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Study of residual stresses in tailor rolled blanked Al5J32-T4 sheets

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Abstract: Several automotive parts such as door panels have been manufactured by using load-adapted blanks for crash optimization and weight minimization. Recently, Tailor Rolled Blanks (TRB) has been introduced to remove the disadvantages of a welding process which was used in joining panel components. TRB offers better structural design capabilities due to the seamless transitions on the panels with different thicknesses. In spite of the advantages of the process, TRB leaves internal stresses in the panel. This residual stresses lower the formability of Tailor Rolled Blanked (TRBed) parts and cause cracks near severe curvature during subsequent forming processes. In this research, the residual stresses of TRBed Al5J32-T4 sheets were studied by X-ray stress analysis, and also microstructure was observed along the rolling direction. In addition, heat treatment was done after TRB process in order to compare the residual stresses to that of the TRBed sheets before the heat treatment.

Key words: tailor rolled blanks; residual stresses; deformation; microstructure

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1. Introduction

For every 10% of weight reduction in vehicles, a 6% to 8% of fuel consumption decreases. Therefore, designing parts to reduce the weight and total cost while maintaining the strength requirements for body structure is important in the current automotive industry. A principle aimed at lightweight body structure is to use more material in areas with high loads and less material in areas with lower loads[1].

Since the 1990s, one research field at the Institute of Metal Forming (IBF) has focused on the production and further processing of flexibly rolled-sheet metal to produce sheets with thickness transitions [2]. Tailor Rolled Blanks (TRB) is the process which controls the rolling gap or force in order to produce different thicknesses of automotive panels. Fig. 1 shows the general concept of TRB process. TRB process enables engineers to vary the thickness along the length of the sheet metals as it is rolled, eliminating the needs of welding local reinforcements in the automotive parts such as inner and outer panels of a door. TRB can reduce the processing costs without compensating safety by removing welding process , and it makes this

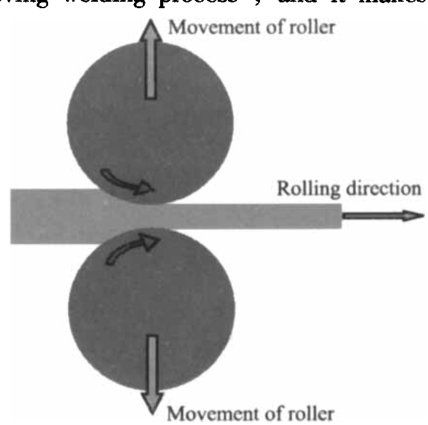

Fig. 1. A schematic illustration of TRB process.

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technology attractive to automotive industries[1].

In spite of the advantages of TRB, it can leave residual stresses in the panel after the rolling process, since the residual stresses are the consequences of deformation processes[3]. Residual stress is defined as the stress which remains in mechanical parts which are not subjected to any outside stresses[4]. It is the result of the mechanical or metallurgical work history of each point in the parts during its manufacturing process. In the presence of mechanical stresses, certain grains oriented in the right direction will reach the yield point before others, which results in heterogeneous behavior when the load is eliminated. Residual stress results from a large number of grains which were affected by plastic forming work[5]. These residual stresses can lower the formability of TRBed sheets and cause cracks near the severe curvature during a subsequent forming process. In addition, residual stresses may cause distortion of panels during machining. As a result, TRBed parts may contain the problems with dimensional stability, and it needs to be re-machined. Thus, studying residual stresses of TRBed panels are important to understand how the residual stresses are developed and how it can be removed before the subsequent forming process. Therefore, residual stresses are of interest to many mechanical engineers and designers.

2. Experimental

Al5J32-T4 sheets produced by Alcoa-Kobe were used in this research since those have been applied in several automotive parts. Their size before TRB process was 1.6 mm in thickness by 100 mm in width, and by 500 mm in length. Al5J32-T4 consists of Al, 5.6 wt.% Mg, 0.33 wt.% Cu with negligible amounts of other impurities.

Two-Roller equipped rolling machine was used for TRB process in Korea Institute of Machinery & Materials (KIMM). Diameter and width of rollers were 250 and 300 mm respectively. The maximum capacity of the rolling machine was 200 t. The speeds of roller used during TRB process were 1.35, 2, 3, and 5 m per minute (mpm), and it was done to compare the stresses of each sample.

ZEISS coordinate measurement system was used to achieve the configuration of TRBed sheets since the TRBed sheets were deformed and elongated after the process. X-stress 3000TM was used to measure the residual stresses along the TRBed sheets by 20 mm distances. Cr Kα was used as a radiation plate, and 30 kV and 7 mA with 15 s exposure time was used for measurement. Olympus BX51M microscope was used for microstructure observation, and TRBed samples were etched by Keller's reagent to see if there are any differences of microstructure depending on the amount of rolling work.

3. Results and discussion

Fig.2 shows the shape of Al5J32-T4 sheets after TRB process. It was produced by 3-D coordinate measurement system. Figs.2(a) and (b) show TRBed sheets manufactured by 1.35 and 2 mpm rolling speed, and both sheets were slightly deformed. However, as the rolling speed increased, more severe deformation was observed. Figs.2 (c) and (d) show severely deformed Al5J32-T4 sheets after TRB process

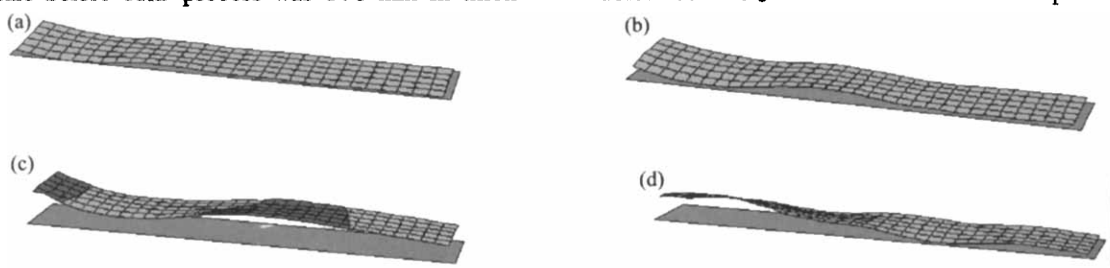

Fig.2. Configuration of TRBed Al5J32-T4 with different rolling speed: (a) 1.35 mpm; (b) 2 mpm; (c) 3 mpm; (d) 5 mpm.