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MODERN JOINING PROCEDURES IN AUTOMOTIVE INDUSTRY

ABSTRACT

Besides standard joining procedures in automotive industry a number of alternative solutions are used, based on specific industrial needs.

This article briefly presents the basic conditions that must be met by the automobiles of new generation and states the reasons for an in-depth change in the concepts of construction and materials used as well as in the joining technology. The new concepts in automotive industry are presented that have proven acceptable and have been fully implemented.

KEY WORDS

automotive industry, joining procedures, changes in design, new materials

1. INTRODUCTION

In automotive industry there have always been discussions and guesses about the directions of strategic development and automobiles of new generation. Presently, under the term »automobile of new generation« one understands automobiles that are / will be substantially more environmentally friendly than the automobiles at present. This is shown in three perspectives: lower fuel consumption per km, lower exhaust gases emissions and a higher grade of planned recycling after the expiry of automobile's lifetime [1]. In most developed industrial countries (e.g. in the USA) new and holistic approaches towards construction of new generation automobiles are being promoted by means of special laws. These laws set the minimum allowed boundaries of gas emissions and assume gradual transfer of responsibility for complete recycling of automobiles to their manufacturers. To meet the new demands as closely as possible the bigger manufacturers of automobiles develop their strategic approaches to research, for which they usually do not present any details [2]. Most common fields of research are: engines, constructional concepts, materials and joining technologies. These fields of research interact and overlap in a large amount, so that they are managed in project approach; the obtained results and conclusions of each respective field are usually transferred to other fields of planned research.

2. CHANGES IN CONSTRUCTION

Changes in construction and using of new materials and new joining technologies have led to substantial reductions of the automobile mass. New generation automobiles are subjected to a planned »diet« and this in turn leads to radical reduction of mass and as a result to reduction of fuel consumption and the production costs as well.

With lower mass of construction and of the whole automobile the passive safety of passengers must not be neglected. This is especially important in the case of a frontal or lateral crash when most of the kinetic energy must be transformed to deformation work of the supporting construction, Fig. 1 and Fig. 2 [3].

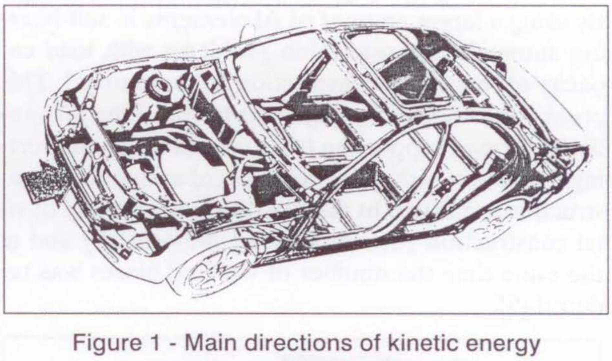


Figure 1 - Main directions of kinetic energy acceptance by a frontal crash

Introduction of new materials and development of new forming and joining technologies enable constructional solutions that were in the past unfeasible or too expensive. Main changes in the concept of new automobile design are seen in: abandoning of lap joints, installations of hydraulically formed tubes and mass use of tailored blanks.

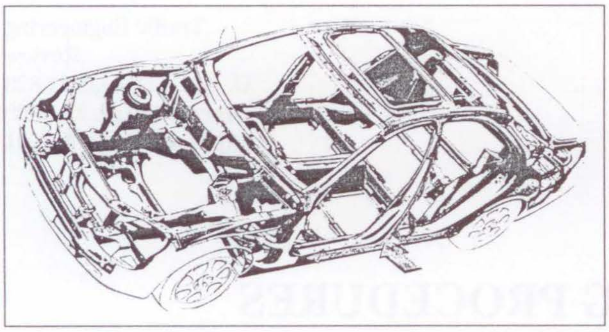


Figure 2 - Main directions of kinetic energy acceptance by a lateral crash

2.1 Welds and weld joints

By abandoning lap weld joints and transfer to butt joints it is possible to reach substantial savings in use of base material. However, this transfer is conditioned with narrower tolerances by preparation of welding pieces and often by change of welding technology, Fig. 3.

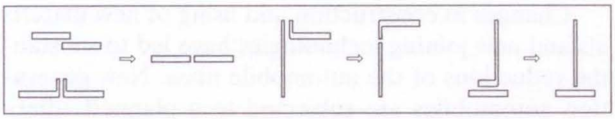


Figure 3 - Characteristic cases of abandoning lap joints and fillet welds

2.2 Hydraulically formed tubes

Hydraulically formed tubes are space beams which are filled with hydraulic oil prior to forming, so it is possible to obtain a substantially higher degree of formability [4]. Usage of these tubes was brought forward especially by body in white (aluminium) design. By using a larger amount of Al elements in self-bearing automobile construction problems with load capacity of the whole construction have occurred. This problem was solved by engineers by installing hydraulically formed supporting tubes, which act as supporting frame on which other elements of automobile construction are fitted. In this way the load capacity of vital construction parts was raised substantially and at the same time the number of welding pieces was reduced [5].

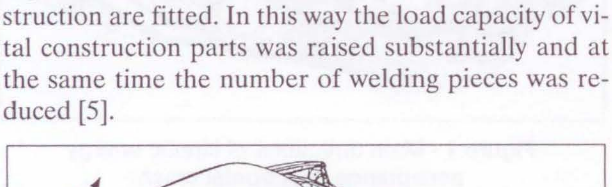


Figure 4 - Installation of hydraulically formed tubes in automobile chassis

2.3 Tailored blanks

Usage of tailored blanks is a constructional approach, that has been theoretically present for the past 30 years [6]. The basic idea of this approach is: »sometimes it is suitable to produce a large homogenous (semi) product from a number of smaller semi-products and give them their primary shape by subsequent joining! (especially by welding)«. The most common reasons for such a – seemingly – wasteful approach are:

- reduction of mass and cost of a (semi-) product
- extension and / or improvement of respective properties of the semi-product (chemical, physical or mechanical);
- reduction of costs of tool manufacturing
- expansion of the spectre of (semi-) products and better flexibility by end-product manufacturing

Automobile doors are one of the most common semi-products, where production by joining of tailored blanks was brought forward.

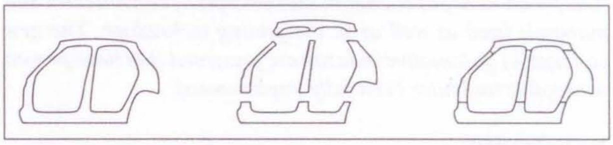


Figure 5 - Manufacturing of automobile doors in the classical way and by the tailored blanks principle

3. INTRODUCTION OF NEW MATERIALS

Next to steel, which is at present (and will surely be for a long time in the future) the dominating material in automobiles, from the beginning a number of other materials were used, e.g.: grey cast iron, Al, Cu, rubber, glass, textile, plastics. In the period between 1960– 1990 the share of plastic materials in automobiles was rapidly rising, due to its low price, good formability and machinability and improving mechanical properties [7]. Since the '90 the share of plastic materials in automobiles has been rising very slowly and other materials are being brought forward, especially metals as: zync-coated steel materials, aluminium with its alloys and high-strength steels. It is the new standards for enhanced passive safety that have contributed to stopping the steep decline of steel share in automobiles. Except for Audi, which implements mostly Al in the construction of A8, other manufacturers are tending towards constructions of high-strength steels and combinations of steel and other materials.

The decision for one or the other material being used for a semi-manufactured product depends on the demanded properties of the semi-manufactured product. Next to chemical, physical, mechanical, forming properties and price, a substantial influence on the choice of one material has also its suitability for common joining technologies.

4. NEW JOINING TECHNOLOGIES

New constructional solutions and materials enable, and often demand, new joining technologies. Next to classical joining technologies in automotive industry, that still prevail in large amount – soldering (arc MAG welding, plug welding, resistance spot welding and resistance projection welding) – more and more frequently and equally new technologies are being implemented, such as: joining by mechanical forming, punch riveting, single-sided resistance spot welding, plasma and laser welding.

4.1 Procedures of mechanical joining by forming

In industrial practice more different procedures of mechanical joining by forming were acknowledged, with or without additional elements – rivets. These procedures were proven in industry as good alternative to classical joining procedures, especially to resistance spot welding. This holds especially in case of joining of zinc – coated materials, aluminium and electrically unconductive materials. Main advantages of mechanical joining by forming are [8]:

- Wide field of application, it is possible to join different thickness and different sorts of materials.
- Joining places are not thermally affected, there is less deformation and residual stress, lower reduction of fatigue strength.
- Well-defined quality and high repeatability grade.
- Ecologically faultless and easy to use.

Disadvantages of these joining procedures are:

- Unevenness of the joining place (hollows, pimples or turn-ups).
- Unsuitable for very hard and tough materials.
- Lower tensile strength of joints.

4.1.1 Joining by system TOX

No **TOX**ic fumes joining system is the new generation of joining technology by Pressotechnik Ltd. company. Most important by this joining procedure is a suitable shape of upper and lower die, that by sufficient stamping force manage to locally key two of the jointed materials together, Fig. 6. The economy of this procedure and its suitability for mass production is assured by pneumato-hydraulic moving of the lower die (large shift H by small force F_H – pneumatic part, small shift h by great force F_h – hydraulic).

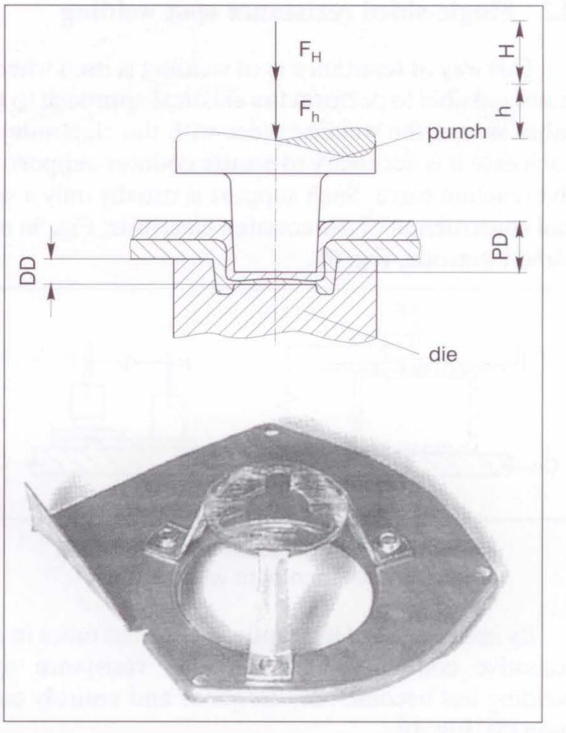


Figure 6 - Principle of joining by TOX system & case: fan support

4.1.2 Punch riveting

Among new riveting procedures in automotive industry different types of rivets are used on different places (blind, hollow, explosive), Fig. 7. When one side of the joint needs to have smooth surface, punch riveting with a semi-tubular rivet is used, Fig. 8. Load capacity of rivet joints depends on the rivets (material, shape and dimension) as well as on the degree of plastic keying of jointed materials [9].

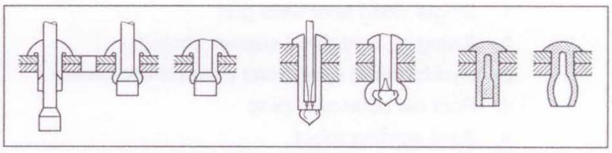


Figure 7 - Joining with blind, tubular and chemical expanded rivet

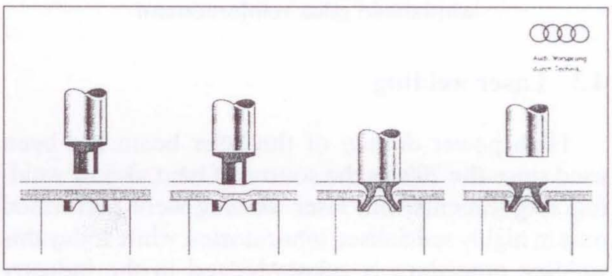


Fig. 8: Phases of punch riveting with a semi-tubular rivet

4.2 Single-sided resistance spot welding

This way of resistance spot welding is used when it is not possible to perform the classical approach to the other side of the welding piece with the electrode. In each case it is necessary to ensure counter-support for the reaction force. Such support is usually only a special construction of the counter-electrode, Fig. 9a or a blind electrode, Fig. 9b.

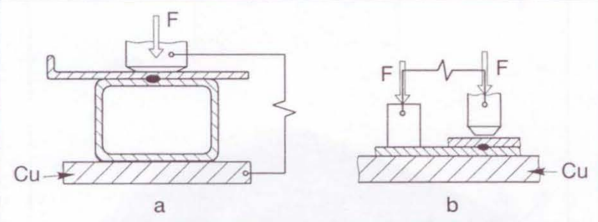
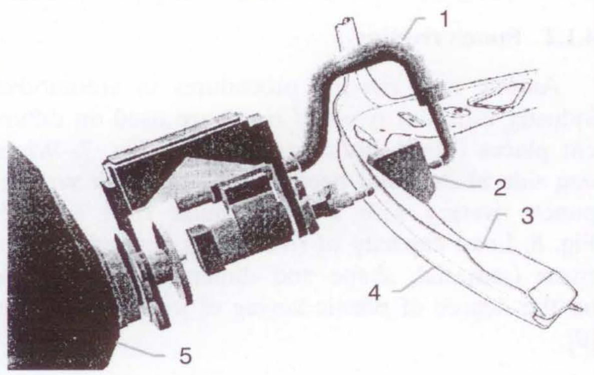


Figure 9 - Typical cases of single-sided resistance spot welding

By installation of hydraulically formed tubes in automotive construction single-sided resistance spot welding has become very frequent and entirely common [5], Fig. 10.



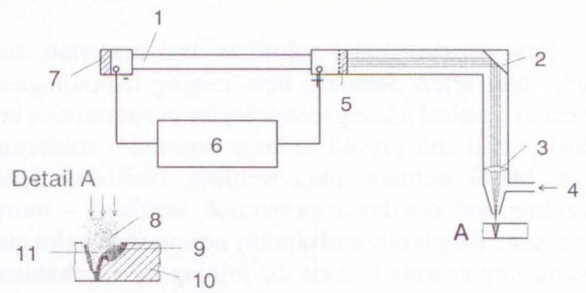
1. Single sided spot weld gun
2. Swing in, contoured copper backup
3. Hydroformed windshield pillar reinforcement
4. Roof rail outer stamping
5. Spot welding robot

Figure 10 - Single-sided resistance spot welding of roof rail outer stamping to a hydroformed windshield pillar reinforcement

4.3 Laser welding

High power density of the laser beam has been used since the 70's as the source of heat also by welding. Experiments with laser welding were performed only in highly specialised laboratories, while today this welding procedure is acknowledged in the industry and comparable to classical welding procedures by quality and by price.

Laser is the acronym of Light Amplification by Stimulated Emission of Radiation and it is a device for production of monochromatic (single-colour) and coherent (symmetric in time and space) light radiation, that can be focused to a very small surface (Fig. 11)



1. active media (area of stimulated emission)
2. directing mirror
3. focusing lens
4. shielding gas
5. semi-permeable mirror
6. excitation power source
7. impermeable mirror
8. area of interaction (laser beam and metal fumes)
9. melt
10. weld
11. metal fumes

Figure 11 - Principal scheme of laser welding

Two types of lasers are used for welding: solid Nd: YAG, power up to 2 kW with wavelength of the light radiation = 1.06 m, that can be transmitted through optical fibres; and gas CO_2 laser, power up to 15kW with wavelength of the light radiation = 10.6 m. In both cases additional gas protection of the weld melt is necessary. For this Ar is used or a mixture of gases Ar, N_2, He, CO_2.

With laser beam it is possible to weld equal or different types of materials of equal or different thickness, Fig. 12.

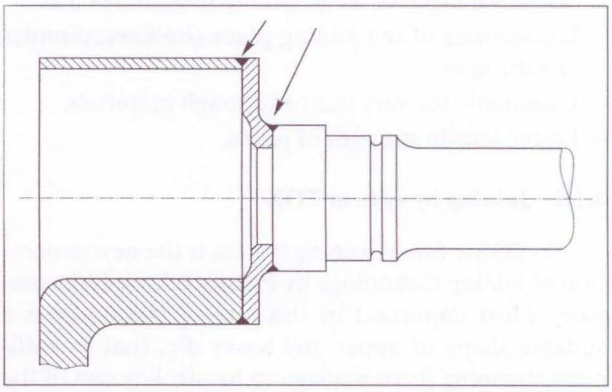
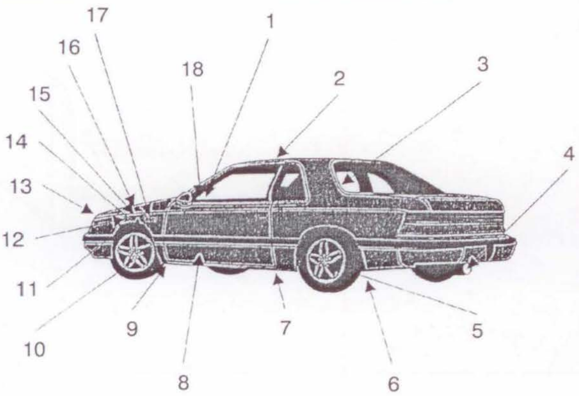


Figure 12 - Typical cases of usage of laser welding

Laser welding is considered in automotive industry today completely equal to all other welding and joining procedures. Main advantages of this welding technology were shown in planning the automobiles of new generation. By solving contradictory demands like: reduction of mass and enhanced rigidity, both at lower production costs; often it shows up that laser welding is the optimal welding technology. Among the well-known manufacturers of automobiles the leader in using this technology is Swedish VOLVO [9]. Depending on the choice of welded material and demanded properties of the weld joints in this technology the choice is also made among different ways of welding (continuous or pulse) and among different sources of power, (Fig. 13).



1. welding of airbag sensors
1000 W Nd:YAG-Laser
2. welding of roof seams
5000 W CO_2-Laser
3. marking and cutting of interior cluster
150 W Nd:YAG / 100 W CO_2-Laser
4. cutting and welding of exhaust systems
1700W, 5000W CO_2, 1000W Nd:YAG-Laser
5. drilling and welding of brake cylinders
500 W Nd:YAG / 1500 W CO-Laser
6. welding of floor panels
1000-6000 W CO_2-Laser
1000-2000 W Nd:YAG-Laser
7. welding of cardan shafts
3000-5000 W CO_2-Laser
8. welding of door constructions
5000 W CO_2-Laser
9. welding of gear wheels
5000 W CO_2-Laser
10. welding of torque converters
5000 W CO_2-Laser
11. welding and disisolating of electro components; 500 W Nd:YAG-Laser
12. welding of electromagnetic valves
13. welding of heat exchangers
500 W CO_2-Laser
14. drilling of oil pressure compensating valves; 500-1000 W Nd:YAG-Laser
15. welding of cup tappets
500 W CO_2-Laser
16. hardening of camshafts
5000 W CO_2-Laser
17. cutting of breaches in car bodies
100-500 W Nd:YAG-Laser
18. cutting of airbag materials
500-2500 W CO_2-Laser

Figure 13 - Main types of welds and used welding sources in welding of VOLVO 850

5. CONCLUSIONS

There are no specific demands being placed on the usage of different technological procedures and the same holds for joining procedures, too. The possible exceptions in this branch of industry can only lie in the fact that all elements of production system are subjected to more rigorous quality and price criteria. These more rigorous criteria result from the existing rigorous and well-detailed legislation and very sharp competition among the numerous manufacturers. This is the reason why in this branch of industry for equal products often a wide range of different technological procedures is used, and the optimal joining technology is chosen for each respective joint.

The article lists and presents only those joining procedures that make a reasonable integrity in strategic approaches to concepts in automobile industry and are at the same time also substantially present in the industry practice.

POVZETEK

SODOBNI POSTOPKI SPAJANJA V AVTOMOBILSKI INDUSTRIJI

V avtomobilski industriji se, ob standardnih postopkih spajanja, uporablja še vrsta alternativnih rešitev, ki izhajajo iz specifičnih potreb tovrstne industrije.

V članku so na kratko predstavljeni osnovni pogoji, ki jim morajo zadostiti avtomobili nove generacije in navedeni so razlogi, ki zahtevajo korenite spremembe tako v zasnovi konstrukcije in uporabljenih materialih kot tudi v tehnologijah spajanja. Predstavljeni so tisti novi postopki spajanja, ki so se v novih pogojih pokazali kot sprejemljivi in se v avtomobilski industriji tudi povsem uveljavili.

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