for car manufacturers, resulting in new development concepts through encompassing three major car assemblies: body, transmission and equipment. From one side, decrease of fuel consumption is achieved by producing more efficient engines, and from the other, by the reduction of total car's weight which can be reached by means of implementation of new technologies, high strength steels, introduction of artificial materials and by replacing steel parts with those made of lighter materials. Body of a car makes some 25% of car's price, while the body's share in total weight is over 30%, in average. Therefore, since 1990 share of aluminum alloys in body's production has been significantly increased. Along with the low weight, its advantages are recycling and corrosion resistance. However, great mass and stiffness reduction affects the safety in collision. In order to reduce car's weight without affecting on safety, promising solution is the use of tailored blanks. These are sheet metals which were welded before forming process. Welded sheet metals can be made of the same or different materials, they can have the same or different thickness, same or different surface treatments (for example galvanized versus ungalvanized), Fig. 1.



Mi-quality of material, ti-sheet thickness, Pi-surface treatment

Fig. 1. Principled scheme of making tailored blanks

The most frequently used welding techniques are laser welding with CO_2 and Nd: YAG (Neodymium-Yttrium Aluminum Garnet) lasers. At the beginning, applications had a joint of two sheet metals in a form of a straight line, but the development of laser equipment has made possible the use of tailored blanks with multiple weld line and tailored blanks with non-linear weld line.

Putting great efforts in new concepts in automotive industry with the aim of mass reduction, decrease of fuel consumption, increase of construction stiffness and passive safety, material and car producers have established international consortium for realization of important projects.

ULSAB-AVC (Advanced Vehicle Concepts) project has been introduced in 1999 by 33 steel producers from all over the world. AVC is project for advanced concept of vehicle from popular European class C (e.g. Golf) and American middle class PNGV (the U. S. Partnership for a New Generation of Vehicles). The aim of the project is achieving the higher safety standards and decreased pollution of environment. Significant mass reduction of some 200 kg and fulfillment of new safety standard has been achieved, as well as decrease of fuel consumption to 3,2l/100km and 86 g/km emission of CO_2.

New efforts are pointed toward finding new materials, now existing just in laboratories, which are going to be used in automotive industry from 2004.

Tailored blanks and tubes account for nearly 40% of the body and closure structures, with hydroformed parts making up more than 20%. Stamping is the predominant steel forming method in ULSAB-AVC, demonstrating this process's continuing effectiveness, even as use of more complex steels grows. More than 70% of the body structures and closure parts make use of this process.

ULSAB-AVC project is based on previously completed ULASAB, ULSAS and ULSAC projects.

ULSAB (Ultralight Steel Auto Body) project was started in April 1994 with the aim of improvement of steel use in automobiles. ULSAB was financed and directed by the consortium of 35 main steel producers from 18 countries, almost all auto companies and governed by the Porsche Engineering and American Iron&Steel Institute (AISI), Southfield, USA. ULSAB project had two stages. First stage, finished in 1995 after 15 months of work, was conducted mainly by Porsche Engineering Service with the aim of presenting an automobile which should have been light, spacious, safe and not so expensive, yet produced by means of existing technologies and with accessible materials. The costs of the second stage were about 20 millions US $, comparing to 2 millions US $ spent in the first stage. ULSAB project was officially closed in 1999, and main component of this project was production of side body panel. Comparison of conventional and tailored blanks technique of side body panel production was shown in Fig. 2.

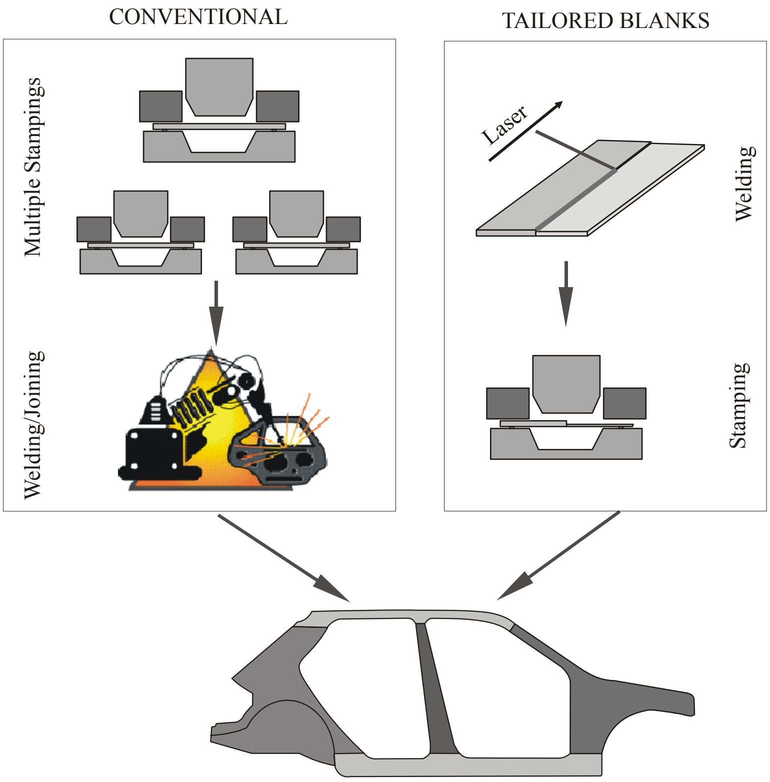


Fig. 2. Comparison of making the side outer by applying conventional and tailored blanks technology

Body side of automobiles usually consists of 5-6 parts having different thickness and material quality. To produce body side it is necessary to have some 20 forming tools and to implement welding operations or spot welding. Utilizing the tailored blanks technology number of necessary forming tools is decreased to 4, with the increase of dimensional accuracy, stiffness and corrosive resistance.

ULSAS (Ultralight Steel Auto Suspension) project was closed in 2000 and 35 companies for steel production from 18 countries participated in it. This has led to significant improvements in production of vehicle suspension parts.

ULSAC (Ultralight Steel Auto Closures) project was closed in 2001 and 31 company participated in it. This project provided significant improvements in design and production of automobiles' doors. ULSAC has the objective of reducing the weight of cars' closures such as doors, hoods, and hatches. The result is a frameless door, which is 42% lighter than the benchmarked average of frameless doors, and does not compromise safety or structural performance. The basis for the mass reduction is the use of high and ultra high strength steels, dual phase steels as well as the introduction of new manufacturing technologies such as tailored blanks and hydroforming.

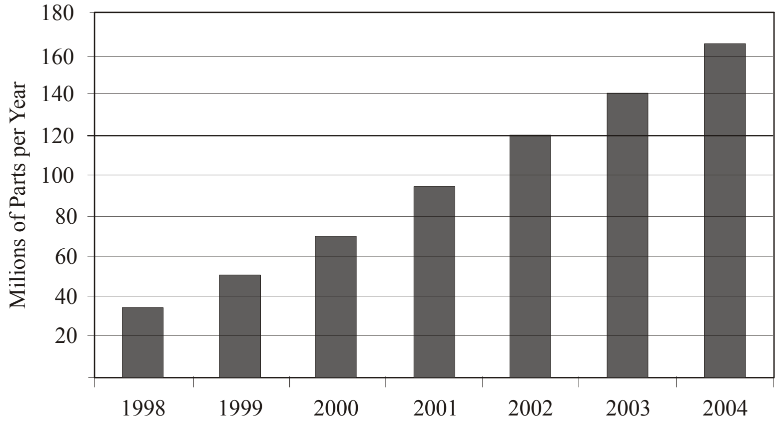


Fig. 3. Estimated worldwide tailored blanks annual demand (in parts produced)

All of these projects have significantly influenced the use of tailored blanks in production of vehicle's body parts. Permanent linear annual growth of worldwide produced tailored blanks is estimated for the future, Fig. 3.

2. EXAMPLES OF TAILORED BLANKS USE

According to experts, one of the most rapid developed techniques in metal processing today is the use of tailored blanks in automobiles and trucks productions. Producers worldwide have accepted such technology; European producers started with smaller, while American producers started with bigger body parts (doors, body sides).

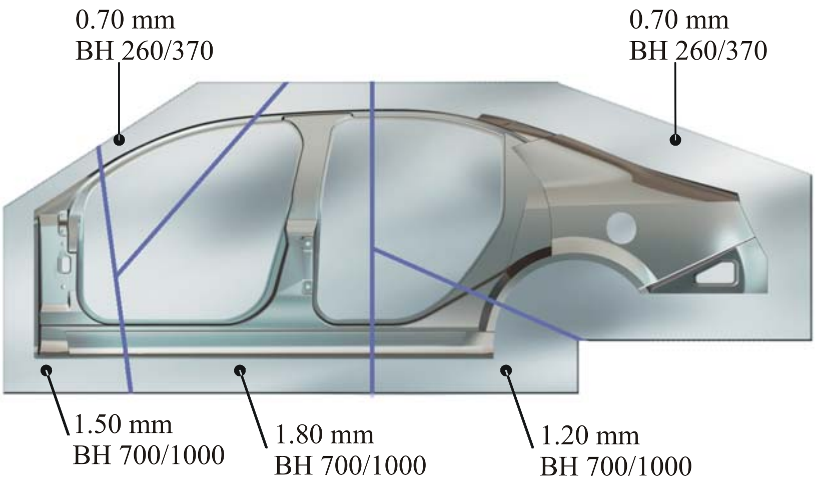


Fig. 4. Side outer panel made of steel tailored blanks

The first European car producer who introduced tailored blanks in car production was Swedish Volvo. In 1979 the laser equipment was delivered to Volvo by Soudtronic AG, Neftenbach, Switzerland - today the leading producer of laser equipment for tailored blanks. After that, Audi started to use tailored blanks in 1995. The first Japanese car producer who introduced these sheet metals in 1986 was Toyota. Significant use of these sheet metals in America started in 1993.

From the beginning, steel tailored blanks were used, but now the share of aluminum-alloy tailored blanks has been significantly raising.

All world major car and truck producers use tailored blanks.

The appearance of a car body side made of tailored blanks is shown in Fig. 4. Before forming, sheets made of different kinds of steel, having different thickness, were cut out and welded.
An example of an automobile part made of tailored blanks consisted of different thickness Aluminum-alloy AA6016A is shown in Fig. 5.

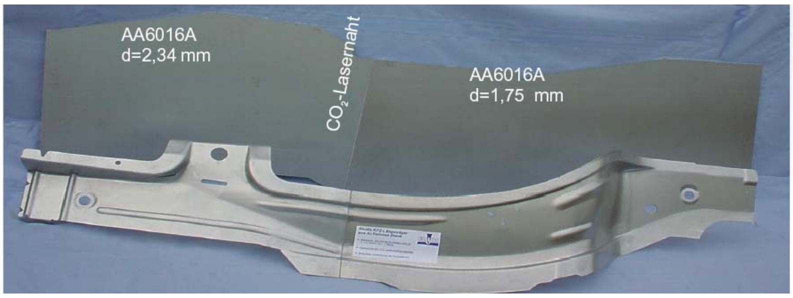


Fig. 5. Part of car body made of aluminum tailored blanks

Main advantage of tailored blanks use is capability of successful fulfillment of demands imposed through new standards to automotive industry. It reflects in:

- reduction of vehicle body weight by elimination of strengthening and sheet overlapping at spot welding,
- improvement of safety at collisions due to increased stiffness of laser welding joint comparing to spot welding joint,
- reduction of manufacturing costs due to less forming tools needed, omission of spot welding and reduction of waste materials.

Besides, tailored blanks improves dimensional accuracy and corrosion resistance of jointed components in critical areas.

3. PROBLEMS AND CONCEPTIONS OF TOOL PRODUCTION

Use of tailored blanks impose a special attention to be paid to tool design due to different strains in different areas of product being formed. At tailored blanks consisting of sheets having different thickness, flow of material transversally to weld line could lead to crack of sheet or to forming of wrinkles, depending on stress state and direction welding joint line in regards to step of bottom blank holder (Fig. 6).

Wrinkles on thinner or thicker sheet could also arise due to positive or negative deviation of nominal sheet thickness. When using such blank holders, thickness deviation should be coordinated with the producer. This problem is present especially at the conventional tools.

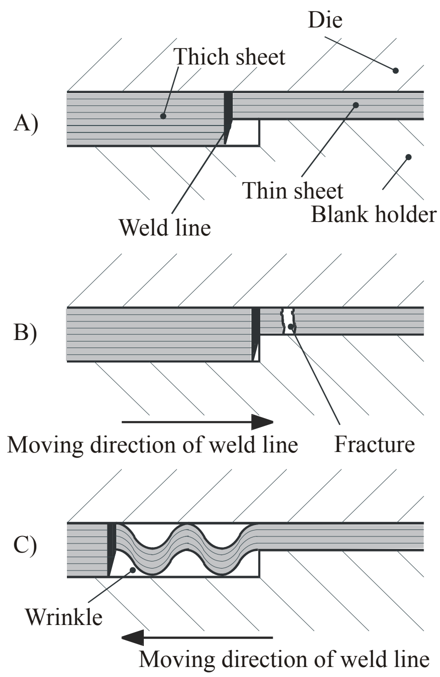


Fig. 6. Problem of material flow

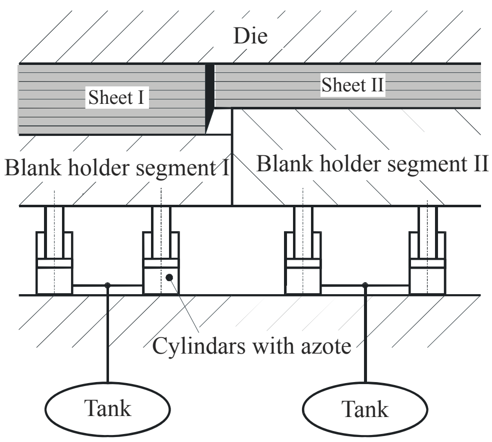


Fig. 7. Tool with the segment blank holders

In order to solve tailored blanks forming problems successfully, new conceptions of tool productions have been applied. At the Institute of Plasticity (IFU) Stuttgart, Germany, concept of segment holders has been developed [5; 10], where the blank holder pressure can be regulated by means of hydraulic or nitrogen cylinders (Fig. 7) or through press drive.

At Northwestern University (Evanston, USA), new approach and apparatus for regulation of deformity in the area of welding joint at aluminum tailored blanks forming. The essence is the use of hydraulic cylinders, regulating blank holder force and movements of weld line during deep drawing, preventing arise of cracks or wrinkles in the area of weld line. Such tool conception is especially convenient for tailored blanks with nonlinear weld line. Concept of tool with pressure regulation in welding joint area and capability of influence on deformity, as well as the change of weld line position during forming process is shown in Fig. 8 [3; 6].

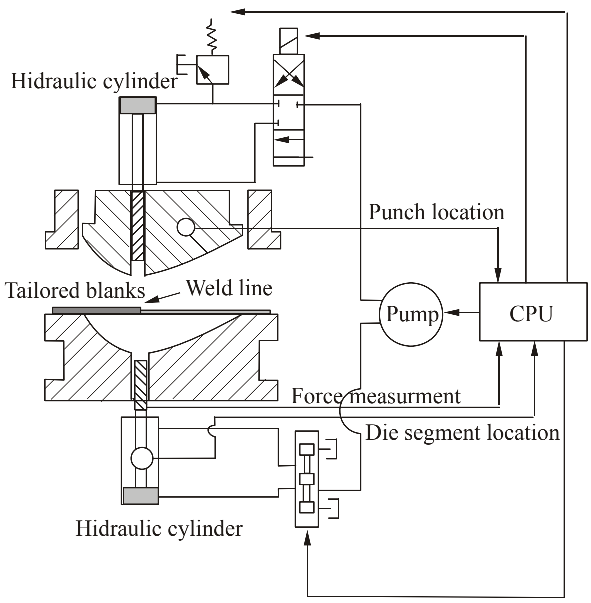


Fig. 8. Tool with local adaptive controllers

Such tool prevents cracks to arise in the vicinity of weld line as a result of inferior material deformability in the area of welding joint and great material strains in a direction transversal to a weld line.

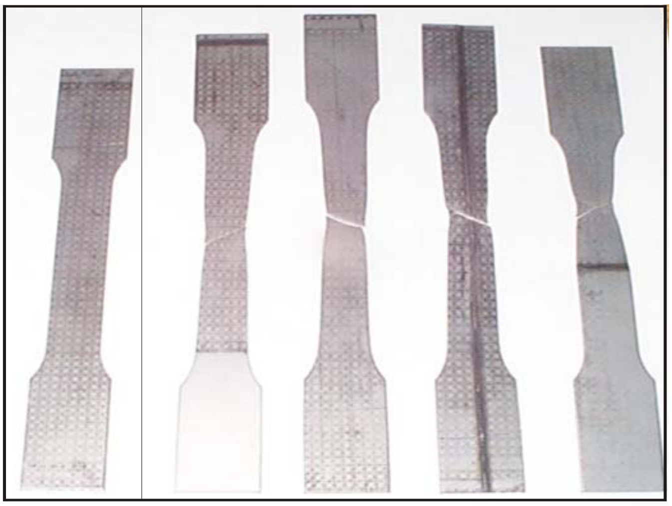
4. EXPERIMENTAL INVESTIGATIONS OF FORMABILITY

Laboratory for Technology of Plasticity at the Faculty of Mechanical Engineering in Banja Luka investigated the formability of tailored blanks produced by laser welding of cold-rolling sheets for automobile bodies marked as ZStE180BH, thickness combination 0.8-1.5 mm. In the paper, in the main, presented the properties of the base material. Mechanical properties were determined by uniaxial tensile test. The size of a specimen were 20 mm width and 80 mm lenght, according to EN 10002. Chemical composition and basic mechanical properties are shown in Table 1. The initial tensile test specimen is shown in Fig. 9a, and specimens as they were after tensile test, for different materials and sheet thickness are shown in Fig. 9b (b1 - non welded sheet 0.8 mm, b2 - non welded sheet 1.5 mm, b3 – weld line parallel of maximum strain, b4 – weld line perpendicular of maximum strain). Differences in elongation are apparent, with total elongation much less at welded specimens.

In Fig. 10 shown stress-strain curves of the base sheets.

Table 1. Chemical compositions and mechanical properties of the base steels

Sheet ticknees	0.8 mm	1.5 mm
Chemical compositions	0.02% C, 0.15% Mn, <0.05% Si, 0.010% P, 0.014% S, 0.028 % Cu, 0.03 % Cr, 0.03 % Ni, 0.07 % Al	0.03% C, 0.15% Mn, <0.05% Si, 0.017% P, 0.015% S, 0.028 % Cu, 0.04 % Cr, 0.03 % Ni, 0.06 % Al
Mechanical properties	$R_{p0,2}$=205.6 MPa, R_m=302.2 MPa, A_{80}=27.99%, n=0.179	$R_{p0,2}$=180.8 MPa, R_m=263.4 MPa, A_{80}=35.56%, n=0.204



a) b1. b2. b3. b4.

Fig. 9. Tensile test specimens

At the tensile test specimens with weld line perpendicular to tensioning direction breaking occurs in the area of thinner material approximately in the middle between clamping point and weld line.

At the tensile test specimens with weld line parallel to tensioning direction crack appears in the weld line at the first, and afterwards in the vicinity of the weld line.

Characteristics of base materials used to form tailored blanks have been determined. However, properties of these materials can not be simply transmitted to tailored blanks since both materials and welding line area flow in different manner during the forming process. This investigation could give values helpful in discussion of formability and comparison of formability of base materials and produced tailored blanks.

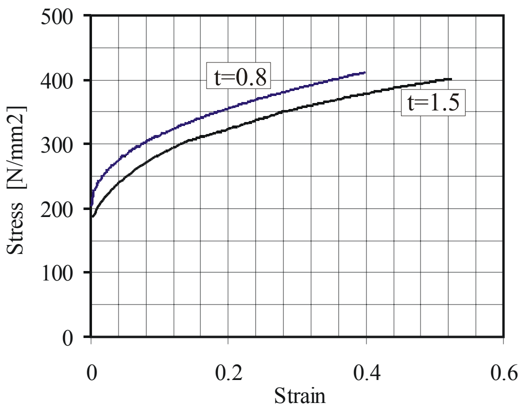


Fig. 10. Stress-strain curves of the base sheets

The quality of the weld in a tailored blanks is critical for a successful forming operation.

For the evaluation of the mechanical properties of the welded metal (which includes the weld bead and heat affected zone in the sheet metal), an analytical procedure has been performed.

The total force on the welded specimen with weld line parallel to the direction of tensile loading, is represented as follows:

$$F = \sigma_1 A_1 + \sigma_2 A_2 + \overline{\sigma}_w A_w \tag{1}$$

$$F = \frac{A_{01}}{e^{\varphi}} C_1 \varphi^{n_1} + \frac{A_{02}}{e^{\varphi}} C_2 \varphi^{n_2} + \frac{A_{0w}}{e^{\varphi}} C_w \varphi^{w} \tag{2}$$

where

A_{0i}, A_i, C_i, n_i (i=1, 2, w) are the initial cross-sectional area, the deformed cross-sectional area, the strength coefficient and the work-hardening exponent of the base metals and the welded metal.

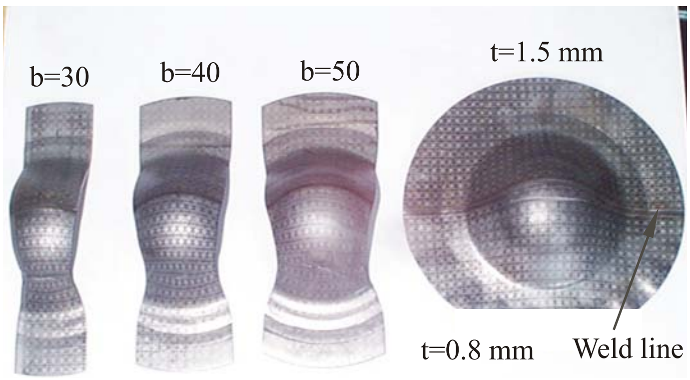


Fig. 11. Spherical punch stretch forming test

The values of the φ are the same in the base metals and the welded metal. A method to determine weld with is using image analysis of metallographic section or to use microhardness profiles.

At punch stretch forming test, according to expectations, cracks appear in thinner material. Direction of crack is parallel to the weld line (Fig. 11). Weld line has been moved then. Strain distributions for the base sheets are shown in Fig. 12 and Fig 13.

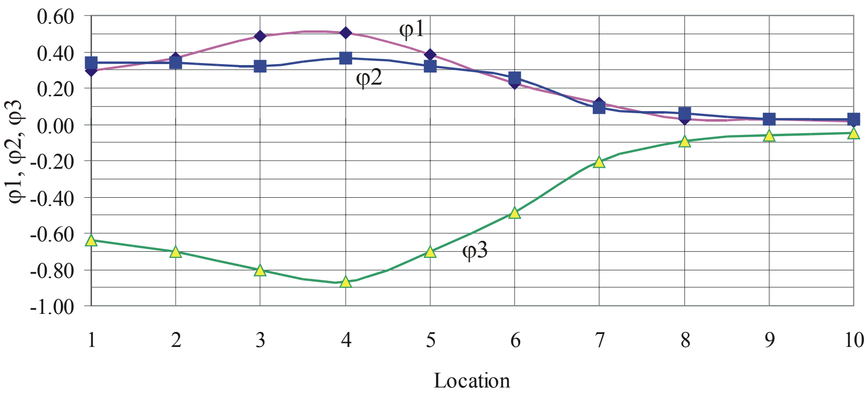


Fig. 12. Strain distribution at the punch stretch test (t=0.8 mm)

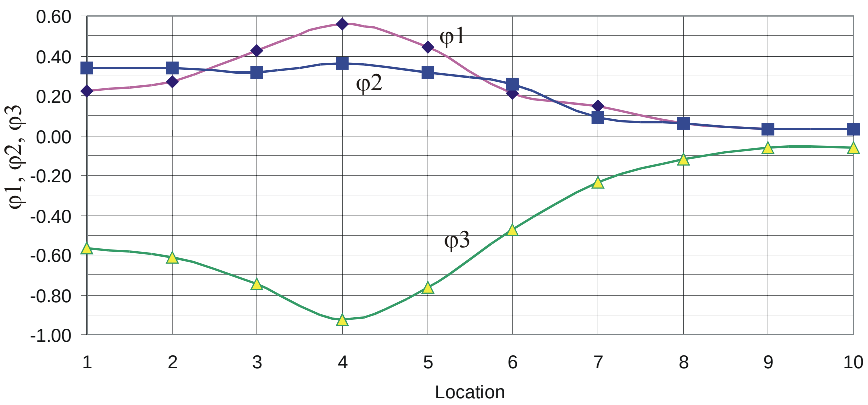


Fig. 13. Strain distribution at the punch stretch test (t=1.5 mm)

5. CONCLUSION

Use of tailored blanks has a significant role in realization of modern concept of automobile and truck production. These sheets are used in production of parts made of steel and aluminum alloys. Thanks to the development of contemporary laser equipment there is growth of sheets with nonlinear weld line significantly broadening the scope of use of such sheets. New concepts in tool and press production are intensively developed and applied enabling holder pressure regulation in different deformity areas during forming process, and possibility of prevention and regulation of weld line movement and material flow during the forming process. Prediction of material behavior during the forming process is important in tool design and creating favorable contact conditions in the area of weld line and other critical places.

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PRIMJENA TAILORED BLANKS U AUTOMOBILSKOJ INDUSTRIJI

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U poslednje dvije decenije došlo je do značajnih promjena u konceptu izrade automobila. Za ostvarenje novog koncepta automobilskih i kamionskih karoserija najveši izazovi su smanjenje mase, povećanje konstrukcione krutosti i pasivne sigurnosti. To je dovelo posljednjih godina do široke primjene tailored blanks od čelika i aluminijskih legura, a zahvaljujući sadašnjem stanju tehnike laserskog zavarivanja koja omogućava veliku brzinu zavarivanja, usku zonu uticaja toplote, te sistem automatske kontrole i otkrivanja grešaka. To su limovi koji su zavareni prije procesa oblikovanja. Pri tome mogu biti zavareni limovi od istog ili različitog materijala, iste ili različite debljine, iste ili različite površine (galvanizirana nasuprot negalvaniziranom). Ostvaruje se kontinuirani linearni godišnji porast broja proizvedenih tailored blanks od čelika povišene čvrstoće i od aluminijskih legura.

Glavne prednosti primjene tailored blanks su:

- smanjene težine vozila eliminacijom pojačanja i preklapanja lima kod primjene tačkastog zavarivanja,
- poboljšanje sigurnosti pri sudaru zbog povećanja krutosti laserskog vara u poređenju sa tačkastim,
- smanjenje cijene proizvodnje zbog manjeg broja alata za oblikovanje, izostavljanja tačastog zavarivanja i smanje otpadaka,
- poboljšanje dimenzionalne tačnosti i otpornosti prema koroziji spojenih komponenata na kritičnim mjestima.

Za uspješno oblikovanje tailored blanks značajna je koncepcija izrade alata zbog smanjenja deformabilnosti materijala u zoni zavarivanja.