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The Effect of Shot Peening Hardening Treatment on Pressure Variation on Mechanical Properties and Microstructure of S45C Steel

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Abstrak

The aim of the research was to determine the mechanical properties and microstructure of S45C steel with automatic shot peening treatment. The shot peening test is used to increase the hardness of steel and microstructure without adding carbon to the steel. S45C steel is classified as medium steel with a carbon content of 0.51%. Variation of shot peening treatment with pressure variations of 5 bar, 6 bar and 7 bar. The steel ball shot uses a size of 0.8 mm, a range of 100 mm, and a shooting angle of 90o. Hardness test using Vickers and microstructure observation using a microscope. The average hardness test results at a pressure of 5 bar were 193.3 VHN, at a pressure of 6 bar with a hardness of 227.2 VHN, and 7 bar with a hardness of 250 VHN. So it can be concluded that the higher the pressure used, the higher the level of hardness obtained. The results of microstructure photos show that the higher the pressure released, the more martensite phase a structure will be obtained, this is directly related to the hardness of S45C steel.

Keywords: Shot peening, S45C Steel, Hardness, Microstructure

1. Introduction

Steel is a type of material that is used by many engineers for various kinds of parts in automotive and industrial engines. Some of the mechanical properties used in testing steel are hardness and microstructure. This mechanical property can be obtained when we look at the material or steel certificate to be purchased. S45C steel is a medium carbon steel class with a carbon content (0.3 – 0.5% C). Moderate carbon content in the material can improve the mechanical properties of the material. One way to improved of the mechanical properties of a metal and make it harder is to use the shot peening process. The use of S45C steel is generally applied in the manufacture of components such as gears, rails, pulleys, sprockets and axles [1].

The maintenance engineering that was mostly carried out on low carbon steel was material surface engineering [2]. Various methods to improve the surface properties of materials were used to improve their performance. Hard coating type surface treatment [3], perform thermochemical modification [4], mechanical treatment [5], and others.

Based on its application, S45C steel can be given surface treatment. The surface treatment process has a very important function because it can change the mechanical and morphological properties of the steel according to the needs. One example of surface treatment is shot peening, which is the surface treatment of materials at low temperatures, then firing steel balls with adjustable speed and pressure continuously until plastic deformation is produced.

The parameter used in this study is the effect of automatic shot peening used on surface hardening. Tests that will be carried out include hardness, microstructure, and macro photos. Researchers are interested in discussing research on how the effect of automatic shot peening on the surface hardening process on the mechanical properties and morphology of S45C steel structures.

This research attempts to improve the mechanical properties of steel using heat treatment and surface treatment. This study aims to determine the effect of annealing and shot peening on S45C steel with changes in pressure. The annealing treatment was carried out by heating the temperature to 900° C held for 15 minutes, then followed by the shot peening treatment using a pressure of 7 bar and the distance between the nozzles and the surface was 100 mm and using S230 steel balls with a diameter of 0.85 mm.

The effect of the treatment is indicated by changes in the results of the hardness test both in crosswise, as well as the surface hardness and microstructure of the treatment results. The result is a change in the hardness value and a change in the microstructure of JIS S45C from the effects of the annealing and shot peening treatments. The highest hardness was the annealing heat treatment and the 15 minute shot peening treatment of 251.88 kgf/mm2. The surface hardness decreased after the annealing treatment was carried out, then the hardness increased after the shot peening treatment was carried out. The shot peening treatment causes the grain to become finer from surface to subsurface depending on the distance from the surface to the depth of the surface. These changes caused the surface and sub-surface of JIS S45C carbon steel to experience an increase in mechanical properties. [6].

Research using variations in time, shooting distance and pressure has also been carried out by optimizing shot peening gravity using the taguchi method. The factors used in this study were variations in distance of 50, 100 and 150 mm, variations in time of 5, 10 and 20 minutes, and variations in air pressure of 5, 7 and 9 kg/cm². Using 0.8 mm steel ball by testing the properties of hardness, roughness, wear and microstructure on ST 45 steel material [7]. Results obtained are the smallest roughness value of 4.4880 μm using a variation of 20 minutes, 100 mm distance and 5 air pressure kg/cm². The most dominant factor is air pressure with an influence value of 72.60%. The highest surface hardness value was obtained at 240.39 HVN obtained with a time of 10 minutes, a distance of 100 mm and a pressure of 9 kg/cm². The most influential factor is pressure with a value of 43.42%. Then the smallest surface wear value was obtained 0.00039 mm³/kg.m obtained using a time variation of 5 minutes, a distance of 100 mm and a pressure of 7 kg/cm². The most influential or dominant factor is the distance factor with a contribution value of 36.21%. The best microstructure test results were obtained at 10 minutes, 100 mm distance and 9 kg/cm² pressure as evidenced by the results of microstructure grain reduction and the hardness measurement results of 240.39 HVN[8].

The greater the value of pressure and the length of time used, the value of roughness and hardness will increase and reduce the value of wear. Meanwhile, the farther the shooting distance, the roughness value will increase and the hardness and wear values will decrease. [9]. Shot peening can increase surface hardness by changing the microstructure. This change is caused by plastic deformation and residual stresses. This study discusses the effect of the duration of time variations of 2, 4, 10, 20, and 30 minutes on the microstructure and surface hardness. The steel balls used are 0.6 mm in diameter and with an air pressure of 8 bar during firing.

The result of the most optimal violence value with a duration of 2 minutes of shooting time is 380.8 HV, while the maximum violence with a shooting duration of 30 minutes is 523.1 HV. Surface hardness increases due to structural changes on the surface and sub-surface of the shot peening material. The results of the microstructure test obtained by increasing the shot peening duration and increasing the surface hardness value mean that the size of the microstructure below the surface is smaller after the shot peening is carried out. Based on these results, the microstructure is highly dependent on the effect of shot peening duration, the longer the shot duration, the deeper the grain boundary refinement depth [10]. Shot peening can refine the microstructure and increase the hardness value. The longer the shot peening process, the deeper the reduction of the microstructure and the higher the surface hardness value. This research was conducted to determine changes in the microstructure and hardness of AISI 304 in the shot peening process.

Surface treatment with the shot peening process was carried out by adjusting the shooting time variations of 0, 5, 10, 20, 30 and 40 minutes at an air pressure of 7 bar using a steel shot with a diameter of 0.6 mm. The distance between the nozzle and the specimen surface is set at 100 mm. The results showed that a fine microstructure layer was formed on the surface of the shot peening within 5 minutes of firing with a depth value of 95 μm and then the value increased to 158 μm in 20 minutes, meaning that the change in microstructure is highly dependent on the shot peening process.The hardness results also increased gradually and the shot peening times were 0, 5, 10, 20, 30 and 40 minutes. This also increases the hardness numbers to 241, 404, 418, 437, 481 and 496 VHN. These results show that the hardness value obtained at 0 minutes to 5 minutes hardness has increased significantly, while after 5 minutes the surface hardness has not increased significantly. It can be concluded that shot peening can be used to smooth grain and increase surface hardness. the hydram pump must be clean and no dirt can enter at all, because if any dirt is carried into the pump it will interfere with the hydram pump's work, which means that the efficiency of the hydram pump will decrease or be less than optimal.[11].

Shot peening treatment is one of the treatments that aims to provide stress on the surface of a component that can improve the properties of the material against dynamic loads. Besides being able to improve the characteristics of resistance to dynamic loads, shot peening also affects the static characteristics in the form of material hardness and roughness. The parameters used in this study used a firing duration of 2, 4, 6 minutes and then firing angles of 0°, 15°, 30°, and 45°. The diameter of the steel balls used are 0.6 mm and 1 mm. The results obtained are the lowest level of roughness obtained using a steel ball with a diameter of 0.6 mm for 6 minutes and by using a shooting angle of 0° with a value of 1.37 μm, while the best hardness value is obtained through the shot peening process with variations of steel balls. 0.6 mm in diameter for 6 minutes and with a firing angle of 15° with a hardness value of 168.58 kgf/mm². A steel ball with a diameter of 0.6 mm has more effect on hardness and roughness than a steel ball with a diameter of 1 mm. [12]. Shot peening is a cold working process in which a surface portion is shot with a small spherical medium called a steel shot. Each shot that hits the metal will leave a small indentation in the surface. Where the process of shooting steel balls must use high pressure air repeatedly to produce small grains on the surface. The shot peening process is very important because it can improve the mechanical properties of the material [13].

2. Material dan metodologi

S45C steel was obtained from CV Mega Baja Purwokerto Indonesia. Hardness testing and microstructure observation were carried out at the Materials Laboratory at Gajah Mada University, Yogyakarta. The S45C material contains 51% carbon (C), 0.035% surf and 0.8% manganese (Mn). S45C steel has the property of being able to be treated to obtain better mechanical properties. S45C steel has good weldability and machinability. High impact capability with a hardness value of 167 HB. [14].

Figure 1. Speciment and shot peening process

This study uses an experimental method. The research object under study was the shot peening process with the specimen used being S45C steel, this study used the independent variable pressure variations of 5 bar (kg/cm3), 6 bar and 7 bar. Steel ball fixed variable 0.8 mm, angle 90o, firing distance 100 mm. The scheme of the shot peening process can be seen in Figure 2.

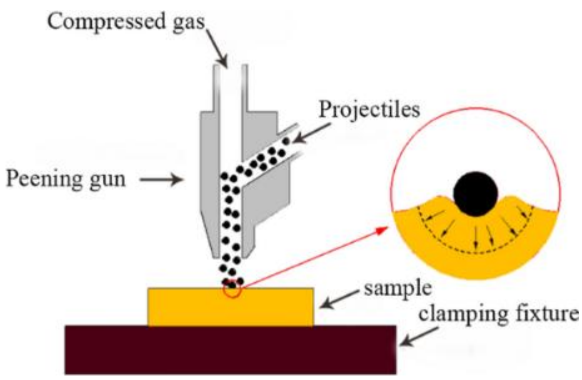
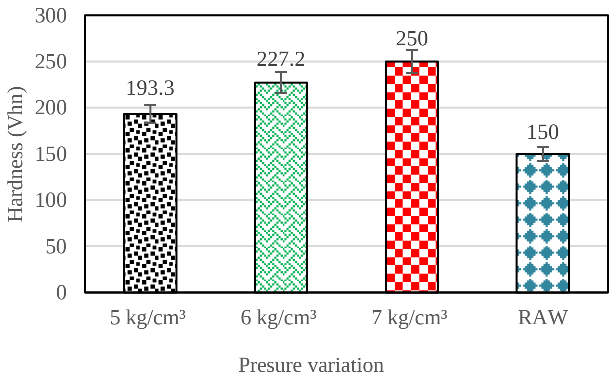


Figure 2. Shoot Peening illustration Process

3. Results and Discussion

3.1. Surface Hardness Testing

Hardness testing uses the Vickers hardness method where testing is carried out on specimens before and after the Automatic Shot Peening process. This test was carried out to determine the highest hardness value in S45C steel specimens. The test was carried out at 3 points on the surface of the specimen with a load of 40 kgf indenter in the shape of a pyramid for 40 seconds on the surface of the specimen without preparation.



Figur 3. Hardness result test

Based on Table 4.1 it can be seen that there was a significant increase in the hardness value of the specimen in the Shot Peening process with pressure variations of 5 kg/cm², 8 kg/cm², and 10 kg/cm². The average value of hardness at a pressure of 5 kg/cm² is 193.3 VHN when presented, it increases by 28.9% from the raw material specimen. Then at a pressure variation of 6 kg/cm³ the average hardness value increased by 227.2 VHN or experienced an increase of 51.5% from the raw material specimen. The hardness value of the shot peening test increased by 33% on S45C steel. [15].

Then at a pressure of 7 kg/cm³ it increased again by 250 VHN or 66.9% of the raw material. The highest hardness value was obtained on the SP 7 kg/cm³ 1 Shot Peening specimen with a value of 257.6 VHN, then the lowest value was obtained on the SP 5 kg/cm³ Automated Shot Peening specimen. Based on these results, it can be concluded that the

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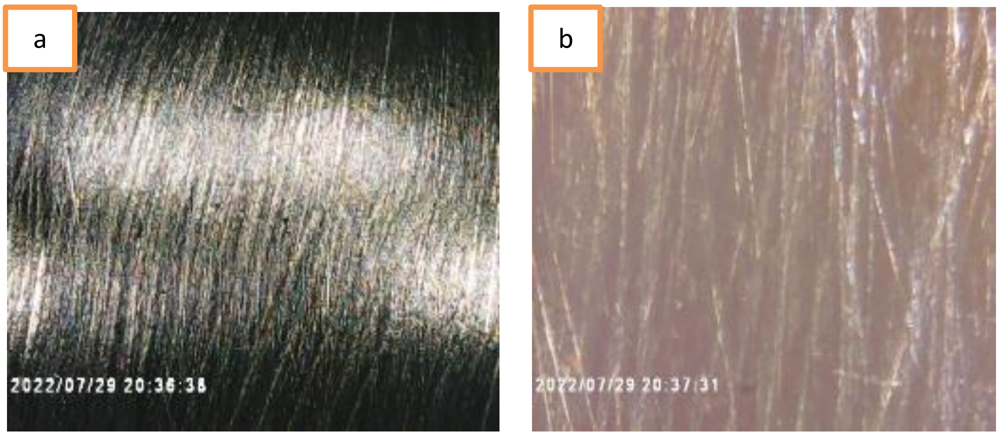
distance in the Shot Peening process affects the surface hardness value. The shorter the distance used, the hardness value will increase. Shot peening treatment can increase the hardness of AISI 316 L steel [16]. The research data showed that the hardness of the specimens increased, this was due to an increase in plastic deformation that occurred on the surface of the specimen after the Peening process which could cause dislocation density. During the Peening process the fired steel balls pulverize and break the surface structure of the specimen into smaller grains. The smaller the grain size of the material, the greater the hardness value of the material. The increase in hardness in S45C steel due to shot peening treatment is due to the high density of dislocations in the microstructure due to steel ball collisions [17].

The longer the shooting distance, the heat transfer process will be more absorbed by the specimen with a closer shooting distance so that the atomic structure changes to become denser so that the hardness value will increase or get harder.

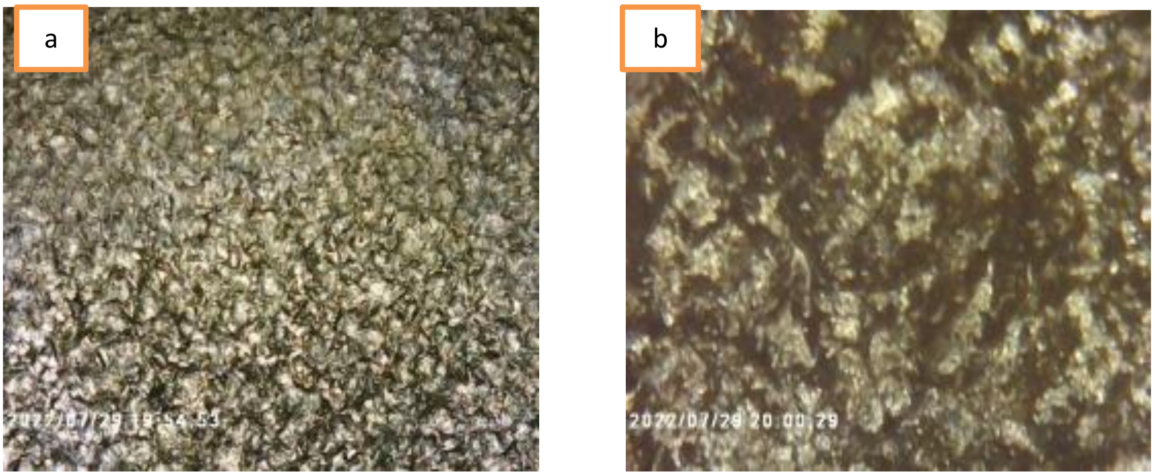
3.2. Macro Photo Result Data

Macro photo testing was carried out at the Wiworotomo Technical High School Laboratory, Purwokerto. Testing using a Digital Microscope to determine the results of the macro structure of the specimen before and after the Automatic Shot Peening process. Magnification using 500x and 1000x and taking macro photos is done in the Shot Peening area and raw material.

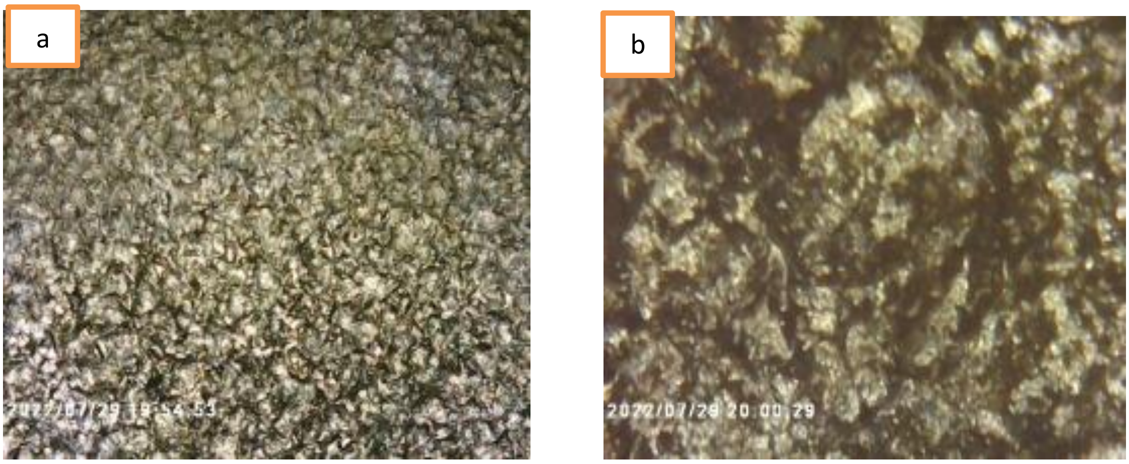


Figur 4. Photo Macro Raw material a) 500x and, b). 1000x

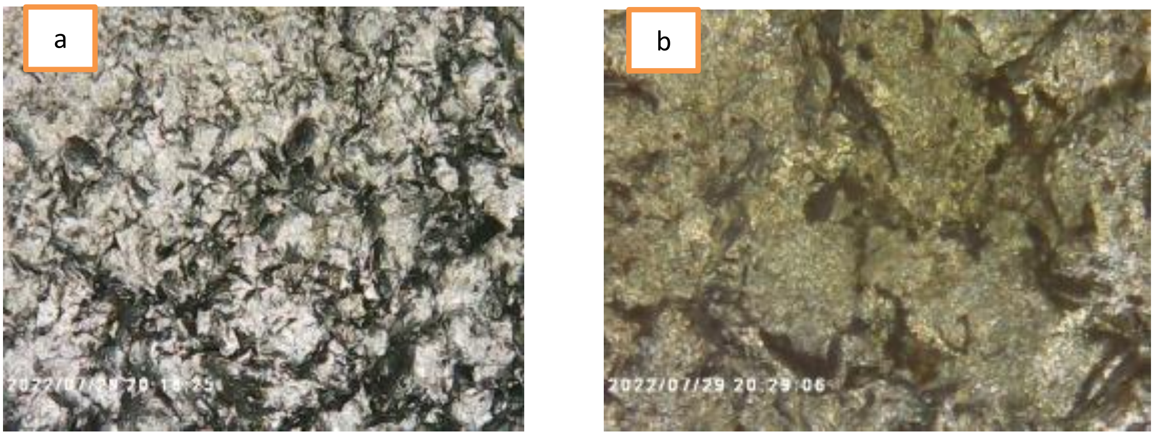
The results of macro photo observations were used to find out and visually distinguish in the macro photo results that there was deformation due to collisions in the Automatic Shot Peening process. In the results of macro photos, the raw material has a smoother surface compared to the specimens after Shot Peening.[18]. S45C steel has low strength and ductility, so many treatments such as shoot peening and heat treatment such as annelling, tempering, and quenching were carried out.[19]. The results of macro photo observations of S34C steel material after the shoot peening treatment with pressure variations of 5,6, and 7 kg/cm2 as shown in Figures 5, 6, and 7, by taking 2 magnifications of 500 x and 1000 x.



Figur 5. Specimen Macro Photo Test Results 5 kg/cm² (a). Magnification 500x, (b) Magnification 1000x



Figur 4. Photo Macro Raw material a) 500x and, b). 1000x



Figur 7. Specimen Macro Photo Test Results 7 kg/cm² (a). Magnification 500x, (b) Magnification 1000x

The results of macro photo observations were used to find out and visually distinguish in the macro photo results there was deformation due to the collision of the automatic shot peening process. In the macro photo results, the raw material has a smoother surface than the specimen after shot peening. The pressure variation of 7 kg/cm² has a surface structure that experiences deep deformation as evidenced in Figure 7. In contrast to the 5 kg/cm² pressure variation, the surface structure is smoother than the 5 kg/cm² and 6 kg/cm² pressure variations as evidenced in Figures 5 and 6. The effect of deformation on S45 C steel was due to the compressive strength of the projectile in automatic shot peening. The

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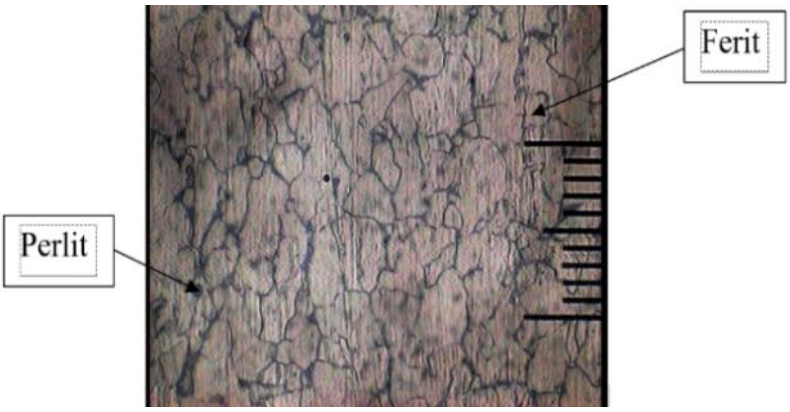
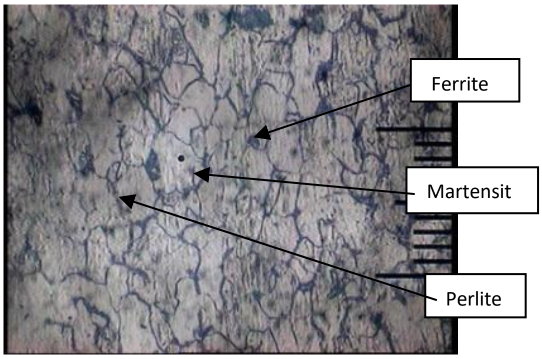
compressive strength of shot peening greatly influences the deformation of S45C steel. [20]. The deformation strength of shot peening was influenced by the strength of the shot pressure and the type of projectile material used. [21].

3.3. Microstructure Photo Result Data

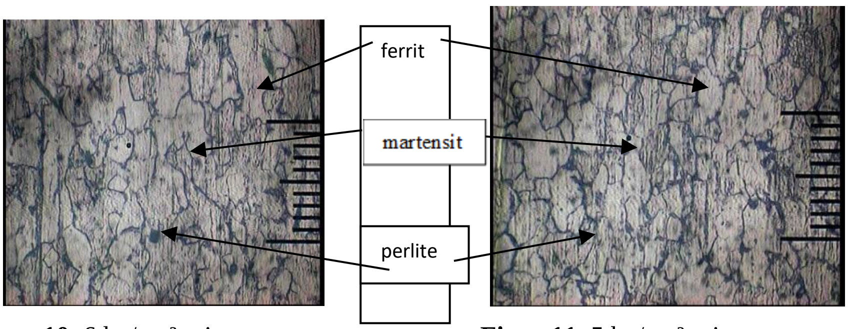
The material that has been tested for Vickers hardness on the surface of the specimen is then followed by microstructural testing, which aims to determine what phases are formed in the test material after the Shot Peening process is carried out with variations in pressure. This microstructure test was carried out at 200x magnification in the middle area of the Shot Peening results location.



Figur 8. Raw material microstructure



Figur 9. 5 kg/cm² microstructure



Figur 10. 6 kg/cm² microstructure **Figur 11.** 5 kg/cm² microstructure

Microstructure testing aims to observe differences in grain boundary sizes on the center surface of the specimen exposed to Shot Peening. The exposed microstructure area is immediately noticeably different from its shape. Differences in microstructure can be analyzed to what effect Shot Peening has on S45C steel specimens on the microstructure as shown in Figure -11. Results of observations of the microstructure of the raw material S45C steel specimen and after being given the shot peening treatment. The results of microstructural observations show that the raw material specimens have an even grain groove, while the specimens that have been treated with shot peening will experience a change, namely a decrease in grain size on the surface of the specimen affected by Shot Peening.[19]. This is due to the collision of pressurized steel balls during the Shot Peening process, causing a reduction in grain size and dislocation density.[22].

In addition to changing the shape of the microstructure of the specimen, the shot peening treatment also resulted in the formation of a new phase as a result of the collision of the steel balls on the surface of the specimen. Figure 8 The phases formed on the surface of the raw material are dominated by balanced pearlite and ferrite phases. This indicates that S45C steel is a medium carbon steel. The shot peening treatment at a pressure of 5 kg/cm² formed a new phase, namely the martensite phase which is marked with a long black line like a needle or shaped (lath martensite) as shown in Figure 9-11. and the formation of a martensite structure which is marked with black lines in the form of lines, where the distance between the formed martensite grains is denser and the grains are more evenly distributed. In the figure it can be seen that the pearlite and martensite structures dominate, which means that the hardness has increased.

Then in Figures 10 and 11, namely the treatment with a pressure of 6 and 7 kg/cm2, the pearlite structure and martensite structure are more numerous, while the pearlite structure is reduced. This shows that treatment with increased pressure results in increased material hardness.[23]

4. Conclusion

The test results obtained are the optimization of the automatic shot peening process of S45C steel material with variations in pressure on surface hardness and microstructure. The shot peening process with pressure variations of 5, 6 and 7 kg/cm² produces the best hardness value, namely at a pressure variation of 7 kg/cm² of 257.6 VHN. The lowest result at a pressure variation of 5 kg/cm² on the test object is 177.4 VHN. The shot peening process can affect the mechanical properties of S45C steel which is characterized by an increase in the hardness value of the S45C steel material as evidenced by an increase in the hardness of S45C steel after the Shot Peening process, and changes in the microstructure of the S45C steel material as evidenced by the formation of a new phase, namely the martensitic phase in S45C steel material. . Shot peening treatment can increase steel hardness and change the martensitic phase structure without adding carbon elements to S45 C steel.

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