Deformation control method of rapid prototyping parts based on laser triangulation

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Keywords: Laser triangulation: Rapid prototyping parts; Deformation control method

Abstract: Aiming at the problem that the measuring equipment used in the off-line measurement of the profile error of super slender helical surface workpiece can not meet the requirements of workpiece length and stable rotation of workpiece, a free-form surface part measurement system based on laser triangulation is proposed. The system is equipped with a laser detection system by using the positioning, clamping, support, motion and control mechanism of machine tool, It is realized by adding moving parts. From the perspective of software control, the general idea and implementation method of laser processing of functionally graded material parts are discussed. The differences of scanning path planning methods between plane and surface in one-dimensional functionally graded material parts are explained; The key technologies in the processing of one-dimensional and two-dimensional FGM parts, such as the calculation method of different material content of one-dimensional FGM parts with the number of layers, the calculation method of slice layer thickness of two-dimensional FGM and so on. The hardware technology platform of on-board laser detection is constructed; In this paper, through the analysis and processing of the collected point cloud data, the section profile of the measured workpiece is drawn. The results show that the system improves the efficiency and accuracy of detection, improves the accuracy of slender helical surface parts, and realizes the accurate measurement of helical surface profile.

1. Introduction

With the development of science and technology and industrial production, there are more and more measurements of surface profile, geometric dimensions, various molds and free-form surfaces, and the requirements for accuracy are higher and higher. In particular, the development of aerospace, automobile industry and mold industry has more and more urgent requirements for high-precision and high-speed measurement of free-form surfaces [1]. The traditional method of manufacturing metal parts has the advantages of long production cycle, high production cost and low design flexibility. It is usually only suitable for mass production, and expensive tools and molds need to be made. However, the parts required in actual production may be single pieces or small batches, which puts forward an interesting topic to people [2]. At present, the probe contact method is mostly used in this measurement, and the contact method has many limitations. It is not suitable for measuring the high-precision surface composed of soft materials that are easy to be scratched; And its speed is slow and efficiency is low [3]. Because FGM is especially suitable for special occasions or extreme conditions, it can improve the service life of parts, improve the service life of the whole equipment, reduce the maintenance cost of equipment, and greatly improve the utilization rate of equipment [4]. It is difficult to realize automation and intelligence in the measurement process. Therefore, it is very important to study the non-contact measurement method, which is also urgently needed in the measurement work [5].

Laser triangulation is a mature ranging method with simple principle and implementation method. It has been widely used in laser ranging sensors [6]. This technology rapidly melts the metal surface locally by high-energy laser beam to form a molten pool, so as to realize the combination of metal raw materials and matrix atomic scale, and can complete the rapid, die free and near net shape of complex metal components [7]. Laser rapid prototyping has the characteristics of rapid solidification, which makes the fabricated metal components have fine dendrite structure

and excellent performance, and its performance index can be equivalent to that of forgings [8]. Laser rapid prototyping meets the main needs of material processing technology, such as short process, low energy consumption, high flexibility, environmental friendliness, integration of forming and microstructure and performance control, so it has attracted much attention in the research and application of various metal materials [9]. With the emergence of these principles and methods and the progress of technology, people pay attention to the research of laser triangular ranging sensor. It is also possible to use laser triangular ranging sensor to obtain large measurement range and high measurement accuracy [10].

2. Laser triangulation technology

2.1. Triangulation measurement principle

Laser triangulation measurement technology is a non-contact displacement detection method. Its principle is to convert the optical signal carrying displacement information into electrical signal, which is recognized and processed by computer. Because the incident light and reflected light constitute a triangle during sensor measurement, it is called the principle of optical triangulation. The optical path system is mainly composed of semiconductor laser, convergent lens, receiving lens, photodetector and subsequent signal processing circuit. As shown in Figure 1:

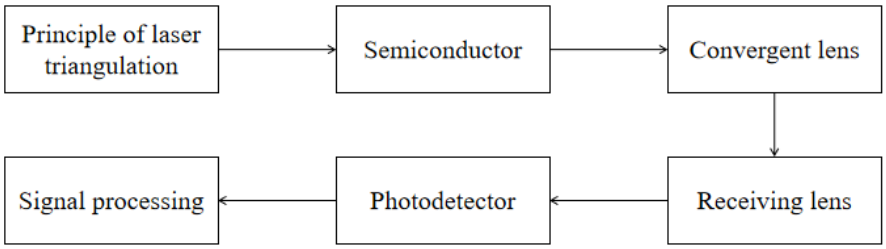

Figure 1 Schematic diagram of laser triangulation measurement

Thin and long parts, such as rack, guide rail, slender shaft, thin-walled gears with medium and small modulus, etc. Due to the particularity of its shape, i.e. slender or thin, it often causes warpage and distortion during conventional treatment. Its deformation amount and deformation orientation are difficult to control and predict, especially the distortion deformation, which is very difficult to correct. After heat treatment, due to the large amount of deformation, it can not be corrected, resulting in a large amount of scrap. Laser heat treatment makes the local and instantaneous quenching area of heat treatment relatively small. As long as the laser parameters are correct and the process method is reasonable, the deformation can be controlled according to its deformation law, and the correction is also very convenient. Laser transformation hardening is characterized by rapid cooling by itself to harden the surface of parts. That is, during laser scanning, the surface heat can be quickly transmitted to the substrate, and the thermal stress of the part can be reduced to control the deformation. The section size of thin and long parts is relatively small compared with the processing surface. The heat of laser radiation cannot diffuse to depth and accumulate in the parts, so that the whole matrix is heat permeable and the temperature rise is very high, resulting in great thermal stress. The plasticity of the treated surface increases, the yield strength decreases, and the thermal stress greatly exceeds the elastic limit of the material, resulting in compression deformation of the surface, which is often regular warpage. This deformation is mainly caused by high substrate temperature and large thermal stress. After the laser triangulation method is adopted, due to the reasonable laser process method and convenient operation, the local deformation and overall deformation are very small, and the deformation fully meets the requirements.

2.2. Deformation control and correction based on

For special thin and long parts, the deformation is still obvious after laser treatment. Therefore, we have improved the process method to avoid or reduce the deformation after treatment, and achieved good results. Quenching and tempering is very important for parts before laser quenching.

After quenching and tempering parts, the non-uniformity of microstructure has been basically improved. Grain refinement is very favorable for controlling deformation after laser treatment. There are usually two methods to harden the gear tooth surface by using broadband beam to scan along the axial direction of the tooth surface. The tooth by tooth scanning method scans the teeth in sequence. That is, every time the laser scans, the gear turns one tooth, and so on. After the treatment of the tooth surface on the same side of the gear is completed, the scanning on the other side is carried out. When laser triangulation is used, the molten pool formed is very small, and parts with precise shape can be made. Because the size of the burning node is similar to the effective diameter of the laser beam, the wall thickness of the parts can be adjusted accurately, which reduces the post-treatment process. There are a wide variety of materials that can be formed. As long as the processed material has low reflectivity to the laser wavelength of the laser used, this material can be treated by lens method. Laser coating manufacturing technology is easy to realize selective cladding, and can be used to repair large metal parts. There is no need to make expensive tools and molds, and the production cost is low. The laser proximity method improves the flexibility of design. By changing the model file, the design engineer can modify and supplement the parts conveniently and economically, and flexibly change the composition of different parts of the parts, so that the parts have excellent comprehensive performance. The production cycle is greatly shortened and the efficiency is high.

3. Laser triangulation manufacturing parts

3.1. Composition of laser direct manufacturing molding system

The laser direct manufacturing and forming system of metal parts is mainly composed of eight modules: laser generator system, powder delivery device, coaxial powder feeder, three-dimensional motion workbench system, cooling water circulation system, argon protection, motion control hardware system and software control system. As shown in Figure 2:

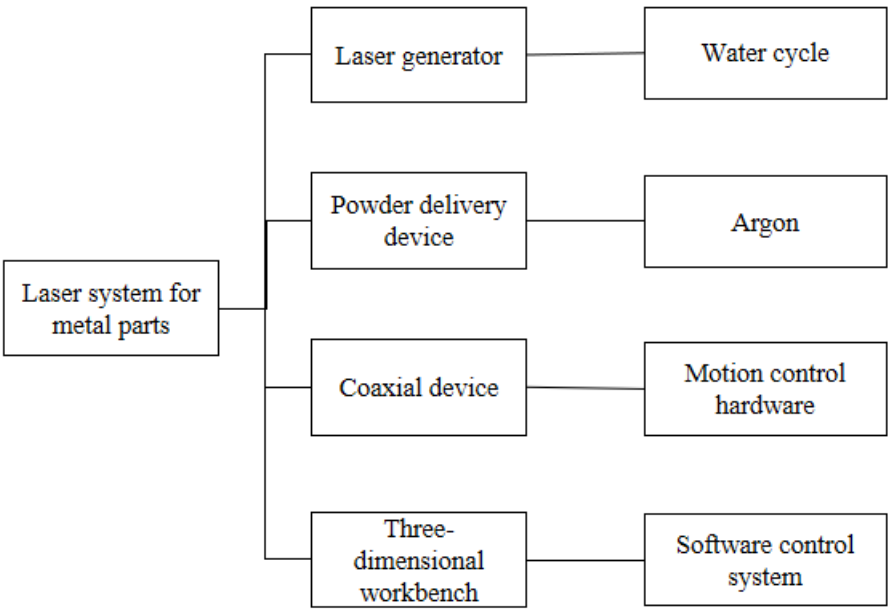

Figure 2 Laser manufacturing and forming system of metal parts

The working behavior of all components of the optical direct manufacturing system is to complete the cooperative movement under the unified command of the industrial control computer. The laser generator system is a necessary part of generating laser. The cooling water circulation system provides circulating cooling water for the laser, shutter, mirror, focusing lens and powder nozzle to take away the heat generated by the laser, so as to avoid burning of hardware equipment. The motion control hardware system is mainly composed of industrial computer, motion control card, switching power supply, stepper motor driver and other hardware equipment. It is the

hardware basis for realizing the automatic forming process. Its main control object is the rotating motion of the stepper motor of the three-dimensional worktable and powder delivery device; The software control system is specially developed to realize the overall control of the laser direct manufacturing and forming system. Only under the control and management of the software control system can the laser direct manufacturing and forming system realize the whole process of complete, orderly and coordinated part forming movement. Laser rapid prototyping technology has many advantages, such as wide range of applicable materials, dense solidification structure, high energy density, etc. these advantages are conducive to the significant improvement of various properties of materials. Therefore, the properties of manufactured parts are higher than those of castings and equivalent to forgings. Therefore, laser triangulation technology has great research and application prospects in the fields of machinery, nuclear energy, aviation, electronics, optics, chemistry and even daily life.

3.2. Laser rapid manufacturing and forming parts processing

Stepper motor is an actuator that uses electric pulse signal to convert electric pulse into corresponding angular displacement or linear displacement. When the stepping driver receives a pulse signal, it drives the stepping motor to rotate a fixed angle in the set direction. The angular displacement can be controlled by controlling the number of pulses, so as to achieve the purpose of accurate positioning. At the same time, the speed and acceleration of motor rotation can be controlled by controlling the pulse frequency, so as to achieve the purpose of speed regulation. The system uses the lead screw nut mechanism to turn the rotation of the stepping motor into the movement of the platform. The laser direct manufacturing and forming system uses the high-energy and high-density laser beam to act on the material surface to rapidly heat up and melt, so as to form rapidly. At present, the processing methods of functionally graded materials mainly include vapor deposition method, plasma spraying method, self propagating high temperature synthesis method, powder metallurgy method and laser cladding method. These methods are more effective for the processing of one-dimensional functionally graded materials, but it is difficult for the processing of two-dimensional functionally graded materials. Under the irradiation of high-power density laser beam, Because the heating time is very short, the cooling speed is very fast, and it is local quenching, and the instantaneous quenching area is very small relative to the size of the part, the expansion and shrinkage deformation caused by the organizational stress and thermal stress are strongly restricted by the whole part, so that the ideal effect of small deformation can be obtained for the parts after laser heat treatment, and the parts after laser heat treatment do not need to be reshaped.

4. Conclusion

This paper presents a free-form surface part measurement system based on the principle of laser triangulation. By adding a laser measurement system to the NC spiral milling machine, the on-machine accurate measurement of slender screw is realized. Compared with the traditional off-line measurement, this technology reduces the labor intensity of workers, improves the efficiency and accuracy of detection, and reduces the investment of measurement cost, It is of great significance to improve the accuracy of slender helical surface parts. The realization methods of laser processing of one-dimensional and two-dimensional functionally graded material parts are discussed, and the key technologies such as the addition of gradient information and material information are solved. It has certain practical value for the popularization and application of laser processing of graded material parts. The measured profile of the surface is obtained through the detection report obtained by the on-machine detection system and the analysis and calculation of the measured data by the measurement software. The error of the measured workpiece is obtained by comparing with the theoretical profile. In addition, for the unknown screw, the workpiece with unknown profile can be measured through the profile reconstruction function, so as to obtain the profile and related parameters of the screw, and the same product can be processed according to the measured results. The measurement system has a wide application prospect.

Acknowledgements

Key scientific research project of Hunan Provincial Department of Education *Research and Exploration on power matching and energy saving control technology of hydraulic excavator* Item No (19A151)

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