Effect of Holding Time and Cooling Media on Heat Treatment Process to Gear Motor Indopart Hardness

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Abstract. Industrial and technological advancements are growing rapidly, closely related to various machine tools, including the metal and construction industries. In the field of machinery many metal elements such as steel are involved. The progress of the metal industry has an important role, especially in the automotive world which uses a lot of metal materials. Therefore an attempt arises to change its mechanical properties in order to change the level of violence. This study aims to determine the level of medium carbon steel hardness (indopart gear motor), and determine the interaction between the two variables and determine the most optimal level of hardness. The method used in this study is the method of observation and literature on the fundamental theories, the sample used in this study is medium carbon steel (indopart gear motor) which is heat treated with a holding time of 60 minutes, 120 minutes and 180 minutes and with water, oil, diesel and air cooling media. Then hardness testing is done. Based on the results of the analysis of the data obtained there is a significant difference in the effect of the average cooling media on the level of violence, there is no significant difference in the effect on the average hardness between the holding time, there is a difference in the effect of the interaction between the holding time and the cooling media. The optimal treatment process is where the holding time is for 180 minutes using water media.

Keywords: Heat treatment; holding time; Gear motor; Hardness

1. Introduction

The progress of industry and technology is growing rapidly, with the increase in the development of human life, the age has also developed rapidly including the metal industry. Because human development is advancing, the technology sector is also developing very rapidly in the hope that all human needs can be met properly so as to be able to meet the needs in the automotive world which uses a lot of metal material. Because almost all tools used by humans are made of metal elements, so metals have an important role in human life and support technology in the automotive field today. Therefore arises human efforts to improve the properties of the metal. Automotive Technology Motorcycles are increasing rapidly in line with the increase in motorcycle sales. Indonesia is one of
the biggest motorcycle vehicle users in the world after China and India [1]. Motorcycle purchases are increasing every year, so the number of motorcycles will certainly increase, AISI Data (Association of Indonesian Motorcycle Industries) shows that in 2018 motorcycle sales were 6,383,108 units and in 2019 there were 6,487,460 units.

So to find out the number of requests that vary, the selection of materials was held. The choice of material can be narrowed according to its use, such as carbon steel. Carbon steel gets top priority for consideration. Because carbon steel is easy to obtain, it is easy to form or has good machining properties and the price is relatively cheap. Because carbon steel gets top priority, it is demanded to modify or improve its properties such as hardness, hardness on the surface, wear resistance due to friction. This requires a heat treatment process to increase the hardness of the material.

Steel will experience heat aimed to improve the structure and to obtain greater mechanical properties. So that heat treatment can also be interpreted as a process of changing the structure of a metal by heating the metal to a specified temperature, holding it at that temperature for a certain period of time and continuing cooling with a certain cooling speed. By hardening the surface will cause the surface layer to be strong or hard and the surface layer will occur residual stress in the form of compressive stress [2].

Heat treatment is the process of heating a material to a certain temperature and then cooled by a certain method. Heat treatment is primarily intended to obtain properties that are suitable for their use, specifically to obtain the required hardness, strength and clay properties. By way of heating and cooling with a certain speed carried out on the metal in the solid phase state in an effort to obtain certain properties of the metal. To prevent wear of the metal, the metal needs to get hardness on the surface only while the core remains tenacious. For this reason, surface treatment is needed.

The heat treatment process reaches a specified temperature and is given sufficient heat holding time then cooling it to a certain rate. The micro structure that occurs after cooling will depend on the cooling rate because the mechanical properties of the steel after the end of a heat treatment process will be determined by the cooling rate. The faster the metal is cooled, the harder the metal's properties will be. Carbon produced from rapid cooling is more than slow cooling, this is because carbon atoms do not have time to diffuse out and are trapped in crystal structures and form tetragonal structures where the empty space between atoms is small so that its hardness increases [3].

So in this case hardening can be done in certain parts according to the needs and functions of the tool. In its operation, the sprocket component is always rubbing against the chain of the motorcycle, from the friction that will cause wear and reduce service life [4]. Understanding the problem above, the research is to find out the effect of variations in holding time and cooling media on the heat treatment process on the hardness value of the indopart motor gear. Indopart motor gear can be seen in Figure 1.

![Indopart motor gear](image)

**Figure 1.** Indopart motor gear

2. **Methodology**

The first step in any heat treatment process is to heat the metal / alloy up to a certain temperature, then hold for a moment that temperature, then cool it to a certain cooling rate. During this heating and
cooling will occur some changes in the microstructure can be a change in the phase or shape of the crystal grains and changes in the structure of this microstructure will cause changes in the properties of the metal.

Before the heating process begins, the first thing to do is cut the gear according to size and then mark the test specimen. This is done because the pasa when experiencing the process of heating the test specimen with one other test specimen has a different treatment.

2.1. The steps of the research carried out are as follows:
   a. Cutting indopart gear motor material used as specimens and in accordance with SNII (Indonesian National Industrial Standards)
   b. By using a chainsaw that is fed water cooling media, so as not to experience changes in mechanical properties in the indopart motor gear specimens
   c. The material used is an indopart gear motor with a size of 18 mm
   d. Using cooling media (oil, water, diesel and air)
   e. Heat treatment with a temperature of 800°C using a material heating oven
   f. Variation of holding time is 60 minutes, 120 minutes and 180 minutes
   g. Use rockwell hardness test equipment to determine the level of violence.

2.2. Hardness Testing

Hardness testing is carried out to determine the distribution of violence by indenting at several points in the material sample. This test is carried out by the Rockwell method in which the test uses a diamond cone steel ball indenter, a loading of (HRD) of 100 kgf and an indentation time of 15 seconds. This test uses the HBRV 187.5A Universal Hardness Tester at the Laboratory of Physical Metallurgy, Department of Mechanical Engineering, Hasanuddin University.

| Specimen | Holding Time | Quenching |
|----------|--------------|-----------|
| A1       | Water        |           |
| A2       | Oil          |           |
| A3       | 60 minute    | Solar     |
| A4       | Air          |           |
| B1       | Water        |           |
| B2       | Oil          |           |
| B3       | 120 minute   | Solar     |
| B4       | Air          |           |
| C1       | Water        |           |
| C2       | Oil          |           |
| C3       | 180 minute   | Solar     |
| C4       | Air          |           |

3. Results and Discussion

The results of the hardness testing of the differences in the material that is subjected to heat treatment with variations in holding time and variations in the cooling media (water, oil and air) can be seen in the table below:
### Table 2. Treatment data hold time of 1 hour

|        | Water  | Oil   | Solar | Air    |
|--------|--------|-------|-------|--------|
| 1 time | 40 HRD | 35 HRD| 34 HRD| 52 HRA |
| 2 time | 40 HRD | 36 HRD| 34 HRD| 50 HRA |
| 3 time | 39 HRD | 35 HRD| 35 HRD| 52 HRA |

### Table 3. Treatment data hold time of 2 hour

|        | Water  | Oil   | Solar | Air    |
|--------|--------|-------|-------|--------|
| 1 time | 38 HRD | 33 HRD| 32 HRD| 50 HRA |
| 2 time | 38 HRD | 34 HRD| 34 HRD| 52 HRA |
| 3 time | 40 HRD | 35 HRD| 35 HRD| 52 HRA |

### Table 4. Treatment data hold time of 3 hour

|        | Water  | Oil   | Solar | Air    |
|--------|--------|-------|-------|--------|
| 1 time | 40 HRD | 33 HRD| 31 HRD| 51 HRA |
| 2 time | 42 HRD | 33 HRD| 31 HRD| 54 HRA |
| 3 time | 41 HRD | 33 HRD| 32 HRD| 53 HRA |

After the test results are obtained, the next value will calculate the average according to the variation of holding time and cooling media. The data generated can be seen in the table below:

### Table 5. The average value of each cooling medium according to holding time

|        | Water  | Oil   | Solar | Air    |
|--------|--------|-------|-------|--------|
| 1 time | 40 | 38 | 40 | 35 | 33 | 34 | 32 | 31 | 27.25 | 24.5 | 25.83 |
| 2 time | 40 | 38 | 42 | 36 | 34 | 34 | 34 | 31 | 24.5 | 27.25 | 30.67 |
| 3 time | 39 | 40 | 41 | 35 | 35 | 33 | 35 | 32 | 27.25 | 27.25 | 29 |
| 4 time | 39.67 | 38.67 | 41 | 35.33 | 34 | 33 | 34.33 | 33.67 | 31.33 | 26.33 | 26.33 | 28.5 |
Table 6. Average value

| Cooling media | Holding time |
|---------------|--------------|
|               | 1 time | 2 time | 3 time |
| Water         | 39.67   | 38.67  | 41.00  |
| Oil           | 35.33   | 34.00  | 33.00  |
| Solar         | 34.33   | 33.67  | 31.33  |
| Air           | 26.33   | 26.33  | 28.50  |

Hardness (HRD) and holding time with variations in the cooling media

Based on the graphic image above, the value of holding time for the water group at 1 hour was 39.67 HRD, the value of holding time at 2 hours decreased to 38.67 HRD and at 3 hours it increased to 41 HRD. As for the oil group, the value of holding time at 1 hour was 35.33 HRD and holding time at 2 hours decreased to 34 HRD and at 3 hours decreased again to 33 HRD. Furthermore, for the solar group the value of holding time at 1 hour was 34.33 HRD, then the value at 2 hours decreased to 33.67 HRD and the value at 3 hours decreased again to 31.33 HRD. While for the air group the value of 1 hour is 26.33 HRD, the value of 2 hours has the same hold time value of 26.33 HRD so that there is no change in the value of hardness and when the holding time of 3 hours increases to 28.50 HRD. So from the diagram above it can be seen that the value of the hardness in cooling water where for the cooling time of water holding time is 3 hours harder than other cooling media.

The lowest level of hardness of carbon steel (indopart brand motor gear) the lowest is to use air cooling media. This process is included in the normalizing process, which is a process of heating the metal until it reaches the autenite phase which is then cooled slowly with a cooling medium. The principle of normalizing is to normalize or soften the metal that has been hardened, and at the highest level of hardness is to use water-cooling media which during the holding time is increasing the level of
hardness, this process includes the hardening process. Whereas in oil and diesel cooling media where the holding time is increasingly decreasing.

4. Conclusion
From the results of research that has been carried out on heat treatment with a temperature of $800^\circ C$ using a material heating oven it can be concluded that:

There is a significant difference in the average hardness between holding times, this is influenced by the variation of the cooling media and also the treatment time used so that it affects the hardness value contained in the indopart gear motor so that there is a difference in the value of the violence in the use of the cooling media that is for the water cooling media 1 hour 39.67 HRD, 2 hours 38.67 HRD, 3 hours 41, for oil cooling media 1 hour 35.33 HRD, 2 hours 34 HRD, 3 hours 33 HRD, for solar cooling media 1 hour 34.33 HRD, 2 hours 33.67 HRD, 3 hours 31.33 HRD and for air conditioning media 1 hour 26.33 HRD, 2 hours 26.33 HRD, 3 hours 28.50 HRD. So for the highest holding time is to use a water cooling media which during the holding time is increasing the level of hardness.

References
[1] R. Edo, “Hiruk pikuk bersepada motor,” 2010.
[2] Klemens A Rahangmetan, Cipto, F. sariman, M. Syahid “Study on effect of temperature smelting pouring to mechanical properties aluminium 7075,” IOP, no. 343, p. 012166, 2019.
[3] Klemens A Rahangmetan, F. sariman, Daniel Parenden “The effect of riser use in the quality of casting Al 7075 for ship propeller,” IJMET, vol. 10, 2019.
[4] H. dan D. Aminoto, Ilmu Bahan. Jakarta: Bumi Aksara, 1999.