ISSN: 2414-1895 DOI: 10.6919/ICJE.202207_8(7).0102

The Motion Planning of CNC System under the Jerk Control

Yao Huang

Beijing Institute of Technology, School of mathematics and statistics, Beijing, 102401, China

Abstract

CNC machining plays an important role in the manufacturing industry. Acceleration and deceleration control is one of the key technologies of numerical control system. This paper mainly discusses the linear acceleration and deceleration control method and the S-curve acceleration and deceleration control method. Linear acceleration and deceleration is controlled by acceleration, which has the simple algorithm and fast execution. However, the acceleration will be abrupt during the machining process, causing the machine to oscillate and lose steps. Therefore, we further discuss the S-curve acceleration and deceleration control method. The S-curve control method is controlled by jerk, so the continuity in the motion process is much higher than the linear acceleration/deceleration control. This paper mainly focuses on the above two control methods. The classification discussion, using the optimization principle, calculates the critical displacement to be interpolated and the motion time in each state for various problems that may occur during the acceleration and deceleration control process. In practical applications, specific motion planning can be determined according to the actual range of displacements to be interpolated.

Keywords

CNC System; Linear Acceleration and Deceleration; S-curve Acceleration and Deceleration; Jerk; Motion Planning.

1. The introduction

The development of advanced manufacturing industry demands more and more high precision and speed of CNC machining. In the process of high speed machining of CNC machine tools, when the system transitions from initial speed to command speed, acceleration and deceleration are needed. In order to make full use of the effective working stroke of machine tools, it is necessary to ask the machine to reach the instruction speed in a short time as far as possible in the processing process, so as to ensure the high speed and accuracy of processing.

In addition, we must also consider the smoothness in the process of acceleration and deceleration, to avoid the speed change is not smooth enough to bring vibration to the machine tool.

And impact, resulting in machining accuracy is affected. Therefore, how to shorten the machining time and make full use of the displacement to be interpolated under the condition of ensuring the smooth transition of the machine tool is the key to the acceleration and deceleration control of the CNC system.

2. The Analysis and Formula

Since the acceleration kinematics formula used in this paper has an initial acceleration of 0 in the acceleration stage and a final acceleration of 0 in the deceleration stage, so On the basis of our derivation, the kinematic formula of uniformly accelerated linear motion is compared. We will not repeat it, and the following is mainly deduced.The kinematic formula of uniform and accelerated linear motion.

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0102

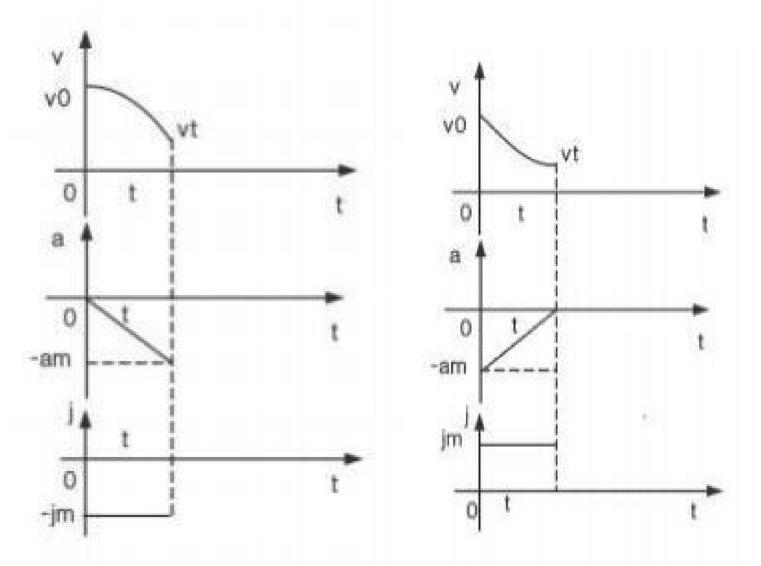

Figure 1. The uniformly accelerated linear motion

As shown in Figure 1, in uniformly accelerated linear motion, the acceleration is constant. Since the acceleration is the derivative of acceleration, it is determined by the derivative.

We can know that the change in velocity in the process with time interval t is the accumulation of acceleration in the corresponding time interval.And we have the acceleration in a uniformly accelerated linear motion of zero.

3. Optimal Proof of Velocity Extreme Curve

Due to the limited driving capacity of CNC machining mechanical system, dynamic characteristics of motion process and geometric characteristics of machining path.

The machine tool has its maximum speed Limit. Theoretically, each interpolation point has its corresponding speed Limit value, and all speed Limit values are connected into Velocity Limit Curve (VLC) of the whole movement process. Our classification discussion is based on the speed extreme curve of each case. The discussion in this paper is mainly based on how to minimize the processing time, as is the optimal defined here.

We first prove the optimal velocity extreme curve by taking the maximum limiting velocity and maximum limiting acceleration given when both initial and terminal velocities are zero.We know that when the machine tool is moving uniformly with maximum acceleration, every point on the broken line is the machine tool corresponding to that moment.The maximum velocity reached, so the broken line represents the velocity at the maximum velocity at the continuous moment of VLC, obviously, there is no other one.The curve L is such that its velocity value is greater than VLC value at the same time.

The above conclusions can be extended to the maximum acceleration, deceleration and linear addition when the initial and final velocity of the machine tool is not zero.

Velocity motion: when the maximum acceleration is constant, the optimal motion planning scheme of the machine tool is the maximum acceleration acceleration deceleration.

In traditional NUMERICAL control devices, exponential acceleration and deceleration and linear acceleration and deceleration control methods are mostly used. That is, in the acceleration and deceleration phase, respectively The method of mutation into exponential function and linear function of time can realize the speed feed at a given position, but the mutation of speed will lead to the discontinuity point of acceleration curve, which makes the flexibility of acceleration and deceleration

ISSN: 2414-1895
DOI: 10.6919/ICJE.202207_8(7).0102

control process low. Based on this problem, we propose an S-curve acceleration and deceleration control method.

The s-curve acceleration and deceleration method is controlled by the acceleration. Since the acceleration image is segmented constant, the continuity of the acceleration degree in the processing process is guaranteed, showing high flexibility, and accurate speed control is also achieved. It is an ideal control method.

In this paper, the simple accelerated motion on the straight line as the foundation, according to the known displacement, the beginning and the end of the speed and other conditions, the accelerated motion on the straight line is classified, that is, the common linear acceleration and deceleration control.

On this basis, we introduce in detail the motion planning of the complicated acceleration motion on the straight line, namely the s-curve acceleration and deceleration control method.

We give the optimal motion planning according to the known conditions for all kinds of s-curve acceleration and deceleration. First, according to the given requirements of initial and terminal velocity, judge whether the process of uniform acceleration is needed in the process of s-curve acceleration and deceleration. After determining the specific state of acceleration and deceleration process, the time and displacement required by the optimal scheme are deduced from the kinematic formula, and the calculated displacement is the critical displacement in all kinds of cases. In practical application, the displacement to be interpolated may be larger than the critical displacement, so we need to add the phase of uniform linear motion into the motion. According to the optimization principle, we select the time when the velocity reaches the maximum in each case and start uniform linear motion.

In view of the two control methods, we discuss all kinds of situations and draw a table for summary, intuitively can be more obvious under different conditions of the machine tool processing movement process, as shown in Figure 2.

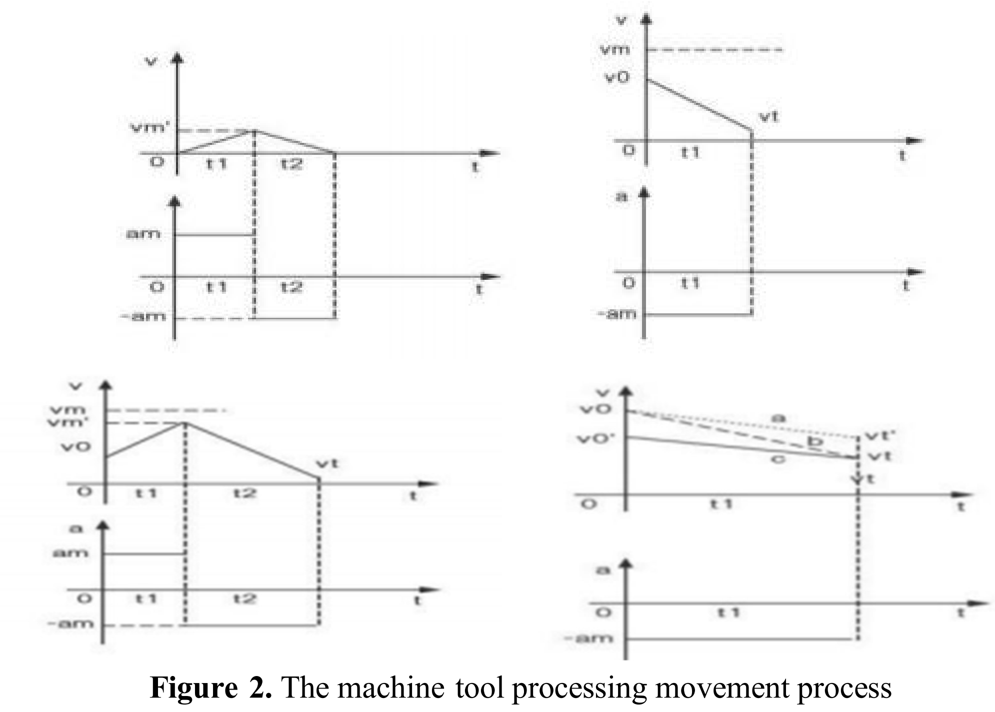

Figure 2. The machine tool processing movement process

More than a straight line is given under the control of acceleration and deceleration motion classification, among them, the velocity is piecewise continuous function of time, and the acceleration piecewise constant, discontinuous piecewise point, if the machine tools in the form of constant

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0102

acceleration, in more complex interpolation motion and path, the easy to oscillate or noise, Damage to machine tools.

In high-speed CNC machining, we should try our best to avoid the sudden acceleration of the machine tool at the end of acceleration and deceleration, because this will lead to strong mechanical impact. The stability of motion is further improved with constant acceleration. Acceleration and deceleration of S-curve can be divided into 7 stages of acceleration and deceleration.

In the next chapter, we will classify and plan the motion according to the displacement distance and the conditions of the initial and final velocity. From the perspective of control, how to use the shortest time to meet the requirements under given conditions is studied.

4. S Curve Acceleration and Deceleration Control Method

As shown in Figure, when the given actual distance S is small, the uniform acceleration and deceleration motion with the maximum acceleration cannot reach the specified final velocity vt, but can only reach vt'. That is, we hope to move with velocity curve B. However, under the optimal condition of given acceleration and acceleration limitation, only curve A can move. At this time, it is necessary to adjust the initial velocity v0, and the adjusted velocity is denoted as V, that is, to move with velocity curve C.

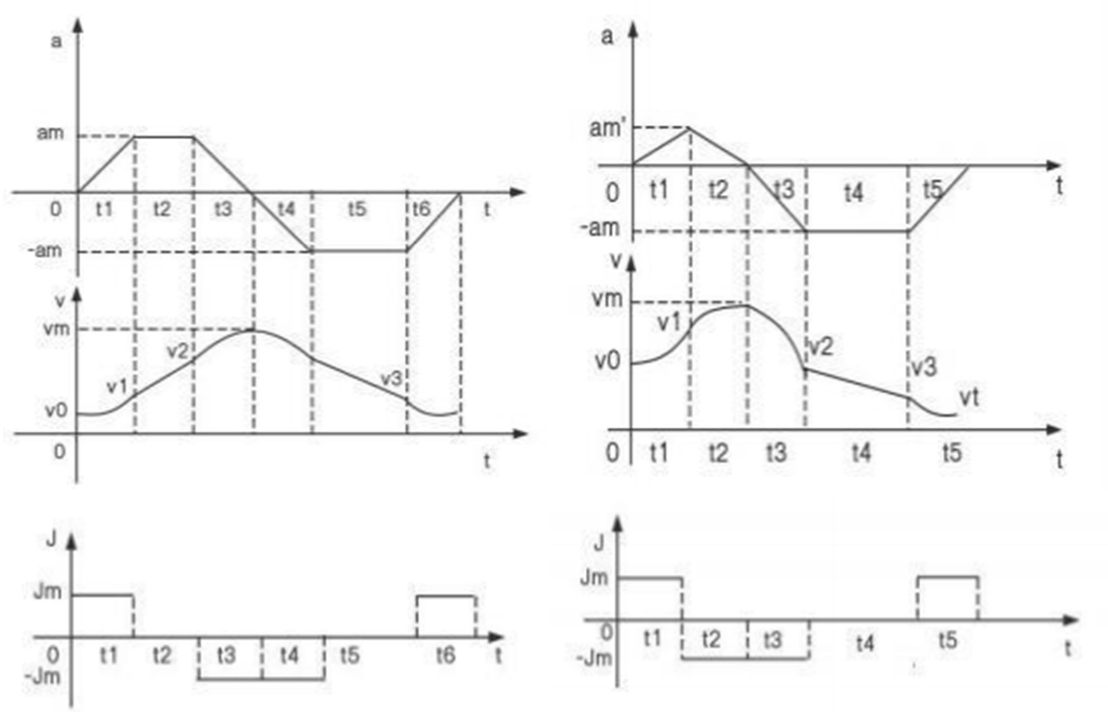

Figure 3. The uniform acceleration and deceleration motion

In this case, according to the given displacement to be interpolated, we cannot realize the feed of the command speed, and the above adjustment of the initial speed is needed. In particular, in order to ensure that the movement of the machine tool is not affected in the next cycle, we must independently adjust the initial speed of this stage, instead of adjusting the reachable terminal speed according to the situation of the machine tool.

In the above six cases, the default maximum speed and maximum limit speed have uniform motion restrictions on the machine tool, and there is no contradiction. Therefore, we carry out the discussion under the condition that the machine tool has not reached the maximum limit speed when it reaches the maximum acceleration.

Volume 8 Issue 7, 2022
DOI: 10.6919/ICJE.202207_8(7).0102

Therefore, we can continue to accelerate to the maximum speed or the machine tool will not accelerate due to the limitation of the displacement to be interpolated.

In addition, we will discuss another case, that is, when the machine tool has reached the maximum speed before reaching the maximum acceleration, it will no longer accelerate, but decelerate to the given final speed or if the displacement to be interpolated allows, The machine will travel at a constant speed for some distance and then decelerate. We will discuss such cases in the next section.

5. Conclusion

The above is the detailed classification of linear curve acceleration and deceleration control method and S curve acceleration and deceleration control method. In the classification of accelerated motion, we divide the motion into 6 categories under the limitation of initial and final velocity and displacement, which include all possible situations of accelerated motion. In fact, in the numerical control system acceleration, for the stability of machine tool movement, we use less acceleration control of linear motion, so we further discuss the s-curve acceleration control method of linear acceleration motion. We divide the acceleration motion on the straight line into 6 types according to its motion track, and calculate the motion time and motion state of each state of the 6 types of motion respectively. The acceleration control method not only ensures the continuity of the acceleration, but also gives the optimal motion planning according to the constraints of the initial and final velocities and the known displacement to be interpolated. It is also feasible in practical application.

References

[1] L.X. Zhang, R.Y. Sun, X.S. Gao, H.B. Li. High speed interpolation for micro-line trajectory and adaptive real-time look-ahead scheme in CNC machining. Science China Technological Sciences, 54 (2011), 1481-1495.

[2] Shi Chuan, Zhao Tong, Ye Peiqing, et al. Research on S-Curve Acceleration and Deceleration Planning ofCNC System [A]. China Mechanical Engineering,2007, 12 (5): 1421- 1425.

[3] Xiong Jin, Liu Wei. Judgment and Calculation ofDeceleration Point in Acceleration and Deceleration Control Based on Exponential Curve [A]. Automation Technology and Application,2013, 32.

[4] Ye Peiqing, Zhao Shenliang. Research on Continuous Control Algorithm for Small Straight Line Segment [J]. China Mechanical Engineering, 2005, 21 (2) : 135- 140.