Induction Hardening for Flat Product

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Abstract — *Induction hardening process is one kind of heat treatment process which can be used to increase the hardness on the surface of steel component. To research the effect of this method, the specimens of CT3 was used. Experience data and results were simulated and set up by 3D electro-magnetic model coupled temperature fields of COMSOL Multiphysics 5.0 software. A three-turns copper coil received the Foucault current from power supply was used for heating the specimens during experiments. The effect of process will be evaluated by measuring the hardness and metallographic techniques of material. Results showed that the martensite affect the hardness off material. The distribution of the hardness area will be depended on the result of achieved temperature located on the surface which is accordance to the shape of induction coil. In the annular zone, martensite appears almost surface areas of the annular zone, while pearlite causes the lowest hardness of the central zone.*

Keywords — *Steel; Induction heating; Flat product, Heat treatment; Mold plate.*

I. Introduction

In injection molding field, the mold manufacturing process is very importance. In this field, for reducing the cost, the mold is usually cut by the common steel, then, the heat treatment will be used at the needed position. In general, the heat treatment is a process that involves a combination of time-controlled heating and cooling operations of metal without changing the product shape that will produce desires mechanical properties and to observe the microstructure after heat treatment [1]. In almost case, the product performance will improve when the strength of material increased [2]. It can be divided into four main processes namely annealing, normalizing, hardening and tempering. These processes are the most significant heat action often used to modify the microstructure and mechanical properties of manufacturing resources particularly steels [3]. Annealing is defined as a heat treatment that consists of heating to and holding at a suitable temperature followed by cooling at an appropriate rate, most frequently applied to make softer iron or steel resources and refines its grains due to ferrite-pearlite microstructure; it is second-hand anywhere elongations and substantial level of tensile power are necessary in engineering materials. Hardening is the heat treatment processes in which increases the hardness of a steel piece by heating it to a certain temperature and then cooling it rapidly to room temperature [4]. Tempering is the process of imparting toughness at the cost of its hardness to an already hardened piece of steel by reheating it to a certain temperature and then cooling it rapidly [5]. The temperature of heating depends on the toughness to be imparted and hardness to be reduced. In normalizing, the material is heated to the austenitic temperature range and this is followed by air cooling. This action is usually approved out to obtain a mostly pearlite matrix, which outcome into power and rigidity higher than in as received condition. It is also used to take away unwanted free carbide there in the as-received example [6].

II. Simulation and Experiment Method

In the metal heat treatment field, the application for the complex part geometry or the large part are always challenger for the engineer. For the first case, the trouble is appeared in the magnetic controlling for the heating method, and the second case, the trouble is the power for heating the large area. In this research, the local hardening method by induction heating coil will be applied for the flat surface to increase the temperature to the critical value, then, the coil will be move slowly to other area for tempering all the flat surface. The research model is shown in Fig. 1 and the experiment model are shown in Fig. 2.

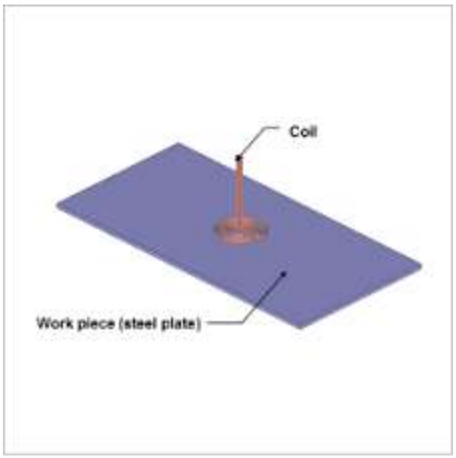

Figure 1. The research model for local induction hardening

Figure 2. The experiment model for local induction hardening

In this paper, for researching the effect of induction hardening method on the flat part, the specimens of CT3 steel were used for the tempering process. Base on the ASTM E23, the chemical composition of these steel types is shown in Table 1. First, the local induction hardening will be applied at the center of the CT3 steel plate with the size of. The main propose of this step is checking the ability of heating step for the flat surface with the heating position as in Fig. 1 and 2. Then, the specimens have the same size as 200 mm x 200 mm x 10 mm with the material of CT3 will be used for experiment. The experiment will be achieved by 5 samples for each case. Then, the hardness will be measured by the Rockwell Hardness Testing Machines. The measurement will be done for all tempering surface by the dividing method as in Fig. 3. For each small area as in Fig. 3, the hardness will be measured 20 times, then, the average value will be represented for the hardness of this area.

TABLE 1. *Chemical Composition of Medium Carbon Steel [7, 8]*

Content (%)	C	Si	Mn	P	S	Cr	Mo	Ni	Cr + Mo + Ni
CT3	0,42 - 0,50	<0,40	0,50 - 0,80	<0,045	<0,045	<0,40	<0,10	0,40	<0,63

Figure 3. Hardness measurement areas.

Base on the heat treatment experiments for CT3 steel, the induction heating parameters will be chosen as: Heating speed: 60^{o}C/sec to 90 ^{o}C/sec; Temperature requirement: 890 ^{o}C to 940 ^{o}C; Time of heat holding: 2 s to 50 sec; Cooling speed: 120 ^{o}C /s to 180 ^{o}C/sec.

For observing the induction heating process as well as the moving speed of the coil, the simulation of 3D electro-magnetic model had been done. In this model, the workpiece and the induction coil will be covered by the air volume. The COMSOL Multiphysics 5.0 software will be applied with the module of Heat Transfer and

Electro-Magnetic. Then, the boundary conditions will be set up as in real experiment with the main parameters as: Frequency: 22000 Hz; Current: 450 A; Distance between induction coil and workpiece's surface: 3.2 mm; Moving speed of workpiece: 2.5 mm/s; Total heating time: 30 sec.

III. Results and Discussions

In this paper, for verifying the ability of heating with the position as in Fig. 1 and 2, the simulation and experiment of induction heating had been done with the CT3 steel workpiece. In this case, the coil will not be moving, and the heating will be achieved with the time of 30 s. The result show that the high temperature is distributed on the ring area. The highest temperature reached to the value of 925 °C. So, this temperature is high enough for tempering the steel. However, due to the characteristic of the spiral coil, the temperature at the coil center is very low. So, this influence will reduce the ability of the hardening process on the steel material. By simulation, the center temperature is just around 720 °C.

For verifying the simulation result, the experiment had been done with the model as show in Fig. 2. The temperature of the workpiece will be measured by the infrared sensor. The result show that after 30 s for heating, the highest temperature was reached to 925.8 °C. This result shows that the simulation had done well with the proper boundary conditions. Base on this result, the hardening process was applied for the CT3 workpiece for observing the hardness increment. In this step, there are 5 workpieces had been tested with the same parameters. Then, the surface hardness was measured by the Rockwell Hardness Testing Machines. Then, the hardness value was averaged and collected. The hardness of these plates was shown in Fig. 4. Based on these results, it shows that the hardness could be increased from 15 HRC to over 50 HRC after 45 s tempering by the stationary induction coil. The same with the temperature distribution, the high hardness is also distributed on a ring area. At the center of the ring, the hardness is much lower than the neighboring area, which is only around 20 HRC to 46 HRC. This is due to the face that the center area is just heated to around 720 °C in the tempering process, with this temperature, the steel could not change the phase.

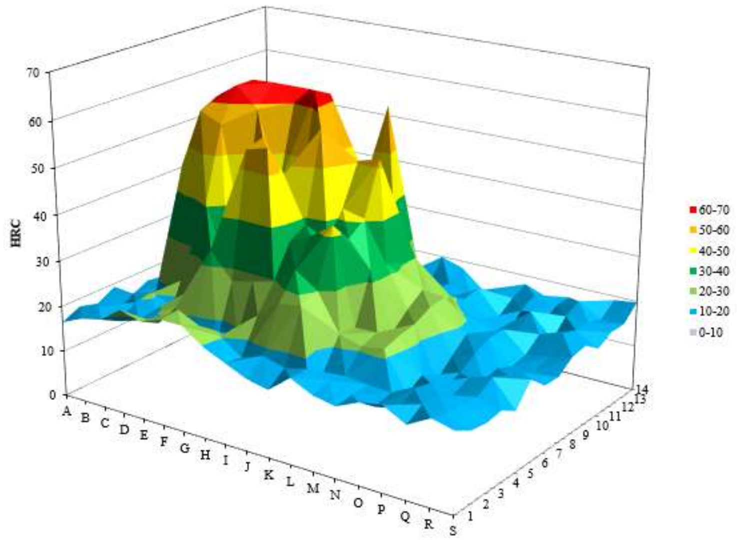

Figure 4. The hardness distribution of CT3 plate after tempering with the stationary coil.

IV. Conclusion.

In this study. the induction hardening process for flat surface carbon steel specimens was performed with the stationary coil and the moving coil. The simulation method was applied for observing the temperature distribution and the moving speed of the coil. Then. the experiment was achieved with the same parameter as in simulation. Based on these results. the following conclusions are obtained:

- With the stationary coil. the CT3 steel was tested. the result show that the temperature distributed on the ring area with the temperature is over 920 °C. which is high enough for hardening the steel. The hardness testing show that the tempering process was increase the hardness of steel from 15 HRC to over 65 HRC with the ring area. The tempering has the influence on the steel to the depth of 3.5 mm. The microstructure of steel was observed. This result show that the martensite phase was appeared at the ring area quite clearly. Both experiment and simulation show that when the stationary coil was used. the hardening effect was not as strong as on the ring area.

- With the moving coil. the CT3 steel was used for testing. The result shows that the hardness was increased on the testing area. This method was improved the surface hardness of plate from 15 HRC to 50 HRC with CT3 steel. In this case. the hardness is quite uniform with the rectangular area.

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