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Research Article

The Effect of Cylindrical Twisting Process on Material in Transition Cone Manufacturing Used in Aluminum Fuel Tankers

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Abstract

While many materials are used in transportation, aluminum and its alloys have become one of the leading materials of the sector for fuel tankers. Thanks to the development of technology, the mechanical properties of aluminum materials have been greatly improved, and the use of aluminum in such applications has increased. Especially 5000 series aluminum alloys have a significant place in the sector. In this research, the effect of the cylindrical twisting process on the material in the transition cone manufacturing of fuel tankers was observed. 0°, 45° and 90° samples were taken to the rolling direction of the 5182 alloy used in the cylindrical bending process. Tensile and three-point bending tests, macro, micro hardness measurements and microstructure examinations of these samples were carried out. Microstructures before and after drawing were examined by scanning electron microscope (SEM). As a result of the tensile test, the highest tensile resistance of 286 MPa was observed for the materials in the 90° direction. In the three-point bending tests, the highest resistance with 358 MPa was observed in the materials in the 90° direction. The average Brinell hardnesses of three different materials were measured as 65.7, 64.8 and 65.1 HB, respectively, and the Vickers hardnesses were measured as 78.9, 79.04 and 79.1 HV.

Keywords: Aluminum, Rolling, Tensile Test, Three-Point Bending Test

Aluminyum Akaryakıt Tankerlerinde Kullanılan Geçiş Konisi İmalatındaki Silindirik Büküm Prosesinin Malzeme Üzerine Etkisi

Öz

Taşımacılıkta pek çok malzeme kullanılırken akaryakıt tankerleri için alüminyum ve alaşımları sektörün öncü malzemelerinden biri olmuştur. Teknolojinin gelişmesi sayesinde alüminyum malzemelerin mekanik özellikleri oldukça iyileştirildiğinden alüminyumlarında bu tip uygulamalarda kullanımın artmasını sağlamıştır. Özellikle 5000 serisi alüminyum alaşımları sektörde önemli bir yere sahiptir. Bu araştırmada akaryakıt tankerlerinin geçiş konisi imalatındaki silindirik büküm prosesinin malzeme üzerine etkisini gözlemlenmiştir. Silindirik büküm prosesinde kullanılan 5182 alaşımının hadde yönüne 0°, 45° ve 90° numuneler alınmıştır. Bu numunelerin çekme, ve üç nokta eğme testleri, makro, mikro sertlik ölçümü ve mikroyapı incelemeleri yapılmıştır. Çekme öncesi ve sonrası mikro yapılar taramalı elektron mikroskobu (SEM) ile incelenmiştir. Çekme testi sonucunda 90 ° yönündeki malzemelerde 286 MPa ile en yüksek çekme mukavemeti görülmüştür. Üç noktalı eğme testlerinde 358 MPa ile en yüksek dayanım yine 90° yönündeki malzemelerde görülmüştür. Üç farklı malzemenin ortalama Brinell sertlikleri sırasıyla 65.7, 64.8 ve 65.1 HB, Vickers sertlikleri ise 78.9, 79.04 ve 79.1 HV olarak ölçülmüştür.

Anahtar Kelimeler: Alüminyum, Hadde, Çekme Testi, 3 Noktalı Eğme Testi

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1. Introduction

With the Industrial Revolution, the need for oil is increasing day by day due to the development of the oil industry and oil-related production industries. At the same time, the need for the logistics of these products has increased. In the field of logistics, fuel tankers are used to transport such oil and its derivatives. Fuel tankers are considered as vehicles under ADR status due to the transportation of flammable and explosive products. ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road), is a directive designed to ensure the safe and orderly transport of dangerous goods on public roads without harming human health and the environment, and also determines the responsibilities, obligations and working conditions of the unloader. The documents and certificates obtained under this regulation for the packers, carriers, operators and drivers of various vehicles carrying hazardous goods are called ADR documents. These vehicles must be arranged in accordance with ADR legislation and must also be driven by drivers with ADR certificate.[1]

The global automotive industry faces challenges in several key areas, including energy, emissions, safety and affordability.[2] Many major decisions and practices are taken to handle these challenges. Particularly, in order to avoid these disadvantages, interest and research on material technologies has increased. Many disadvantages have been reduced to minor levels by improving the materials and developing more efficient materials that can replace existing materials. Steel and its derivatives were generally preferred for the first vehicles used in the automotive and transportation sectors. Although similar materials are used for fuel tankers, aluminum and its alloys have become one of the leading materials of the industry today. Aluminum alloy has started to be preferred as an alternative to steel, iron and other metals for the lightening of vehicles, due to its high specific strength, high hardness, low density, good energy absorption and strong corrosion resistance. 5xxx aluminum alloy is an emerging lightweight material and heat treatable reinforced alloy widely applied in the automotive manufacturing industry. [3,4] Some of the features that make this aluminum a pioneer in terms of fuel tankers; It provides a lower final weight of the structure since it has a low density, does not interact with fuel derivatives such as gasoline and diesel, does not create sparks during an accident and provides increased safety with its high impact absorbing capacity. At the same time, the fact that it is an environmentally friendly material with a 100% recycling rate increases the interest in the material.

Metal alloys formed into flat plates with thicknesses ranging from 0.1 mm to 25 mm are called 'sheet'. Sheet materials are products that have been made flat by hot or cold rolling method, which is one of the plastic forming processes from blocks called billets (ingots). The sheets, which are alloyed according to the final user's request and have thickness values, are presented for use in the form of rolls or sheets of certain sizes.

Aluminum sheet products are used in many areas in industry. Due to the increasing demand in aluminum sheets, especially in the mold and automotive sector, aluminum sheet material shaping studies have gained great significance. [5] Aluminum materials in industry are preferred because of their low carbon footprint, compliance with legal regulations, 1/3 weight gain compared to steel, high damping behavior against impacts, fuel savings and their contribution to cost improvements. The underlying reason for their use in fuel tankers is their lightness and high strength, as well as the fact that they do not react with gasoline and diesel and do not create sparks.

2. Material and Method

2.1.Production Of Aluminum Alloys

In this study, the change of mechanical properties of 5182 series aluminum alloys used in the construction of fuel transport tankers, depending on the rolling direction, was examined. The transition cone which is present in fuel vehicles is demonstrated in Figure 1. The aluminum alloy used in this study was produced in 6 mm thick flat sheets by the Twin Roll Casting (TRC) method. The chemical composition of the alloy is given in Chart 1. Samples were taken from these plates from 0°, 45° and 90° directions to the rolling direction and their mechanical properties were examined comparatively. Figure 2 shows where the samples were taken from the plate.

Table 1. 5182 Chemical Composition of Aluminum Sample.

Chemical Composition (%)								
Mg	Mn	Si	Fe	Cu	Cr	Zn	Ti	Ni
3,80-4,80	0,2–0,5	Max. 0,4	Max. 0,4	Max. 0,25	Max. 0,15	Max. 0,4	Max. 0,15	Max . 0,4

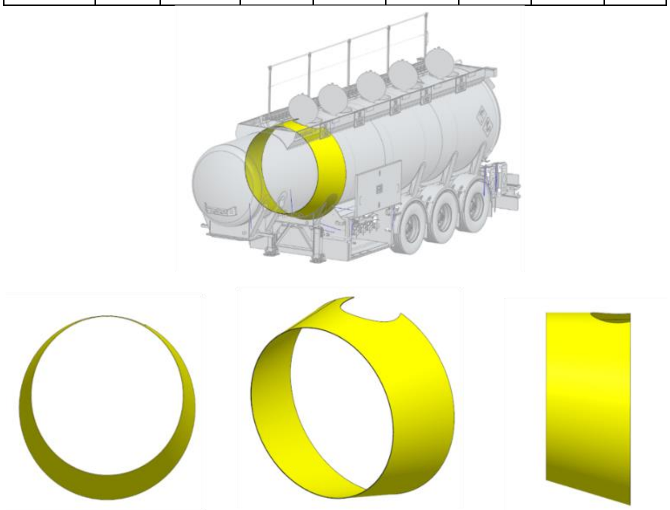

Figure 1. Transition Cone in Fuel Tankers

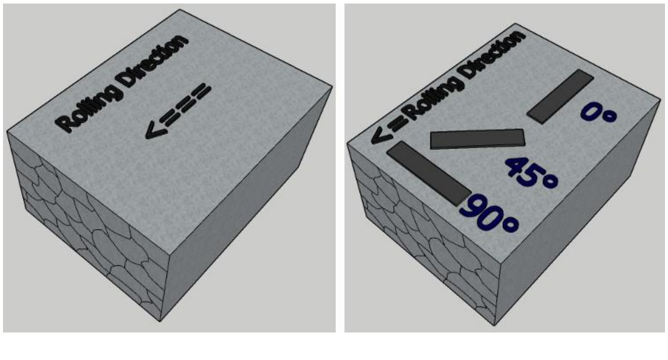

Figure 2. Rolling Direction of the Plate and Samples Extracted from 0°, 45° and 90° Directions According to the Rolling Direction.

When evaluating the mechanical properties of metals, it is assumed that they are not directional (isotropic). However, since the rolling method causes plastic deformation in flattened products, elongation is observed in the shapes of the grains along the rolling direction. For this reason, the material does not show the same features in all directions, this situation is called anisotropy. In this article, the effect of anisotropy originating from the rolling direction on the twisting process will be examined.

In fuel tankers, there are height differences between the tractor and the junction point and the axle. This structure, which is called the gooseneck in body/platform type trailers, is designed with a cone-shaped transition at the junction point of the cylindrical section and tank section at the rear and the high tractor at the front in order to achieve optimum volume in tankers. This part, which is called the intermediate cone, is in the form of an off-axis cone by design. As an intermediate cone manufacturing method, the sheet metal is cut with CNC plasma in a predetermined shape and bent with the three-point cylinder bending method.

2.2.Characterization Studies

Microstructures of the samples extracted from three different directions were visualized by JEOL brand scanning electron microscope (SEM). For microstructural studies, the samples were subjected to appropriate metallographic processes and etched with Keller's solution. Images of the samples were taken on the 3367 device according to ASTM-E8 standards. Three-point bending tests were also conducted on the Instron 3367 model device. Samples for tensile and three-point tests were prepared according to standards and 3 samples were used for each parameter. The hardness of the samples was measured from the cross section, the hardness of the core of the sample was measured. Brinell hardness measurements were made under a 67.5 kg load, by taking 5 as hardness value. Vickers hardness measurements were carried out by applying 50 grams of load for 10 seconds and making 5 measurements. Finally, the mean and standard deviations of 5 measurements in hardnesses were calculated.

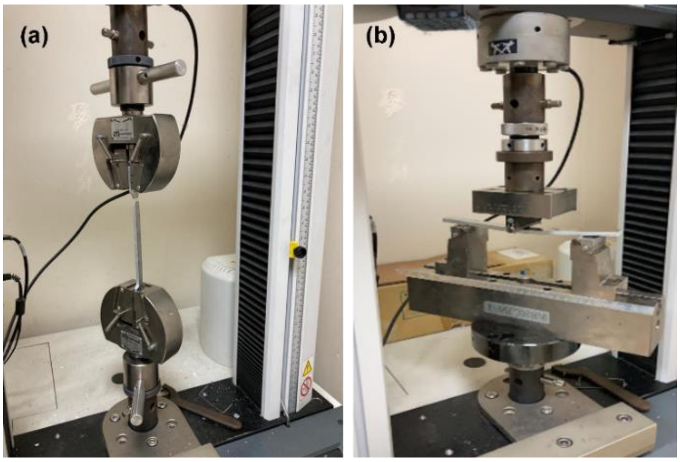

Figure 3. Tensile Test and 3-Point Bend Test

3. Results

The microstructure images taken by scanning electron microscope (SEM) of the samples taken from 0°, 45° and 90° directions with respect to the rolling direction are given in Figure 4. In Figure 4a, the microstructure image of the material in the 0° direction is given. In samples in the 0° direction, the grains are usually large in size and the coarsest grain size is about 70 μm. The microstructure of the samples in the 45° direction is given in Figure 4b. The grain size of the samples in the 45° direction is smaller compared to the samples in the 0° direction. The microstructure images of the sample taken from the 90° direction with respect to the rolling direction are given in Figure 4c.

The average macro and micro hardness values of the samples taken from three different directions according to the rolling direction are given in Figure 5. Brinell (HB) method was preferred for macro hardness and Vickers (HV) method was chosen for micro hardness. The average macrohardness values of the samples taken from 0°, 45° and 90° directions were measured as 65.7, 64.8, 65.1 HB, and the average microhardness value as 78.9, 79.0 and 79.1 HV, respectively.

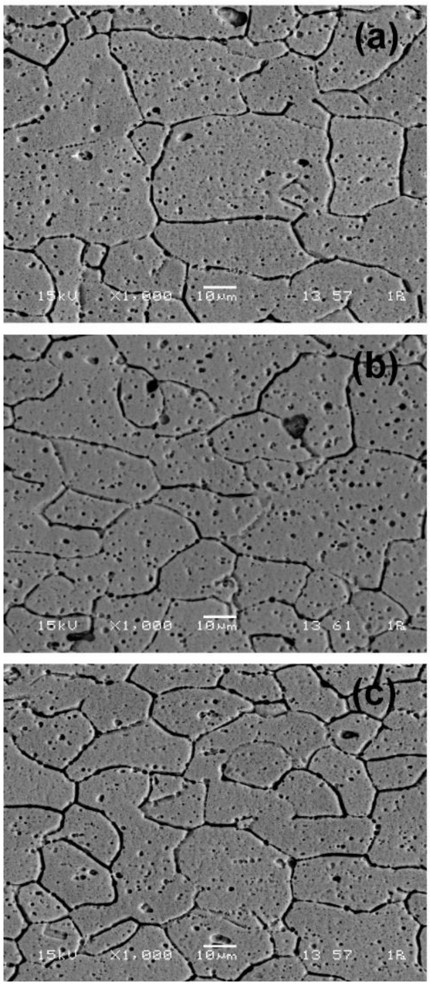

Figure 4. Test Sectional Microstructure View of Samples Cut from Three Different Angles; (a) 0°, (b) 45° and (c) 90°

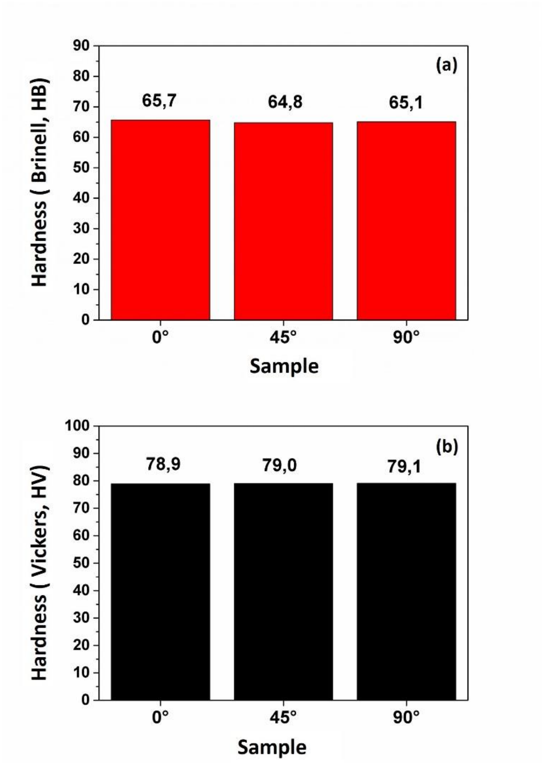

Figure 5. Macro Hardness and Micro Hardness Values Taken from the Samples

Tensile and three-point bending tests were carried out in order to compare the mechanical properties of the samples taken from different directions in accordance with the rolling direction. The images of the samples after the tensile and three-point bending tests are given in Figure 6. The stress-strain graphs obtained as a result of the tensile tests of the samples taken from 0°, 45° and 90° directions are given in Figure 7. The yield strength of the sample in the 0° direction is 165 MPa and its tensile strength is 272 MPa. The yield and tensile strengths of the sample in the 45° direction were 170 MPa and 278 MPa, respectively. The yield strength of the sample in the 90° direction was calculated as 180 MPa, and the tensile strength was calculated as 286 MPa. Among the samples taken from three different directions, the sample in the 90° direction has the highest yield and tensile strength. It was observed that the sample in the 0° direction had the lowest yield and tensile strength.

Table 2. Mechanical Results of 5182 Aluminum Sample

Sample	Yield Strength (Mpa)	Tensile Strength (Mpa)	Tensile Force (N)	% Elongation (mm/mm)
0°	165	272	16320	22
45°	170	278	16680	23
90°	180	286	17160	24

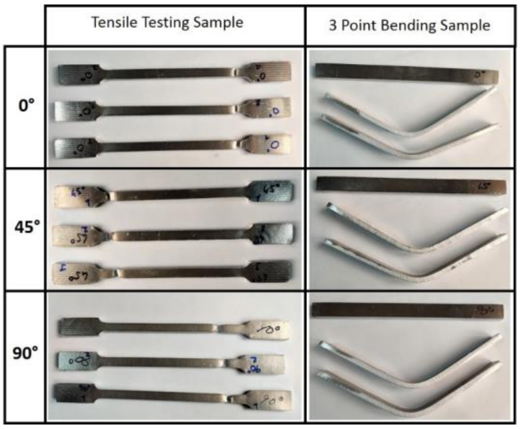

Figure 6. Images of test samples

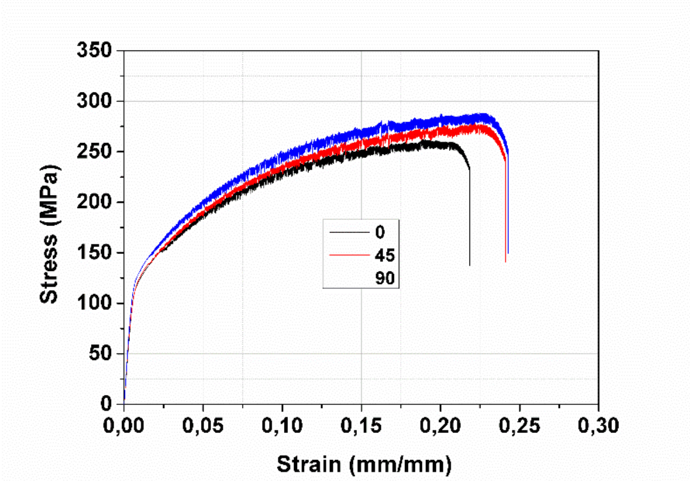

Figure 7. Engineering Stress-Strain Curves of 5182 Aluminum Alloys Made to Samples at 0°, 45° and 90°

3-point bending test results of the samples taken from three different angles are given in Figure 8. Among the three samples, the flexural strength of the sample in the 90° direction was the highest with 358 MPa, and the flexural strength of the sample in the 0° direction was the lowest with 340 MPa. The bending strength of the sample in the 45° direction was 348 MPa and a value between the values of the 0 and 90° samples. Three-point bending tests displayed parallelism with the tensile test results. The higher flexural strength in the 90° direction sample is due to its smaller grain size. As the grains in the material get coarser and the grain boundary decreases, a decrease in the stiffness and strength of the material is observed.

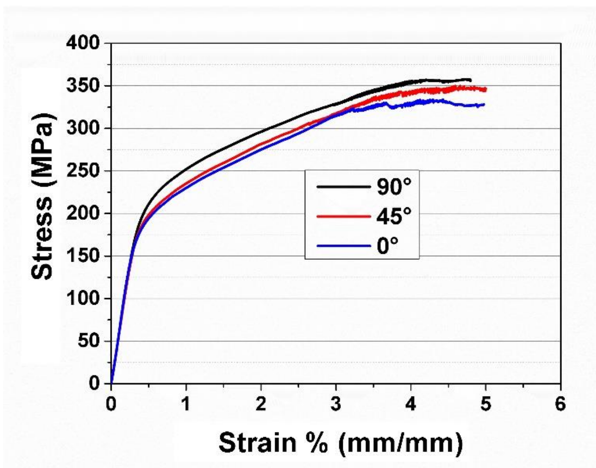

Figure 7. 3-Point Bend Test of Sample at 0°, 45° and 90°

4. Conclusions and Recommendations

When compared to 0° and 45°, the samples in the 90° direction have smaller grains and the grain size ranges from 8-30 µm. Depending on the rolling direction, the grain size of the samples and the grain boundaries they contain change. It was observed that the grain size was maximum in the samples in the 0° direction parallel to the rolling direction, while the grain size was minimum in the 90° samples perpendicular to the rolling direction. This stems from the rolling process. With the rolling process, the grains show elongation towards the rolling direction, and they become thinner and narrower from the directions perpendicular to the rolling direction.

When both macro hardness and micro hardness values of the samples taken from 0°, 45° and 90° directions are examined, it is seen that the average hardness values are the same. The hardness of the materials does not change depending on the direction.

Yield, tensile strength and tensile strength of the three materials are shown in Table 2 The hardness of the materials does not change depending on the direction. The higher yield and tensile strength in samples in the 90° direction can be explained by the Hall-Petch mechanism [7]. The samples in the 90° direction are the samples perpendicular to the rolling direction. It is clearly seen from the microstructure images taken by SEM that the samples in this direction have smaller grains and more grain boundaries compared to the samples in the other direction. As stated in the Hall-Petch mechanism, these grain boundaries prevent dislocation movement and lead to an increase in strength. Therefore, the smaller the grain of the material, the more grain boundaries there will be. The greater the grain boundary, the more restricted the dislocation movement will be [8-13].

In this study, samples were taken from 0, 45 and 90° directions depending on the rolling direction and their microstructure, hardness and mechanical properties were investigated. Obtained results are given below.

Microstructures and grain sizes of the samples extracted from three different directions were examined with SEM. As a result of the examinations, it was seen that the sample in the 0° direction had the largest grain, and the sample in the 90° direction had the smallest grain.

The macro and micro hardnesses of the samples in 0, 45 and 90° directions were measured, and the hardness values were found to be very close to each other.

The mechanical properties of the samples were investigated by tensile and 3-point bending tests. Tensile and 3-point bending tests were similar to each other. The tensile and three-point bending strengths of the 90° direction sample were of the highest value, while the tensile and flexural strengths of the 0° direction sample were of the lowest value.

5. Acknowledge

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