Holding Iron Surface FCD 40 using Electrochemical Hard Chrome Method on Die-Cutting Two Tons

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***Abstract:* - Material hardening is a process method that is carried out to make materials that begin with standards become stronger and more resilient. The material used is nodular cast iron (Ferro Casting Nodular (FCD)) which has a composition of above 2.06% carbon, tensile stress 40 kg / mm2, with elongation of 12 minutes, and has a material hardness of 201 (BHN). The method used to harden the surface is the electrochemical hard chrome process with added hardening material is chrome. Material is carried out by electrochemical diffusion by providing electrical voltage, as well as the addition of heat given, so that the material becomes harder.**

The results of electrochemical hard chromium surface hardening can harden the surface better and harder, so that it is used in industry and society. Rockwell hardening value is 62.82 HRC equivalents to VHN 768 and BHN is 702.2. In this hardening process uses 270 amperes of electric current, with a temperature of 60ºC and a holding time of 20.

***Keywords*:Material,Electrochemical, Surface, Hardness, Hard Chrome.**

I. INTRODUCTION

The development of reliable and up-to-date technology is the use of industrial materials that can be processed and developed by the industry to become equipment that is strong, reliable, and durable in use so that companies obtain equipment that is reliable, strong, in the production process, its utilization and profit, production. more and more quality. Heat treatment is the treatment/application of heat to the material to provide/change the physical properties of the material (Setiawan, 2012), then provide rapid cooling (using liquid media, very fast cooling, such as water, cooling air, granules). water (spray water) and so on to the material so that the material hardens rapidly starting from the surface to the core/middle of the material This process is called quenching (fast cooling) (Setiawan, 2012).

The application of this heat requires very large energy and economy. large in the manufacturing process. In the results of this process, the material will harden quickly, and give the ductility value that occurs in the reverse (becomes smaller / lower). This material will experience hard and brittle (easily broken, if subjected to a shock load). this material in the industrial world is not profitable, so it needs to be improved from its physical and mechanical properties Hardening by using the quenching method, care should be taken to avoid distortion of the material, cracks, or not achieving the desired hardness (Karmin, 2012). This process requires a very long time, due to the preheating, further heating, holding time heating and cooling.

Hardening of materials is the hardening of the materials using the material hardening method (setting the TTT) so that the materials to be made are better? The use of this method also requires a large amount of energy, where the material is given heat energy until it reaches the melting point of material. Giving heat energy requires temperatures up to 500 ºC were getting this much heat energy, so the producers need a lot of fuel and the capacity used is on a large industrial scale. The process in TTT also takes a long time and provides great economic value, and it takes a long time to cool it down so that it gets the required material. The hardening process is the process of heating the steel above the austenitizing temperature to obtain very hard properties of a material, and it is held at a certain holding time and cooled rapidly in a cooling medium (Sumiyanto & Abdunnaser, 2017). The hardness that can be achieved depends on the cooling rate, carbon content, and size of the object. In alloy steel, the type and amount of alloy will be affected by the hardening ability.

Plating is the process of transferring ions from the cathode to the material anode to cover the material to be shinier, attractive, avoid corrosion, and have better economic value. The plating process is often called the electrochemical (electrochemical) of the material by using an electric voltage to move the chemical so that it covers the surface of the desired material. Some of this gilding process uses heat transfer, some do not. Where the process depends on the needs desired by the manufacturer. The addition of heat to this gilding system will result in / cause the surface of the material to be better and harder, so this process is often used for the die-manufacture process because it can withstand large and reliable loads. Utilization of this plating is often referred to as electrochemical hard chrome, where the added material given to the core material is chromium. Chromium material has a fairly high hardness value, so it is often used by manufacturers in electrochemical plating processes to harden and improve the surface structure and appearance of the material. In general, in the process of forming the surface hardening of the core materials using electrochemical hard chromium, it is relatively more economical, compared to hot treatments, carburizing (a hardening process by adding carbon) to the material. Electrochemical hard chromium coating can be used on steel, iron, and copper (Miller et al., 2017; Topayung, 2011).

The use of hard chrome in the industrial sector is very large and wide, so it is used in the process of forming die-cutting materials. Die-cutting is indispensable for material hardening, where the cutting process between plate material and cut object is very necessary. One of the die cutters that need to be hardened is die-cutting for chain manufacturing. If the die-cutting is not hardened, it will often result in poor cut results and frequent repairs. The material used for die-cutting is Steel (SKD), but economically, the purchase of SKD material is relatively expensive compared to FCD 40 (nodular ferro casting). SKD is a steel material that is re-treated for hardening of all materials so that economically the price can reach 3-4 times as much. The hardening process on the surface of the plate (plating) can be used by using a hard chromium electrochemical process which can harden the surface layer, while the inside remains ductile (ductile). This process can be done effectively, that is, in the hardening process, it takes a relatively short time (making the hardening depends on the provision of an electric current, by providing a large electric current, the time required for hardening is relatively shorter. In other words, we must know that materials to be hardened by the surface and the time is best), and efficient in the working process can work on small to large objects, where the work can use a tub/place that is adjusted to the workpiece to be hardened.

Production facilities and infrastructure require fine detail, resulting in a perfect product. Die-cutting is a product that is produced in the form of metal cutting with a force that must be greater than its tensile stress. By knowing the existing tensile stress, it is necessary to pay attention to the amount of force exerted to cut the existing object, that is, it must be greater than the tensile stress. If the force exerted on the product material is smaller, the product will not be cut off and not completely formed. The thickness of the raw material also affects the amount of force applied to make the desired product. With the thickness that will be made into a product, the die-cutting that will cut the iron/metal plate raw material must be calculated properly, how much force is required, how many times the material can withstand the load to be received, and must be given the appropriate die cutting material and provide a fairly good surface hardness treatment. So that the problem of die-cutting does not occur problems, namely the die-cutting becomes damaged (break) which disrupts the course of production operations, requires a long repair time to replace (repair), and can affect the lifetime of the die-cutting being operated. Another problem is the material used for die-cutting can withstand corrosion/rust, where the material in the form of carbon iron is more prone to rust (Fontana & Greene, 1987; Yunaidi, 2016). So, it requires a process of containment (protection) against corrosion which causes die-cutting to wear out, break down, and shorten the operating life

The working process using the electrochemical hard chrome method is an economical method for having strong, hard materials, and improves the surface structure and beautifies the appearance, but behind that, it has several problems that arise in obtaining strong, hard, surface-repairing materials, namely: 1. How is the electrochemical hard chromium manufacturing process? 2. How much electricity is used to make electro-chemicals? 3. How long will it take? 4. How much heat is applied to get good hard chromium?

The objectives of electrochemical hard chromium research are as follows: 1. Want to know the process of making electrochemical hard chrome is good and correct. 2. Knowing the amount of electricity needed when making electrochemical hard chrome. 3. Knowing the time used for the formation of electrochemical hard chromium. 4. Knowing the temperature required to heat the materials so that they have good strength, resistance to loads, and prevent corrosion.

In this study, several parameters to be observed in the electrochemical hard chromium process are as follows: • Changes in the amount of electricity that is given during the electrochemical process (250 Ampere, 270 Ampere) with a voltage of 5 Watts. • The amount of temperature change that will be carried out in an electrochemical process (50°C, 55°C, 60°C). • Changes in the time spent on electrochemical processes (20 minutes, 30 minutes, 40 minutes).

II. THEORETICAL STUDY AND HYPOTHESIS DEVELOPMENT

Iron is a material that is often used daily by the industrial world, to produce materials, units, and equipment that are ready to use for life in society. Iron has good conductivity properties, is a good heat transfer material, and can flow electricity easily. Various kinds of materials are produced to make equipment that suits the needs of industry and the general public. Nodular cast iron or which is very often referred to as Ferro Casting Ductile (FCD) is iron that is used by manufacturers to make manufacturing products according to their needs. FCD 40 is a cast iron with a carbon composition above 2.06% having pearlite and / or ferrite matrices and containing spherical graphite (Suratman & Bandanadjaja, 2002; Xiong, Cai, Wan, & Lu, 2011). Data on the characteristics of the FCD 40 material can be seen in table 1.

Table 1. Mechanical Properties of Nodular Cast Iron 700 According to JIS Standard(Gouveia et al., 2018)

No	Quality	Tensile strength (Kg/mm2)	Elongation (%)	Hardness (BHN)
1	FCD 37	37	17 min.	179 max.
2	FCD 40	40	12 min.	201 max.
3	FCD 45	45	10 min.	143 s/d 217
4	FCD 50	50	7 min.	170 s/d 241
5	FCD 60	60	3 min.	192 s/d 269
6	FCD 70	70	2 min.	229 s/d 302
7	FCD 80	80	2 min.	248 s/d 352

FCD 40 iron has low tensile strength mechanical properties, which is 40 kg / mm^2, with an elongation of 12 minutes, and has a smaller material hardness of 210 (BHN). Iron FCD 40 is widely used in machining, because the melting point of iron is smaller than cast steel (Suratman & Bandanadjaja, 2002). The Fe-C balance image can be seen in Figure 1 below.

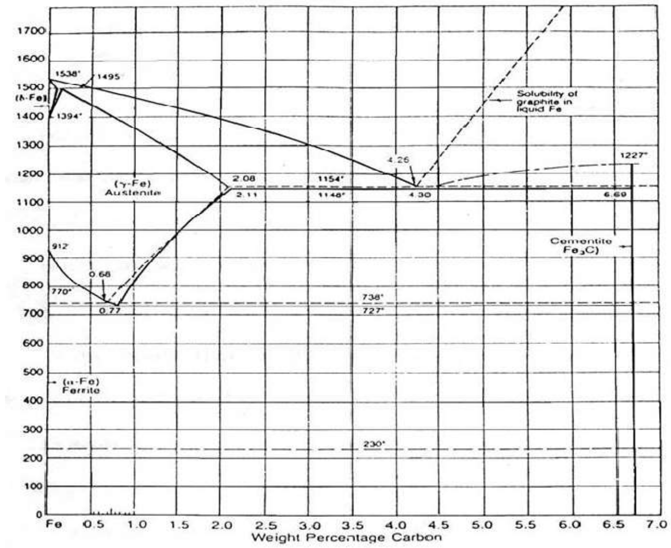

Figure 1. Fe - C balance

Surface hardening using the electrochemical hard chromium method is a treatment that can be done to increase the surface hardness of the material (Strese, Boeck, & Steinbach, 2017; Yusuf, 2015). Providing hardening by electroplating with chromium added material gives a hardness value of 737 - 852 BHN, while coating by diffusion produces a hardness of the material of 1100 BHN. The maximum amperage used in electrochemical processes is 8 amperes and the time used is 60 minutes (Topayung, 2011). On the surface of medium carbon steel that was electroplated with a nickel layer, the surface hardening occurred from 205.5 VHN to 329.6 VHN with a length of time carried out for electroplating for 15 minutes (Garcia-Giron et al., 2018).

Cutting dies are equipment in the manufacturing industry to cut metal materials of desired thickness with a given force so that a uniform metamaterial is formed in a more efficient time and of good quality. The metal cutting process consists of three stages, namely: the first stage is, the material which is given a force load that does not exceed the yield point limit, then the material will return to its original state. In the second stage, the material that is given a force load that exceeds the yield point will experience deformation, and the metal material will not return to its original state. In the third stage, the material that is given a load exceeds its tensile stress, it will experience a fracture. In this third stage, the cutting die provides a force load, so that the metal material being processed will experience cutting (fracture). In the table below, several metal materials have a maximum tensile stress limit.

Table 2. Tensile Stress of Metal (Cooper, Rossie, & Gutowski, 2017).

Material	Shear Strngth (Lb/in^2)
Lead	3,500
Tin	5,000
Aluminum	8,000
Zinc	14,000
Copper	22,000
Brass	33,000
Steel 0.10 C (annealed)	35,000
Steel 0.10 C (cold rolled)	43,000
Steel 0.20 C (annealed)	44,000
Steel 0.20 C (cold rolled)	55,000
Steel 0.30 C (annealed)	52,000
Steel 0.30 C (cold rolled)	67,000
Stainless Steel	57,000
Silicon Steel	67,000

Metal material that will be cut by cutting dies during the process, experiences deformation which can be seen in the angular characteristics of the perforated material or the pressure force of the metal material. The lower part of the metal material has a larger angle, so the metal material that is cut and thrown away will more easily get out of the bottom side of the die-cutting. While the top has a smaller angle and can cut metal from the load force that exceeds the shear stress limit. The schematic image can be seen in the picture below

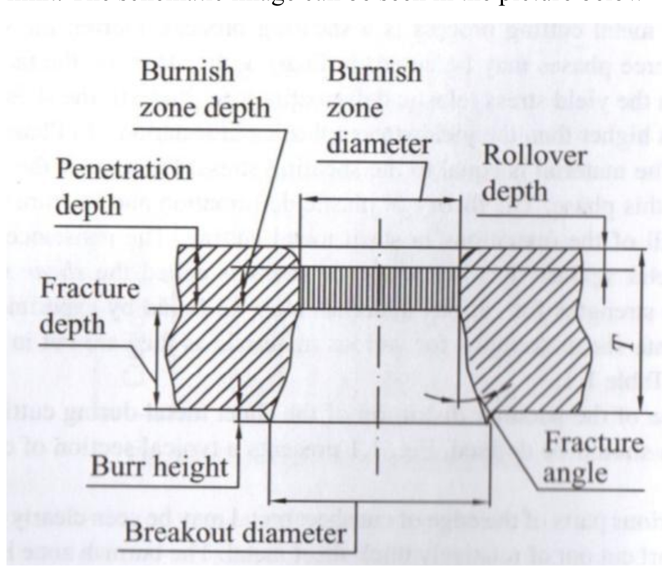

Figure 2. The Characteristics of the Angle of the Perforated or The Material of Sheet Metal

When the die cut is operating, there is an upper part (punch) that provides pressure to press the metal material, and a lower part (die) that will hold and cut the metal so that the desired object is formed. In this process, there must be an appropriate clearance when cutting the metal material between the punch and die.

The equations that can be expressed to show the clearance between punch and die are as follows [11]:

$$c = \frac{Dd-Dp}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where: Dd = Diameter of die (mm) Dp = Punch Diameter (mm) c = Clearance (mm). The gap between the punch and die needs to be paid close attention, if there is an improper clearance, it will result in the result of cutting the metal material to be imperfect and become damaged. The clearance images between the right and the wrong ones can be seen in the image below.

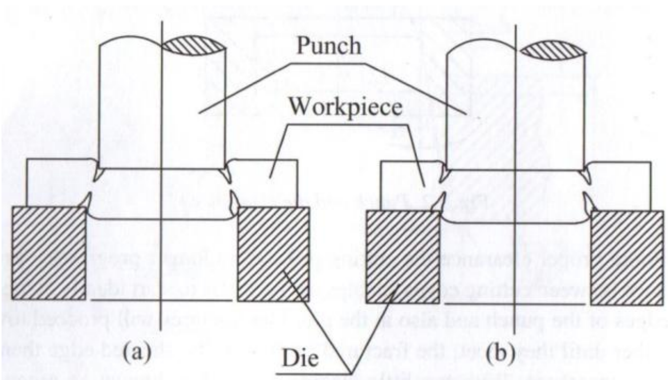

Figure 3. Compliant clearance (a), Non-conforming clearance (b)

Cutting dies in the process of cutting metal materials requires a force/loading that exceeds the shear stress of metal. The cutting process in a cutting die can be stated as follows (Cooper et al., 2017):

$$F = p.T.\tau m = 0.7\ L.T\ (UTS) \ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where: F = Force (kg) P = Size of Cutting Hole (mm) T = Thickness of material (mm) τm = Maximum Stress (kg / mm2)

The testing process is a step taken to determine the ability, strength, hardness, ductility, and corrosion resistance of a material. Testing can be done by various methods for one material capability that you want to know. In general, testing is divided into 2 (two), namely: Destructive testing (damaging the workpiece material) and non-destructive testing (without damaging the workpiece material during testing). Tests are carried out to determine the toughness, strength, ductility of materials which are destructive tests are such as hardness testing, tensile testing, compression testing, shock testing, and others. Each material before use needs to be tested for the material/metal as above, with the general purpose and objective of knowing the main properties of the material/metal, both in terms of strength, resistance, and other properties to a load that is will be given. The hardness of a material can be defined as the resistance of the material to the pressure forces of other, harder materials. This stress can be in the form of scratching, reflection, or indentation of the hard material against the surface of the test object (Brunete et al., 2018).

Electrochemical Hard Chrome is a surface hardening process in metal using a method/process of providing electricity to the workpiece to be hardened by using chemical liquid as a medium for conducting cathodes and anodes in the process of removing the hardener in the form of chrome on the core material of the workpiece to be hardened. In the basic electrochemical process of hard chrome using anode, cathode, and electrolyte solution. All three sections are used in the literature dealing with coating materials.

Metallographic testing is a technique or science for looking at structure micro and macro material. The microstructure of the metal can be obtained through the process of preparation of metallographic specimens. To analyze the structure, recognizing the phases in the microstructure, based on a macro scale or scale micro. The stages in conducting metallographic testing are as follows(Emanuela & Marion, 2017; Skelton & Gandy, 2008):

a. Cutting, namely cutting the test object according to the cross-section will be observed (using Discotom-2 cutting machine)
b. Mounting (framing), is done to facilitate handling/handling of the specimen which is small or has an irregular shape which will be difficult to handle especially at times sanding and polishing when not mounting.
c. Grinding, namely the process of leveling the surface of the test object using water-repellent sandpaper in sequence starting from a roughness of 120, 240, 360, 400, 700, 800, and 1200, during the grinding process it is given water to prevent oxidation on the surface of the test object.
d. Polishing, namely smoothing and removing scratches during the grinding process using a velvet cloth (polishing cloth) and a diamond paste with a smoothness level of 6 µm, 1 µm, and ¼ µm. As a cooling medium used Lubricant Blue or 96% alcohol.
e. Etching, namely reacting the test object with etching material so that it can bring out the microstructure image clearly. (the etching process uses 2%).
f. Viewing, observations made using optical microscopes and electron microscopes. The results of the metallographic test can be obtained a certain microstructure, knowing the% of a certain phase and grain size. In medium carbon steel by using the metallographic test, it can be seen that the microstructure in the form of grains and phases in it. The initial process for metallographic testing is mounting, sandpaper, polishing, etching, after which observers are carried out under a microscope (Geels, Fowler, Kopp, & Rückert, 2007).

III. RESEARCH METHODS

Nodular cast iron (FCD) is a material that is cast iron with a round graphite shape. Where FCD has good physical and mechanical properties, so it is widely used for construction, mechanization, and automotive needs, and others. In the FCD hardening process, it can be done by hard chromium electrochemical method surface hardening. The research framework of electrochemical hard chrome is as follows:

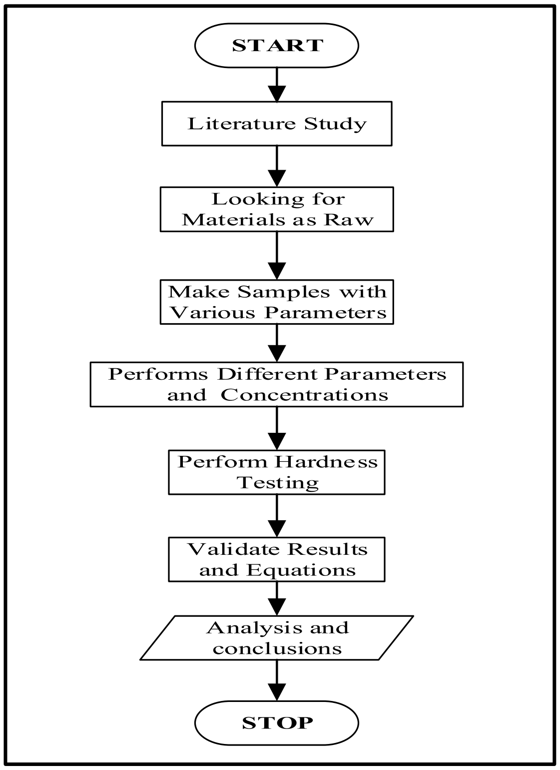

Figure 4. Research Scheme

The method that will be done is to use an experimental method, where this method wants to change the variable and see the results and consequences that will occur from the process. The sample preparation that has been done will then be carried out again with the hard chrome electrochemical hard chromium method. In the surface hardening process, it is divided into several stages, namely: (1) Provide a sample of 1 piece which will be hardened using an electrochemical with an electric current of 250 Ampere for 20 minutes. Then provide back as much as 1 pc which will be hardened by electrochemical with a voltage of 250 Ampere for 30 minutes. The last session was to provide a sample of 1 pc, then provide electrochemical surface hardening treatment using a voltage of 250 Ampere for 40 minutes. (2) Provide 1 pcs sample which will be hardened using an electrochemical with an electric current of 270 Ampere for 20 minutes. Then provide back as much as 1 pc which will be hardened by electrochemical with a voltage of 270 Ampere for 30 minutes. The last session was to provide 1 pcs sample, then give electrochemical surface hardening treatment using a voltage of 270 Ampere for 40 minutes. In the next process, an experimental method will be carried out on the sample, namely as follows: (3) Provide 1 pcs sample/treatment which will then be heated on the sample object. The first sample stage was heated using a temperature of 50ºC for 20, 30, and 40 minutes. (4) Then provide back 1 pcs of sample/treatment which will be heated for 20, 30, and 40 minutes with a temperature of 55ºC. (5) Finally, provide back 1 pcs of sample/treatment which will be heated for 20.30, and 40 minutes with a temperature of 60ºC.

Table 3. Electrochemical Hard Chrome Treatment Process

No. Object	Current (Ampere	Temperature (ºC)	Time (minutes)
1	250	50	20
2	250	50	30
3	250	50	40
4	250	55	20
5	250	55	30
6	250	55	40
7	250	60	20
8	250	60	30
9	250	60	40
10	270	50	20
11	270	50	30
12	270	50	40
13	270	55	20
14	270	55	30
15	270	55	40
16	270	60	20
17	270	60	30
18	270	60	40
19	Without Hard Chrome Treatment		

IV. RESULTS AND DISCUSSION

Shaving dies is a process used to perforate a workpiece and cut a plate (blank) as a workpiece to be produced by these dies. This anniversary forms the part that will be processed properly and accurately. Processed workpieces must be consistent and continuous, with a fast pressing (punch) and a fast-moving die shoe, plate cutting, and fast punching. The shaving dies system can be seen in the image below.

Dies is a combination of several parts of iron and steel components that are assembled into one unit to produce a workpiece product from an iron plate by punching, shaping, bending, and cutting the iron plate. The use of dies, in general, has spread in several manufacturing industries, with various sizes, various shapes, various weights (weights/tonnages) which are used by the manufacturing industry to make workpieces effectively, efficiently, and can make workpieces with accurate and productive precision. Die-making in some manufacturers can be done using traditional machines, namely by using milling machines, drilling machines, scrap machines, and lathes and taps. In the manufacturing process with conventional machines, some results are less accurate and less precise. Making and combining parts is still sometimes less precise. So, it takes quite a long time to manufacture. Several methods have been developed in the manufacture of dies, manufacturing, and manufacturing have developed technology to obtain better accuracy, better precision, better results, andmore effectiveness and efficiency. The CAD/CAM program has been developed to make machines on a CNC basis, where the objects to be made will be more precise and effective, and efficient by programming and making them automatically.

FCD 40 is a metal material that is a Ferro Casting Ductile, has metric pearlite and/or ferrite, and contains nodular graphite. The percentage of carbon held is above 2.06%.

The workpiece that is used for the testing process is the FCD 40 workpiece, where the workpiece is made by casting using sand casting. The workpiece that is formed using sand casting is made with dimensions of 300 mm x 150 mm x 20 mm. The results of the casting workpiece can be seen in the following figure:

Figure 5. FCD 40 Sand Casting Workpiece

In this workpiece drawing, the FCD is formed using sand casting, where the molten iron inlet hole is inserted in the middle of the workpiece. The insertion of the workpiece in the middle is intended to facilitate the process of evenly entering the liquid iron (FCD 40) into the mold and there is no hardening of the liquid iron in the middle of the workpiece, so that the drying of the workpiece occurs perfectly. If the workpiece is drying, only partially it becomes hard in the middle and the other part is empty of liquid iron, which means that air is trapped in the casting. On the side, there are 4 (four) air exhaust holes and also holes to see whether the liquid has filled all parts. Thus, the molten iron has filled all parts of the mold and there is no air trapped in the mold which causes the workpiece to become solid (not perforated). Furthermore, the workpiece that has cooled and hardens, is carried out removing the workpiece (FCD 40) from the casting by breaking / dismantling the casting, and then cleaning from the sand. The final step is to cut and grind the inlet and outlet with a grinder, so that the workpiece (FCD 40) becomes a plate shape with a size of 300 mm x 150 mm x 20 mm.

Objects with a size of 300 mm x 150 mm x 20 mm will be subjected to a hardness and metallographic testing process with several different treatments. Initially, the workpiece will be marked with a process. The workpiece that has been prepared will be measured using a ruler and marked with a pencil, so that part of the specimen that will be processed will be seen. The workpiece is divided into 20 equal and equal parts.

Figure 6. Marking

When cutting a workpiece, we should not cut immediately with a very strong pressure, because with a strong pressure it will erode the cutting edge immediately, and make the grinding machine flammable. In the process of cutting with a grinding machine, the writer cuts slowly (increasing and lowering the grinding wheel) as often as possible, so that the results obtained on the workpiece become smooth and the grinding machine does not heat up quickly, which results in the grinding machine being damaged (burning).

Figure 7. Initial Cutting of the Workpiece

The process of aligning the workpiece is reducing the uneven parts of the workpiece by cutting the top surface of the workpiece. The workpiece is clamped using a vise, and the bottom part is held/supported by using iron supports so that the workpiece does not move which results in the workpiece becoming wavy or stratified. Cutting the workpiece causes the milling machine to become hot because it touches/cuts the workpiece, so cooling is needed using a water cooler. A water cooler is milky white, by providing cooling water, the workpiece, and the machine chisel the milling cuttings are not hot and no longer emit smoke. The cooling process aims to cool the workpiece, as well as to preserve the tool blade of the milling machine.

Figure 8. Workpiece Cooling

Workpieces that have been refined using a grinding machine will produce smooth and bright silver-colored workpieces. This refining process uses a hand grinding machine with a very fine grinding wheel. This process is carried out repeatedly and with a slow movement back and forth of the grinding machine.

Before the workpiece to be carried out electrochemical hard chrome, the workpiece that has been refined by a grinding process, the next step is to give the workpiece numbering. The numbering of the workpiece is given to recognize the material that has been treated, and there is no error in data collection, as well as analyzing the workpiece for the next process.

In the workpiece/material hardening process (FCD 40), several treatments are carried out on the workpiece. 18 pieces of workpieces that have been prepared for the hardening process are prepared. In the first workpiece, an electric current of 250 Ampere, 5 volts is given, with a temperature holding of 50ºC, and the time is given to drain the electric current for 20 minutes. The next process, given the same electric current, voltage, and temperature (250 Ampere, 5 Volt, 50ºC) by giving the electricity flow time for 30 minutes. Next, give treatment to provide the same electric current and give electricity flow time with a time of 40 minutes. The time difference between one workpiece and another is 10 minutes). Then give the difference for flowing electric current with a limit of 250 Ampere and 270 Ampere, temperatures between 50°C, 55 ° C, and 60°C, while the time is 20 minutes, 30 minutes, 40 minutes.

In the process of testing the hardness using the Rockwell method, the author tests the hardened workpiece using hard chromium. In the initial process, the author first prepared the Rockwell tester as a workpiece hardness test. The author places the objects that have been numbered on the part/placement of the workpiece. The selection of the workpiece to be tested is a smooth, even, and even plane. The next stage is to regulate the load that will be provided by the test equipment to determine the hardness. The load given is 150 kg (1471 kgf) with an indenter of a cone diameter of 120º. Setting the load is followed by setting the tester needle at zero, and then pressing the loading. The test is carried out 5 repetitions for each workpiece, and the results of the hardness test are recorded. Testing with as many as 19 pieces (one test object without hard chromium treatment (No.19), 18 workpieces subjected to hard chromium treatment) the workpiece will be taken on average, so it can be seen that the test data that has been carried out for the hard chrome process has the effect of workpiece hardness. The results of Rockwell hardness testing that have been carried out can be seen in the following table.

Table 4. Rockwell Hardness Testing Results

No	HRC					Average
	1	2	3	4	5	
1	58.3	58.3	58.8	59.2	57.8	58.48
2	59.2	59.2	60.1	57.3	55.2	58.2
3	51.1	56.3	57.3	55.2	58.8	55.74
4	49.8	64	59.2	63.3	59.2	59.1
5	62.5	62.5	62.5	60.1	58.8	61.28
6	60.1	59.2	59.7	59.7	60.1	59.76
7	60.1	68.8	61	60.1	60.1	62.02
8	56.3	49.8	61.8	62.5	61.8	58.44
9	60.1	62.5	60.1	61.8	63.3	61.56
10	57.8	59.2	60.1	63.3	63.3	60.74
11	61	62.5	63.3	61.8	61.8	62.08
12	62.5	60.1	61.8	59.7	59.7	60.76
13	58.8	60.1	61	61	60.1	60.2
14	60.1	59.7	61	59.7	58.8	59.86
15	61.8	60.1	59.2	61.8	59.2	60.42
16	63.3	62.5	62.5	63.3	62.5	62.82
17	62.5	60.1	60.1	63.3	61.8	61.56
18	62.5	61	59.7	60.1	59.7	60.6
19	55.2	53	57.3	57.3	56.3	55.82

Table 5. Hard Chrome Treatment Vs Rockwell Hardness Testing Results

No. Spec	Current Strength (Ampere)	Temp (ºC)	Time (minutes)	Average Rockwell Hardness Testing
1	250	50	20	58.48
2	250	50	30	58.2
3	250	50	40	55.74
4	250	55	20	59.1
5	250	55	30	61.28
6	250	55	40	59.76

No. Spec	Current Strength (Ampere)	Temp (ºC)	Time (minutes)	Average Rockwell Hardness Testing
7	250	60	20	62.02
8	250	60	30	58.44
9	250	60	40	61.56
10	270	50	20	60.74
11	270	50	30	62.08
12	270	50	40	60.76
13	270	55	20	60.2
14	270	55	30	59.86
15	270	55	40	60.42
16	270	60	20	62.82
17	270	60	30	61.56
18	270	60	40	60.6
19	Without Hard Chrome Treatment			55.82

The graphic image of testing the hardness of the workpiece against the hard chromium treatment of the workpiece can be seen in the graph below.

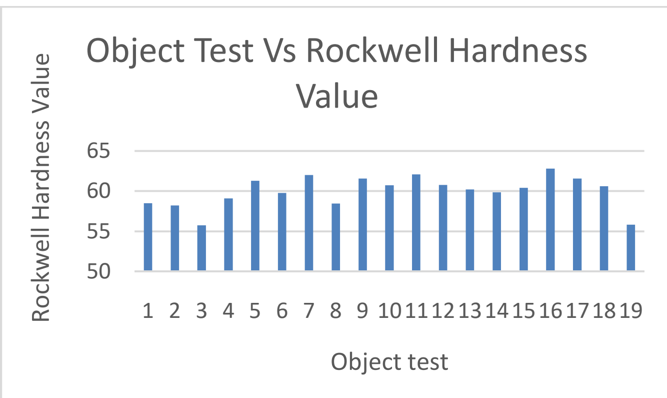

Figure 9. Graph of Object Test VS Rockwell Hardness Value

From the graphic image above, it can be seen that the workpiece that was treated with hard chromium had higher hardness values, namely HRC 58.48 and HRC 58.2 (no.1 and 2) compared to the hardness value of the workpiece that was not treated with HRC 55.82 (no. 19). The hard chromium hardened workpiece number 3 is HRC 55.74, which has a hardness value below that of workpiece no.19 (HRC 55.82). This workpiece has an error in the surface hardening process. The surface of the workpieceNo.3 visually looks almost like a test material/workpiece that is not done hard chromium. So that the hardness value almost matches the workpiece that is not hardened. Testing workpiece number 4, there is a significant increase in hardening, because the treatment time is large enough for 20 minutes with an electric current of 250 minutes and a temperature that is maintained at 50 ° C. Workpiece hardness increases by HRC 59.1 compared to No. 19, without hard chromium treatment. Giving a temperature of 55º also gives a significant level of hardness of HRC 61.28 compared to the workpiece that is not done at HRC 55.82 (no 19). On workpiece No.6, the hardness also increased by HRC 59.76. In the next stage, the authors tested the workpiece by providing an electric current of 250 Amperes, with temperature differences starting from 50ºC, 55ºC, and 60ºC, and giving a holding time of 20 minutes, 30 minutes, and 40 minutes. From the results of the hardness testing, there was an increase in hardness compared to the test object that was not treated (HRC 55.82), namely: HRC 62.02, HRC 58.44, and HRC 61.56. In this process, the chromium hardening treatment provides hardening of the workpiece.

Furthermore, the authors tested the workpiece which was given an electric current of 270 Ampere with a temperature treatment of 50ºC - 60ºC. In this process, the authors also gave different time holding times, namely from 20 minutes, 30 minutes, and 40 minutes. The results of the Rockwell hardness test, namely the workpiece increase in hardness by HRC 60.74, HRC 62.08, and HRC 60.76, indicates that by treating the hard chromium workpiece, the workpiece will be harder than the untreated workpiece (HRC 55.82 (no 19)). By looking at the results of the tests that have been carried out by the author for testing the hardness of the FCD 40 workpiece that has been subjected to hard chromium treatment, the workpiece has increased its hardness level by 12.5%, namely HRC 62.82 which is treated with an electric current of 270 Ampere, 60 ºC, and a holding time of 20 minutes, compared to objects that were not subjected to hardening treatment.

V. CONCLUSION

The research that has been conducted by the author in conducting the FCD 40 Iron Surface Hardening experiment with the Electrochemical Hard Chrom Method at 2 Ton Die Cutting can be obtained from the following conclusions: 1. The process of making electrochemical hard chrome requires electrical equipment (power plants/transformers) with a constant voltage and has a large electric current (7,000 Ampere), chemical fluids (electrochemical electrolyte) for intermediates, cathodes, and anodes in the form of chromium, as well as tubs. Shelter. 2. The process provides a voltage of 380 Volt and an electric current of 270 Ampere on the surface hardening process of FCD 40. 3. The time required for the formation of good hard chromium is the holding time of 20 minutes. 4. As for the best heat retention is to use heating of 60oC on hard chromium hardening.

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