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# Effect of annealing to the mechanical Properties and microstructure of stainless steel foil for sensor of large automobile

***Abdul Aziz*[a,1], Alfi Eko Putera[b]**

[a]*Department of Metallurgical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa*

[b]*Advance for Material Processing and Engineering Laboratory, Mechanical System Engineering, Tokyo Metropolitan University*

[1]Corresponding author: azizabdul@untirta.ac.id

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ABSTRACT

The SUS 316 thin metal foils have widely used in the field of industries, such an electronic, industries. The aim nof this research wants to clarify the effect of annealing and quench temper to the mechanical properties of SUS 316 thin metal foils. The SUS 316 thin metal foil (TMF) after annealing and quench temper treatment at 900 $^{o}$C for 3 hours were studied by uniaxial tensile and microstructure analysis. The SEM-EBSD investigation used for microstructure analysis. The result of this research shown that the difference of uniaxial tensile test occur in SUS 316L with different grain size (Dg) such as 1,0 um until 9,0 um. Martensitic phase transformation (MPT) occur in SUS 316 TMF as shown in SEM-EBSD result. The microstructure change indicated by the change of grain misorientation (GMO) in SUS 316 TMF fine grains and coarse grain.

ABSTRAK

Baja SUS 316 ultra tipis telah banyak digunakan di dunia industri, khususnya industri elektronik. Tujuan dari penelitian ini adalah untuk menjelaskan efek dari aniling dan quench temper terhadap sifat mekanik dari SUS 316 baja ultra tipis. Baja ultra tipis SUS 316 setelah perlakuan aniling dan quench temper pada suhu 900oC selama 3 jam dipelajari dengan pengujian tarik dan struktur mikro. Investigasi dengan menggunakan SEM – EBSD digunakan untuk menganalisis struktur mikro. Hasil dari penelitian ini bahwa perubahan dari nilai kekuatan tarik terjadi pada SUS 316 dengan berbagai beasaran butir, baik itu dari besar butir 1,0 um sampai besar butir 9,0 um. Tidak ada fasa martensit terjadi pada SUS 316 ultra tipis, seperti yang ditunjukan oleh hasil analisis dari SEM - EBSD. Perubahan struktur mikro ditunjukan oleh perubahan grain misorentation (GMO) pada baja ultra tipis SUS 316 berbutir halus dan berbutir kasar

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## 1. Introduction

Austenitic stainless steel foils (ASS) thin metal foils (TMF) has wide application in electronic, bio assay, biomedical industry. The wide application for kinds of industries have received much attention in this decades. There are several issues in microforming technology such as size effect, limited materials and increasing cost for mass production [1-4].

When uniaxial tensile test applied to ASS TMF thin metal foils, the microstructure change occcur and the change of mechanical properties occur in ASS TMF [3-4]. The change of microstructure affect to the mechanical properties of TMF [5-6]. When ASS TMF subjected with uniaxial tensile test, twinning and dislocation interaction occur. The larger of twinning occur larger in the surface than the inner of ASS TMF [7]. After uniaxial tensile test, the stacking fault energy (SFE) in ASS TMF increase [8]. The microstructure change in ASS TMF occur not only by unixial tensile test, but also affected by the difference of the strain rate [9]. The uniaxial tensile test, not only affect to the microstructure change, mechanical behavior of ASS TMF but also affect to the phase transfromation in ASS TMF such as austenite to become martensite phase [10]. The fewer grains that exist in the ASS TMF affect to the failure behavior and materials flow in ASS TMF [10]. Beside that, in the TMF such as copper and pure titanium, the fracture strain decrease dramatically with the decreasing thickness from 0.3 mm until 0.1mm [11]. It needs to be clarifieid the relationship between change of the microstructure and plastic deformation behavior in TMF [8-11]. The change of microstructure that affect to the surface roughness depend on the grain size and thickness of TMF [12].The decreasing grain size affect to the increasing yield stress in TMF after uniaxial tensile test [13].

The benefit of this research in industrial fields are for electronic, biomedical, sensors industries. From the previous research, the deformation in the weak and strong grains have great effect to the mechanical properties of TMF. The dependency between change of microstructure and plastic deformation behaviors such as uniaxial tensile test behavior still not clarified yet. The aim of this study want to clarify the relationship between the microstructure change and the uniaxial tensile test result in ASS TMF SUS 316L.

## 2. Research Methodology

### *2.1. Materials*

The ASS TMF materials obtained from Komatsu Seiki Koaskusho.co.,ltd Nagano japan. The thickness of ASS TMF rolled with thickness until 0.1 mm and heat treated to remove the residual stress. The chemical composition of ASS TMF SUS 316 L shown in table 1.The SUS 316 L consist of high chromium element that prevent from the corrosion with form passive layer of $Cr_2O_3$ in the surface of the ASS TMF. Furthermore the SUS 316L consist of highly nickel element that will increase the toughness of ASS TMF SUS 316L.

**Tabel 1.** Chemical Composition of SUS 316 [4]

| | C | Si | Mn | P | S | Ni | Cr | Mo |
|---|---|---|---|---|---|---|---|---|
| Min | | | | | | 12.00 | 16.00 | 2.00 |
| Max | 0.030 | 1.00 | 2.00 | 0.045 | 0.030 | 15.00 | 18.00 | 3.00 |
| | 0.012 | 0.66 | 1.20 | 0.035 | 0.001 | 12.22 | 17.41 | 2.07 |

According to the chemical composition in table 1, the SUS 316L TMF has high chromium as ferrite former and high nickel element as austenite former. Ferrite phase in ASS TMF affect to the highly SUS 316L toughness sand ductility but low in strength. The austenite phase in ASS TMF affect to highly toughness, strength and ductility of SUS 316L TMF. The strength and ductility of SUS 316L TMF become superior than the other ASS TMF. The various grain size (Dg) in SUS 316L TMF affect to the mechanical properties behavior in SUS 316L TMF.

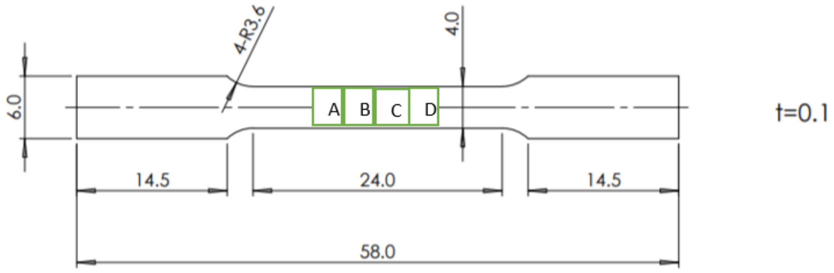


**Figure 1. Specimen of SUS 316L TMF**

ASS TMF SUS 316 L has dimensions such as width 4.0 mm, 0.1 mm in thickness and 20 mm in gauge length. The specimen was made according to the DIN 50125 standard. The specimen of SUS 316L was made in dog bone type as shown in Figure 1.

### *2.2. Method on Thin Metal Foils Characterization*

The samples of SUS 316L TMF were cleaned using ethanol and vibrated using ultrasonic vibrations for 30 minutes. The samples were heat treated for 1 hour at 400ºC to remove residual stress then quench temper applied at 900ºC for 3 hours. Then the samples subjected with tensile test step by step until five stages with 1.0 % strain level. Then the microstructure investigated. Besides that, uniaxial tensile test subjected until fracture to investigate the mechanical properties of ASS TMF. The uniaxial tensile test using AG-IS 50 KN produced by Shimadzu Corporation. The capacity of tensile machine was 50 KN. Surface roughness also measured for every stages using Confocal Laser Microscope VE 8800, produced by Keyence Co.

The microstructure behavior investigated using SEM-EBSD machine. The SEM-EBSD machine used SEM SU-70 Hitachi High Technology with mode normal. The emission current was used at 16 µA and pixel binning was 8x8.

## 3. Results and Discussion

### *3.1. The Activated Carbon Preparation Effects on Ammonia Adsorption*

As shown in figure 2, the stress strain curve show that the fine grain has higher strength but lower ductility than the coarse grain. Based on stress – strain curve, it is difficult to deform in the fine grains of ASS TMF SUS 316. The coarse grains have higher ductility than the fine grains. The higher ductility increase significantly for the grain size (Dg) of 9.0 µm. The ductility for the Dg since the size is 1.36 µm until 3.0 µm are quite similar. It means the mechanical properties for the fine grains (Dg 1.36 µm) until 3.0µm) are similar.

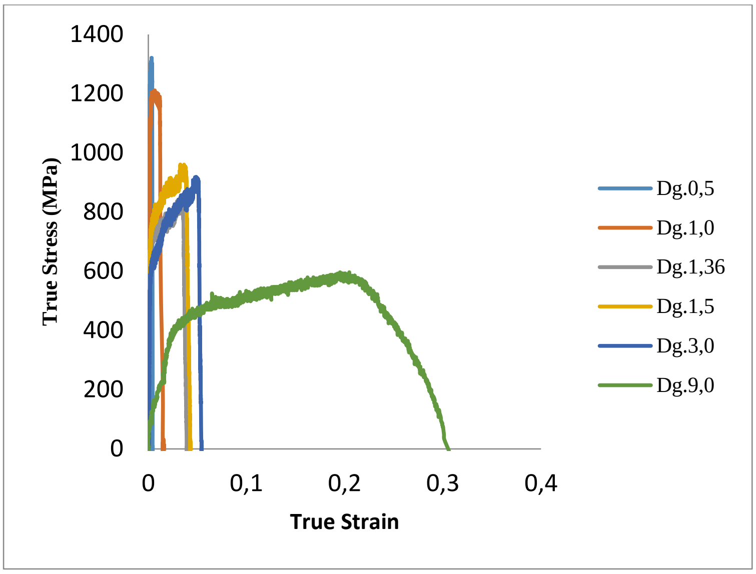


**Figure 2. Deformation behavior of thin metal foils.**

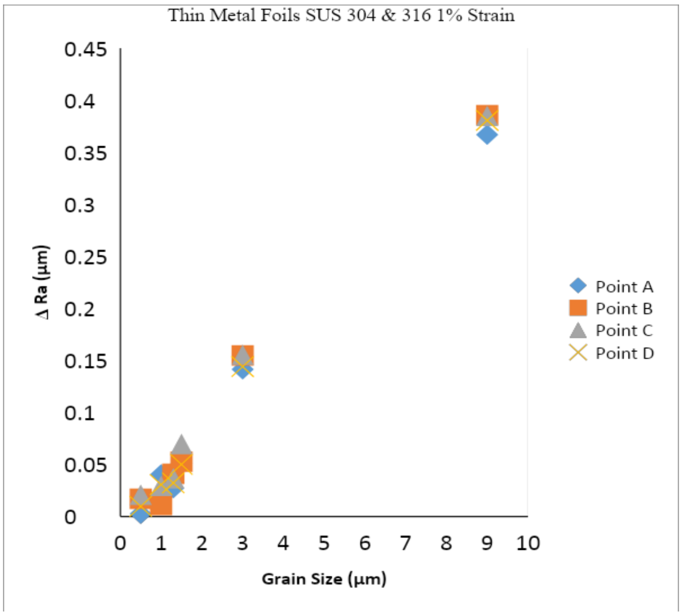


**Figure 3. 1%true strain**

The figure 3 show that the surface roughening increase proportional with the increasing strain level. The surface roughening increase higher for the coarse grain than the fine grains. It means the grain deformation and the inhomogeneous grain strength in the coarse grain is higher than the fine grains. The fine grains are more homogeneous than the coarse grain, thus the surface roughening behavior in fine grains are lower than the coarse grain. The homogeneous and in homogeneous grain depend on the strength distribution in the grain. The more homogeneous strength distribution in the grain will show the more homogeneous of the grain. The more inhomogeneous strength distribution in the grain will show the more inhomogeneous of the grain.

As shown in Figure 4a and 4c, the red color is austenite. As no color change, it means there are no phase transformation during plastic deformation. The austenite as a stable phase not change to the other phase according to the uniaxial tensile test in ASS TMF SUS 316L.

The microstructure result show that there are no martensitic transformation (MPT) in the microstructure as shown by SEM – EBSD investigation in figure 4a, b,c and d. It means there is no MPT effect in mechanical properties of ASS SUS 316 TMF. The result of tensile test and surface roughening affected by the dislocation interaction known as grain interaction effect. The misorientation (GMO) has an effect to the mechanical properties and surface roughening behavior [6].

The grain deformation in fine grains as shown in Figure 4b are homogeneous. The grain deformations are not severe in fine grains. According to the grain deformation result, the fine grains have homogeneous grain deformation. The grain deformation in coarse grains have homogeneous grain deformnation. The grains deformation in the coarse grains are severe. According to the grains deformation result as shown in figure 4d, the coarse grains have inhomogeneous grains deformation.

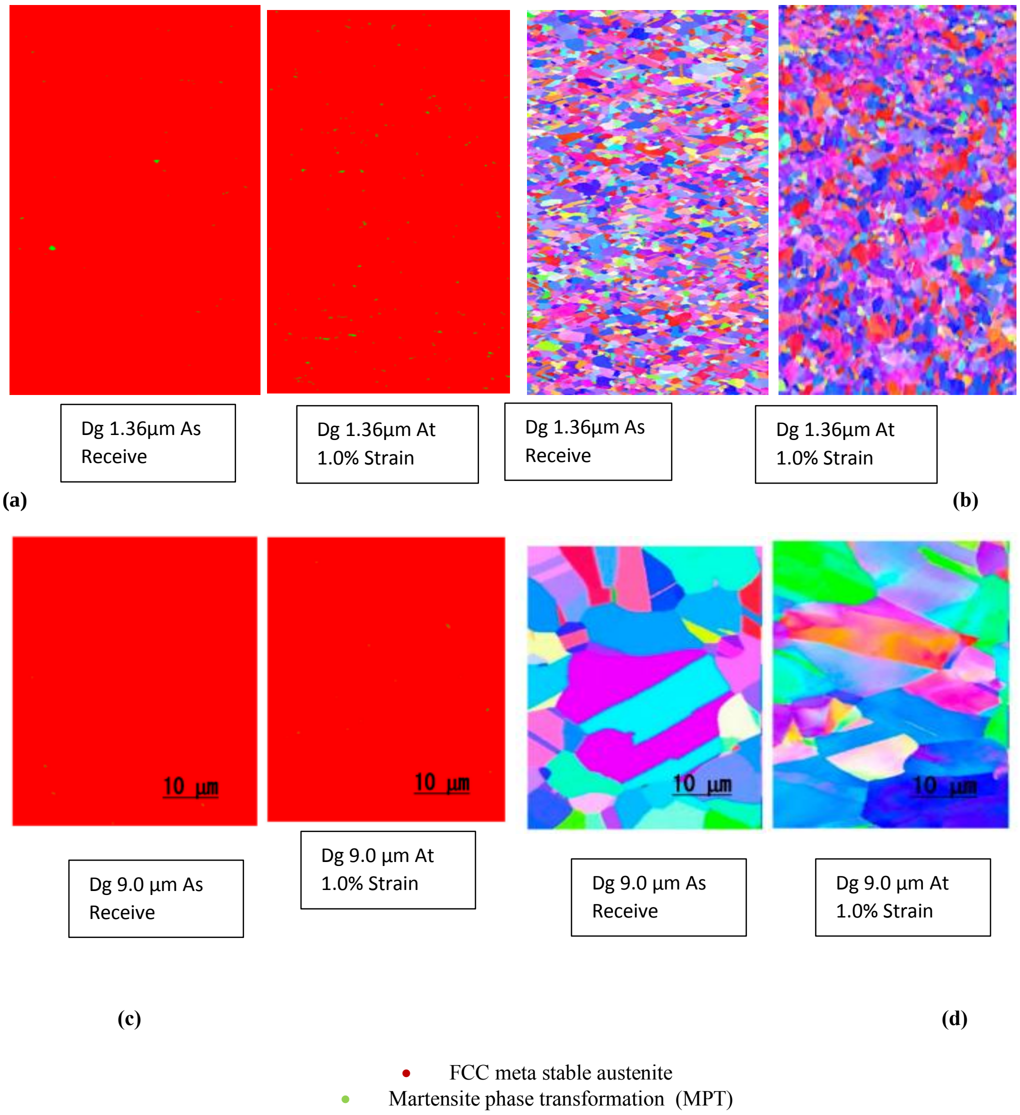


**Figure 4. The SEM – EBSD result in ASS TMF of SUS 316**

## 4. Conclusion

The conclusions of this research are as follow

1. MPT not occur in ASS TMF SUS 316L both in fine and coarse grains at 5.0% strain level in accumulation.
2. The grain deformation in coarse grain is larger than fine grains.
3. The ductility in coarse grain is higher than fine grains but the strength of the fine grain is higher than coarse grain.
4. Surface roughening increase higher for the coarse grain than fine grain for the same strain level.
5. The GMO is a factor that affect to the surface roughening behavior of SUS 316 Thin Metal Foil.

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