Speed Optimization Design of Stacker in Automatic Stereoscopic Warehouse Based on PLC

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Abstract. The S-type speed control is applied to the motion control of the stacker, and the S-type speed curve control is simulated by MATLAB to verify the feasibility of the optimal design. In practice, Siemens S7-300 is used for PLC programming to realize S-type speed curve control technology of stacker. The high efficiency, real-time and accuracy of the design realized the effective optimization of the speed of the stacker in the automatic stereoscopic warehouse.

1. Introduction
Automatic Storage & retrieval system (AS/RS) is a kind of automatic control warehouse system which can automatically store and store goods instead of manual processing and is controlled and managed by computer[1,2]. In order to meet the needs of the development of new-type stereoscopic warehouse, the optimization design of acceleration and deceleration curve algorithm for automated stereoscopic warehouse is proposed. The computer software MATLAB is used for simulation and Siemens S7-300 PLC control is used to improve the transportation system of the stacker in the automatic three-dimensional warehouse from two aspects of stable speed change and accurate stop, so that the stacker can accurately position between the shelves, and the speed is stable during acceleration and deceleration, which ensures the safety and accuracy of storage and retrieval of goods.

In this optimization, the main safety parameters are set as follows[3]:
- Rated lifting capacity of stacker: 300kg;
- The maximum horizontal traveling speed of stacker in X direction: 1.5m/s;
- Maximum lifting speed of stacker loading platform in Y direction: 0.15m/s;
- Telescopic speed of fork of stacker in Z direction: 0.15m/s.

Under the constraints of the above rated parameters, the cargo space difference between the stacker and the target address is taken as the speed gear selection condition. Suppose the difference is D, If D \leq 2, set the stacker to low speed; if 2 < D \leq 10, set the stacker to medium speed; if d > 10, set the stacker to high speed. We can improve the efficiency of loading and unloading goods on the premise of ensuring safety by the setting. Figure 1 is the automatic operation flow chart of the stacker control system. From the diagram, we can see the mutual control and feedback relationship between the stacker and the computer, remote controller, monitoring machine and other equipment. If the computer control system fails, the operation of the stacker can be carried out through the buttons on the panel when the computer system is overhauled, and the stacker can move forward, retract and stop manually.
2. Analysis of S-curve Algorithm

Through the analysis of the algorithm, it can be seen that constant acceleration is not suitable for actual speed control, so it is necessary to seek an algorithm without abrupt change in acceleration, that is, acceleration rises slowly when accelerating, and decreases slowly when decelerating[4,5]. This acceleration is time-varying and the algorithm is not fixed, which can be illustrated by the S-shaped curve obtained from the mixture of parabola and trigonometric function. Figure 2 shows the S-type curve of velocity and acceleration. It can be seen from the figure that the speed curve combines the graphic features of parabola and trigonometric function, and the acceleration is symmetrical in acceleration and deceleration parts. Taking the positive acceleration part as an example, the acceleration curve can be divided into three parts, namely, linear rise, constant speed and gentle and linear descent.

The maximum speed formula is as follows:

\[ v_{\text{max}} = v 3(nT) = A_{\text{max}} \cdot m \cdot T + A_{\text{max}} \cdot nT \]

\[ = A_{\text{max}} \cdot (t_m + t_x) \]  

Where: \( V_{\text{max}} \) is the highest speed; \( A_{\text{max}} \) is the highest acceleration value; \( t_m \) is the time consumed by linear ascending and descending acceleration parts; \( t_x \) is the time of uniform acceleration part.

It can be concluded from experience that, if \( t_x = 2t_m \), it can ensure the reduction of energy consumption in the movement of objects. By setting \( V_{\text{max}} \) and \( A_{\text{max}} \), the S-type velocity curve can be obtained. The program flow chart of S-type speed curve is shown in Figure 3.
3. Matlab simulation of S-type velocity curve
After simulation, the speed curve of stacker S-type horizontal operation is obtained, as shown in Figure 4. It can be seen from the figure 4 that it took 33.9s to complete the whole operation of the stacker. The acceleration simulation curve is shown in Figure 5. It can be seen from the figure that the ascending acceleration stage of the stacker is 2-13s, the acceleration value is increased from 0 m/s² to 0.14m/s², while the acceleration value of the stacking crane in the deceleration stage reaches the maximum value of 0.22m/s² in 26-30s.

4. Realization of PLC program by S-type speed control
Through PLC programming, the stacker control system with S-type speed curve is realized. Its main advantages are strong calculation ability, fast execution speed of instructions and saving operation
time. Figure 6 shows the structure diagram of its control system. If the accuracy of the system is low, we should choose a relatively low sampling rate, so as to reduce the amount of calculation as much as possible. If the accuracy of the system is to be higher, we must choose a relatively high sampling frequency. The timing interrupt is used to transmit the real-time speed to the inverter to control the curve shape. Figure 7 shows the control process.

![Flow chart of S-type velocity curve in the PLC program of the control system of the stacking machine.](image)

Figure 6. Flow chart of S-type velocity curve in the PLC program of the control system of the stacking machine.

![Working flow chart of S type speed curve module PLC](image)

Figure 7. Working flow chart of S type speed curve module PLC

The main components of control system software are main program and interrupt program. The flow chart is shown in Figure 8.

5. Conclusion
The S-type speed control curve is more suitable to control the stacker in the automatic warehouse. Based on the analysis of the S-type speed curve, the fixed roadway distance and the maximum time consumption of the automatic stereoscopic warehouse are set. The MATLAB simulation results show that the stacker can run quickly, stably and accurately within the predetermined 40s. PLC technology to achieve S-type speed control, so that the computer software and hardware resources are reasonable use, avoid the waste of storage space, greatly improve the calculation efficiency, the operation efficiency and economic benefits of the automated stereo library.
Figure 8. Main program flow chart

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