FEASIBILITY STUDY OF MANUFACTURING OUTER CAR BODY PARTS WITH USE OF DP500

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Abstract

Due to environmental concerns and safety regulations in the automotive industry the development of strong and lightweight cars has been a very significant topic in the last years. One of possible solutions to this matter is to use materials with lower density or lower thickness. However, the demand to increase passive safety requires using of materials of higher strength. The goal of this research is to evaluate feasibility of selected outer body parts using HSS steel, DP500 (dual-phase). DP500 provides higher yield and ultimate strength than conventionally used mild steel at the expense of lower ductility, plastic anisotropy ratio and strain hardening exponent. Impact of different geometrical shape and influencing process conditions and parameters are discussed in this article. The evaluation of feasibility is performed in software AutoForm R6. This research is carried out in cooperation with ŠKODA AUTO, a.s.

Keywords: Sheet metal forming, HSS, DP500, feasibility, outer car body parts

1. INTRODUCTION

In order to reduce air pollution produced by automobiles, new ways of car weight reduction are to be found. An area where mass reduction could be achieved is outer car body panels. Outer car body parts are mostly characterized with demanding design. Used materials must generally have great ductility and plastic properties. The principal task of outer body panels is to separate passengers from the outer world and to attract potential customers. Panels must also meet criteria, including stiffness, dent resistance, oil-canning and buckling load. Stiffness is the most important parameter in customers view and is a function from both material and geometry. [1]

Currently used steel materials are limited by their low tensile strength and thickness, therefore bending stiffness must be enhanced with complex part geometry e.g. feature lines. Nowadays, three different approaches are possible in reducing the weight of outer body car parts.

Parts made of alloys with lower density than steel has (e.g. aluminium, magnesium, titanium, plastics) are more challenging and expensive to produce. Even though aluminium has lower Young's modulus and to achieve equivalent stiffness material with higher thickness must be used, panels are ca. 40% lighter than comparable steel parts.

Very perspective material is sandwich plate system (SPS) comprising two metal plates bonded with a polyurethane core. It combines the strength of steel and low weight of plastics. These materials have high flexural stiffness and buckling resistance. Qualitatively equivalent panels made of SPS have slightly higher weight than aluminium panels but cost significantly less. Current insufficiency is lack of technology of hot-dip zinc coating and phosphating of SPS and that they cannot be welded with MIG and MAG welding methods because of their structure. Problematic area is delamination between layers. Individual sheets can be joined with spot welding special mode or bonded with glue.

Third possibility is to use steel material with higher yield strength so that lower thickness of entering sheet can be used and thus panels can be lighter. Feasibility of selected part with use of dual-phase steel is discussed in this article.

2. MATERIALS USED FOR OUTER CAR BODY PARTS

Sheet metal forming is characterized with an unceasing planar state of tension that varies from uniaxial stress, through shear stress to biaxial stress. Due to shape complexity of outer car panels a one simple formability index cannot be set. Formability of material therefore results from mechanical properties. [2]

A ratio of Proof strength to Tensile Strength is perceived as one of the most important formability index. This ratio indirectly expresses amount of plasticity supply and it is desired for this value to be as small as possible. Plastic strain ratio, $r_{m/20}$, is ratio of true width strain to true thickness strain, its value is desired to be the highest possible. Strain hardening exponent, $n_{10\text{-}20/Ag}$, is relevant especially for biaxial strain thus its higher value delays necking. For clarity and better understanding the difference, hardening curves of CR4 and CR290Y490T-DP are shown in **Figure 1**. Peak count and type of surface finish are also relevant parameters to forming process. [3]

Selected mechanical properties of commonly used steels and dual-phase steel CR290Y490T-DP (known as DP500) are mentioned in **Table 1**. Chemical composition of CR290Y490T-DP is shown in **Table 2**.

Table 1 Mechanical properties of Cold Rolled Steels according to VDA 239-100

Steel grade	Proof strength	Tensile Strength	Elongation after fracture	Plastic strain ratio	Strain hardening exponent	Bake hardening
	$R_{p0,2}$	R_m	$A_{80\ mm}$	$r_{m/20}$	$n_{10\text{-}20/Ag}$	BH_2
	MPa	MPa	%	-	-	MPa
CR4	140 - 180	270 - 330	≥ 39	≥ 1.6	≥ 0.20	-
CR5	110 - 170	260 - 330	≥ 41	≥ 1.8	≥ 0.22	-
CR180BH	180 - 240	290 - 370	≥ 34	≥ 1.3	≥ 0.17	≥ 30
CR210BH	210 - 270	320 - 400	≥ 32	≥ 1.2	≥ 0.16	≥ 30
CR290Y490T-DP	290 - 380	490 - 600	≥ 24	*(≈1.0)*	≥ 0.15	≥ 30

Table 2 Chemical composition of CR290Y490T-DP according to VDA 239-100

C %	Si %	Mn %	P %	S %	Al %	Ti+Nb %	Cr+Mo %	B %	Cu %
≤ 0.14	≤ 0.50	≤ 1.80	≤ 0.050	≤ 0.010	0.015 - 1.0	≤ 0.15	≤ 1.00	≤ 0.005	≤ 0.20

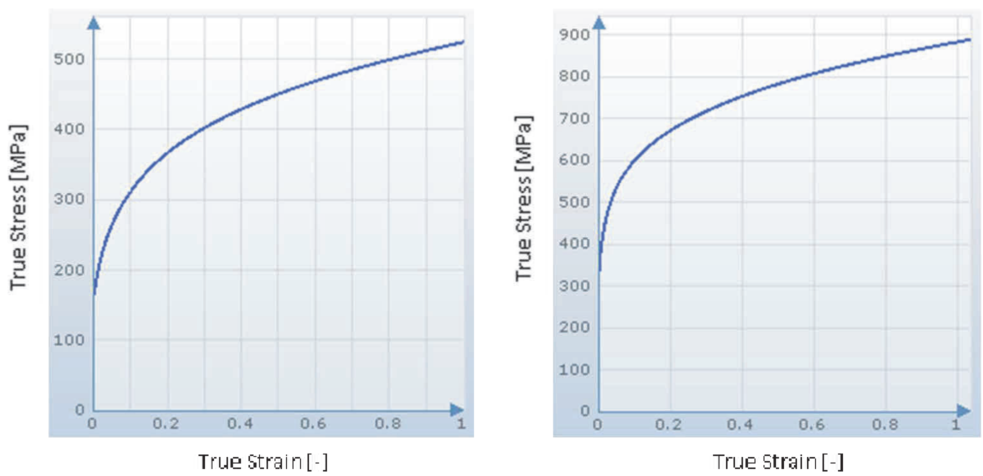
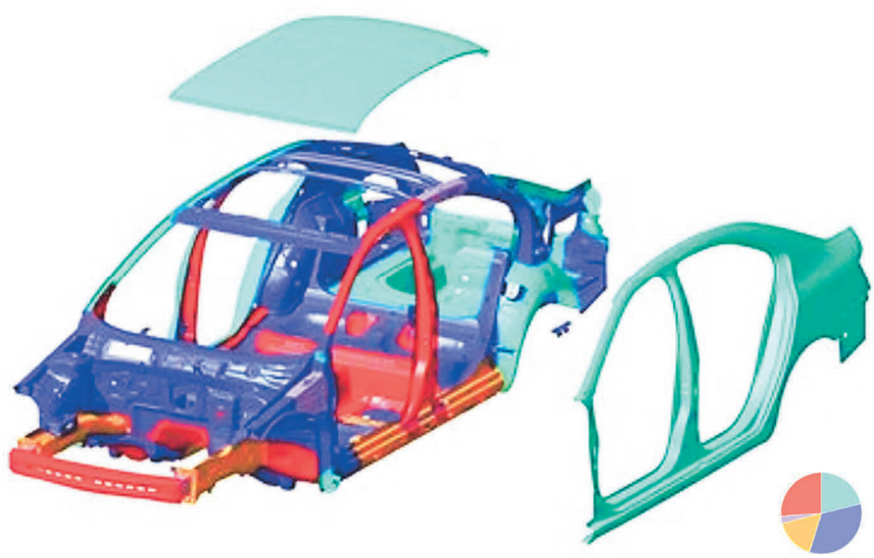


Figure 1 Hardening curves of CR4 (left) and CR 290Y490T-BH (right)

3. FEASIBILITY OF LOWER TAILGATE PANEL WITH USE OF DP500

HSS, UHSS, AHSS and PHS have been successfully implemented into production of safety cage components. **Figure 2** shows content of specific steel groups in ŠKODA Octavia III. Further application of HSS materials for production of outer body panels is a possibility to reduce weight of these parts. HSS generally provides, in comparison with enlisted commonly used mild steels, higher proof strength and ultimate strength at the expense of lower ductility, plastic anisotropy ratio and strain hardening exponent.



Steel Type	Yield Strength	Percentage
Low Strength Steel (LSS)	≤ 200 Mpa	21.2%
High Strength Steel (HSS)	200 - 400 MPa	33.6%
Ultra High Strength Steel (UHSS)	400 - 700 MPa	16.2%
Advanced High Strength Steel (AHSS)	700 - 1000 MPa	2.9%
Press Hardening Steel (PHS)	1000 - 1200 Mpa	26.1%

Figure 2 Content of specific steel groups in BIW of ŠKODA Octavia III [4]

Material CR290Y490T-DP is a dual phase steel and was chosen as a HSS representative. Dual phase steel structure consists of a fine-grained ferritic matrix and hard martensitic phase in the form of islands. This combination allows material both to have high value of proof and ultimate strength and to exhibit unique high initial strain hardening rate. [5,6].

In order to study feasibility of the material, SEAT Ateca lower tailgate panel was virtually stamped. The numerical simulation was performed in AutoForm R6 and results of numerical simulation are shown in **Figure 3** and **Figure 4**. Forming of this panel was simulated both with CR4 and CR290Y490T-DP material. The CR4 simulation matches with currently produced part. The CR290Y490T-DP simulation is based on CR4 simulation though several process parameters were modified in order to obtain best results.

The result of numerical simulation shows that even in case of a geometrically simple lower tailgate panel, materials can't be simply interchanged. This fact is observable in **Figure 3**. The course of CR290Y490T-DP FLC is more concave and the curve position indicates lower values of acceptable strain.

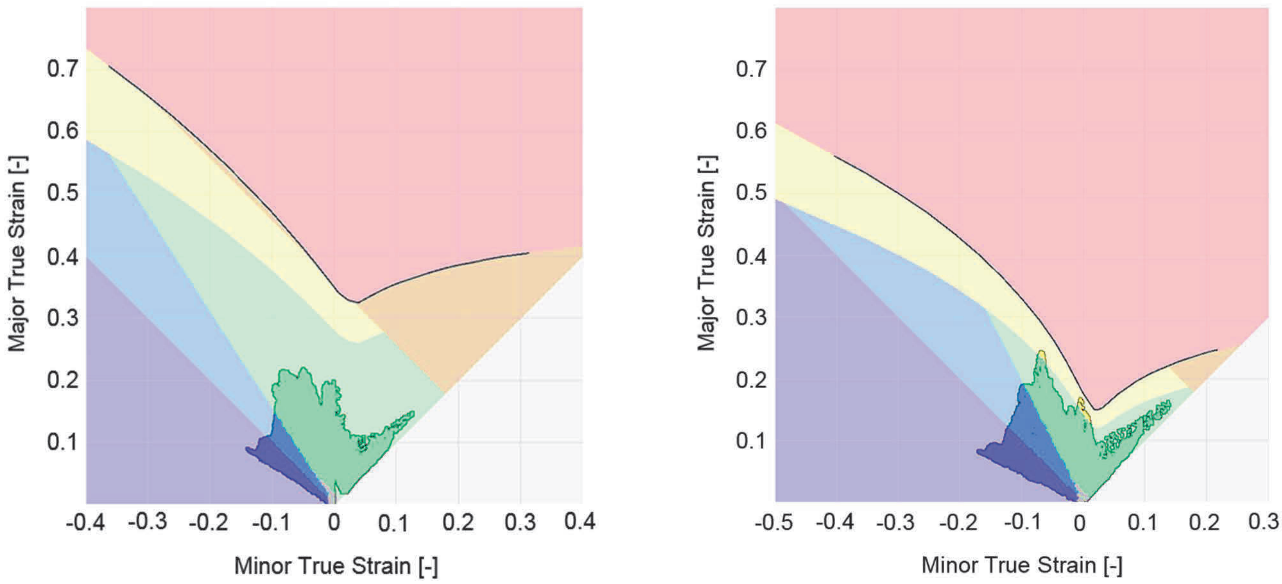


Figure 3 FLD after deep-drawing operation of CR4 (left) and CR290Y490T-DP (right)

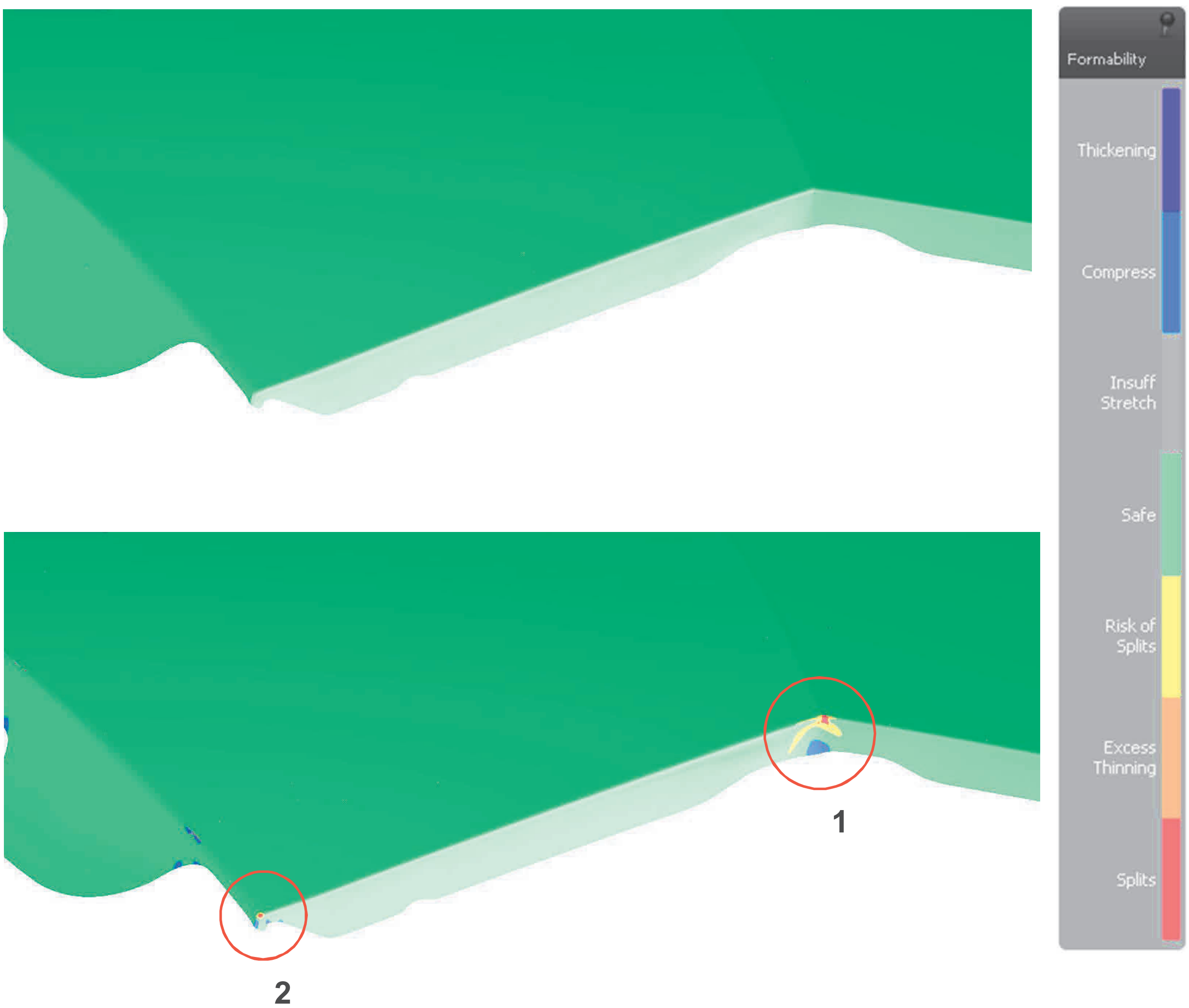


Figure 4 Comparison of Seat Ateca lower tailgate panel made of CR4 (above) and CR290Y490T-DP (below)

During the process, 2 problematic areas has emerged in deep drawing operation. It turned out, that CR290Y490T-DP steel tends to split in corners. These issues can be eliminated with geometry modification.

Splits occurring in area 1 could be eliminated through modification of part rim used for hemming. Geometry change suggestion is shown in **Figure 5**. This principle is used as well for alteration of parts made of LSS.

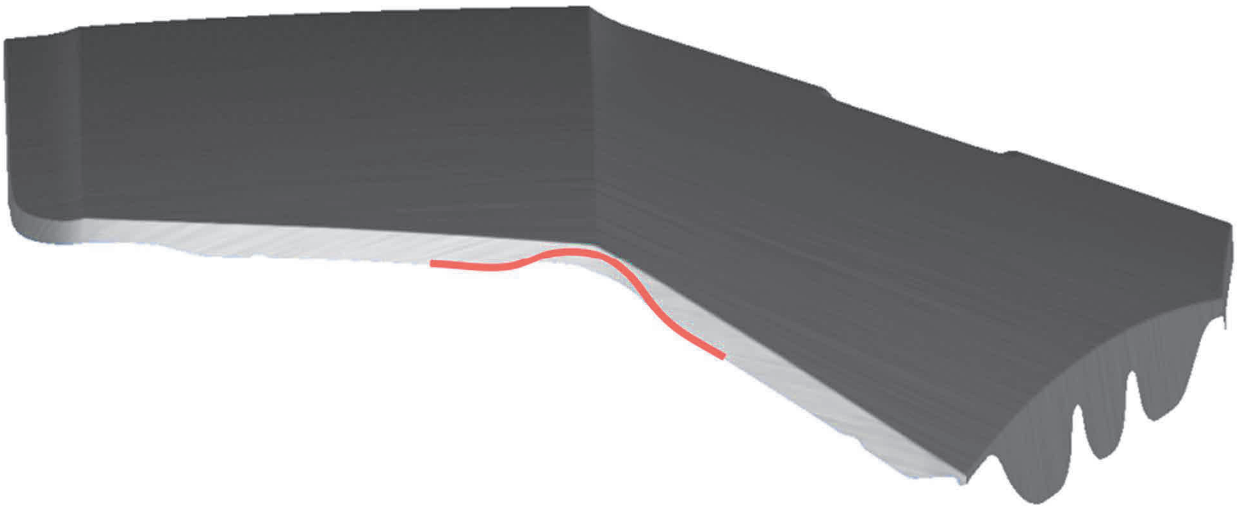


Figure 5 Geometry modification in area 1

Splits occurred also in the corner in area 2. Because the rim in this area cannot be furtherly modified, the corner must be rounded with bigger radius ca. 2.5 mm. Proposed modification is shown in **Figure 6.**

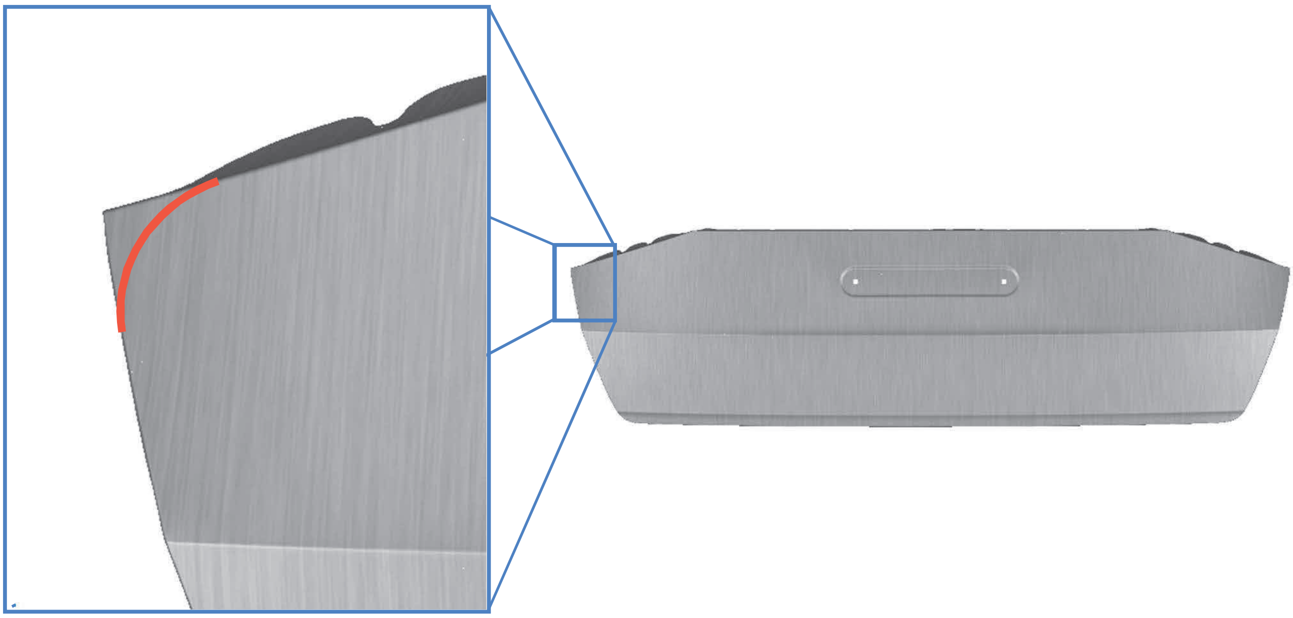


Figure 6 Geometry modification in area 2

4. CONCLUSION

This article deals with problematics of weight reduction of outer body car parts, which is a significant topic for carmakers. Three possible ways of weight reduction are mentioned in the introduction. Different formability indexes are discussed. Mechanical properties of commonly used mild steels are enlisted. Feasibility study of Seat Ateca lower tailgate panel was performed and two problematic areas have emerged. A possible solution to both problems was presented. This article is to be apprehended as an introduction to the topic of possibility of HSS materials application in automotive industry.

It is certain that currently used materials cannot be easily swapped with HSS materials and that geometrically simple parts must be investigated first. Successful application of HSS must also develop from cooperation of both design and tool construction. Any sharp corners and edges must be avoided in outer car body parts and the draw depth must also adapt to material forming limit. Consequently, both springback and wear of forming tools must be taken into concentration. 3rd generation of AHSS steel is being developed at the moment and mentioned methodology could be used for this new application as well.

ACKNOWLEDGEMENTS

The research was financed by SGS16/217/OHK2/12.
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