Redesign and Remanufacturing the Shot Peening Machine: Model and Experiment

Henny Pasandang Nari\textsuperscript{1}, Mahadir Sirman\textsuperscript{1}, Rusdi Nur\textsuperscript{2,∗}, M. Iqbal Mukhsen\textsuperscript{2}

\textsuperscript{1}Mechanical Engineering Study Program, Politeknik Ilmu Pelayaran Makassar, Jalan Salodong Biringkanaya Makassar 90552 South Sulawesi Indonesia. \textsuperscript{2}Mechanical Engineering Department, Politeknik Negeri Ujung Pandang, Jalan Perintis Kemerdekaan Km. 10 Makassar 90245 South Sulawesi Indonesia.

E-mail: \textsuperscript{∗}rusdinur@poliupg.ac.id

Abstract. Stainless steel is a material that is corrosion resistant and can be used as an implant material (type 316L). Cold treatment can only increase stainless steel’s hardness, one of which is the shot peening process. This paper aims to remanufacture the shot peening machine for laboratory-scale testing purposes. The methodology used in designing the device, making all the necessary components, assembling it, and testing the shot peening machine with several specified parameters. The conclusion that can be obtained is the shot peening machine has been well designed and remanufactured and has appropriately functioned based on the performance that has been shown in the testing of stainless steel 316L.

1. Introduction

All kinds of human needs are increasing from year to year. Likewise, many problems arise both in the industrial sector and in the world of health. One of the issues that arise from the health sector is stainless steel, which is often used in the medical world. Problem cases occur in the medical world, i.e., the use of stainless steel as an implant material in grafting broken bones. In joining a fractured bone using an implant plate, orthopedic doctors’ materials are titanium and stainless steel. The implant material itself must have higher corrosion resistance due to direct contact with the human body. Human body fluids contain many aggressive ions that can cause corrosion, and the implant material must also be malleable to conform to the contours of human bones.

Stainless steel is a material that resistant to corrosion and is easier to form than titanium, so the cost of developing it can be cheaper [1]. However, because the hardness level of stainless steel is below the titanium material, stainless steel needs to go through additional treatment before it is ready to be used as an implant material [2]. Besides, stainless steel has low carbon content, making it challenging to do heat treatment. Therefore, stainless steel is preferable to undergo cold treatment. The cold treatment process is the process of machining [3,4], sandblasting [3,4], and shot peening [5].

This activity uses the shot peening method on the stainless steel surface, which can change the material’s surface structure due to the impact of the steel shot. The shot peening process can increase the surface hardness of the stainless steel implant material. With the method of firing the steel shot to the stainless steel material’s surface, it is hoped that abrasive will not
occur due to abrasion by the steel shot itself. The use of steel shot is a method that is friendly to health than the sandblasting way that uses silica sand which can adversely affect the respiratory tract inhaled during the spraying process. This paper aims to redesign and remanufacture the shot peening machine for laboratory-scale testing purposes.

2. Methodology
In this part of the methodology, the remanufacturing process will be explained along with the working process, and then experimented with predetermined parameters.

2.1. Materials and Tools
The material to be used in the shot peening machine testing is stainless steel AISI 316L. While the steel balls used for shooting the material is steel shot type S-230 with 0.6 mm diameter.

2.2. Remanufacturing and Assembly
The shot peening machine consists of several components, both made and purchased. The parts purchased are the spray gun, the suction hose, the host connected to the compressor, and the specimen holder’s vise, while the other components have several parts as described in table 1.

2.3. Experimental setup
The shot peening machine has already made all the components entirely and assembled them to function correctly. Next, the experiment is carried out by referring to the experimental schematic as shown in Figure 1. The parameters used in the test are the shooting time variation (0, 15, 30, 45, and 60 minutes) and the shooting angle (0° and 45°).

![Figure 1: Schematic of shot peening process](image)

3. Results and Discussion
In this section, the results of remanufacturing shot peening machines will be described clearly and will be accompanied by discussion.

3.1. Results
The shot peening machine has been remanufacturing and can be seen in Figures 2 and 3.

The following table shows the average results for all specimen testing, namely the surface roughness test and the material hardness test.
Table 1: Part of the shot peening machine includes the process and tools used

| No. | Components | Making process | Materials and Tools |
|-----|------------|----------------|---------------------|
| 1.  | Frame     | • Cutting a plate (thickness of 2 mm) according to a predetermined size  
• Cutting brackets according to the specified size  
• Connecting each part using electric welding  
• Perforating the parts that have been determined for the installation of components | • The at-37 plate of 2mm thickness  
• brackets  
• Electrodes  
• Hand Grinder  
• Welding machine  
• Steel ruler  
• Elbow ruler |
| 2.  | Base     | • Cutting a 40 x 40 bracket to the specified size  
• Connecting the brackets according to a predetermined size using an electric welding machine | • Brackets  
• Electrodes  
• Hand Grinding  
• Welding machine  
• Steel ruler  
• Elbow ruler |
| 3.  | Door     | • Cutting the metal strip (20 x 5 mm) to the specified size  
• Cutting acrylic (5 mm thickness) to predetermined sizes  
• Cutting a 3 mm thickness plate to be used as a hinge  
• Making bolt holes in iron and acrylic using a drill  
• Connecting the plate to be used as a hinge to the metal strip  
• Connect the acrylic to the metal strip that has been fixed using bolts and double tape | • Metal strip (20 x 5 mm)  
• Plate (3mm thickness)  
• Acrylics (5mm thickness)  
• Bolt (5 mm)  
• Double tape  
• Hand Grinder  
• Drill machine  
• Drill bit (5 mm) |
| 4.  | Acrylic wall | • Cutting three pieces of acrylic in sizes 470 x 320 each  
• Drilled several parts to support the installation of other components | • Acrylic (5 mm thickness)  
• Hand grinder  
• Drilling machine |
| 5.  | Stand for Spray Gun | • Cutting the plate according to the predetermined size  
• Drilled several parts to support the installation of other components | • Plate  
• Drill bit  
• Bolt  
• Nut  
• Hand grinder  
• Drilling machine |
| 6.  | Door hinge shaft | • Connect the nut on the hinge by welding it as a holder | • Nut  
• Shaft  
• Electrode  
• Welding machine  
• Hand grinder |
| 7.  | Stopper for Spray Gun | • Cutting the plate according to the predetermined size  
• Drilled several parts to support the installation of other components | • Plate  
• Drill bit  
• Hand grinder |
3.2. Discussion
Based on the results of remanufacturing the shot peening machine and testing data has been performed, it can be said that the surface roughness obtained will increase sharply after shooting.

**Figure 2:** Design of shot peening machine

**Figure 3:** Result of remanufacturing the shot peening machine

| Shooting Time (minute) | Surface Roughness (Ra) | Hardness (BHN) |
|-----------------------|------------------------|----------------|
|                       | Angle shoot 0° | Angle shoot 45° | Angle shoot 0° | Angle shoot 45° |
| 0                     | 0.10           | 0.38           | 117.56        | 117.56          |
| 15                    | 2.55           | 2.26           | 146.38        | 138.46          |
| 30                    | 2.40           | 2.11           | 148.84        | 142.26          |
| 45                    | 2.26           | 2.06           | 149.11        | 144.15          |
| 60                    | 2.25           | 2.04           | 150.54        | 146.68          |
the specimen for the first 15 minutes. In the next 15 minutes, the resulting surface roughness decreased slightly. The surface roughness did not change significantly after 45 minutes and 60 minutes, as shown in Figure 4. The effect of surface roughness on shooting time showed the same trend for 0° and 45° shooting angles, respectively. Similar results were obtained in the study by Mukhsen et al. [6], in which it was concluded that the timing of firing influenced the surface roughness induced in the shot peening. The effects of shot peening conditions on medium carbon steels’ surface characteristics with different heat treatments were investigated [7]. 3D finite element modeling was used to determine surface topography changes affected by the shooting parameters and processing time [8]. In addition to finite element modeling, other researchers have also discussed the stability and reduction of extensive test features [9–23]. Other studies investigate the influence of controlled shot peening (CSP) parameters (S110, S230, S330, and S550) on the treated material [24].

![Figure 4: Surface roughness in different shooting time for the shot angle of 0° and 45°](image)

Meanwhile, for the material hardness response, there is a similarity between the surface roughness responses. The hardness obtained will increase after shooting the specimen for the first 15 minutes. In the next 15 minutes, the resulting hardness increased slightly. The hardness did not change significantly after 45 minutes and 60 minutes, as shown in Figure 5. The effect of surface roughness on shooting time showed the same trend for 0° and 45° shooting angles, respectively. In a similar study, the results of shot peening conditions on medium carbon steels’ surface characteristics with different heat treatments were investigated [7]. The hardness of the surface was considerably lowered during the tempered workpiece was shot-peened. The hardness distribution shows work softening near the surface. In another study, the main objective was to determine the main factors of the shot peening (SP) process of AISI 1060 high carbon steel on microhardness, grain size, and residual stress [25].

4. Conclusion
Based on the results of the redesign, remanufacturing, and experiments on the shot peening machine, it can be concluded as follows: The shot peening machine can be adequately and wholly remanufactured to the specifications in the shot peening test, which is intended for laboratory-scale purposes. The shot peening machine’s performance also provides a reliable ability to increase the hardness and the surface roughness desired for the implant material.
Figure 5: Hardness in different shooting time for the shot angle of 0° and 45°

References
[1] Gurappa I 2002 Characterization of different materials for corrosion resistance under simulated body fluid conditions Mater Charact. 49(1)73–9
[2] Iqbal M, Prasetya D, Mahardika M, Suyitno S, Arifvianto B, Prihandana GS, et al. 2011 The effect of sandblasting on AISI 316L stainless steels InProsiding Industrial Research Workshop and National Seminar. p. 58–61
[3] Elias CN, Oshida Y, Lima JHC, Muller CA 2008 Relationship between surface properties (roughness, wettability and morphology) of titanium and dental implant removal torque J Mech Behav Biomed Mater. 1(3)234–42
[4] Piattelli A, Scarano A, Piattelli M, Calabrese L 1996 Direct bone formation on sandblasted titanium implants: an experimental study Biomaterials. 17(10)1015–8
[5] Oshida Y, Sachdeva R, Miyazaki S, Daly J 1993 Effects of shot-peening on surface contact angles of biomaterials J Mater Sci Mater Med.
[6] Mukhnen MI, Nur R, Af Yusuf MA, Rakka C 2020 The influence of shooting conditions during shot peening of stainless steel on surface roughness InIOP Conference Series: Materials Science and Engineering.
[7] Harada Y, Yakura R 2010 Effect of shot peening on surface characteristics of carbon steel with different heat treatments InIAP Conference Proceedings.
[8] Bagherifard S, Ghelichi R, Guagliano M 2012 Numerical and experimental analysis of surface roughness generated by shot peening Appl Surf Sci.
[9] Shiyi Liu, Zhenning Su, Ming Li, and Longtan Shao. Slope stability analysis using elastic finite element stress fields. Engineering Geology, 273:105673, 2020.
[10] Yufeng Tian and Zhanshan Wang. A new multiple integral inequality and its application to stability analysis of time-delay systems. Applied Mathematics Letters, 105:106325, 2020.
[11] Mustafa Turkylmazoglu. Single phase nanofluids in fluid mechanics and their hydrodynamic linear stability analysis. Computer Methods and Programs in Biomedicine, 187:105171, 2020.
[12] M. Kusban, A. Susanto, and O. Wahyunggoro. Feature extraction for palmprint recognition using kernel-pca with modification in gabor parameters. In 2016 1st International Conference on Biomedical Engineering (IBIOMED), pages 1–6, 2016.
[13] S. Dale, H. M. Silaghi, and C. Costea. Procedural and software development of a liapunov-based stability analysis method for interpolative-type control systems. In 2013 17th International Conference on System Theory, Control and Computing (ICSTCC), pages 156–159, 2013.
[14] S. Lian, S. Minami, S. Morii, and S. Kawamoto. Analysis method of voltage stability for bulk power system by p-v and q-v curves considering dynamic load. In 2009 IEEE/PES Power Systems Conference and Exposition, pages 1–6, 2009.
[15] S. Lian, S. Minami, S. Morii, and S. Kawamoto. A novel construction method of decentralized systems and stability analysis for bulk power system. In 2009 IEEE Power Energy Society General Meeting, pages 1–6,
[16] A. Monica and Narayanappa. Transient stability analysis of tngt power system. In *2014 IEEE 8th International Conference on Intelligent Systems and Control (ISCO)*, pages 149–154, 2014.

[17] A. V. Platonov. Stability analysis for nonlinear mechanical systems with non-stationary potential forces. In *2020 15th International Conference on Stability and Oscillations of Nonlinear Control Systems (Pyatnitskiy’s Conference) (STAB)*, pages 1–4, 2020.

[18] R. Safari and B. Tavassoli. Stability analysis of networked control systems with generalized nonlinear perturbations. In *2014 Smart Grid Conference (SGC)*, pages 1–6, 2014.

[19] L. Shen and H. Xiao. Delay-dependent robust stability analysis of power systems with pid controller. *Chinese Journal of Electrical Engineering*, 5(2):79–86, 2019.

[20] H. Xuedong, D. Ruhu, C. Gengxin, L. Zhi, and X. Shangxue. The research and application of stability control system operated on qipanjing industrial park isolated power system. In *2016 China International Conference on Electricity Distribution (CICED)*, pages 1–4, 2016.

[21] Y. Yang and H. Shu. Power system stability analysis and control based on pmu. In *2011 International Conference on Computer Science and Service System (CSSS)*, pages 3376–3379, 2011.

[22] Muhammad Kusban, Adhi Susanto, and Oyas Wahyunggoro. Combination a skeleton filter and reduction dimension of kernel pca based on palmprint recognition. *International Journal of Electrical and Computer Engineering (IJECE)*, 6(3):55–3261, 12 2016.

[23] W. Yu, Y. Xue, J. Luo, M. Ni, H. Tong, and T. Huang. An uhv grid security and stability defense system: Considering the risk of power system communication. *IEEE Transactions on Smart Grid*, 7(1):491–500, 2016.

[24] Mylonas GI, Labeas G 2011 Numerical modelling of shot peening process and corresponding products: Residual stress, surface roughness and cold work prediction Surf Coatings Technol.

[25] Maleki E, Unal O, Reza Kashyazadeh K 2019 Efficiency Analysis of Shot Peening Parameters on Variations of Hardness, Grain Size and Residual Stress via Taguchi Approach Met Mater Int.