5 Axis CNC Tire Surface Prototype Machine

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Abstract:

Nowadays, the usage and need of vehicle tires increase as the usage of motorized vehicles enhanced. The design and production of economical and safe vehicles with less fuel consumption are very important in the automobile industry. The decreasing of friction between the tire and road depends on the optimal tire parameters. Similarly, a better road grip and safe braking distance are also among of the important parameters. In order to improve these parameters, the design of tread pattern of tires is very important as much as the material of tires. The tread patterns are processed on the mold during the tire production. On the other hand, CNC lathes (Computer Numerical Control) are employed for machining on the molds. The more complex tread patterns, the more need for 5-axis CNC lathe increase. In this study, a development of 5-axis CNC lathe prototype is aimed for tire mold. The prototype that will be produced in this work is not only a tread pattern machine but also it has capable of marking on the tire surface. The algorithms based on advanced mathematical derivation were developed to operate CNC lathe properly. Besides, the studies based on spline methods are proceeding to increase the sensitivity of the prototype machine.

Key words: Spline model method, 5 Axis CNC, tire mold, tire surface prototype machine.

1. Introduction

CNCs are an industrial machines used in many different branches of industry. They are basic and essential machines for the sectors that require precision, standardization, and rapid production. Therefore, CNC machine tools takes place of conventional machining in day by day in many industrial operations.

Many surface required for processing in industrial applications has irregularities. Because of irregular curvatures in the workpieces, machining applications are not easy processes. Besides, 5-axis surface irregular curvature increases the need of CNC machines. Namely, while the surface complexity increases, the need for 5-axis CNC machine gets more crucial [1-3]. The manufacturers of tool and molds have opinion that 5-axis CNC machines have more efficiency around 10 and 20 times than that of 3-axis CNC machines [4-5]. The operation time is reduced up

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to 85 % in the 5-axis machine tools since they use advanced cutting techniques [6]. 5-axis CNC machine molds, are used in the manufacture of turbine blades and aircraft parts. These parts typically have complex geometries. When compared 3-axis CNC and 5 axis CNC machines, 5-axis CNCs have high machinability and surface quality [7-12].

Recently, 5-axis CNC machines have gained more importance as the production rate increases at industrial operations. The most important advantages of 5-axis CNC is good surface quality, less processing time, low installation and low operating costs [13]. In order to obtain better surface quality, one of the issues that most of the researchers search in the last 30 years is to determine the cutting path in the best way automatically [14-19].

One can find many researches in the literature about the machining operations similar to the subject of this study. From the industrial point of view, many industrial companies operate to work on improvement of manufacturing and CNC machines. In this study the mathematical model by subtracting 5-axis CNC machine tools, mechanical and software design were studied [20].

2. 5 Axis CNC

In the industry for aerospace, automotive, defense, molding and medical components, production of the machine parts are the most encountered processes. For the production and machining of the parts, various computer-aided design tools are developed. Applications such as surface and solid modeling get easier in this way. Besides, these products are becoming important as the production design. Computer aided manufacturing packages developed in recent years has been working to meet this growing need. Due to geometrical constraints the processing of complex surfaces, 3-axis milling also required to connect multiple parts. In order to produce a piece of one binding, 5-axis machine tools have been developed [21]. In this study, it is aimed to be manufactured as a 5-axis CNC prototype will be used in many different sectors including tire industry. The biggest feature that separates this 5-axis CNC machine from tire mold pattern and the other 5-axis CNC machine is the cutter motor (Spindle Motor) which is very high head speeds. Normally a 5-axis CNC machine head speed 6000-8000 rev / min works. The head speed of 5 axis machines that will do the marking process aimed in this study should be approximately 40,000 rev / min. The purpose of the need for high speed, is related to the size of the cutting tool. For the cutting diameter of the cutting tool is less than 1mm, high speed is required in order to remove material from the mold surface. During the marking process in complex geometries is to allow tool not to crash mold when machining. Also, the machine body is made from steel casting construction in operation, the pieces will be able to process more precise. The rigid body structure is expected to be realized higher quality product in this way.

2. 1. 5 Axis CNC Mechanical Design

A unique mechanical design for the prototype machine was determined in this study. The mechanical design has been implemented precisely so that it can be used in different sectors. By

planning design principles, prototype machine design was made in computer software. Mechanical calculations and technical drawings were performed on a computer. The mechanical design of the prototype machine work is completed. Firstly, a preliminary design studies were carried out in the computing environment in the study. Then, some changes and revisions were performed on the preliminary design. Drawing of pre mechanical design work is shown in Fig. 1. After some modifications and optimizations, the final version of the prototype machine was designed as shown in Fig. 2.

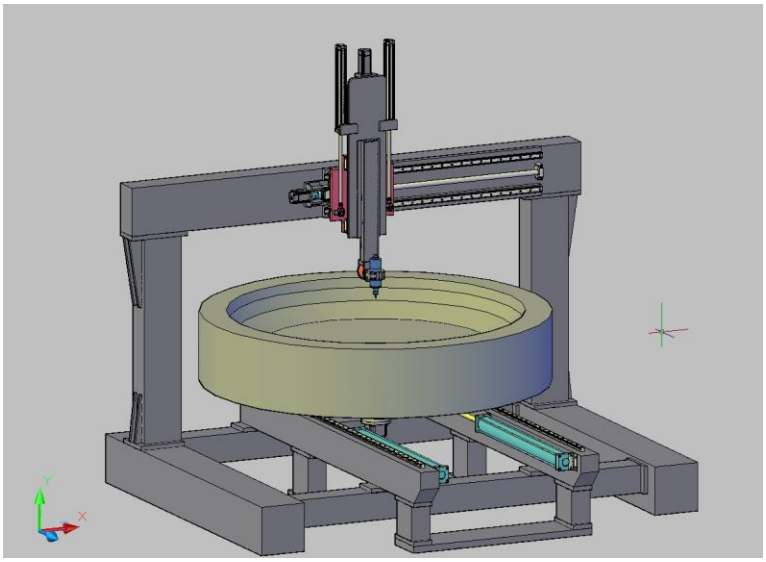

Figure 1. Pre Mechanical Design

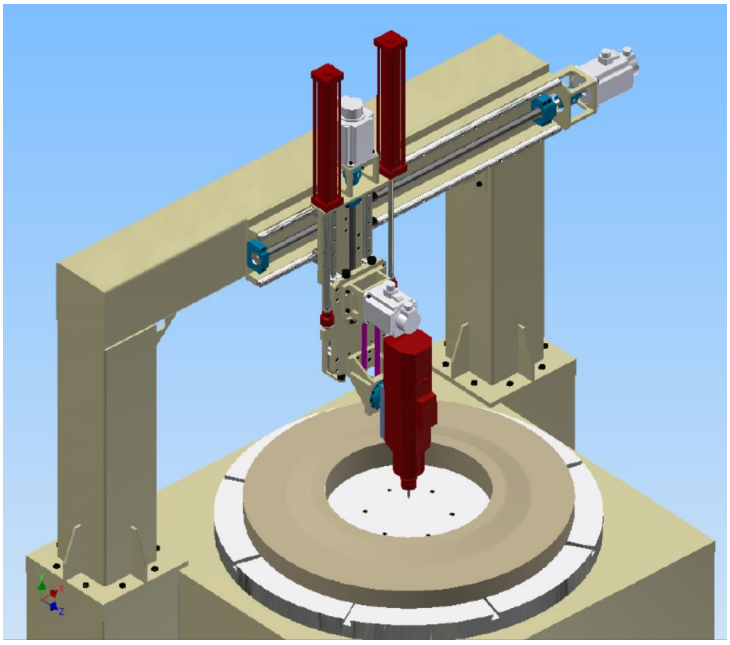

Figure 2. Revised Mechanical Design

2. 2. 5 Axis CNC Software Design

The most important innovative aspect of this project is to develop a specific and original software. For this aim, a comprehensive literature search was made for the software. Many software using similar characteristics machine were examined. The most important job in this stage is to figure out the mathematical model of the drawings on the computer environment. For this purpose, Autodesk AutoCAD software was examined. The studies about the DXF files generated by different drawing program have been investigated. After examining files created in the Numerical Control (NC) environment, a unique software research work was developed. To determine the accuracy of the software output, many tests were carried out on 3-axis CNC machine. It was observed that the 3-axis CNC machine working is simultaneously with this software algorithm. Moreover, the algorithm is verified by controlling NC files. A satisfactory accuracy for the coordinate's axis was obtained in the experiments.

It is aimed to use different techniques for trajectory interpolation of the cutting tool on the work piece. For instance, 'spline' method for fitting function between two points gained importance. When degree of interpolation polynomial increases, function becomes long and complex and the actual curve between points has largely deviations compared to real curve arises. The reasons of this problem for this polynomial are, not containing information about the gradient at these points, the formation of poorly conditioned systems equations and rounding errors. Polynomial interpolation which is closest to real function must use all points of trajectory.
In this study, it is aimed to acquire more precise and faster processing capability to cutting tool tip with this polynomial interpolation type. Products will emerge in the desired quality by following trajectories of CNC cutting tool tip. A part from unique software algorithm flowchart is shown in Fig. 3. The length of the particle size is calculated using the Euclidean distance. Euclidean distance is the Pythagorean Theorem which is a measure of distance from a point to another point of based on the linear method. To compare the classification according to the number of generated data sets, computer compares with the average of the new data by scanning the entire data set and the object is assigned to the closest cluster.

n - dimensional Euclidean distance for $X=(x_1, x_{2,}, ..., x_n)$ $M=(m_1, m_{2,}, ..., m_n)$ points is calculated as in Eq. 1. Eq. 1 shows line distance. Eq. 2 shows distance for circle or arc.

$$\sqrt{(x_1-m_1)^2+(x_2-m_2)^2+...+(x_n-m_n)^2}=\sqrt{\sum_{i=1}^{n}(x_i-m_i)^2} \quad (1)$$

$$|Arc|=\frac{2\pi r}{360}|\alpha-\beta| \quad (2)$$

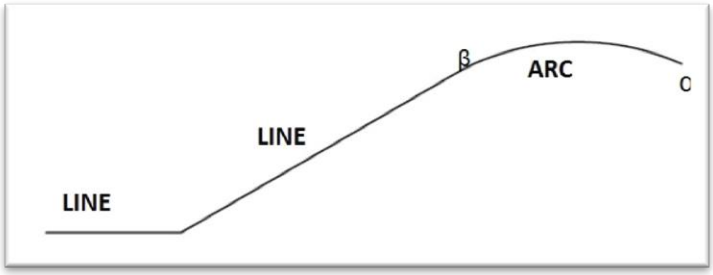

Figure 2. The Illustration of Line and Arc

In Fig. 2, a sample trajectory is shown and it is used for algorithm accuracy. Fig.3 shows how this algorithm works.

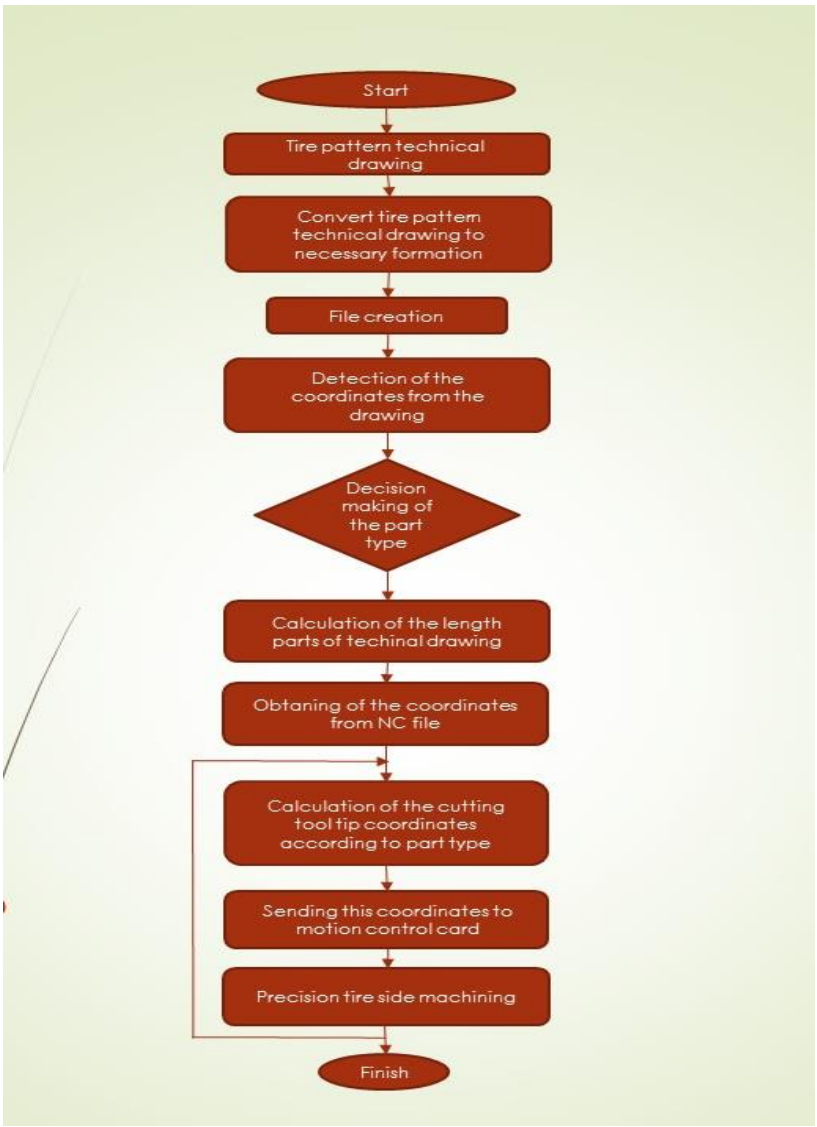

Figure 3. Software Algorithm Flow-Chart

3. Conclusions

In this study, a 5-axis CNC machine design has been implemented in a computer environment. Mathematical models for software algorithm to be used in the prototype machine were developed. Software algorithm according to the trajectory plan was created from the NC file. For next studies it is planned to integrated Spline model for more sensitive and fast trajectory tracking.

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