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HEATING AND QUENCHING PROCEDURE ON THE MAKING OF TRADITIONAL BLACKSMITH STEEL WITH HIGH QUALITY

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ABSTRACT

Blacksmith is a people's business that has been going on for a long time in Indonesia. Based on the experience that has been obtained from time to time and hereditary, the blacksmith industry has been done by the community to meet the needs of agricultural and household utensils. However, observe to this people's business, now it decreases with various causal factors, such as the ease of imported goods on the market with lower prices. Many creative efforts need to be carried out so that these people's businesses remain and increasingly develop, among others by improving the quality of the process of a blacksmith so that their products are quite competitive. This article describes the results of the research in the laboratory regarding the physical processes of heating and quenching under blacksmith, which the results have been applied to community service activities at the Suger Kidul villages in Jember Regency. The study aimed to find the most appropriate procedure for steel tool manufacturing processes so that the blacksmith products have high quality as high hardness. The physical process for blacksmith process is heating and quenching. This study analyzes the proper heat (temperature), proper processing time, and proper media for heating and quenching to produce good harness quality of the product.

Keywords: blacksmith, heating, quenching, hardness

INTRODUCTION

The steel, especially in the form of leaves and wheel discs, is a material that widely used as raw material for blacksmith products as everyday life tools such as hoes, sickles, machetes, crowbars, and others. The quality of the produced tools can be seen from the level of hardness, brittleness, elasticity, and tenacity. However, what about the blacksmith activities continuity in the community show that there are two essential things, namely (1) improper marketing management and (2) poor quality of production. Both of these seem to reduce further the selling power of these tool products where many similar imported products entering the local market with competitive prices and quality.

For this reason, it is necessary to make several breakthroughs to help revive the production of blacksmith production in the community in order to be popular again as in the past. One is to conduct laboratory research studies to obtain qualified products. The study is to improve the heating process through the creation of efficient furnace designs [1], [2]. A more recent study [3], [4] also concerning heating kitchens or stove [4]. In addition to paying attention to the heating method, a forging method also investigated, which made special forging tools mechanically [5].

Another research about blacksmith metals is the connection with the physical process of making tools. One is to improve the quality of tools through laboratory research on the physical manufacturing process. Several studies analyze how desired properties can produce iron steel metals. In this metal study, what is usually studied is the temperature of heating and cooling and also the media for cooling the heated steel. Therefore a professional treatment is usually needed through the process of heating and quenching during the quality of the product. With both of these processes, hardness and brittleness can be raised or lowered to get a product with specific characteristics desired according to the intended use. Heat treatment through heating and quenching can be used to improve the mechanical properties of steel such as hardness, tension stress, and tenacity. Several studies on this [6] analyzing several cooling media and their relation to the level of hardness of the material. Another study of how the hardness of materials by the influence of steel heating temperatures followed by cooling on oil and water media [7]. The effect of heating and cooling duration on steel strength in the processing process also examined [8]. Therefore, studies on blacksmith metal are an old topic, but because they have real application benefits to the community, studies are still being carried out with various research objectives and desired novelty.

Based on the purpose of the application, steel can be used as a household tool, agricultural tools, and as a construction tool. For household applications, it can be realized in forms such as knives, sickles, and machetes where the pointed parts of material tool structures will often be affected by external forces such as friction which allows for deformation or deformation that can reduce sharpness. In general, the iron steel blacksmith process uses the process of heating and rapid cooling (quenching), although in general, the perpetrators of blacksmith do not know this technical term. In heating, steel (used/broken) is heated to a specific temperature where the actors of blacksmith only use hot red of hot steel visually as a heating parameter before being forged or before cooling. In the quenching process, the steel that has been burning hot is then dipped into the cooling medium to undergo a rapid cooling process. Traditional blacksmith workers generally do not understand the physical reasons for this action. With these two processes, various tools are made every day by workers based solely on hereditary experience and knowledge. However, the workers need to know how the heating and quenching process needs to be applied appropriately during the process. The proper time to work on heating and how quenching is done to get the right tools to need to known. Although not knowing the physical reason behind the two processes. Physically, different heating and quenching treatments will produce microscopic structures of different materials. Heating (related to heating temperatures) are different, and quenching (both duration and cooling media) will produce different tool characteristics (level of hardness, tenacity). An excellent tool must be made based on the proper heating and quenching process. Based on this view, material research on blacksmith is the topic of research in this article. In this study, the results of laboratory studies concerning the process of blacksmith steels making that involve physical as heating and quenching processes that taking into account the heating and cooling time, consider variations in cooling media as well as heating and cooling temperatures. This study aims to find the right process for the process of making steel, which produces materials with the right level of hardness.

METHOD, APPARATUS, AND MATERIALS

Preparations

There are two methods used in this study, namely heating and quenching methods (from now on abbreviated as H and Q respectively) which are carried out sequentially. The goal is to produce final steel with specific violence. In this study (laboratory scale) only provides H_heat and Q_cooling without any forging process as in blacksmith in general, to get the desired shape by forging. In this study, the steel material used is the leaves of used cars which are mostly sold in used goods flea markets. The test material (sample) is provided in the form of pieces from a plate per leaf made with a width of approximately 2 cm x 2 cm in the shape of a plate; all provided from the same material. The H process is carried out by giving high heat, i.e., the sample is placed on the coals of wood charcoal with the temperature of the sample measured by using Infrared laser thermometer (DEKKO FR-7822 Infrared Thermometer 1050 Celsius) which can measure temperatures up to 1250 °C. The Q process is carried out by immersing the hot steel from the H process to the cooling medium of certain materials (in this study using pure water, new engine oil, and used engine oil. The medium Q must be maintained at the same initial temperature for each sample treatment (for water it is not a problem because at any time we can remove water which has been used with a new one, but not so with oil because every time it is used to cool down, the temperature will rise significantly and it must be waited to do the Q process in the next sample. Various ways can be used to cool the Q medium after being used quickly, i.e., oil container inserted into cold water or ice water).

The tool used to prepare the sample is a heater stove with a specific design (adjusted for sample size) with heat measurements carried out with a laser thermometer. Cooling medium containers are provided in metal cans so that the high sample heat does not damage them. The results of the H and Q samples were tested for the level of hardness with a hardness meter Leeb TH120. In this study, the material hardness testing was carried out at the Mechanical Engineering Laboratory of the University of Jember.

FIGURE 1. Leeb Hardness Tester TH120

Preparation of the samples (used steel) for H and Q carried out at Laboratorium Fisika FMIPA Universitas Jember.

FIGURE 2. A prototype of the experimental stove and Thermometer Laser Dekko FR 7822

The materials used in this study were steel from leaf spring of car suspension (FIGURE 3) which were cut into squares about 2 cm x 2 cm in size about 0.6 cm thick using an electric grinder (FIGURE 4). The stove is made of French plaster (gypsum) to generate high heat from burned coals. Fire coals are produced from wood charcoal, which is widely sold in traditional markets. The rapid heating of the furnace increase by electric blowers are used i-th sizes ranging from 2", 2.5" and 3" diameter to increasing generated heat (FIGURE 2 and 5).

FIGURE 3. Leaf spring of a car.

FIGURE 4. Samples of blacksmith steels for an experiment.

Experimental Procedure

The procedure for retrieving data (samples ready for testing) can be described as follows: (1) prepare a sufficient amount of charcoal in the heating furnace; (2) burn on the charcoal then turn on the electric blower; (3) wait for the sufficient generated heat to be evenly distributed; (4) place the sample on the top of the holder, covering the square hole (FIGURE 5); (5) Heat the sample to the desired temperature by measuring the temperature using a laser thermometer (remember at this stage it must be ensured the temperature measurement is right); (6) Ensure that all the heat from the furnace can burn the sample properly as seen from the sample, which immediately burns evenly in just a few minutes); (7) During the H process, immediately prepare a cooling medium in a metal vessel with selected cooling medium materials such as water and oil. Make sure the coolant's initial temperature is the same for each sample treatment; (8) Immediately after process H, continue the Q process by taking a heated sample from the furnace and immediately insert it into the medium Q; (9) treatment of the Q process, there are several ways, namely the duration of the process of Q and the type of medium Q process. The duration of the Q process can be several seconds to several minutes, depending on the purpose of the experiment. In this study, Q took several variations, namely 5”, 10”, 15”, 20”, 25”, 30”, 35”, and 40” (seconds); (10) immediately take the Q-processed sample from the cooling medium (it is usually freezing for the water medium so that it is not dangerous to be taken by hand); (11) this process of H and Q is repeated for various samples with various treatment schemes to obtain the characteristics of material hardness; (12) samples of process H and Q are sent to the Lab Test, the hardness of the material for further analysis.

FIGURE 5. Left: Wood Stove with the sample holder. Right: stove, holder, and holder cap.

FIGURE 6. Quenching process of heated sample.

RESULTS AND DISCUSSION

The results of observing and testing the hardness of materials can be presented as follows with some limitations:

1. The measured temperature is the highest temperature in the H process, which is read on the screen of a laser thermometer where two laser dot reference points coincide together when the metal is heated in the furnace.
2. The measured hardness of material from steel is given in BHN units (Brinnel Harness Number) with and obtained from the average measurement of 3 points in the sample.
3. Each point on the graph of the analysis results represents one steel metal sample after receiving H and Q treatment and then testing the BHN value.

Furthermore, several treatments of the H and Q processes produce the following characteristics:

Treatment 1: Clean Water Cooling Medium (T = ± 26 C)

1. Before the H and Q process, the hardness of the sample had a value of Hd = 184 BHN

2. All Temperatures of H, T_H = ± 810 C, the cooling time t_Q was varied.

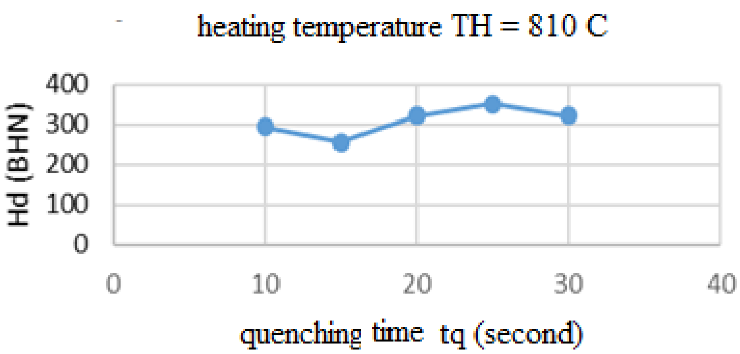

FIGURE 7. Steel hardness with constant heating temperature and various quenching time in the water.

3. All Temperatures of H, T_H = ± 914.5°C, the cooling time t_Q was varied.

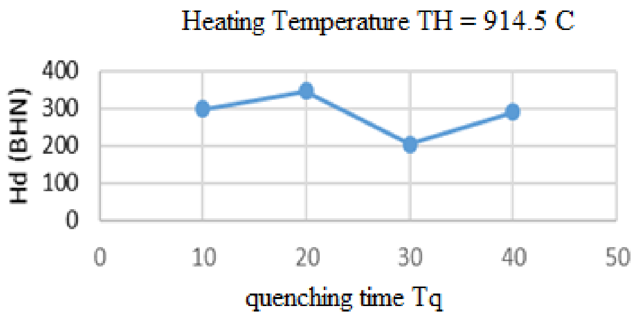

FIGURE 8. Steel hardness with T_H = 914,5 °C, variation of quenching time in water 26°C.

4. Heating with variation temperatures T_H with constant quenching time t_Q = 20” in water 26°C

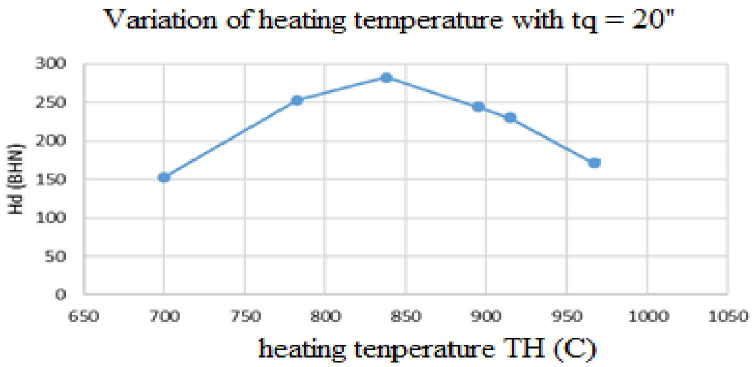

FIGURE 9. Steel hardness with variation T_H and constant t_Q in water 26 C

Conclusion 1: Clean Water Cooling Medium (T = ±26 C)

From points 1 - 4 above, it can be concluded that to obtain the hardest steel, the best heating, and quenching treatment can be carried out on steel material by the following process: (i) Heating 800 < T <900 °C; (ii) Quenching 20 seconds < t_Q < 25 seconds; (iii) Obtained hardness 282 < Hd <353.

Treatment 2: Oil Cooling Medium

Treatment 2.1: Fresh Oil (Federal brand), Variety T_H, Constant t_Q = 30”

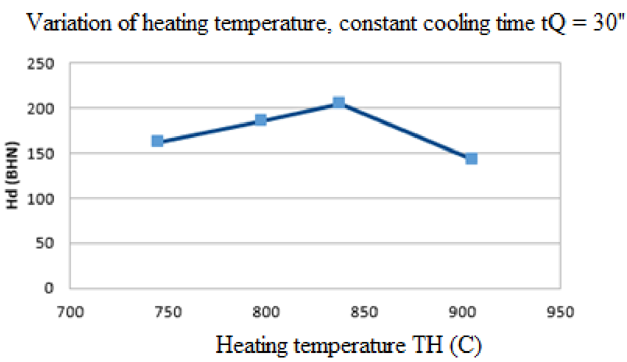

FIGURE 10. Steel hardness with various heating temperature, and constant t_Q = 30” (Fresh oil).

Treatment 2.2 : Used Oil, Variety T_H, Constant t_Q = 30"

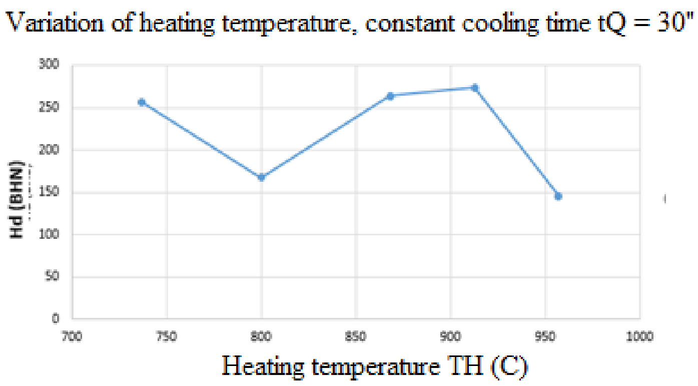

FIGURE 11. Steel hardness with various heating temperature, and constant t_Q = 30" (used oil).

Conclusion 2: Oil Cooling Medium

FIGURE 11 shows at a macro scale that there is a relationship between the level of hardness of the material and the heating temperature and the cooling process, where the relationship is not linear, and the best hardness value at a temperature of around 900 ^oC. This expression is still too early to conclude the results of the study comprehensively. For this reason, it is necessary to research theoretically and test the microscopic structure of materials.

From the graph analysis above, a temporary conclusion can be drawn:

1. For the new oil cooling medium then quenching time t_Q = 30 seconds, achieved the highest hardness of 204 BHS at heating temperature 838.2 ^oC.
2. For used oil cooling medium than at the quenching time t_Q = 30 seconds, achieved the highest hardness of 273.25 BHS at a heating temperature of 912.6 ^oC.
3. Cooling of fewer than 30 seconds in this study was not chosen because the sample was still too hot when lifted from the cooling medium so that it was not expected to reach a hard steel structure for long enough time t_Q.
4. In general, cooling in oil is much slower than cooling in water
5. From points 1 - 4, it is concluded that getting hard steel in oil cooling medium is recommended to use used oil with a minimum heating temperature of 900 $_oC$ and a minimum cooling time of 30 seconds
6. More extended cooling has not been done in this study.

From this study, if we compare the results with previous researches (reference [6 - 8])), in this work we have examined various variations of the treatment as well as heating temperature, cooling temperature, cooling time, sequence of heating and cooling processes, cooling media used for can produce steel with a high level of hardness. It is reflected in the interim conclusions above. This research for the author is a preliminary experimental study, so the results of this study are new and still require further follow-up studies.

Implementation in the Field (Blacksmith Area)

The procedures H and Q above have been tested in the field (blacksmith places). Steel raw material was given to one of the blacksmith worker (Pak Abdullah) in Suger Kidul village, Jember Regency, to make two similar tools with two ways: the old process and the new process. At the time of manufacture, until the desired tool is formed, the two tools are carried out the same process. Namely, heating is forged according to the habits of the worker. After the desired tool is formed, it is then trimmed and smoothed with an electric grinder. After that, the final stage is to apply the new method/procedure above. The impressive thing is that the craftsmen are familiar with the use of used oil in the manufacturing process, but they do not know how to apply the quenching and heating process appropriately, only the daily habits of using oil do not make the quenching and quenching material tight. After the two tools were successfully made then the collision test was carried out to determine the hardness of the tool in the easiest way is that the two devices were fought with each other on the sharp part. From the results of this test, the depth of the stab wounds (arrow FIGURE 12) appears on the knife A (old method) at least twice as deep as knife B (with the new method in this study). This provides a conclusion (preliminary) that the procedure for making iron-cutting tools using the heating and quenching method set out in this study is good enough to produce high-hardness steel tools. Henceforth it is necessary to have laboratory tests on products that have been made to ensure the accuracy of the procedures that have been obtained. Therefore, the conclusions in this study can be considered as preliminary research/studies.

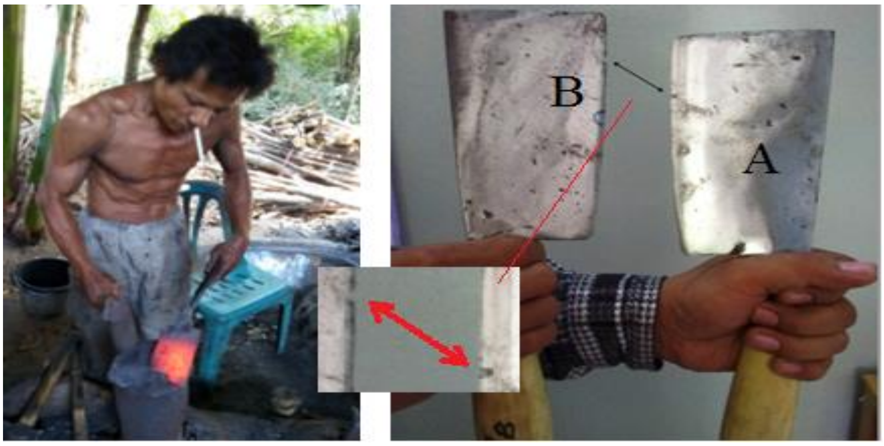

FIGURE 12. Comparison between two products: old way and new way steelmaking.

CONCLUSIONS

From the process of H and Q for both the cooling medium above, which is water and oil, the results of observations show that cooling with a water medium results in a higher level of hardness of steel than oil medium both new oil and used oil. The use of used oil produces better violence than new oil. In this study, the material flexibility test has not been carried out, and only the material hardness test is carried out. By looking at the process of cold metal that is very long compared to cooling in the water, it is suspected that cooling in the oil will produce a higher degree of ductility than cooling in water, where the process of releasing energy from long hot metals is possible to allow material atoms enough time to move to reach the equilibrium state with its surroundings so that a better level of tenacity can be obtained.

Therefore, we conclude that in order to achieve a high level of hardness and sufficient level of tenacity, the process of making iron tools can be carried out in a multilevel process according to the following procedure: (1) Prepare the raw steel material of blacksmith, heating to about 900 C; (2) Then Quenching in the water (26 C) about 1-2 seconds long time for sharp side of a product (about 1 cm immersed in the water); (3) Following quenching in used oil at that sharp part at about 30 seconds minimally; and (4) Follow full quenching in the water (all part of steel product) in the water (26 C) for quenching time about $20 < t_Q < 25$ seconds.

This research still needs to be complete verification-verification in various experimental conditions. Therefore, this research needs to be carried out further in-depth research in order to obtain more comprehensive conclusions specifically involving measuring the tenacity of the material and measuring the microscopic structure of the material using the relevant XRD, SEM, and testing.

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