Research on feed motion control based on fuzzy PID short arc milling

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Abstract. The short arc machining technology uses special current waveform produced by the special power supply of short arc for discharge processing, and there is a more obvious arc generation when discharge. The PID controller consists of three links, the proportion link, the integral loop and the differential link. PID control requires strict tuning of controller parameters, so that when the parameters change, PID controller parameters cannot be adjusted with the change of the controlled object, and self-optimization will lead to larger system overshoot. The paper presents research on feed motion control based on fuzzy PID short arc milling.

1. Introduction
Fuzzy control is a kind of control method based on fuzzy set theory. The fuzzy controller consists of four parts: 1) fuzzification, which refers to mapping the input quantity to a suitable response domain range. Then the process of converting the correct data into the appropriate language value or fuzzy set. Database and language (fuzzy) control rule set. Database provides necessary definitions for domain discretization and membership functions of language control rules [1]. Language control rules mark control objectives and domainers' control strategies. 3) reasoning machine. According to the fuzzy input and fuzzy control rules, fuzzy reasoning solves the module relation equation and obtains fuzzy output. 4) fuzzy decision, which plays the role of fuzzy inference. And produces an accurate or non-fuzzy control effect.

The manufacturing industry, especially the ability and level of the equipment manufacturing industry will determine the economic strength, national defense strength, comprehensive national strength and in the global economy competition and cooperation ability, determines a country, especially the developing countries to realize modernization and national rejuvenation process. As has just entered the middle stage of industrialization in developing countries, we must be sober to improve the manufacturing industry, especially the overall capacity of the equipment manufacturing industry and the overall competition ability is very important for their own development. Therefore, we must be firm and indomitable spirit of perseverance to develop a manufacturing power to the road.

The manufacturing industry level depends on the level of technology and equipment, technology and equipment requirements for the continuous improvement of the level has spawned a generation of advanced manufacturing technology and equipment, a kind of short arc machining technique is one of them. This section mainly introduces "the source of this research" discharge parameters acquisition system of short arc machining in the background and significance of this paper is to study the content and importance.
The so-called PID, is the integration of proportion, integral and differential control. The proportional controller is the principle of automatic control in the most typical use, also widely used, can be regarded as a proportional amplifier [2]. The main advantages of the proportional controller is its simplicity, but its disadvantage is the existence of steady state error.

The modern control system, more and more large scale systems are more and more complex, traditional control theory and methods have been unable to meet the requirements of control [3]. Intelligent control is developed based on the classical control theory and modern control theory, control theory, artificial intelligence and computer science combined with intelligent control mainly. Fuzzy logic control, neural network control and real-time expert system. The main objective of the study is not only the object, but also includes the controller itself.

The fuzzy theory is developed in the fuzzy L.A. Zadeh professor of electrical engineering at the United States Department of Berkeley University of California was founded in 1965 to set up on the basis of mathematical theory, including the theory of fuzzy sets, fuzzy logic, fuzzy reasoning and fuzzy control and other aspects.

2. Analysis of error free tracking technology by fuzzy PID controller
The milling machine mainly refers to the machine tool that uses the milling cutter to process many kinds of surfaces on the workpiece [4]. Usually the milling cutter rotates the motion mainly, the workpiece (and) the milling cutter moves as the feed motion. It can process the plane, the groove. Milling machine is a machine tool for milling workpiece with milling cutter. Besides milling plane, groove, gear tooth, thread and spline shaft, milling machine can also process more complex surface. The efficiency is higher than the planer.

Milling machine can process plane (horizontal plane, vertical plane, groove (keyway T-groove, swallowtail groove, etc.), tooth dividing parts (gear, spline shaft, sprocket, spiral surface (thread). Helical grooves) and various curved surfaces. In addition, it can also be used for machining and cutting off the surface of rotary body, inner hole, etc. When the milling machine is working, the workpiece is installed on the worktable or on the accessories such as the dividing head, and the milling cutter rotates mainly [5]. With the feed movement of the worktable or milling head, the workpiece can obtain the needed machined surface. The productivity of the milling machine is higher because of the multi-blade intermittent cutting. Simply speaking, the milling machine can mill the workpiece.

Milling machine spindle center line and the work table. The table has three parallel vertical horizontal and vertical direction can be moved. A longitudinal worktable can in the horizontal plane to rotate around 0 - 45 degrees. Such as the reasonable choice of accessories and tools, machinery parts of almost any shape milling.

The center line of the spindle of milling machine is perpendicular to the working table. Some vertical milling processes need to be tilted to a certain angle because of processing needs, so that the milling inclined plane can be tilted. The vertical milling machine is usually used for milling plane inclined planes or trenches, gears and other parts.

This milling machine has enough rigidity, suitable for powerful milling, machining large parts, such as planes, trenches, etc. the machine tool is equipped with two axes, three axes or even more spindles for Multi Tool and multi station milling. The production rate is very high [6].

Boring and milling machining center has been widely used in the production. He can undertake milling in small parts or complex surface. The milling machining center can conduct drilling, milling and boring cutter, wire lines and other comprehensive processing, in a clamping workpiece can automatically replace the tool, milling, drilling, reaming, boring, threads and other processes.

The PID controller consists of three parts, the proportional link, the integral loop and the differential link. In classical control theory, PI (proportional integral) control is equivalent to a lag correction link, and PD (proportional derivative) control is equivalent to a lead correction link. Conventional PID control.

$$u = k_p e + k_i \int e dt + k_D \frac{de}{dt}$$  \hspace{1cm} (1)
With the continuous development and progress of science and technology, many new types of equipment have put forward higher and higher requirements for the overall performance and various comprehensive technical indicators, especially in the field of aerospace, military industry and special industries.

In order to meet the special requirements of the products, the materials used in the products are often required to different performance indicators. Among them, the hardness, strength and toughness of materials often become one of the important technical indicators of materials. The shortage of machining means has gradually become a technical problem in front of the machinery manufacturing industry.

The surface removal of tough materials such as high toughness has always been one of the difficult problems in mechanical manufacturing, although grinding machines can be used at present. EDM machine tools and carbon-arc gas explosion machining technology for this kind of material surface removal processing, but there are a lot of limitations [7].

Although the grinding machine can be particularly hard, super strong. High toughness and other difficult to be machined material surface removal processing, but because grinding belongs to contact processing, processing efficiency is low, tool wear is serious, processing cost is high, processing cycle is long [8]. Therefore, it is difficult to meet the economic and efficient processing of the above materials, generally only used in the finishing of parts. EDM machine tools belong to non-contact machining, but EDM belongs to spark discharge machining. And the workpiece must be immersed in the oil tank, not only the processing efficiency is low, but also the size of the workpiece is greatly limited. Generally used in mold parts cavity processing and special curve processing.

![Figure 1. The use of carbon arc gas explosion processing workers labor intensity.](image)

The use of carbon arc gas explosion processing workers labor intensity is very large, processing efficiency is not very high, and the workpiece after processing there is carbon, Carburizing [9]. Therefore, the development of an economical and efficient machine tool which can remove the surface layer of hard, super-strong and high performance materials is bound to play a positive role in the mechanical manufacturing industry.

The advantage of differential controller is to provide a larger correction before the error becomes bigger. The disadvantage is that the output control is not generated when the error is not changed, and it is sensitive to noise and amplifies high frequency noise.
PID controller, as the name implies, combines the characteristics of proportional control, integral control and differential control. Combining these three controllers together with the controller. PID controller can eliminate the shortcomings of single controller, and it can be expressed as follows: three.

\[ \eta(t) = k_p e(t) + k_i \int e(\tau) d\tau + k_d \frac{de}{dt} \]  \hspace{1cm} (2)

The core of the theory of fuzzy control is based on fuzzy set theory, the natural language control strategy of people into the description of the algorithm language computer can accept the output control algorithm. But it is sure that it can not only achieve the success of control, but also can simulate human thinking mode, the control of some mathematical object the model cannot form. Fuzzy concept is more suitable for people's observation, thinking, understanding, and decision making, this ambiguity is more suitable for the objective phenomena and things. "Decision fuzzy control" feature is a "language".

The fuzzy control technology has become an important branch of intelligent control technology, it is a kind of advanced algorithm and novel technology. Since 1974, the British Madani (E.H. Mandani) after the engineers first according to the fuzzy controller composed of fuzzy set theory is used to control the steam engine, in the development of 30 years, fuzzy control the technology has been widely and rapidly.

Now, fuzzy control has been widely used in metallurgy and chemical process control, industrial automation, intelligent household appliances, instrumentation, automation, computer and electronic technology application and other fields.

Especially in traffic control, robot, robot control, flight control, auto control, elevator control, nuclear reactors and household appliances control, performance and its application value is very strong. And there are fuzzy and fuzzy calculation chip Machine products available in China. The fuzzy controller is started in 1979, and has been defined, the performance of fuzzy controller, algorithm, robustness, implementation method, circuit stability, the rules for self adjustment etc. a lot of achievements. The famous scientist Tsien Hsueshen pointed out that the theory of fuzzy mathematics and its application to in twenty-first Century China's national strength and destiny.

3. Design of PID Controller based on Fuzzy rules

Application of laser processing in the domestic industry has a wide range of Suo, but the use of many restrictions in infrared laser to heat processing methods, this paper UV laser cold processing mode, such as micro drilling.

Refers to the so-called UV light source wavelength of about 150~400 nm in distribution, is currently being used in UV laser in industrial applications mainly has two kinds, the first is the excimer laser gas (ExcimerLaser) is another kind of light source with Nd: YAG laser through nonlinear frequency doubling crystal conversion technology (nonlinear crystal conversion) and infrared wavelength conversion a wavelength of ultraviolet light.

Excimer laser is the use of two kinds of reactive gas under normal conditions, but the excitation energy will be combined into unstable molecules rapidly after dissociation and release ultraviolet light, the "excitiedimer" literally a excimer laser. The widely used species mainly include XeC1 (308nm), KrF (248nm). ArF (193nm) excimer laser at three wavelengths. The excimer laser is a pulsed laser, each pulse can carry electron beam drilling finished figure (seven) shows. Energy is all in the highest UV laser.

The milling machine is the first by American E. Whitney in 1818 created the horizontal milling machine. In order to spiral groove milling twist drill, the American J.R. Brown in 1862 created the first universal milling machine for lifting milling machine prototype of.1884 before and after the emergence of Longmen milling machine.20 century appeared in 20s semi automatic milling machine worktable, using automatic conversion block the block can be completed "feed - fast" or "fast - feed".

After 1950, the milling machine is developing very fast in the control system, digital control application can greatly improve the degree of automation of the milling machine. Especially after 70s,
the digital microprocessor control system and automatic tool changing system used in milling machine, milling machine to expand the processing scope, improve the machining accuracy and efficiency.

Figure 2. NC programming milling machine.

With the intensification of mechanization process, NC programming has been widely applied to machine tool operations, which has greatly released labor force. NC programming milling machine will gradually replace manual operation. The requirement for employees will also be higher and higher, and the efficiency will also be higher and higher.

In milling, the rotation motion of milling cutter is the main movement, and the movement of workpiece is feed motion. Milling speed, feed rate, milling depth and milling width are called milling parameters. As shown in Figure 1.

Milling speed refers to the maximum diameter of the cutting edge of the cutter line speed, \( V, \text{ M} / \text{s} \);

Feed mill refers to each rotation of the workpiece cutter moving distance, denoted by \( F, \text{ the unit is } \text{ mm} / \text{r} \);

Milling depth (depth) refers to the size of the cutting layer is parallel to the axial direction of the cutter measurement, with \( AP \) said, the unit is \( \text{mm} \);

Milling width (side cutting depth) refers to the size of the cutting layer, a direction perpendicular to the axis of cutter for measurement of \( AC \) unit \( \text{mm} \) [10].

Figure 3. Base on the rotary indexing head, spindle rotating parts, dividing head spindle with rotating parts.

Base on the rotary indexing head, spindle rotating parts, dividing head spindle with rotating parts in the vertical plane vibration or horizontal, vertical or inclined position, indexing, indexing swing handle, drives the dividing spindle by rotating the worm. Than the number / head i= worm worm gear tooth number =1/40 the transmission of the dividing head, when the handle through the ratio of 1:1 of a spur
gear drive the worm to rotate in a week, when the worm wheel drives around 1/40 weeks, if the number of $Z$ divided the entire circumference of the workpiece is known, then each part requires dividing spindle $1/Z$ ring, then $n$ turns the handle to rotate the dividing head can be calculated by the formula.

$$\text{e} = \{\text{NB}, \text{NM}, \text{NS}, Z, \text{PS}, \text{PM}, \text{PB}\}$$

Milling parameters selection principle: usually rough machining in order to ensure the necessary tool durability, priority should be given to the side cutting depth or depth of larger volume, second is to increase the amount of feed, and finally choose the suitable cutting speed according to the tool durability requirements, such as selection of cutting speed on tool. The greatest degree the amount of feed, the minimum cutting depth or side effects of cutting depth; finishing process in order to reduce the system's elastic deformation, must use smaller feed at the same time, in order to suppress the bue. The carbide cutter should adopt the high cutting speed, high speed steel cutter should be used to lower cutting speed as the milling process does not produce bue, also should use the cutting speed is greater.

4. Research on feed motion control based on fuzzy PID short arc milling

It will solve many problems of machining of short arc machining technology popularization and application of power, one can solve the difficult to actively develop and promote the use of materials and processing technology progress, also will further promote the emergence and application of new materials, to promote the material industry and related industry development short arc machining tool. And the power once entered into the industry will make the processing method of mechanical processing industry is more diversified, also has a positive role in promoting the development of the machinery industry.

The social benefits of the development of short arc machining machine tools are mainly shown in the following aspects:

(1) improve the working environment

Due to the processing of short arc machining noise less than 75 decibels, will not cause noise pollution; at the same time, the working process of short arc machining, does not produce carbon arc gas explosion and other harmful gases generated by the electric machine and dust pollution, will provide a good working environment for the operator.

Figure 4. Membership function diagram of system input and output.

(2) it is beneficial to environmental protection

The short arc machining machine provides a good working environment for the operator, because it does not produce it.

The pollution of harmful gases and dust will be very beneficial to the protection of the surrounding environment and the atmosphere.

(3) promoting the development of related industries

Due to the high efficiency of processing short arc machining technique is especially suitable for hard materials, and has good processing stability, low energy consumption, raw material saving, no noise pollution and obvious technical advantages, bound for metallurgy, machinery, aviation, aerospace, petroleum, provides an efficient and practical method of hard material processing chemical industry that
can solve these industries using hard material processing encountered technical problems, will promote the technological progress and further development.

(4) promote the birth of new materials

Due to the short arc machining technique can solve the construction industry using hard material processing encountered technical problems, will improve the feasibility of these industries with hard material in the key parts in the design and promote the positive use of hard materials, which will further promote the birth of a new type of material.

Nd:YAG wavelength is 1064 nm (nanometer), using the frequency doubling technology to do 2 times, 3 times, 4 times or even 5 times, because the wavelength and frequency is inversely proportional to the wavelength of laser light, so we can get 532355266 and 213 nanometers, of which 532 is green, the rest are generally UV light. Referred to as the UVYAG.UVYAG and excimer laser light is not the main doubling technology is energy conversion efficiency is very low, so the energy of each pulse is usually below 1mJ, can carry energy is quite low, but due to a excimer order than UVYAG per pulse time (about 4–7ns), so there is enough high peak pulse power, pulse frequency plus UVYAG can reach more than 1KHZ, so it is suitable for use in single point drilling (singleholedrilling) or direct writing (Directwriting) working mode.

![Figure 5. Feed motion control based on fuzzy PID short arc milling.](image)

It should be used to process planes, steps, grooves, forming surfaces and cutting parts on the milling machine.

The milling cutter is divided into various types of common use according to its purpose:

The cylindrical milling cutter for machining plane horizontal milling machines. In milling cutter tooth distribution on the circumference according to the tooth shape into straight teeth and helical teeth two. According to the rough and fine tooth number of two teeth. The spiral coarse teeth cutter tooth number, tooth high strength, large chip space, suitable for rough machining; fine tooth milling cutter is suitable for finishing.

(2) face milling cutter: for vertical milling machine, end milling machine or Longmen milling machine, there are all kinds of cutter teeth on machining plane, end face and circumference, and also have coarse teeth and fine teeth. Its structure has 3 kinds: integral, insert toothed and indexable.

(3) end mills: for machining trenches and stepped surfaces, etc., the cutter teeth can not feed along the axial direction when they work on the circumference and end faces. When the end teeth of the end milling cutter pass through the center, they can be fed axially (usually two edged end mills are also called keyway milling cutters, which can be fed axially).

5. Summary

Discharge processing special current waveform of short arc machining technique produced by the special power supply and short arc discharge, arc obvious. For short arc discharge, there are a lot of discharge characteristics are not clear, such as the inter electrode voltage under the same electric field
strength $E$ varies with the $H$ distance between poles, pole spacing characteristic the dielectric strength corresponding to the strength of the electric field and the fluid medium, in the process of discharge voltage, current waveform changes, are yet to be carried out in-depth research.

Although the PID control has some unsatisfactory aspects, but because of its advantages is very obvious, in the field of industrial process control has occupied the leading position, and control technology research and application of the entire world has done a lot of research on PID control, efforts to improve the performance of the PID control system. Based on PID control, and combined with the a variety of other control technology, the formation of a variety of PID control technology.

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