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The Influence of Shot Angle Variation at the Process of Dry Shot Peening to the Surface Roughness and Corrosion Resistance of the AISI 316L Austenitic Stainless Steel

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Abstract*–*AISI 316L is the austenitic stainless steel type that widely used in biomedical implant and artificial organs. This material's cannot be hardened by heat treatment but the mechanical strength could be increased by cold working process. Dry shot peening is the one of cold working process in which the surface specimen bombarded with spherical media called shot to produce a compressive residual stress layer and modify mechanical properties of metal's surface. The objectives of this research are to investigate the effect of shot angle variation of dry shot peening process on the surface roughness and corrosion resistance of AISI 316L.

Keywords—shot angle, dry shot peening, surface roughness, corrosion resistance.

I. INTRODUCTION

In the medical world, biomaterial is defined as a synthetic or natural material suitable for use in constructing artificial organs and prostheses to replace bone or tissue. The biomaterial is widely known as the implant medical device, for instance, knee implants, hip implants, shoulder implants, ankle implants, and elbow implants. In the biomedical world, biomaterial should have several main requirements such as biocompatibility, great mechanical forces and fatigue strength, low modulus of elasticity, fine corrosion and wear out resistance and having a material surface roughness required to accelerate the process of recovery and protein absorption to the implanted biomaterial. Several types of metal can be functioned as the material of biomedical implants with a particular application such as a combination of cobalt (dentistry and cardiovascularapplication),titanium (orthopedic and craniofacial application), and stainless steel (orthopedic, craniofacial, and otorhinology application)**[1]**.

AISI 316L austenitic stainless steel is a metal which is most recently used for application of biomedical implants. This material has a minimum content of chromium by 18% and the nickel composition by 8% that aims to generally increase the corrosion resistance and having a molybdenum content to increase the corrosion resistance at the chloride solution **[2]**. AISI 316L austenitic stainless steel has a non-specific magnetic, cannot improve its quality through the process of heat treatment, and biocompatible in nature. This kind of steel has a tenacious excess with the specification of tensile strength by 200 Mpa so having a formability characteristic which is similar to the carbon steel. However, the tensile strength can be significantly increased until 2000 Mpa through the cold working process **[3]**. The type of cool working used is dry shot peening method.

Dry shot peening is a type of cool working performed at the material surface by shooting the steel spherical media in a particular size repeatedly with high intensity so its able to result in an indent and residual stress at the material surface of indent result. This kind of method is able to change the physical and mechanical characteristic, roughness surface, improving the fatigue resistance, and is able to increase corrosion resistance because of the compressive residual stress which appears as the result of dry shot peening process**[4,5]**. Compressive residual stress is able to avoid the fracture of the material surface because of the work load. Some of the examination parameters at the process of shot peening has a significant influence on the mechanical and physical characteristic. Such a parameter is, among other things, type and size of steel ball material, the number of shot angle, treatment duration, the hard and speed of steel ball shooting to the trial material.

The objective of this study is to find out the influence of shot angle of steel ball during the dry shot peening process using the angle parameter by 45^0, 60^0, 75^0, and 90^0 to the surface roughness and corrosion resistance of the AISI 316L austenitic stainless steel. This research compares the rate of roughness and corrosion resistance between pre-treatment material and post-shot peening process.

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II. RESEARCH METHODS

The material used to conduct this research was the AISI 316L austenitic stainless steel with the chemical composition 67.04 % Fe, 1.736 % Mn, 16.672 % Cr, 10.638 % Ni, 2.405 % Mo, 0.678 % Si, and 0.12 % N. Before performing dry shot peening, the material was firstly given a treatment of solution annealing by heating the material at the heater electrical furnace with temperature of 1100^0 C, 30 minutes later was followed by the process of holding and quenching with the medium of cold water. After performing a pre-treatment process, the trial specimen was given the 15-minute treatment of dry shoot peening using a variation of torch shot angle by 45^0, 60^0, 75^0, and 90^0. The specimen at the surface roughness test has a dimension of 10 x 10 x 3 mm, while the specimen at the corrosion test is a cylinder with 12 mm in diameter and 3 mm in thickness.

The measurement of surface roughness was performed at the raw material surface and on the surface of process result of dry shot peening using surface roughness tester, while the process of corrosion resistance test was conducted using Galvanostat PGS 201T in the medium of Phosphate Buffer Saline (PBS) solution with the Composition of Sodium chloride (NaCl), Potassium chloride (KCl), sodium hydrogen phosphate (Na_2HPO_4), and Monopotassium phosphate (KH_2PO_4). The corrosion test result shows a data in form of corrosion stream (I_{corr}) and corrosion potential (E_{corr}) used as the analysis of corrosion rate at the AISI 316L specimens in the time units.

III. RESULTS AND DISCUSSION

Figure 1 shows the result of roughness surface examination of the AISI 316L austenitic stainless steel specimen.

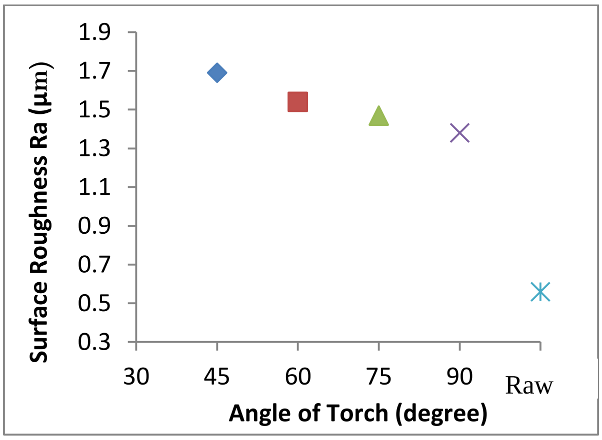

Fig.1: The Effect of Shot Angle To The Surface Roughness

The graphic of the examination test shows that the parameter of surface roughness decreases along with the increase of steel ball shot angle at the process of dry shot peening. The value of the surface roughness of the AISI 316L Austenitic Stainless Steel before being given dry shot peening is 0.56 µm and then experiencing the increase of roughness value until the highest roughness value by 1.69 µm during the torch shot angle by 45^0. This is caused by the higher the shot angle of the steel ball, the lower the shaped-indent pattern as the result of steel ball crash at the specimen surface. The higher the shot angle of the shot peening process, the better the result of the steel ball indent at the layer which is shaped on the material surface as the result of shot peening process. The layer shaped has a rough grain structure so having a result to the low of surface roughness value. The lower the shot angle of steel ball, the lower the force distribution to the radial directions at the specimen surface, so the basin shaped, do not indent another hill basin which has been shaped proportionally; therefore, the value of roughness resulted is getting high since the number of the shaped-indent result. In a similar vein, the higher the shot angle of the shot peening process, the higher the force distribution in the radial direction at the trial specimen surface so is able to indent the hill basin that has been shaped. This causes hills and valleys of basin resulted by the number of shot peening angel have low roughness rate.

Figure 2 shows the result of specimen corrosion test with solution annealing treatment and dry shot peening process.

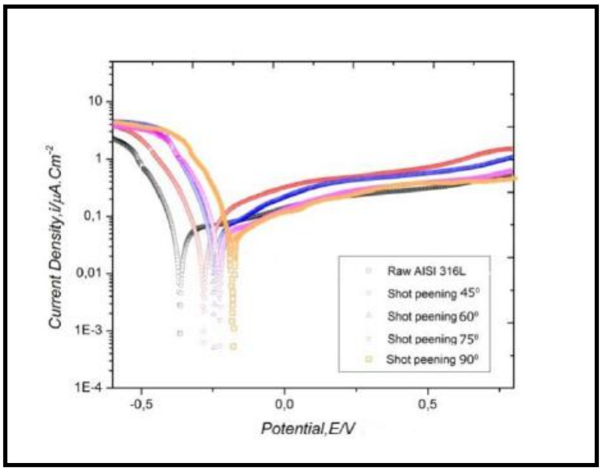

Fig.2: Result of Corrosion Test of the AISI 316L

Corrosion assessment process of this study was conducted using electrochemical concept. Figure 2 shows the polarization difference between raw material and trial material which is given solution annealing treatment and then followed by dry shot peening process. The result of corrosion test shows that solution annealing treatment followed by dry shot peening process has a higher corrosion potential value (E_{corr}) compared to the corrosion potential value of the raw material. This is caused by the solution annealing process able to minimize carbide precipitation at the grain boundaries. Carbide precipitation is able to cause sensitization/corrosion so having a potential to decrease the corrosion resistance of trial material because of grain boundaries corrosion. Corrosion potential increase of the AISI 316L Austenitic Stainless Steel along with the shot angle increase at the dry shot peening process is caused by the influence of compressive stress during the steel balls shooting at the specimen surface. The higher the shot angle of the steel ball, the higher the compressive stress of the specimen surface. The number of the compressive stress will have an effect to the finer the grain shaped at the specimen surface. The fine grain resulted from the process of dry shot peening is able to increase the holding capacity among the grain so minimizing the grain porosity and passivator in nature which is able to increase passivation that can decrease oxidation/corrosion reaction.

IV. CONCLUSION

With regard to the explanation above, it can be concluded that the method of solution annealing and the parameter of shot angle at the process of dry shoot peening has an influence on the surface roughness rate and the corrosion resistance of the AISI 316L Austenitic Stainless Steel implant. The higher the shot angle of the steel ball, the smaller the value of surface roughness. The highest value of surface roughness is 1.69 µm which is got from the torch shot angle of 45^0, while the lowest value results at the shot angle of 90^0. Solution annealing treatment followed by dry shot peening is also able to increase the corrosion resistance of the AISI 316L Austenitic Stainless Steel. The result of corrosion examination shows that the higher the torch shot angle, the more positive the value of the resulted-corrosion potential (E corr). The more positive the value of corrosion potential will have an effect on the passivation material over the oxidation/corrosion reaction.

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