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Investigation of Usibor 1500 Formability in a Hot Forming Operation

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The hot forming process included heating metals to a temperature in the austenite range, transferring the austenitized sheet from the furnace to a press, forming and simultaneously quenched. In this work, Usibor 1500 steel was hot stamped using water-cooled prototype mould. Micro structural analyses as well as tensile tests and hardness measurements of hot stamped samples were performed. The results showed that most of austenite microstructure was changed into martensite by the hot forming. The tensile strength and hardness value were up to 1485 MPa and 492 HV1, respectively. On the other side, hot stamped parts presented mechanical properties higher than cold stamped parts.

Keywords: Usibor 1500; 22MnB5; hot forming; hot stamping; optical microscopy; mechanical properties.

1. INTRODUCTION

Manufacturing technologies of sheet metal forming is rapidly developed in recent years. Nowadays; deep drawing, incremental sheet forming, and hot forming become very popular in sheet metal forming. Reducing the vehicles weight and increasing strength bring use of hot stamping processes. Hot stamping is one of the most productive methods of forming processes. The process was developed and patented in 1974 by NJA, which later merged to SSAB Hardtech and is today known as Gestamp Hardtech [1]. Hot stamping is a non-isothermal sheet metal forming technique where the blank is heated at about 900 °C, hold there long enough and then placed between cooled dies, formed and quenched simultaneously. Two different hot stamping processes exist as direct and indirect hot method.

While the direct process starts with a plain blank that is heated up to austenitization temperature, directly formed, and subsequently quenched in one process step.

The indirect process uses a preformed component which is heated up to austenitization temperature and quenched in a water cooled dies afterwards [2].The boron alloy steel 22MnB5 boron steel with an Al-Si layer named Usibor 1500 is commonly used in the hot stamping. This process and material are used for A and B pillars, bumper beams, side rails, door beams etc.

The advantages of hot stamping process of the boron steel are i) very high formability ii) forming of complex geometries iii) high toughness iv) high elongation at brake v) independence of material properties on the forming depth vi) good dimensional tolerances vii) good weldability viii) well suited for crash applications [3].

Several investigations were conducted to investigate the hot forming process [4 – 12]. Ying et al. [4] investigated the hot forming process of 22MnB5 steel. In this paper, the blank was formed and water-cooling mould was quenched simultaneously during the process of hot stamping. Yanagida and Azushima studied also the coefficient of friction in hot stamping was measured using a tribo simulator under dry conditions [5]. Merklein et al. [6] developed a heat able quenching tool for determining the thermal properties of 22MnB5. Abdulhay et al. [7] examined the thermal conductance estimation to improve the sheet metal during hot stamping process. For this purpose, they designed and developed an experimental device developed to estimate the thermal contact resistance at the part/tool interface. Hongtu et al.[8] focused on crash behavior performance of hot forming steels experimentally and analytically. A 2D coupled thermo mechanical FEM was developed to simulate sheet metal hot forming process for U channel part by Liu et al [9]. Liu et al. [10] investigated the influence of cooling rate and blank holder force on phase transformations and spring-back during hot sheet metal forming. Bai-liang et al. [11] studied numerical simulation of hot stamping process for anti- collision part. Ying et al. [12] examined crack and spring-back phenomena of hot stamping parts. Güler et al. [13] investigated effect of heat treatment parameters on the microstructure and mechanical properties of 22MnB5 steel. The heat treatment was conducted within the temperature range from 700 °C to 950 °C, air and water cooling techniques were applied to the specimens.

The main aim of this study is to achieve hot forming process using a prototype mould. The other aim is focused on investigation into microstructure and mechanical properties of the Usibor 1500 steel after being hot stamped. In this context, micro structural evaluation, hardness measurements, and tensile tests were performed. The results showed that the mechanical properties and microstructure of hot formed Usibor 1500 steel conformed to the literature.

2. EXPERIMENTAL DETAILS

2.1. Characteristics of Investigated Material

Mechanical properties of the material examined in the study, is called Usibor 1500 are shown in Table 1.

Usibor 1500, with a material thickness of 1.7 mm has an aluminum-silicon precoating differently than 22MnB5. The chemical composition of the material was measured

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by Optical Emission Spectroscopy (OES) machine and the chemical composition is shown in Table 2.

Table 1. Mechanical properties of Usibor 1500

Young's Modulus (GPa)	222
Tensile Stress (MPa)	543
Yield Stress (MPa)	418
Hardness (HV1)	191

Table 2. Chemical composition of Usibor®1500 (in mass %)

Elements								
C	Si	Mn	P	S	Cr	Ti	B	Ni
0.19	0.649	1.13	0.0096	0.0021	0.192	0.0327	0.0030	0.0189

In the as-received condition, Usibor 1500 steel shows a fine grain ferritic-pearlitic microstructure with the hardness value of 191 HV1 (Fig. 1). The microstructures of the ferritic-pearlitic microstructure were observed under optical microscope and the hardness of the specimen was measured with a 9.81 N (HV1) load.

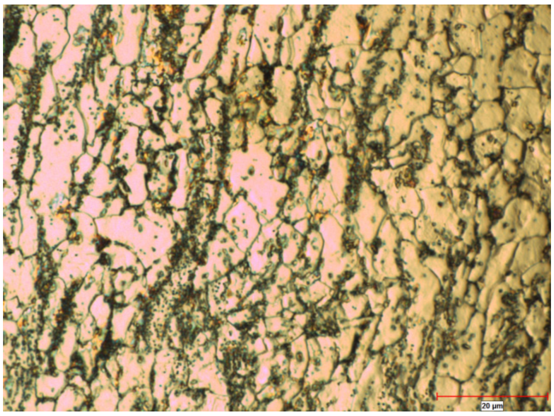


Fig. 1. Microstructure of Usibor®1500-as received

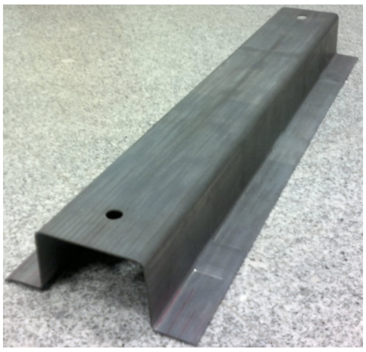


Fig. 2. Hot formed product

After hot forming process, a 2.5 until 3 times increase of the Usibor 1500 material yield and tensile strength above 1100 MPa and 1500 MPa can be achieved. This situation is related to martensitic microstructure transformation during quenching operation. For that reason, the sheet must be austenitized and then cooled with a rapid cooling.

2.2. Hot Forming Process

The experimental set-up of hot stamping press has water-cooled punch and dies. The die and the punch were made by tool steel. The cooling systems were in the punch and die so that quenching was started as soon as forming begins. The samples were rectangular blanks with length and width of (642×264) mm with 1.7 mm thickness. Pressing force was 6300 kN and pressing speed was 24 mm/s.

The Usibor1500 steel was placed into a 930 °C oven and held for 5 minutes to obtain a homogeneous austenitic microstructure. After the 5-min hold time, the blank was removed from the oven and put on prototype hot forming mould, then quenched, and formed respectively in the pres. The elapsed time from removing the sheet to manufacturing the final product was 25 s. The final product is seen in Fig. 2.

3. RESULTS OF MECHANICAL PROPERTIES, HARDNESS PROFILE AND MICROSTRUCTURE

After hot forming process, tensile test samples were cut off the formed material. Cutting process was achieved from upper and lateral surfaces of final product by using laser method as seen in Fig. 3. Two samples were cut off a final product for each surface and six specimens were examined for each condition. All tensile tests were performed on a UTEST 25 ton universal tensile testing machine. Dimensions of the tensile specimen are shown in Fig. 4.

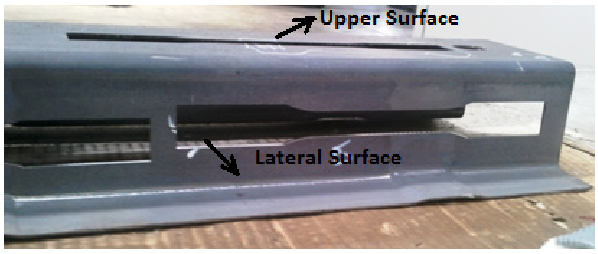


Fig. 3. Tensile specimen surfaces cut from final product

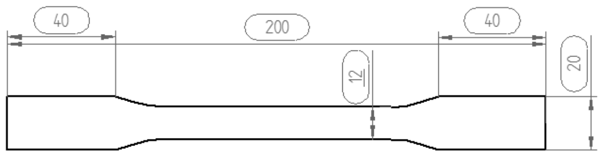


Fig. 4. Dimensions of the tensile specimens (mm)

On the other hand, these samples were used to evaluate microstructure. For evaluating microstructures, the specimens were grinded, polished and etched with Nital 3 % to observe, with an optical microscope Nikon Eclipse LV150. These specimens were finally used to measure micro hardness. Hardness measurements were carried out by Vickers hardness in the HV1 scale using MH-3 Micro-vickers hardness tester.

Table 3 presents average tensile strength of materials. Hot-formed parts showed higher tensile properties than as received materials and this process nearly tripled tensile strength. On the other hand, there is a little difference among the surfaces. Tensile strength value of upper surface was higher compared to that of lateral surface.

Table 4 shows average hardness value of lateral and upper surfaces. According to the values, the hardness of the specimens remained almost unchanged. Otherwise, the tensile strength increases as the hardness decreases. In this case, the findings of Table 3 and Table 4 are compatible with each other depending on this assumption.

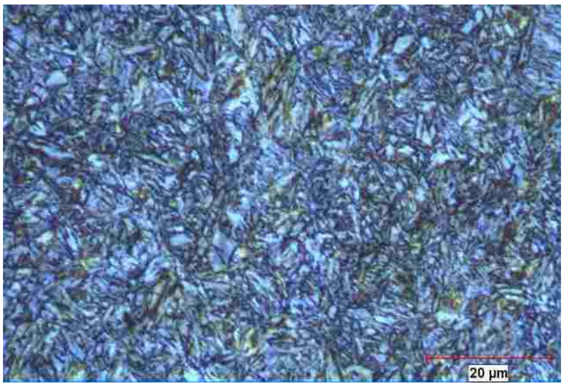
Table 3. Comparison of tensile strength

	Tensile strength (MPa)
As-received	543
Upper surface	1485
Lateral surface	1466

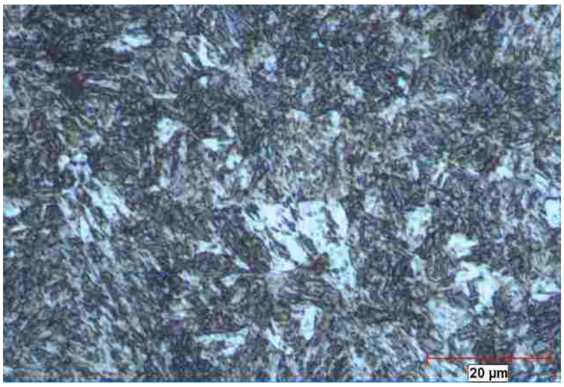
Table 4. Micro-vickers hardness results

	Hardness (HV1)
Upper surface	483
Lateral surface	492

Fig. 5 shows example micrographs of hot-formed Usibor 1500 steel cut off the upper and lateral surfaces. According to these pictures, martensite laths were very clear for upper surface through comparison with lateral surface. This was because cooling rate of upper surface was higher, compared to lateral surface. It can be explained by the fact that the upper surface of the mould stays in contact longer with the sheet.



a



b

Fig. 5. Optical micrographs of samples (a) lateral surface (b) upper surface

According to [8], the average tensile strength of hot-formed material was 1416 MPa and average hardness was 447 HV with the martensite microstructure. For that reason, findings of the current study mentioned before are in agreement with [8].

4. CONCLUSION

In this research, the effect of hot stamping process on mechanical properties and microstructure of Usibor 1500 for a prototype mould was investigated. The results showed that:

Hot stamped material presented higher tensile strength than as delivered material. The tensile strength and hardness value reached 1485 MPa and 492 HV1 respectively. The effect of cooling medium on mechanical properties and hardness of Usibor 1500 steels are important, during hot forming process. According to micrographs, the microstructure of the hot formed material showed martensitic phases. These findings showed that the hot forming process using a prototype mould was verified through comparison with literature. Furthermore, additional research should be done to investigate effect of cooling rate and measuring this.

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