Word Enhancement of Tongue Depressor Hardness by Heat Treatment and Shot Peening

Rudianto Raharjo\textsuperscript{1,*}, Haslinda Kusumaningsih\textsuperscript{1}, Teguh Dwi Widodo\textsuperscript{1}, Redi Bintarto\textsuperscript{1}, Maya Widiasesanti\textsuperscript{2}, Mirza Pramudia\textsuperscript{3}

\textsuperscript{1}Departement of Mechanical Engineering Brawijaya University Indonesia
\textsuperscript{2}Dental Polyclinic Community Health Centres Patikraja Indonesia
\textsuperscript{3}Departement of Mechanical Engineering Trunojoyo University Indonesia

*e-mail: rudiantoraharjo@ub.ac.id

Abstract. Tongue depressor is a tool commonly used in the medical world in health examinations especially in the mouth area. Tongue depressors generally is made by wood that is considered biodegradable. Currently, metal material has been used as a material tongue depressor like stainless steel because it is considered more easily sterilized so it can be used repeatedly. The main content of human saliva is acid which tend to corrode metal. For that, the use of stainless steel as a tongue depressor has a deficiency that is easily corroded. Therefore, other metal materials such as AISI 316L Stainless Steel which are stainless steel with low carbon content (0.03\% C) are required and have high corrosive resistance. With low carbon content AISI 316L Stainless Steel is suitable for surgery tools and diagnostic tools. The reduction of metal corrosion rate can also be done by the shot peening process by hitting the surface of the material by using a steel ball medium (stainless steel ball). The balls are fired using a gun blaster with high pressure so that the material surface collides with the steel balls that cause a strong impact on the surface of the material. Due to the strong impact resistant material surface, the AISI 316L Stainless Steel grain structure will be softer that the material has better mechanical properties. Shot peening increase the material hardness, therefore heat treatment is required to reduce the hardness so that AISI 316L Stainless Steel material can be used as tongue depressor which need strong but flexible. AISI 316L Stainless Steel with dimensions 30 mm long, 30 mm wide and 2 mm thick is used as a test material. The process of shot peening is done using a compressor and gun blaster. After the shot peening, the specimens are heated in an electric furnace with temperature variations of 750\(^\circ\)C, 800\(^\circ\)C, and 850\(^\circ\)C and holding time for 2 hours then cooling process is full annealing and normalizing. Furthermore, a hardness test was conducted. In the heat shooting process the heat treatment and cooling method selection also influence the level of hardness, for heat treatment. Annealing temperature 750\(^\circ\)C with cooling method in furnace, the hardness of material increased to 177.68 VHN, while in other heat treatment experience increase of hardness.

Keywords; Tongue depressor, Shot Peening, Annealing, Normalizing, Hardness, AISI 316L Stainless Steel

1. Introduction
Tongue depressor is a tool commonly used in the world of health in health examinations especially in the mouth area. Material properties required for use as tongue depressor include not easily corroded, easily sterilized, strong but flexible. Tongue depressor material in general market is made by wood
because it is considered biodegradable but only disposable. In addition, stainless steel metal material has also been applied as a tongue depressor because it is easily sterilized but easily corroded when exposed to acidic saliva.

Improved results and product quality requires a research process. Products in the field of industry include automotive products, household utensils, electrical appliances, medical devices and materials used for development. Production processes often used in industry include casting, forging, welding, machining, and molding. The results of the process will produce a product with a variety of quality and quantity. In order for the product to meet the needs of consumers and to compete in the market, the selection of the right manufacturing process will produce products that suit consumers’ wishes and be able to compete with other industries [1].

In addition to the manufacturing process, in working on the material will also affect the quality of the products obtained. There are two types of work, cold (cold working) and hot (hot working), both the work is used to modify the properties of a material. Cold working aims to modify the mechanical properties of materials based on the deformation process [2][3]. Cold work is used to modify properties on materials that cannot be done with heat treatment. Cold work is divided into several groups, namely, shearing, drawing, bending and squeezing.

Materials carried out with cold work will be used as a base material for the manufacture of medical devices that will directly come into contact with the body of living beings. In the process of making medical devices it is not allowed to have any harmful substances contained in a material that may interfere with patient safety while in use. By using cold work on medical equipment it is expected that no harmful elements can affect the organs in living things [4].

The alloy that is often found in medical devices is AISI 316L Stainless Steel. AISI 316L Stainless Steel is stainless steel with low carbon content (0.03% C) and has high corrosive resistance (4 cores). With low carbon content AISI 316L Stainless Steel is suitable for surgery tools, diagnostic tools. Due to the many surgical tools and diagnostic tools used the AISI 316L Stainless Steel has to be reinforced surface and enhanced its tensile strength by cold work [5].

In the fields of medical, medicine, obstetrics or nursing are needed a tool to support the work. One such support tool is a diagnostic tool. This tool serves as a diagnostic tool of a disease. One diagnostic tool is a tongue depressor. this tool serves to press the tongue, in order to see more clearly the situation in the throat, whether there are abnormalities, for example there is inflammation such as pharyngitis, tonsillitis etc. [6].

One of the cold working used to improve the mechanical properties of AISI 316L Stainless Steel is shot peening. Shot peening mechanism is to hit the surface of the material using a steel ball (Stainless Steel ball). The balls are fired using a gun blaster with high pressure so that the surface of the material collide with the steel ball which causes a strong enough pressure on the surface of the material. Because the material surface is subjected to strong pressure, the AISI 316L Stainless Steel grain structure will be softer that the material has better mechanical strength.

The process of shot peening causes the material hardness to increase [7], for it needs a heat treatment process to reduce the hardness so that AISI 316L stainless steel material can be used as a strong but flexible tongue depressor. The Shot Peening process produces plastic deformation, and from this plastic deformation the granular structure of the AISI 316L material becomes smoother. The shot peening process itself transforms austenite into martensite reversing process from martensite to austenite can be done using annealing process [8][9].

2. Research Methodology
This research is a laboratory-scale experimental study that aims to determine the effect of heat treatment on AISI 316L stainless steel which has undergone a shot peening process. AISI 316L Stainless Steel with dimensions 30 mm long, 30 mm wide and 2 mm thick is used as the test material shown in Figure 1.

The stainless steel ball used in this study was 5 mm in diameter. The shot peening process is performed using a compressor with constant guarded pressure of 6 bar and gun blaster with nozzle diameter and suction is equal to ¾ inches as shown in the study installation shown in Figure 2.

After the shot peening process, the specimens are heated in an electric furnace by temperature variations of 7500C, 8000C, and 8500C and holding for 2 hours then cooling process is full annealing
and normalizing. Furthermore, the hardness testing process is carried out for known AISI 316L stainless steel hardness after heat treatment process.

Figure 1. Dimensions of Specimens in Units mm.

The distance of firing is 2 cm and the shot peening process is for 10 minutes continuously. The shot peening process begins by turning on the compressor and adjusting the air output pressure of 6 bar by using the valve, when adjusting the output pressure of the gun blaster condition in the open condition, then we turn the pressure regulator valve up the needle in the output regulator to the 6 bar. After completion set the output pressure of 6 bar, prepare the specimen and taped to the tub, after the specimen is ready to insert the stainless steel ball into the tub. Perform the shot peening process by adjusting the firing distance of 2 cm and then inserting the hose to suck the ball.

Figure 2. Research Installation

3. Results and Discussion

3.1. The Effect of Shot Peening on Hardness
Shot peening is one of the cold working of surface treatment. In the process of shot peening, small balls as abrasives are fired onto the surface of a metal at specific speeds and conditions to give an indentation mark and produce a compressive residual stress so as to improve the fatigue strength. The process of shot peening can be seen in Figure 3.

Figure 3. Shoot peening Process

Cold working process is able to change the grain structure of a material becomes smaller / smoother. This is shown in the microstructure picture of the specimen before and after being subjected to shot peening treatment as in Figure 4.
Specimens that have been shot peening have a higher hardness compared to raw material without shot peening. This can be seen in Figure 5. The closer the distance from the shoot peening surface, the value of the hardness increases. This is in accordance with previous research, the process of shot peening impacts the grain size changes in the surface area furthermore affect the value of the surface hardness [10].

The grain size change in this study can be seen in Fig. 4. The smallest grain size is on the surface closest to the surface affected by the shot peening and the grain shape enlarges by estrange from the surface. The smoother (small) grain structure of a material, the high of material harness. Hardness value at AISI 316L surface layer that did not get shot peening treatment that is equal to 157.1 VHN, while for AISI 316L surface layer result from shoot peening showed increase to equal to 189.9 VHN.

3.2. Effect of heat treatment on hardness

Figure 6 shows that the effect of heat treatment affects the hardness. Visible at a distance of 50 μm from the surface indicates that the higher the heating temperature and the cooling rate used, the greater the hardness value, it is caused the higher the temperature used then the grain structure on AISI 316L Stainless Steel material will become homogeneous.

In the heat shooting process and the selection of cooling process also affect the level of hardness, for heat treatment. Annealing temperature 8500 C with the cooling process in the kitchen hardness 241.9 VHN, while the heat treatment normalizing temperature 8500 C with the cooling process through the room temperature is 249.8 VHN.

This is because in Annealing is the process of heating the steel above the critical temperature (723 °C) and then left for some time until the temperature evenly followed by cooling slowly while keeping the outer and inner temperatures approximately equal to the desired structure by using a cooling medium in the furnace to the room temperature. The resulting granules are generally large / rough, the phase is soft and gives shape capability to the metal. While normalizing is a process of heat treatment by cooled at room temperature, normalizing also produces a more homogeneous chemical structure, the grains
formed smaller and smoother, so that will give a better response, the normalizing process resulting of harder and stronger material than annealing.

**Figure 6.** Graph correlation of Heat Treatment Shot peening Process on hardness at 50 μm

The cooling process will affect the grain size of the material. The grain size changes are shown in Figures 7 and 8. The microstructure photographs (Figures 7 and 8) show the difference of grain size, this is due to the selection of cooling medium also affect the grain and hardness level of AISI 316L Stainless Steel material.

**Figure 7.** (a). Microstruktur Pictures AISI 316L Stainless Steel by Annealing 750°C, (b). Picture Microstructure AISI 316L Stainless Steel dengan Annealing 800°C, (c). Picture Microstructure AISI 316L Stainless Steel by Annealing 850°C.

**Figure 8.** (a). Picture Microstructure AISI 316L Stainless Steel on Normalizing 750°C, (b). Picture of Microstructure AISI 316L Stainless Steel on Normalizing 800°C, (c). Picture of Microstructure AISI 316L Stainless Steel on Normalizing 850°C.
4. Conclusion
In the result of the shot peening process of heat treatment and the selection of cooling method also affect the level of hardness, for heat treatment Annealing temperature 750°C with cooling method inside the furnace resulting on homogeneous of hardness between the surface to the layer, furthermore it suitable for use tongue depressor that able to bend.

References
[1] Zaleski R., Gorgol M., Zaleski K., 2012. Positron annihilation lifetime study of steel surface modification by shot peening. Physics Procedia 35, 92 – 97.
[2] Jen Gubicza, Moustafa El-Tahawy, Yi Huang Hyelim Choi, Heeman Choe, János L. Lábár and Terence G. Langdon. Microstructure, phase composition and hardness evolution in 316L stainless steel processed by high-pressure torsion. Materials Science and Engineering A, 657 (2016) 215-223D. Kornack and P. Rakic, “Cell Proliferation without Neurogenesis in Adult Primate Neocortex,” Science, vol. 294, Dec. 2001, pp. 2127-2130.
[3] Widodo, T. D, Raharjo, R., Sugiono, Wahyudiono, A, 2018. Effect of Low Temperature Steel Ball Peening on the Hardness of SS 316L, Key Engineering Materials, Vol. 791, pp. 105-110.
[4] Arifvianto B, Suyitno, Mahardika M, P. Dewo, P.T. Iswanto, Salim U.A., 2011. Effect of surface mechanical attrition treatment (SMAT) on microhardness, surface roughness and wettability of AISI 316L. Materials Chemistry and Physics 125, 418–426.
[5] D. Ratner, Jack E. Lemons, Frederick J. Schoen, Allan S. Hoffman.. Biomaterial Science. Academic Press.
[6] Yao-Chia Liu, Chen-Hwan Cherng., 2017. A modified tongue depressor facilitates the insertion of ProSeal laryngeal mask airway: Comparison with digital and introducer techniques. Journal of the Chinese Medical Association 80.
[7] J. Marteau, M. Bigerelle, P.-E. Mazeran, S. Bouvier., 2014. Relation between roughness and processing conditions of AISI 316L stainless steel treated by ultrasonic shot peening. Tribology International.
[8] E. Dryzek, and M. Sarnek. 2014. Reverse Transformation of Deformation Induced Martensite in Austenitic Stainless Steel. Acta Physica Polonica A Vol. 125
[9] Y. Mine, Z. Horita, Y. Murakami, 2009, Acta Mater. 57 2993 -3002.
[10] E. Dryzek, M. Sarnek, M. Wro 'bel., 1996. Reverse transformation of deformation-induced martensite in austenitic stainless steel studied by positron annihilation, Institute of Nuclear Physics.