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Experimental Design of Hard Facing Welding in Crusher Clinker Cooler Hammer With Factorial Methods

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***Abstract*—The research begins with the idea of how to add a weld metal alloy to the worn surface of the hammer crusher so that it can be reused. The aim is to produce a hammer crusher that is tough, and abrasive to the equipment on the cooler clinker. There has been a fair amount of previous research on hard facing carbon steel and some equipment, but not specific to heavy work such as hammer crusher. The method used is the true experiment design and factorial experimental method. Both of these methods are used either direct observation or combine or cross all factors: electrode level, treatment, temperature, for each level of other factors in the experiment by calculating ANOVA. The test results show that one type of electrode that is converted to the same level, treatment (temperature and quenching) affects the hardness of the hard facing hammer crusher. The controller of this study was carried out metallographic testing with a true experimental design.**

Keywords—hammer crusher, hard facing, factorial experimental

I. Introduction

In the cement industry, one of the machines that work quite hard is the crusher, both in the preparation of raw materials for the crusher unit and in the semi-finished material preparation unit, namely the grate cooler unit, where there is also a jaw crusher or clinker breaker before the clinker material is brought to the silo for storage. In this process, the clinker material undergoes a process of decreasing the temperature from 1400°C in the rotary kiln to 100°C in the cooler. Likewise, the volume of clinker chunks is reduced to become like an aggregate rock. This material reduction process uses a hammer on the clinker breaker. Its function is to expand the clinker area that is exposed to air, thereby accelerating natural cooling in transit by the conveyor belt mechanism to the clinker silo [1]. Clinker is the semi-finished material of the cement manufacturing process.

For this purpose, this research discusses a lot about the hammer crusher on the clinker breaker. This tool hits rocks or clinkers, namely chunks of large material into smaller materials [1]. Besides that, the hammer also gets a temperature that is hot enough both in its process and the remaining heat from the rotary kiln so that the hammer wears out quickly. If the hammer wears beyond the allowable limit, the clinker that is hit will produce a large enough chunk and will not pass the screen. Eventually, the production of the clinker breaker will decline from its designed capacity. To overcome this problem by improving the wear and tear of the hammer crusher by re-welding the layer layers repeatedly. The electrode used is a wear-resistant electrode called hard facing technology [2]. Considering that the welding electrode used in the hammer crusher is a special hard electrode, the heat treatment used is a temperature of 800°C-900°C and is lightened in free air and with volume air using a blower, so that dislocation defects in the material can be avoided.

The hard facing must be a composite is a protective layer with a high hardness material and a coarse microstructure exhibiting strength [3].

Hard facing with the SMAW process is one of the most widely used techniques because it is very easy to apply [2]. Welding consumables can be divided into groups according to their properties and wear resistance. Iron-based alloys include martensite alloys, austenitic alloys, and alloys with a high carbide content [4]. In SMAW welding, the material flux and the type of electricity are important. Flux plays a role to stabilize the arc flame and the removal of stable metal liquid grains [5]. The general specification of the Edzona 260 welding electrode is C 0.5; Mn 0.3; Ni 0.4; Kr 7; Si 0.4; Fe Bal; V 0.5 and Fonta FN 600 C 0.45; Mn 0.4; Si: 0.6; Cr: 7,3; Mo: 0.4; V 0.6. The two types of electrodes with the same International Standard are DIN 8555: E 6 - UM - 60. To realize the improvement of the hammer crusher with a hard facing, research was carried out using the following road map steps (figure 1):

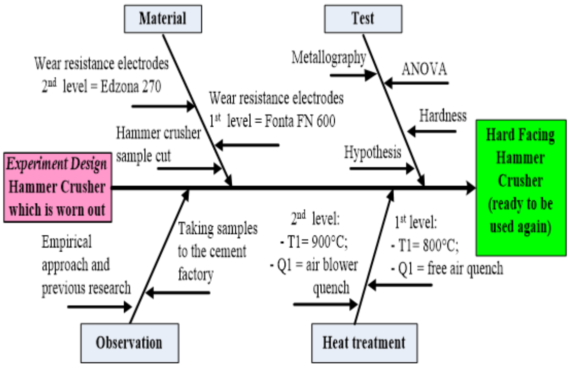

Fig. 1. Research road map with cause effect diagram.

A good experimental design can result in improved production processes, reduced process variability, reduced design and development time, reduced operating costs [6]. A factorial design is a design in which in one situation is tried simultaneously from two or more single experiments. In factorial experiments, in addition to knowing the effects of each factor, it is also possible to know the combined effect (interaction) of the factors tried. Factorial experiments with two factors are often found in multilocation trials [7]. Cause-and-Effect Diagrams are tools that help identify, sort, and display possible causes of a particular problem or quality characteristics [8].

II. Methodology

Research is a system of thinking and acting, meaning that various factors and actions must be thought and carried out so that goal can be achieved [9]. Although other elements may have influenced this design, in general, the scientific approach has been fulfilled. The research begins with the idea of how to add weld metal to the hammer crusher surface and reuse it according to its function. The aim is to produce a hammer crusher on cooler clinker that is tough, tough, and resistant to friction. The research was conducted by using test samples from two types of electrodes with the same specifications which were welded with SMAW. More in-depth research was carried out to ensure better results with more perfect welding. Welding is carried out by trying to reduce welding defects so that the parts of the weld area can be disclosed by the metallographic test in more detail.

The research stages are depicted in the flow diagram in Figure 2.

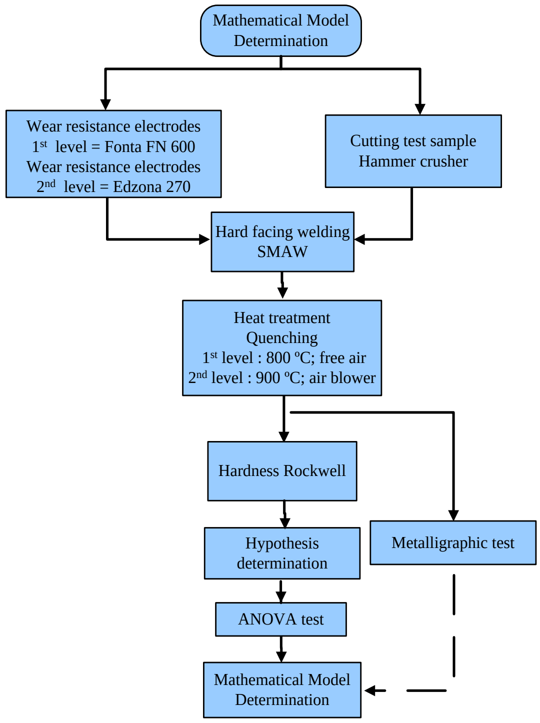

Fig. 2. Flow chart.

The research method used is an experimental methodology. Experimental methodology is research that carried out by manipulating the object of research and the existence of deliberate control over the object of the study [10].

The True experiment design and action are carried out for all direct observations and work on hummer crusher sample making, heat treatment processes, hardness testing, and metallographic testing.

The factorial experimental method is an experiment that combines or crosses all certain factors at each level from other factors in the experiment. Factorial experiments are experiments in which all (almost all) treatments of a particular factor are combined or crossed with all (almost all) treatments of each other factor that is in the experiment. [7]. In factorial experiments, it can be seen the influence of a factor individually and the influence of factor interactions. To test the significance of the influence of factors and their interactions, one of them is by using ANOVA. After implementing the experiment and obtaining the necessary data, the next step is to determine the hypothesis and ANOVA test with one way ANOVA at the significance level (α) = 5%. After the ANOVA test was carried out, it then determined a mathematical model in which the factorial experimental data processing used Minitab software.

III. Results and Discussion

A. Test Implementation

The table format of the hardness test results on treated carbon steel is made in the following matrix form (Table 1):

TABLE I. Hardness Test Format on Hammer Crusher Heat Treatment Results

Type of electrode equivalent	**Treatment (T=Temperature; Q= Quenching) T1=800°C, T2=900°C,Q1=free air, Q2=air blower**			
	T1Q1	***T1Q2***	***T2Q1***	***T2Q2***
Edz.270	32,07	38,18	36,91	39,55
	32,25	39,20	36,02	39,49
	34,70	39,01	35,89	38,56
	34,18	37,27	36,37	40,12
	31,98	39,18	35,66	39,64
Fon. 600	33,22	37,99	35,14	39,12
	32,33	39,21	37,28	38,01
	33,41	36,14	34,01	38,29
	32,64	37,01	37,18	39,58
	32,16	37,45	37,20	39,07

B. Hypothesis Determination

- H01: There is no significant difference between electrode factors affecting hammer crusher
- H11: There is a significant difference between the electrode factors in influencing the hammer crusher.
- H02: There is no significant difference between the temperature factors in affecting the hammer crusher hardness.
- H12: There is a significant difference between the temperature factors in influencing the hammer crusher hardness.
- H03: There is no significant difference between the quenching factors in affecting the hammer crusher hardness.
- H13: There is a significant difference between the quenching factors affecting hammer crusher.
- H04: There is no significant difference between the interaction of temperature factors and quenching factors in influencing hammer crusher.
- H14: There is a significant difference between the interaction of temperature factors and quenching factors in influencing hammer crusher.

C. ANOVA Test

Before testing the ANOVA, normality tests were carried out on 40 experimental data as follows (table 1 and table 2:

TABLE II. Factor Information

Factor	**Type**	**Levels**	**Values**
Type of electrode equivalent	Fixed	2	Edz.260; Font. FN. 600
Treatment	Fixed	4	T1Q1; T1Q2; T2Q1; T2Q2

TABLE III. Coefficients

Term	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	36,567	0,147	248,36	0,000	
Type of electrode equivalent					
Edz.260	0,245	0,147	1,66	0,105	1,00
Treatment					
T1Q1	-3,673	0,255	-14,40	0,000	1,50
T1Q2	1,497	0,255	5,87	0,000	1,50
T2Q1	-0,401	0,255	-1,57	0,125	1,50

Answering from the hypothesis determination that has been determined above, from the ANOVA table information and regression analysis can be simplified as follows:

$$y = 36{,}567 + 0{,}245x + 1{,}497x1 + 2{,}567x2$$

Where:

x = Type of electrode Edz. 260

x1 = Treatment T1Q2 (Interaction of Temperature 800 ° C and Quenching Air Blower

x2 = Treatment T2Q2 (Interaction of 900 ° C Temperature and Quenching Air Blower

From this equation it can be explained that the Edz.260 electrode type has more effect on hardness than the Font.FN 600 electrode type. This may be due to the influence of the chemical composition of carbon (C) on the EDz.260 electrode is greater than that of Font.FN 600.) and Quenching (Q) shows that both temperature (T1) 800 ° C and temperature (T2) 900 ° C both have an effect when interacting with Quenching (T2) Air Blower. This means that the type of air blower electrode has a very significant effect on hardness (HRC) in this study.

D. Metallography

The function of the metallographic test in this test is in addition to seeing the metallographic phenomenon of the weld area, it also wants to control the results of how the effect of the type of welding wire, temperature and quenching if it is related to the hardness according to the results of the ANOVA test and linear regression.

Fig. 3. Metallography of the weld area; (a) and (b) Heat treatment 800°C and 900°C with free air quenching in welding using the Edzona 260 electrodra and Fonta FN 600.

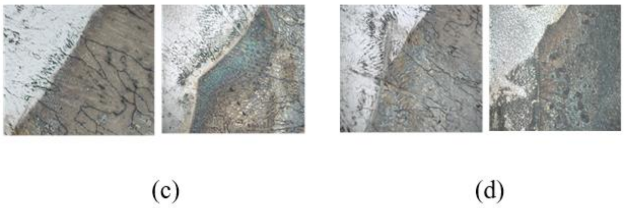

Fig. 4. Metallography of the weld area; (c) and (d) Heat treatment 800°C and 900°C with air blower quenching in welding using the Edzona 260 electrodra and Fonta FN 600.

To further explain the two types of electrodes in Figure 3 and figure 4 metallography above, it is necessary to pay attention to their chemical composition. The two specifications are DIN E6 UM-60. Edzona 260 and Fonta FN 600. The specifications of the two types of electrodes are the same although they differ slightly in the explanation of their chemical composition and hardness. In general, the metallographic image shows that due to the influence of the alloy, namely the alloy of Chromium and Manganese, it forms bright and grey crystals of austenite. From the metallographic image, it can be seen that the area being welded is the boundary of the lighter area on the left side and the darker area on the right as the holding material. It can be seen that the Edzona 270 electrode material is slightly darker than the Fonta FN 600 electrode material. This is due to the effect of the chemical composition on the Edzona 260 Carbon (C) electrode which is slightly higher so that it is slightly harder. from the welding of electrodes FN 600 Fonta. electrode which also serves to increase the hardness but does not exceed the influence of Carbon (C). The brighter area is due to the high chromium content of about Cr = 7%, which has rust-resistant properties and forms brighter, rust-resistant white crystals of austenite. While the darker right side is the original material, namely hammer crusher, and a buffer layer with a chemical composition containing C = 1.14%; Si = 0.49%; Mn = 13.36%; P = 0.07%; Si = 0.04%; Cr = 1.89%. The material with the buffer layer is darker due to the high chemical composition of Carbon (C) and Manganese (Mn). Even so, the hardness test results showed that the hardness of the material was only at 192 HB or around 12-15 HRC. With the addition of chromium, it will increase the hardness on the hammer surface to help with tough work, especially for materials that have high impact such as limestone, clinker, and others.

From the explanation above, it can show how the influence of the control variable (metallography) can explain the cause-and-effect relationship of the experimental design in the previous explanation.

IV. CONCLUSION

- Linear regression Equation Y = 36,567 + 0,245X + 1,497X1 + 2,567X2 shows that the Edz.260 electrode has more effect on hardness than Font. FN 600. This can occur because the chemical composition of carbon (C) is greater in the chemical composition of the Edz electrode. 260.
- The quenching blower media factor has a more dominant influence on the hardness than the free air factor.
- The metallographic control function displays the metallographic image of the Edz electrodes. 260, showing perlite is darker and contains more carbon than the metallographic image of the FN 600 Fonta electrode. This could illustrate the hardness of the Edz electrode. 260 is harder than the Fonta FN 600 electrode.
- In general, the metallographic structure of the two types of electrodes formed is an alloy of chromium (Cr) and manganese (Mn) alloys to form white and bright austenite crystals that are corrosion resistant.

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