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Research paper

Analysis of traction motor axle cap repair programs using technology numerical control

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Abstract

In the process of a product manufacturing has a significant role in low costs of the production. Due to this case, the railway workshop has employed the numerical machine to repair the train component damages. This paper aims at analyzing a repairing program of the GE 761 traction motor axle cap using a technology numerical control (TNC) 355. The TNC itself is included on a category of a numerical control which is a method in operating a manufacturing machine automatically. The numerical data are needed to provide a part that is used by the machine which is known as a part program. The part program is processed by the machine to activate the motors that run the machine. This paper has analyzed 4 programs to repair the axle cap.

Keywords: *Analysis; axle cap; program; traction motor; technology numerical control.*

1. Introduction

The metal cutting process using cutting tools is a process that has often known in the process of product manufacturing. The railway workshop has an important role to fix the train component damage. One of the tools to repair the train component damage has been using a metal cutting tool machine which is a technology numerical control (TNC). Buying new train components is an expensive way to replace the components since it can be repaired. So, to low the production cost it needs to be repaired using a machine. The rapid development of technology in the production techniques has a capability to ease the production fields. The tool machines those are controlled by the computer system have roles to handle the part of production issues especially in the accuracy [1]. Basically, in repairing the train components it still encourages the capability and experience of the machine operator. It can be summarized that the development of production technology in increasing a product quality shall be done. The main aspect, in this case, is mastery of machining process technology. The basic parameter process machining is absolute to be mastered so it can be applied appropriately to the process conditions that must be carried out in various circumstances.

The numerical control (NC) tool machine roles more in the industrialization factors. One of the prominent characteristics is the ability to produce the same machinery products in mass quantities. This characteristic is very difficult to do when still using manual machine tools [2]. The working system of the TNC machine tool is a tool movement controlled by a computer system, an operator just needs to enter data in the formation of certain program instructions. Even in a complete system, all the processes in making a set of machines can all be done automatically [3].

Nowadays, there are many machining processes that use high-strength tools, so that they can be used at high cutting speeds. This affects the machining process that is carried out and takes place very efficiently. Other things that are done to reduce production costs are the use of coolant, which is intended to increase tool life. Although at this time various types of engine coolant have been found so that for certain processes the selection must be done correctly. This paper addresses at processing of repairing GE 761 traction motor axle cap using a lathe of TNC 355. The use that continues to operate certainly results in wear on the metal, especially this traction motor of the train. So improvements need to be made to minimize procurement costs which are quite expensive.

2. Numerical Control

The concept of automatically controlled industries is the main purpose of the automation revolution. A simple production machine and its mechanism that existed at the latest of the year 1700s has been replaced by the automatic mechanism and transfer line at the end of year 1900s thus continued with the cutting tool machines. In this era, the cutting tool machines were still using simple control. The industry's demands for production speed and product accuracy are difficult to obtain with manual engine operation, therefore automatic machining processes are needed in this case and must be involved in the industrial process. It is based on the assumption that the machining steps of a part of industrial processes can be written in such program instructions and the control system of a machine can read it, so that part of the program instructions can do automatically control the engine without the need for a human operator. The part programming is considered to the turning point of the industries of the metal cutting to meet the demands of designs with tight tolerance which it can't be done by the machinery with the manual approaching. The manual in here does not mean that it would be worked by human only but in some cases, it also means the majority of the works is done by the human than computerization.

The opinion about the part programming was seriously confirmed in the second world war when the United States (US) army needs a fighter jet and missile the war field, the realization could not be filled by the manufacturing process conventionally. So at last, the US government in the year of 1947 made a contract with John

Parson through the Parsons corporation to develop a dynamic system and the accuracy of manufacturing, which was to bring precision and design changes easily and cheaply. Then Parson subcontracted to Massachusetts Institute of Technology (MIT) in 1951 to develop a control system. In the year of 1952, MIT developed and demonstrated the three-axis Cincinnati Hydrotel milling machine called the numerical control (NC) engine. The existence of the NC has opened a new era of automation. This machine had an electromechanical controller and used punched cards.

The technology of the NC uses the principle based on the regulation of motion of the propulsion system of tools such as cutting and feeding but it is controlled through a programming part. The NC program is a set of statements that can be understood by an engine control system and converted into signals that can move spindles and drives. The NC has been defined by Electronic Industries Association (EIA) as a system whose actions are regulated through direct entry of numerical data at a point. The system must automatically interpret at least some parts of the data. The numerical data needed to produce those parts is called a part program. The first generation of the NC machines used vacuum tubes and the second generation used improved electronic tubes and finally used solid-state circuits. The first and second generation read program parts stored in a medium called punched tapes. A part program is stored on a punched tape which can be read by the engine controller. The third generation uses the integrated circuit (IC) and read-only memory (ROM) technology from the computer hardware to the controller so the NC machines and the third generation are commonly referred to as computer numerical control (CNC) machine tools. Further developments are added monitors to visualize editing of part programs. The technology numerical control (TNC) machines provide storage from program parts directly to the memory from the machine computer [4]. The TNC concept allows operating machine tools directly from memory. Programs that are always used routinely in operations are programmed in a subroutine or also called canned cycles and stored directly into a read-only memory (ROM). The fourth generation of NC machines has the ability to store better which is using a bubble memory technology, faster memory access, and macro reliability. This generation group is called numerical control machines. The NC hardware has undergone steady improvements, but the NC software is still experiencing rapid development [5]. Software development from NC is commonly called computer-aided manufacturing (CAM).

Numerical control is a term used to describe machine movement control and various other functions that use instructions expressed in a series of numbers and are controlled by an electronic control system. The term computerized numerical is used when the control system uses an internal computer. The internal computer allows additional program irregularities, program editing, running programs from memory, diagnostic controls and machine checks, routine or special work, and the ability to change inch/metric/absolute scale. Both systems are shown in Figure 1. The control unit is built into the main engine. At this time, usually, a part program contains a combination of machine tool codes and machine-specific instructions. It contains information about the geometric part and movement information to move the cutting tool, feed rate and additional functions such as turning the coolant on and off, spindle rotation direction, etc. programmed based on finishing surface requirements and tolerance.

Figure 1 shows the schematic of the technology numerical control (TNC) engine. The machine control unit (MCU) is also called a controlling unit that is considered as the brain of the NC machine. It reads part programs and controls machine tool operations. after reading the part program, it will give the command code and instructions to various control loop (CL) from the axis of the machine movement. The MCU forms two functions, namely reading data and controlling the machine. The MCU consists of two units namely data processing unit (DPU) and the control loop unit (CLU). The DPU functions to read data and distribute the coding of information and provide data to CLU. The CLU receives data from the DPU and converts it to the control signal. Data usually provides control information such as new positions needed from each axis, the direction of motion, speed and additional signal control to the relay. The CLU also instructs the DPU to read new instructions from the part program if needed, arranging drive systems that are connected to the leadscrew machine and receive feedback signals on the actual position and speed of the engine axes. The NC controller controls all functions of the machine from a motion control until an auxiliary control. The motion controller due to this term is the tool position, speed, and orientation whereas the auxiliary controller is a revolution per minute of the spindle, tool change, coolant, and fixture clamping.

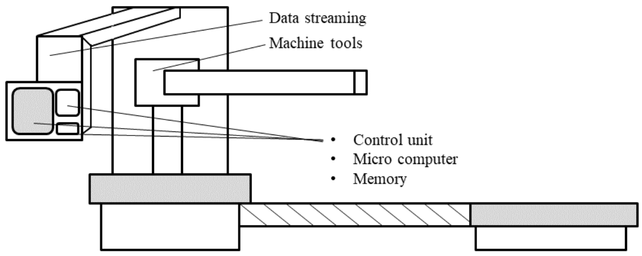

Fig. 1: Technology numerical control schematic

The classification of the machining process in terms of the type of tool and the relative motion between the tool and the workpiece have several terms. The chip as the result of cutting is formed due to the relative motion between the tool and the workpiece, and the tool used in the cutting is adjusted by the cutting method and the final shape of the cutting made. The relative motion of the tool to the workpiece produced by the cut surface can be separated into two types of movement components, namely cutting and feeding. The cutting motion is a chisel movement or movement of a workpiece which causes cutting while feeding motion can be interpreted as a movement to expand the cut surface. The combination of these two movements results in the machining process being grouped into seven different types of processes, i.e. cylindrical grinding, drilling, milling, turning, sawing, shaping/planning, and surface grinding.

The implementation of the machining process is influenced by several interrelated matters, all of which can be freely determined by the operator, but due to limiting conditions, such as the strength of chisel material and surface quality of the product, several basic elements are needed so that an efficient process is obtained. The five parameters due to this process are cutting speed, ς (meter per minute); cutting time, τ (minute); depth of cut, δ (millimeter); feeding speed, ξ (millimeter per minute); and rate of metal removal, ϖ (cubic centimeter per minute). These five machining process parameters are calculated based on the dimensions of the workpiece, tool, and magnitude obtained from the machine tool. The number of machine tools can be arranged according to the type of machine. Each process that is reviewed is determined by two important tool angles, namely, rake angle and main cutting angle. These two angles affect the chip cross section which plays a role in determining the cutting force and tool life. The equation of these five parameters could be shown in (1), (2), (3), (4), and (5), respectively.

$$\varsigma = \frac{\eta . \rho_m . (1+\gamma)}{2000} \quad (1)$$

Definition 1: *This is an equation of the cutting speed average where η is a number of cycle per minute (cycle per minute) and ρ_m is a machining length (millimeter) which is sum of a workpiece cutting length, ρ_w (millimeter); initial length, ρ_i (millimeter); and end length, ρ_e (millimeter). While γ is a speed ratio between forwarding speed and backward speed. The result of this ratio should be less than 1.*

$$\tau = \frac{\varepsilon}{\xi} \tag{2}$$

Definition 2: *This is an equation of the cutting time where ε is a workpiece cutting width (millimeter).*

$$\delta = \frac{\varpi}{\kappa\varsigma} \tag{3}$$

Definition 3: *This is an equation of the depth of cut where κ is a feeding motion (millimeter per cycle).*

$$\xi = \eta.\kappa \tag{4}$$

Definition 4: *This is an equation of the feeding speed.*

$$\varpi = \alpha\varsigma \tag{5}$$

Definition 5: *This is an equation of the rate of metal removal where α is multiplication between chip thick before being cut off and chip width before being cut off or it is also a multiplication between κ and δ.*

While spindle rotation speed, σ (revolution per minute) is shown in (6).

$$\sigma = \frac{\varsigma_c \times 1000}{\delta \times \pi} \tag{6}$$

Definition 6: *This is an equation of the spindle rotation speed where ς_c is a cutting speed and π is a constant which has a value of 22/7.*

It is impossible to eliminate the involvement of the human totally from the machine operating processes. There is no automatic machine capable of making a decision in the words form. Its ability depends on the manual respond or the computer program that has been set up while the decision is made when making programs [6]. Through the program, the machine controller is given the instruction reflecting a decision in the process. However, perhaps the NC machine for a further generation could be considered to embed some intelligent programs and add some components for working on the production process due to the fourth industrial era [7]. It gets the intelligent numerical control instead. With this machine could be more reducing the production costs since it could have a piece of knowledge.

3. Axle cap of GE 761 traction motor

An axle cap of GE 761 traction motor in its implementation is a railway axle. It forms a cylindrical shape and large cylindrical hole parts are used as magnetic commutators. This shows that the axle will work a number of styles that will cause wear because it is swiped too often. So it needs to be repaired to reposition the axle cap surface. One way to speed up the repair process is to use the TNC lathe, where part programs have been created and then executed to act as the program does. The operation of TNC machines is enough with operators who are experienced in turning only because the program instructions are available. So that technically, the repair and operation of the TNC have been understood and that is sufficient as one production system tool because what is done is only to repair the axle cap.

Before making repairs, the axle cap must be known to be precisely and accurately measured so that it makes it easy to make the program. The axle cap sizes are measured through a fixture, the distances between holes, and the thin/thickness is very important to be described. The dimensions of the GE 761 traction motor axle cap are shown in Figure 2.

The axle cap that is worn, perforated, and cracked needs to be welded first so that after it has been lathed with TNC, the condition is as before, in addition, to maintain the life of the axle cap itself. The obstacle to repairing this axle cap is the thin thickness of weld. Repairing the axle cap in this way makes production costs less because it doesn't have to bring in a new axle to replace the worn axle cap. By bringing in a new axle cap, it will cost a lot because it imports goods from abroad.

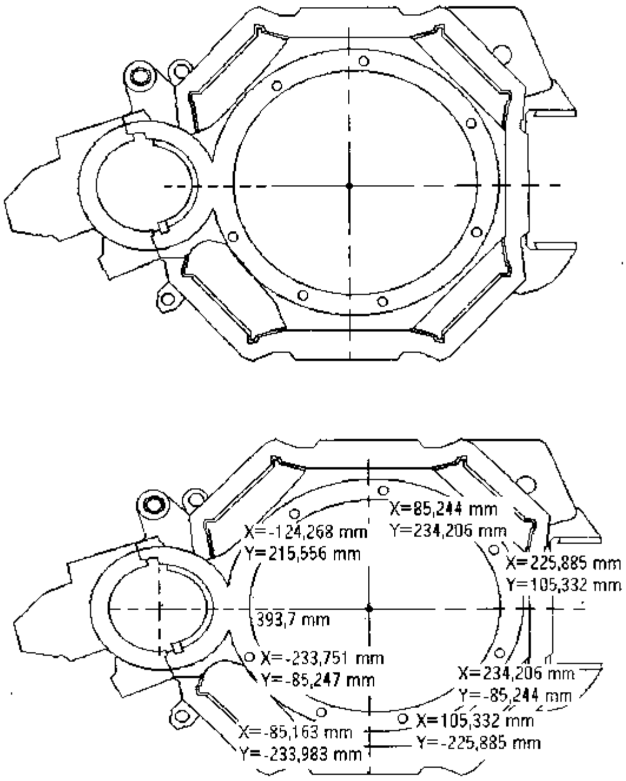

Fig. 2: Axle cap of GE 761 traction motor

4. Result and Discussion

Programmed part programs must always be initialized first. The compensation value is referenced to the zero tool, where for devices that are longer than the zero tool, it will be marked as a positive, while devices shorter than the zero tool will be marked as a negative. The tool size definition needs to be programmed, so the operator is required to be observant in using the tool to be used, in addition to making it easier to use the tool when it wants to be installed for the next works. In using the tool, the operator can use tool numbering to be used in defining the characteristic of the tool so it would not matter for the next program since it will be stored in memory. This is usually very useful when using program instructions for repairing many axle caps. When the program has stopped from a series of improvement programs, it can be continued with the replacement of tools from the original device. The spindle rotation speed used in this axle cap repair process is always set. Linear milling is carried out in the coordinates of X and Y. It must always be placed at the center as zero point (0) as shown in Figure 3.

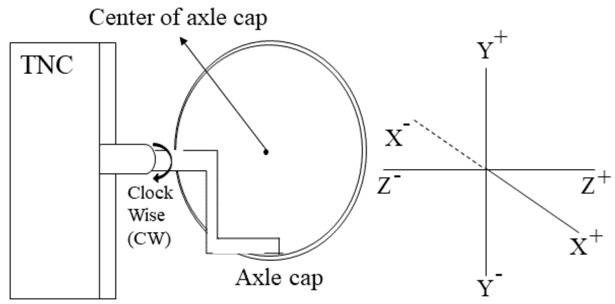

Fig. 3: Position of TNC and axle cap

An initial of feeding speed is set at the start with lower than when it is milling and the spindle is set to rotate clockwise. For conditions where it is working, the feed speed is programmed into 3000 and if the tool is used too long, then to reduce the heat from friction between the tool and the object can use coolant so that the heat that occurs can be minimized. This process lasts until it's finished by moving the work area above which axle cap is placed. This paper uses 4 programs for repairing the axle cap i.e. program of small hole axle cap, leveling the small hole axle cap surface, forming the main hole axle cap, and finishing the main hole axle cap. These programs can be written as pseudocodes as shown below,

1. Program of small hole axle cap

Start
Define tool 2: Left = +95, Right = +50;
Set position Z = 0 & Spindle speed=25 RPM;
Set position: X & Y='0' & Set feeding speed 1000 meters per minute;
Set feeding speed 3000 meters per minute;
A position of the milling process => left contour with 10 mm backward working table;
A position of the milling process => at the contour with 16 mm forward working table;
Set right milling;
Circle motion => radius 10 mm;
Set center of the circle with X & Y = '0';
Set position Y = +115 mm;
Circle motion => radius 10 mm;
Set coordinate position: X & Y='0';
Back working table 10 mm;
End;

2. Program of levelling the small hole axle cap surface

Start
Define tool 2: Left = +95, Right = +50;
Set position Z = 0 & Spindle speed=100 RPM;
Set position: X & Y='0' & Set feeding speed 1000 meter per minute;
Position of the milling process => left contour with 10 mm backward working table;
Set feeding speed 3000 meter per minute;
Position of the milling process => at the contour with 5 mm forward working table;
Set right milling;
Circle motion => radius 10 mm;
Set center of circle with X & Y = '0';
Set position Y = +147 mm;
Circle motion => radius 10 mm;
Set coordinate position: X & Y='0';
Back working table 10 mm;
End;

These 2 programs are used to work for the small hole axle cap as shown in Figure 4.

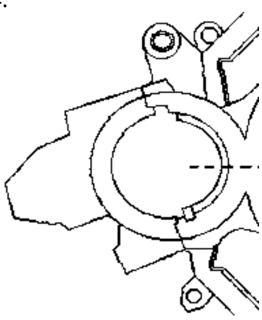

Fig. 4: Small hole axle cap

3. Program of forming the main hole axle cap

Start
Define tool 3: Left = +65, Right = +60;
Set position Z = 0 & Spindle speed=10 RPM;
Milled linearly with X = -393.8;
Set tool => center of axle cap;
Set working table => Z = -20;
Set feeding speed 50 meter per minute;
Working table forward;
If position Z = -195 then working table backward 10 mm with feeding speed=1000 meter per minute;
Else working table forward;
End;

4. Program of finishing the main hole axle cap

Start
Define tool 20: Left = +130, Right = +60;
Set position Z = 0 & Spindle speed=10 RPM;
Milled linearly with X = -393.8;
Set tool => center of axle cap;
Set working table => Z = -20;
Set feeding speed 50 meter per minute;
Working table forward;
If position Z = -190 then working table backward 10 mm with feeding speed=1000 meter per minute;
Else working table forward;
End;

The programs of forming and finishing of axle cap are almost similar, except that the difference between the two programs is the difference using tool sizes. The axle cap forming program uses a tool with a length of 65 mm from the long zero tool reference and its radius of 60 mm while the axle cap finishing program uses a tool with a length of 130 mm from the length of the zero tool and its radius of 60 mm.

5. Conclusion

For repairing GE 761 traction motor axle cap using a lathe of TNC 355 in this paper has been shown and implementing 4 programs. The part programs contain thinking about machine operation so that if this program already exists then no expert operator is required to operate the machine where this does not apply to the operation of conventional machine tools. But behind that, part programmers are required to understand manufacturing requirements such as a chisel, coolant, fixture design, data use machinability, and engineering processes. In addition, operators are required to understand and recognize the functions of TNC machines and machining processes. Generally, the main components of a conventional cutting machine are similar to TNC cutting machine tools. One difference is that the TNC regulatory system is controlled automatically through a part program.

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