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A Discrete Algorithm of S-shape Acceleration and Deceleration

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ABSTRACT: *A new control algorithm for S-shape acceleration and deceleration is proposed. An accurate solution is calculated before interpolation process. The speed curve was constructed by five segments, and position, velocity, acceleration and jerk requirement can be satisfied.*
Keywords: *S-shape Acceleration and deceleration; Interpolation Algorithm; CNC*

I. INTRODUCTION

Acceleration and deceleration control is an important part of the CNC system. In order to ensure that the machine tool in the start or stop when the movement is stable and the impact is small, it must be designed specifically rules for the acceleration and deceleration control. The adaptive flexible acceleration and deceleration algorithm will directly affect the accuracy and efficiency of the numerical control system. The traditional linear acceleration and deceleration mode, which exist the discontinuities of acceleration, is easy to cause the vibration of the machine [1]. Consequently, the oscillations of feed speed decrease both the surface quality and machining efficiency.

The traditional S-shape acceleration and deceleration control algorithm parameters are more, the calculation is relatively complicated and the program running time is long, which directly affects the machining efficiency of NC machine tools [2, 3, 4]. Therefore, the author proposes a simple algorithm for S-shape acceleration and deceleration control. In this paper, a discrete model is established, which can simplify the calculation of interpolation and improve the efficiency of interpolation [5, 6, 7].

The article is divided into two parts: Firstly, the formula of the S-shape acceleration and deceleration is derived. Secondly, the author analyzes the advantages of the algorithm

II. Formula derivation of S-shape Acc/Dec

Assuming that the maximum speed of linear interpolation is v_m, the maximal acceleration/jerk is a_m and j_m respectively. Small linear segment distance is S. Acceleration and deceleration period number is n. Uniform speed period number is m. The velocity diagram is shown in Fig.1. The distance can be calculated by

$$S=\sum_{i=1}^{n}\frac{j_m}{2}i^2+\sum_{i=1}^{n}(v_m-\frac{j_m}{2}i^2)+\sum_{i=1}^{m}v_m+\sum_{i=1}^{n}(v_m-\frac{j_m}{2}i^2)+\sum_{i=1}^{n}\frac{j_m}{2}i^2=(2n+m)v_m$$

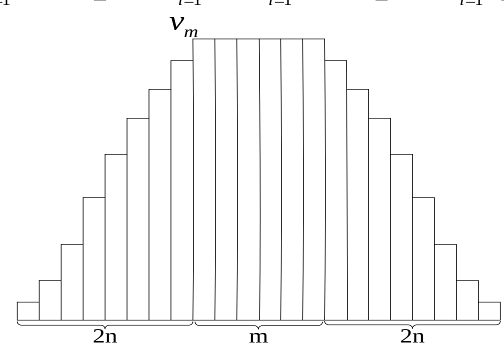

Fig 1 Discrete velocity graph

If the distance S is large enough, the speed can achieve v_m. The required number of acceleration period is

$$n=floor(\sqrt{v_m/4j_m})$$

Constant period number can be obtained by $m=floor(S/v_m)-2n$.

Based on the above formula, we can see that the constant speed is v_m when $m > 0$; conversely, the maximum speed will not reach only acceleration and deceleration process. The following two cases are discussed respectively.

2.1 The maximum speed v_m

Owing to the data m and n are rounded down, there may be a residual distance S_r.

$$S_r = S - (2n + m)v_m$$

The residual distance is allocated averagely to the acceleration and deceleration part. As shown in Fig.2, the velocity is Δv . $\Delta v = S_r / 4n$

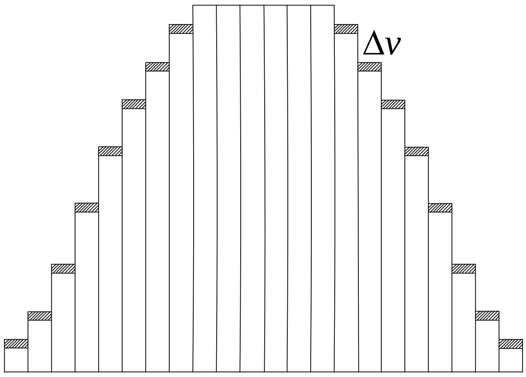

Fig 2 Corrected speed chart

After adjustment, in addition to the last period in the acceleration and the first period in the deceleration, the value of acceleration and deceleration will invariant. So, it will obtain the maximum velocity v_m. The speed of the i period can be depicted by

$$v = \begin{cases} \frac{j_m}{2} i^2 + \Delta v & 1 \le i \le n \\ v_m - \frac{j_m}{2}(2n - i)^2 + \Delta v & n \le i < 2n \\ v_m & 2n \le i < 2n + m \\ v_m - \frac{j_m}{2}(i - 2n - m)^2 + \Delta v & 2n + m < i \le 3n + m \\ \frac{j_m}{2}(4n - m - i)^2 + \Delta v & 3n + m \le i < 4n + m \end{cases}$$

2.2 The maximum speed less than v_m

If the maximum speed can fail to reach v_m, we can think that there will have a constant speed period. The velocity will be supposed by $v'_m = j_m(n+1)^2$. As shown in Fig.3.

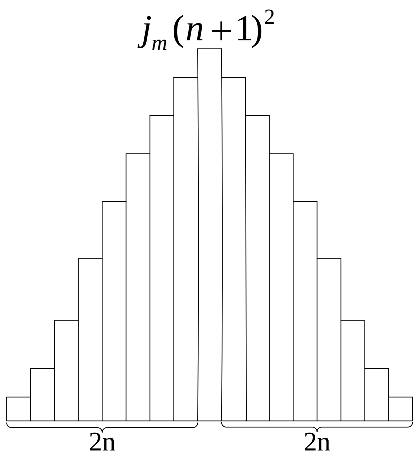

Fig 3 Graph of the maximum speed less than v_m

The total distance S can be computed by

$$\begin{aligned} S &= \sum_{i=1}^{n}\frac{j_m}{2}i^2 + \sum_{i=1}^{n}(v'_m - \frac{j_m}{2}i^2) + v'_m + \sum_{i=1}^{n}(v'_m - \frac{j_m}{2}i^2) + \sum_{i=1}^{n}\frac{j_m}{2}i^2 \\ &= (2n+1)v'_m \\ &= (2n+1)(n+1)^2 j_m \end{aligned}$$

The n can be obtained.

$$n = floor[(-1 - \sqrt[3]{A_1} - \sqrt[3]{A_2})/3] - 1$$

Where $\begin{cases} A_1 \approx 1 - 28S/j_m \\ A_2 \approx 1 + S/j_m \end{cases}$

The constant speed distance is equal to $S - 2nv'_m$. Therefore the constant speed period number m can be derived.

$$m = floor((S - 2nv'_m)/v'_m) = floor(S/v'_m - 2n)$$

There will have a residual distance S_r.

$$S_r = S - (2n+m)v'_m$$

As shown in Fig.2, we do the same method. So, it will not reach the maximum velocity v_m. The speed of the i period can be described by

$$v = \begin{cases} \frac{j_m}{2}i^2 + \Delta v & 1 \le i \le n \\ v'_m - \frac{j_m}{2}(2n-i)^2 + \Delta v & n \le i < 2n \\ v'_m & 2n \le i < 2n+m \\ v'_m - \frac{j_m}{2}(i-2n-m)^2 + \Delta v & 2n+m < i \le 3n+m \\ \frac{j_m}{2}(4n-m-i)^2 + \Delta v & 3n+m \le i < 4n+m \end{cases}$$

III. Algorithm analysis

(1) During the pre-processing phase, the algorithm has been determined the number of n and the constant speed period number m. Therefore, in the process of interpolation, it is not necessary to calculate the deceleration point without each interpolation period.

(2) The residual distance is averagely assigned to the acceleration and deceleration phase. When the distance of each axis is an integer multiple of the pulse equivalent, there is no end point positioning error.

(3) The algorithm uses the float point calculation, and is more suitable for software interpolation. Since it is a discrete algorithm, some data can be directly made into a table, which greatly reduces the computation time.

IV. Conclusion

In this paper, a new algorithm of linear acceleration and deceleration based on time division is proposed. The algorithm is not needed to calculate the deceleration point at each time of interpolation, which can reduce the calculation amount of the interpolation process, and can precisely locate in the interpolation process. The algorithm can eliminate the fluctuation of the acceleration discontinuity. To guarantee the continuity of the velocity and acceleration, which can avoid machine vibration attributing to the sudden change of the acceleration, should employ S-shape acceleration and deceleration scheme that may improve the machining efficiency and quality.

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