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The effect of cold and hot reformation process to mechanical properties of deformed automobile chassis material

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1. Introduction

Automobile and other road vehicles are industrial products which include material and production technologies. Even though the use of aluminium and polymer materials increases in automotive industry, ferrous materials (steels) are used at the rate of nearly 70% [1]. Steel materials are intensely used in automotive industry because of their properties such as high strength, formability, fine processing, weldability, coatability for protection against corrosion, and repairability [2, 3]. The use of Advanced High Strength Steels, AHSS, has increased to reduce the price and vehicle weight in automotive industry. Especially with the use of high strength steels, the thickness of steels used in chassis and bodywork can be decreased at the rate of 10-15% and a decrease of 20-30% can be ensured in total vehicle weight [4].

Micro-alloyed steels, which are commonly known with the name of high strength low alloy (HSLA), have been developed in USA. HSLA steels have a higher strength than carbon structural steels [5, 6]. Micro-alloyed steels are a material group which has very good properties such as high strength, high toughness, brittle fracture safety at low temperature, perfect weldability and resistance to corrosion with the application of various hardening mechanisms and suitable thermomechanical processes at the same time [5, 7]. HSLA steels, which are intensively used in gas and petrol pipelines, and off-shore constructions, have increased in the production of forged products for automotive industry in the recent years. While HSLA steel approximately in the rate of 27% is used in body structures of small cars, it is used approximately in the rate of 34% in mid-sized luxury vehicle body structures [6-10].

Automobile and other vehicles have a body which is designed to carry their own weights and loads put on them. Automobile bodies consist of two main parts; chassis and bodywork. The chassis part is the main structure which carries bodywork and includes various systems of automobile. Thus, chassis is required to have high performance (resistant) and be rigid. Also, lightness, easily assemblability, and economy are among properties required in a chassis [11-12]. HSLA steels are generally used in chassis production in small cars. HSLA steel sheets are produced with deformation method (deep drawing) by being pressed since they have a combination of high strength and formability [9, 10].

As a result of the development of technology, motor vehicles entering into human lives have affected human lives by increasing their diversity. The increase in vehicle number has caused traffic problem especially in cities. Traffic accidents have also increased with the increase in vehicle number. Vehicles are damaged as a result of traffic accidents. Chassis and bodyworks of vehicles which are damaged by various reasons (being crushed, bending, warping, corrosion etc.) are repaired and brought to use by being transformed into their old standard surface flatness with various processes. When this process is performed, cold and hot reformation processes are applied. In this study, damaged automotive chassis material was reformed by using cold and hot reformation processes. The effect of reformation process choice (cold and hot process) on mechanical properties of chassis material was examined.

2. Experimental

In this study, high-strength low alloy (HSLA) steel material (2 mm thickness) with S320GD+Z quality (DIN EN 10326), which is used in chassis production, was used. Chassis material of HSLA steel was produced as galvanised (coated with Zn). This car part is a sub-frame part among main carrier elements of Small Car Body Structure. Since it has a high strength and formability combination, such materials are preferred by car manufacturers for chassis elements. Table 1 illustrates chemical composition and mechanical properties of HSLA steel.

Table 1

Chemical and mechanical properties of HSLA steel

Chemical composition, wt %						
C	Si		Mn	P		S
0.10	0.10		1.00	0.02		0.025
Mechanical properties						
Yield strength, MPa		Tensile strength, MPa			Elongation, %	
437		490			26	

Chassis produced from HSLA steel were deformed in hydraulic press as in Fig. 1. The chassis were reformed by applying cold process (CP) at room temperature and heat treatment (HT) at approximately 800°C. Original and deformed chassis parts are shown in Fig. 1. Samples used in destructive-tests were prepared by being cut with wire erosion method (Fig. 1). Tensile test samples were prepared in accordance with EN 6892-1 standard. In each group, three test samples were used. Tensile tests were performed in 1 mm/min speed by using InstronTM 8503 universal test device and yield strength at 0.2%, and ultimate (max.)

tensile strength were determined. The average of the results was calculated. In Charpy V-notch impact tests were made for samples of R, CP, and HP. The sample size for Charpy impact test is 10 mm × 2 mm × 55 mm. The sample had a V-shaped notch with a flank angle of 45° and depth of 2 mm. The tip radius of notch was 0.25 mm. Before the test process, samples were positioned on two anvils with a span of 40 mm. In each group, five test samples were used. The energy absorbed at fracture *E* was obtained by calculating simply the difference in potential energy of the pendulum before and after the test such as Eq. (1):

$$E = m\,g\,(h - h'), \tag{1}$$

where *m* is the mass of pendulum; *g* is the gravitational acceleration; *h* is the fixed height of pendulum hammer; and *h'* is the increasing maximum height of pendulum hammer. The average of the test results was calculated. In hardness tests, measurements were taken from 9 points by using the universal device and their mean was determined. Bending test samples were prepared in accordance with TS 282 EN 910 standard. Bending processes were performed in 1 mm/min speed with Instron^{TM} MFL System type device.

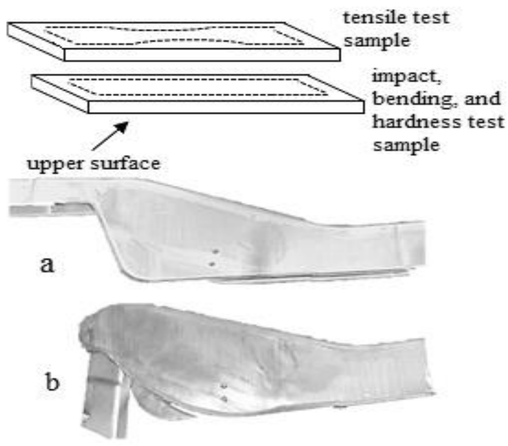
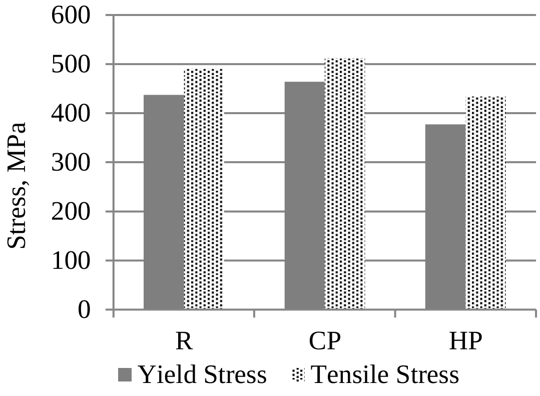


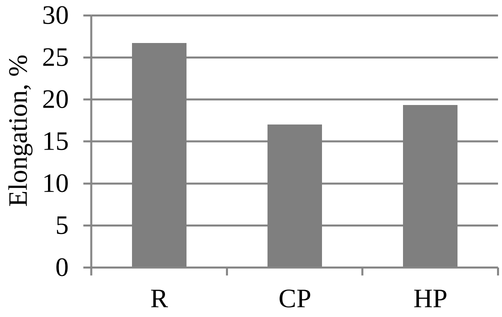
Fig. 1 Chassis part: a - original; b - deformed

3. Results and discussion

Chassis materials produced from HSLA steel were deformed and reformed with cold reformation process (CP) and hot reformation process (HP). During sheet metal bending and opening processes the deformation zone is tightened. Meanwhile, the material thickness reduces slightly. The situation causes small changes in mechanical properties of materials. However, during the reformation process, some specimens approximately 800°C. Therefore, the material properties of some specimens change by heating. Due to changes in material properties, to compare the effect of thinning occurring in very small amounts in the samples were difficult in the study. Thus, tensile tests were performed on materials to which reformation process was applied, and the obtained results were compared with reference sample (R). Fig. 2 illustrates mechanical properties of HSLA steel samples.



a



b

Fig. 2 Mechanical properties of HSLA steel samples: a - yield strength, tensile strength; b - % elongation

Fig. 2, a illustrates yield and tensile strengths of HSLA steel. Yield strength of reference material was determined as 437 MPa, tensile strength was found to be 490.3 MPa. When cold reformation procedure was applied to deformed HSLA steel; there was an increase of 446.3 MPa in yield strength, and an increase of 512 MPa in tensile strength. This situation is associated with the fact that HSLA steel was reformed by using cold reformation process. Cold deformation increases dislocation density and rearranges dislocations [13]. With increasing dislocation density in HSLA steel, there was an increase of 2.1% in yield strength, and an increase of 4.4% in tensile strength. When hot reformation process was applied to deformed HSLA steel at approximately 800 °C, there was a decrease of 377.5 MPa in yield strength, and a decrease of 433.8 MPa in tensile strength. When compared with reference sample, it was determined that yield strength of HSLA steel which was reformed with hot reformation process decreased at the rate of 13.6%, and its tensile strength decreased at the rate of 11.5%. HSLA steels (micro-alloyed steel) gain high mechanical properties with the application of suitable thermomechanical processes and various hardening mechanisms at the same time. Thus, a suitable thermomechanical process is required to be performed on HSLA steels (sheets) with micro-alloying. Thermomechanical process is preliminary deformation made by controlled rolling at 1000-1200°C and last deformation at 700-800°C. As a result of these processes, the microstructure is ensured to be made of fine grain ferrite or bainite by using various rates of cooling. Depending on cooling conditions, small amount of pearlite or martensite can also be obtained [13-15]. However, it was observed that the features which HSLA steel gained with thermomechanical process decreased with reformation process and this situation affected mechanical properties negatively (Fig. 2, a). Fig. 2, b shows the effect of cold and hot reformation process on % elongation of HSLA steel. Elongation amount of reference sample was determined as 26.7%. It was found that elongation amount of HSLA steel to which cold reformation process was applied was 17%, and elongation amount of sample to which hot reformation process was applied was 19.3%. According to these results, application of cold reformation process to HSLA steel which was exposed to deformation gave better results.

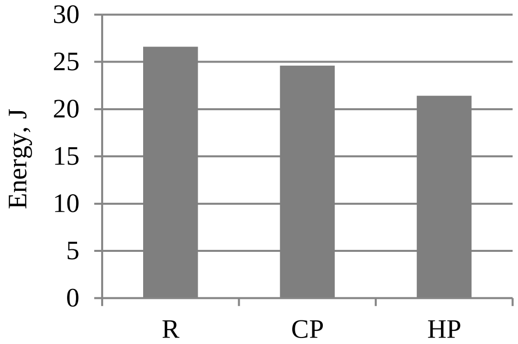


Fig. 3 Absorbed energy of HSLA steel samples

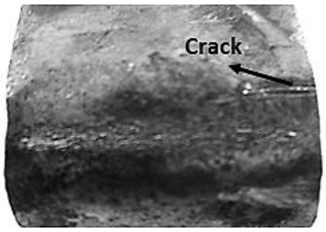


Fig. 4 Crack occurring on sample to which heat treatment was applied

Fig. 3 shows fracture energies of reference material and samples, which were subject to cold reformation process and were heated up to approximately 800°C and subject to hot reformation process, after Charpy V-notch impact test. As a result of impact test applied to reference material, fracture energy was obtained as 26.6 Joule. It was observed that fracture energy (24.6 Joule) of sample which was exposed to deformation and reformed by cold reformation process decreased at the rate of 7.5% compared to reference sample. This decrease was determined to be up to 19.5% in the sample to which hot reformation process was applied (21.4 Joule). HSLA steels have high strength and high toughness properties with the application of thermomechanical processes [13, 14]. However, micro cracks occurred on the surface of samples during cold and hot reformation processes which were performed after the deformation of chassis material. Fig. 4 illustrates the crack occurring on sample to which heat treatment was applied. Micro cracks caused the samples to be fractured with lower fracture energy. Especially with the progress and growth of these micro cracks occurring during hot reformation process, the samples could not absorb the load on them against dynamic impacts and broke with low fracture energy.

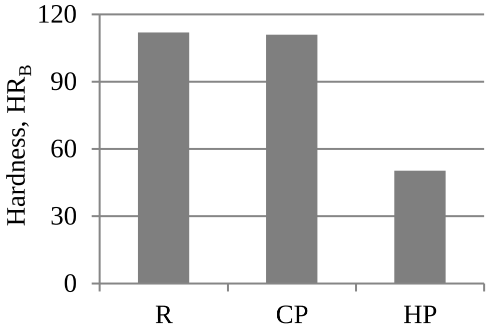


Fig. 5 Hardness changes of HSLA steel samples

Hardness test was performed on materials to which cold and hot reformation processes were applied and the obtained results were compared with reference (R) sample. Fig. 5 illustrates hardness test results. When hardness test results were examined, it was found that hardness values of reference sample and sample to which cold reformation process was applied were the same (112 HR_B). Hardness of the samples, which were deformed and reformed by using hot reformation process, decreased approximately at the rate of 55% and was determined to be 50.3 HR_B when compared to reference sample. Chassis hardness is required to be high especially on front part of automobile and protect the motor and people in it during an accident. If chassis in the automobile which is damaged because of an accident has to be reformed with hot process, chassis hardness needs to be brought to original chassis hardness by using a suitable heat treatment at the end of reformation process.

180^o bending tests were applied to HSLA steel samples as stated in standards. Fig. 6 illustrates surface images of samples to which bending test was applied. When surface images of samples were examined, it was observed that the surface of reference material was smooth and no surface defect occurred. However, as a result of bending test of samples to which cold reformation process was applied and which was heated up to approximately 800°C and subject to hot reformation process, it was observed that cracks and notches occurred especially on edges. These surface defects affected mechanical properties of samples negatively.

a b c

Fig. 6 Images of HSLA steel samples after bending test: a - reference; b - cold process; c - hot process

4. Conclusions

Cold and hot reformation processes were applied after HSLA steel, which was used as automobile chassis material in the experimental study, was deformed. The effect of reformation process on mechanical properties of HSLA steel material was examined and the following results were determined:

1. When yield and tensile strengths of chassis steel, which was reformed with cold reformation process

after deformation, were compared with reference sample; even though it increased in low amounts, as the result of hot reformation process, a decrease of nearly 14% occurred in mechanical properties of HSLA steel.

2. Cold and hot reformation processes after deformation decreased % elongation amount of HSLA steel.

3. Hot reformation process decreased hardness of HSLA steel almost at the rate of 55% after deformation.

4. Cold and hot reformation processes after deformation affected surface quality of steel material. In this case, it caused to decrease mechanical properties (yield, tensile, and impact strength).

5. As the result of repair and maintenance performed by applying heat treatment, mechanical properties of the materials were negatively affected. It is required to apply a series of heat treatments in order for these materials to have original properties again.

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THE EFFECT OF COLD AND HOT REFORMATION PROCESS TO MECHANICAL PROPERTIES OF DEFORMED AUTOMOBILE CHASSIS MATERIAL

S u m m a r y

Vehicles are damaged as a result of traffic accidents. Chassis and body parts of damaged vehicles are reformed by using cold and hot deformation methods. High-strength low alloy (HSLA) steel material coated (galvanised) with S320GD+Z quality (DIN EN 10326) zinc, which is used in chassis production, was used in this study. Steel sheet materials were damaged. Damaged automotive chassis material was reformed with cold and hot reformation processes. Tensile, notch impact, bending and hardness tests were applied to the reference material which were not deformed and materials to which reformation process was applied. In the light of obtained results, the effect of reformation process on mechanical properties of automotive sheet was determined.

Keywords: automotive sheet, HSLS steel, cold and hot reformation, mechanical properties.

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