Application of Automatic Motor Control System Based on Sensor Technology

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Received 17 June 2022; Revised 10 July 2022; Accepted 18 July 2022; Published 27 July 2022

Academic Editor: Balakrishnan Nagaraj

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In order to solve the application problems in motor automation control, a motor automation control system based on sensor technology is proposed. Sensor technology has been widely used in the field of automation. Therefore, when studying sensor technology, we should also study its specific application in the process of motor automation control. This paper briefly introduces the sensor technology in electromechanical automation control, discusses the application of this technology in various fields, and analyzes the development trend of sensor technology in electromechanical automation control in the future.

The experimental data show that in the motor starting phase, the sensorless SRM using the observer can quickly identify the given speed, quickly approach the given speed in 0.05 seconds, and make the motor run faster and reach a stable state. The application of sensor technology has greatly improved the quality and production efficiency of mechanical manufacturing.

1. Introduction

Sensor technology first belongs to an intelligent technology. Sensor technology can timely perceive various changes in the external environment and can timely transmit the perceived situation to the computer. This process is very rapid and timely. Therefore, the computer can timely collect the signals sent by the sensor, process the data accordingly, and then issue other instructions [1]. This process is an electromechanical automatic control process and also has the trend of intelligent development. Generally speaking, sensors only have the function of sensing. However, with the continuous development of science and technology, sensors can not only receive signals but also send signals to transmit signals. In the past, in the process of electromechanical automation control, due to the imperfect development of sensor technology, data transmission errors often occur, which makes the follow-up work very inaccurate. However, the use of sensor technology can well resist this problem, because the sensor first has the function of transmitting information. Therefore, the sensor can avoid errors in the transmission process [2]. For example, in the automatic welding of the machine by relevant personnel, the reasonable application of the arc sensor can facilitate the correct acquisition of machine information and can also convert the physical information sensed by the sensor into specific electricity, which can greatly improve the working efficiency of the robot. Through the application of external sensor technology, the external environmental information can be timely monitored and collected, and the working environment of the machine can also be identified to a certain extent [3]. The application of sensor technology can provide more reliable information for the operation of the machine, so as to ensure the correct operation of the machine. On the other hand, due to the continuous application of internal sensor technology, the machine can be controlled through sensor technology. In addition, the sensor technology can also facilitate the timely monitoring of the operation of the machine. It can not only timely transmit the valuable information generated by the machine system during operation but also ensure that the machine can timely detect the changes in the external environment, so as to take corresponding protective measures [4]. In the process of machining, the sensor technology can not only facilitate the vibration of machinery but also accurately measure the components with dynamic characteristics, which can greatly improve the quality of
corresponding products. It can also timely feedback the abnormal conditions in the mechanical aspects of the system during operation to the control system and solve the adverse effects caused by the abnormal conditions. In the actual production process, we should take the product demand as the main purpose to deeply adjust the control mode, which can greatly improve the safety of machining. Therefore, the application of sensing connection technology can not only ensure the safety of machining technology but also reduce the adverse effects in case of negative conditions [5]. First of all, for the application in the production site, the sensor technology can facilitate the new and accurate measurement of the position of the machine tool and the corresponding running speed and can also master other factors of deformation or vibration, which can greatly improve the accuracy of machining and can also timely reduce the manual workload, in order to give full play to the application of the sensor technology in machining. In the actual application process, the staff can also further monitor the processing process in time, so as to make sure that the processing process is in the correct process without errors. In addition, the final application description of machining accuracy is also an important application of sensor technology [6]. Machining accuracy control is a very important content for machining. By using the scanning sensor, the related work of workpiece contour measurement can be solved as soon as possible. At the same time, it can make the obtained data very accurate. The third application is the application of automotive automation control. At present, automated vehicles are being developed in an orderly manner. The sensor technology is the most important technology in the electronic control system. In general, the sensor will be installed in the vehicle’s control system and engine control system [7]. At present, sensor technology has been attached importance by many industries. The reasonable application of sensor control technology to office equipment and factory assembly lines can not only significantly improve the production effect but also accelerate the development of enterprises. Sensors have a great impact on the operation of electromechanical automatic control system, so in order to better play the effect of sensor technology. Relevant personnel of the electromechanical automation control system must timely inspect and maintain the electromechanical automation system according to specific conditions, so as to improve the automation system level [8]. Therefore, strengthening the application and research of sensor technology can make it very useful in mechanical automatic control.

2. Method

2.1. General. Generally speaking, the sensor is composed of conversion circuit, conversion element, sensitive element, etc., as shown in Figure 1.

Among them, the conversion circuit is a circuit that converts the output of the sensor into a circuit that can transmit and process electricity. The conversion element refers to an element that converts the information detected by the sensitive element into a circuit or electricity parameter. The sensitive element refers to an element that can sensitively sense and detect information and respond according to the specified relationship [9]. In practice, some sensors are only composed of a sensing element and a conversion element, while others are combined into one. The simplest one must be composed of a sensing element, which can convert the output power when detecting information, such as a thermometer. According to the working principle, there are many types of sensors, including resistance, capacitance, inductance, piezoelectric, hall, and photoelectric. It is classified according to the detected physical quantity, including displacement, proximity, speed, temperature, force, torque, pressure, acceleration, and other types of sensors. The second classification method intuitively shows the purpose of the sensor, which is the most concerned by customers and is easy to select; sensors are divided into proximity sensors, inductive sensors, capacitive sensors, photoelectric proximity sensors, temperature sensors, magnetic sensors, optical fiber sensors, photoelectric encoders, etc. As the name suggests, proximity sensor means to detect the proximity of the detected object without contacting it and send the specific results in the form of switch signals. There are usually inductive, capacitive, photoelectric, hall, and other sensors [10]. Inductive sensor is mainly used to detect objects with metal properties. It is characterized by high repeatability, high positioning accuracy, high action frequency, convenient installation, applicable to various environments, and can be widely used in industrial production [11]. It is mainly composed of LC high-frequency oscillation, signal processing, and switch amplification circuits, as shown in Figure 2.

Capacitive sensor is mainly used to detect metal objects, insulating liquid, or powder objects; its main working principle is to use the electrode plate of the capacitor as the detection surface, while the external material is the insulating medium between the two electrode plates of the capacitor. If the insulating medium changes, the electrical capacity will also change [12]. No matter what object, as long as it accepts or leaves the capacitive sensor, the dielectric constant of the sensor will change, making it output the corresponding switching signal. Figure 3 is a schematic of the sensor.

Photoelectric proximity sensor is mainly used to convert photoelectric signals into electrical signals. Its core sensitive element is photoelectric devices, using photoelectric effect as the working principle [13]. Sensor technology refers to a new type of intelligent technology. The principle of this technology lies in the “perception” of the external environment. By acquiring information and transmitting it to the computer, we can make corresponding actions based on this. In the electromechanical automation control, the function of sensor technology is mainly to collect information, acquire and process the measured nonelectric signal, then convert it into electrical signal, and finally provide corresponding support for the system operation.

Switched reluctance motor (SRM) is widely used in aerospace, electric vehicles, and other fields because of its simple structure, strong fault tolerance, many control modes, suitable for high-temperature, and high-speed environment [14]. The rotor position must be measured during the control and operation of the SRM. The existing position sensors such as photoelectric position sensor and magnetic sensitive
position sensor have some problems. Their accuracy is easy to be disturbed by the external environment. When the number of motor phases increases, the number of components used will also increase, making the system circuit more complex and increasing the volume of the system. They are not suitable for applications in aircraft and other occasions with strict volume requirements. At the same time, too many sensors reduce the reliability of the system. Therefore, the sensorless rotor position estimation based on the electrical parameters of the motor has become a research hotspot. At present, a variety of sensorless technologies have been proposed, each of which has its corresponding speed application limit range, which can be divided into two categories: low-speed starting and medium-high-speed starting. There are phase current waveform method, pulse injection method, and modulation and demodulation method for sensorless technology during start-up and low-speed operation, and the main methods are conducted phase injection pulse method and nonconducted phase injection pulse method. During medium- and high-speed operation, the interval of conducting phase current in an electrical cycle is large, and the interval of nonconducting phase detecting injection pulse is small. Therefore, observer method, flux linkage current method, and neural network method, etc., are mainly used [15]. In addition, there are additional capacitance and additional inductance coil detection methods. Because the installation of additional components reduces the reliability of the system, these two methods are rarely used. The rated parameters of the switched reluctance motor prototype studied in this paper are shown in Table 1.

Each type of sensorless has its speed application limit. In order to cover the whole speed range, two or more technologies must be combined to estimate the rotor position by using the observer method. The effect is good. However, the tracking accuracy of the rotor position angle in the motor starting phase is low, which is easy to make the winding turn on and off not in time, resulting in torque fluctuation [16]. In view of this shortcoming, this paper combines the sliding model observer (SMO) with the phase current gradient method, adds the position error correction module in the traditional SMO, and sets the threshold. When the motor starts and runs at low speed, the error detected by SMO method exceeds the threshold, and the phase current gradient method is used to detect the rotor position. When the motor is running at medium high speed, the error detected by SMO method is less than the threshold value. SMO method is used to detect the rotor position, which expands the speed application range of sliding mode observer method, ensures that the accurate estimation of rotor position can be realized in the starting stage, avoids large torque ripple, and realizes the estimation of rotor position in the full speed range.

2.2 Principle of Rotor Position Detection Based on Sliding Mode Observer. The schematic diagram of rotor position detection based on sliding mode observer method is shown in Figure 4. In the system, the speed difference obtained by the difference between the given speed \( \omega \) and the speed \( \dot{\omega} \) detected by SMO is transformed into the given control quantity through the speed regulator composed of PI control or fuzzy control. This paper temporarily analyzes it with reference current [17]. The difference between the reference current and the actual current is used to control the on-off of the power converter. The actual phase voltage and phase current obtained from the motor operation can observe the phase winding flux linkage of the motor through the flux observer. The observed values of the flux linkage and rotor position angle can be obtained through the SRM model.
The difference between the actual value and the observed value of the phase current is set as the input of SMO, and its output is the estimated value of the motor speed and rotor position angle.

According to the basic principle of switched reluctance motor, its state equation (1) is

\[
\begin{align*}
\dot{\psi} &= U - Ri, \\
\dot{\omega} &= -\frac{F}{J} \omega + \frac{T_e - T_L}{J}, \\
\dot{\theta} &= \omega, \\
T_e &= \sum_{j=1}^{N_{ph}} T_j(i, \theta).
\end{align*}
\]

(1)

3. Results and Discussion

The proposed sensorless torque ripple suppression is verified by using the established MATLAB/Simulink simulation platform [18]. The motor adopts three-phase 12/8 pole SRM with rated voltage of 514 V and rated power of 18.5 kW. Set the opening angle of the motor as 2°, the closing angle as 32°, the given speed as 1000 r/min, and the load torque as 4.6 n·m. Firstly, the SMO method is used to simulate the nonposition sensor. When starting, the current chopping limit is 60 A. After starting, the cosine torque distribution function control mode is adopted. The torque comparison results before and after the application of the observer are shown in Figure 5. It can be seen that in the motor starting stage, the sensorless SRM using the observer can quickly identify the given speed, quickly approach the given speed within 0.05 seconds, and make the motor run faster and reach a stable state.

When the rotor position estimation error correction module is added, the position where the stator and rotor of the motor begin to overlap is obtained by detecting the jump edge of P3 pulse from low level to high level, and the speed is obtained. The inductance of the motor is calculated by establishing an accurate inductance model for P2 pulse detection. It can be seen from the working principle of switched reluctance motor that the inductance changes little with the current when the stator and rotor begin to overlap, so it is approximately considered that the inductance at the position where the stator and rotor begin to overlap, i.e., the inductance at \( \theta_{\mu} \), is a constant value, and the inductance threshold is slightly larger than the inductance when the stator and rotor overlap, but it cannot be too large, because the significance of P2 pulse eliminating multiple zero crossings of the current gradient will be lost if it is too large. Therefore, the inductance threshold should be properly selected, where LP is taken as 0.008 H. Set the simulation step size as 10-5 s, take phase a as an example, get the actual phase current of the motor, phase current and current gradient filtered by the low-pass filter, P1 pulse signal, and get the phase a inductance, filtered inductance, P2 pulse signal, and P3 pulse signal [19]. The simulation results show that P3 pulse can well detect the sudden change of current slope and obtain the position where the stator and rotor of the motor begin to overlap. However, this method also has certain limitations. When the current has high-order harmonics, it is difficult to completely eliminate the harmonic influence after filtering. At the same time, the filtered signal has small changes in amplitude and phase compared with the original signal; that is, it is difficult to have both good filtering effect and small distortion. In addition, it is considered that the speed is unchanged before P3 pulse jump, and there is also a certain error. Using the phase current gradient method and sliding mode observer method, the phase a rotor position angle of the motor and the comparison error between them are obtained. During the motor starting process, when the error is less than 2°, the rotor position estimation error correction module is cut off, and the rotor position angle obtained by the observer is used to determine the on-off of the power tube of each phase winding. The rotor position estimation error correction module can eliminate the torque ripple caused by the large observer estimation error during motor starting. After the motor enters the stable operation stage, the large torque ripple will lead to the change of the electromagnetic characteristics of the motor, which is not conducive to the estimation of the rotor position. In the simulation, it can be seen that the control mode of cosine torque distribution function has large torque fluctuations. When the torque distribution mechanism is improved and the current loop and torque loop control are adopted (the allowable current error is set to 0.3 A, and the allowable torque error threshold is 0.5 n·m), the motor speed, torque, phase torque,

| Parameter                  | Numerical value |
|----------------------------|-----------------|
| Motor model                | Three phase 12/8 pole SRM |
| Rated power/kW             | 18.5            |
| Power supply voltage/V (DC)| 514             |
| Load condition             | 50% rated load  |
| Rated speed/(r/min)        | 1000            |
| Maximum speed/(r/min)      | 1350            |

Table 1: Prototype parameters.
and phase current after the motor runs stably are obtained [20]. It can be seen from the simulation analysis that by adding the rotor position estimation error correction module, the flexible switching between the phase current gradient method and the sliding mode observer estimation method is realized, which ensures the rotor position estimation accuracy in the motor starting stage and effectively suppresses the torque fluctuation caused by the low estimation accuracy of the rotor position angle in the starting stage.

4. Conclusion

With the rapid development of science and technology, as an important link, the development of sensors is very extensive, especially in the field of electromechanical automatic control. Therefore, we should attach great importance to the development of sensor technology, promote faster information exchange, and better serve human production and life. This paper presents the application of motor automation

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**Figure 4**: SRM sliding mode observer control system block diagram.

**Figure 5**: Torque comparison results of switched reluctance motor before and after observer application.
control system based on sensor technology. Mechanical manufacturing is the most important in industrial production. Electromechanical automatic control makes mechanical manufacturing get rid of artificial control, especially the application of sensors, which greatly improves the quality and production efficiency of mechanical manufacturing. Sensor technology plays the role of control, monitoring, and feedback in the process of mechanical manufacturing and promotes the improvement of mechanical manufacturing accuracy. This technology is especially suitable for the occasions that need four-quadrant operation. In addition, this method does not need any additional hardware. Although the control algorithm involves square root and arccosine calculation, which increases the overall amount of computation, it is acceptable for existing digital signal processors and microcontrollers. Therefore, it is easy to realize, modify, and apply to other types of switched reluctance motors. These characteristics make this method very practical, reliable, and low cost and can be accepted by many low-cost variable speed applications. The experimental results fully verify the position sensorless scheme proposed in this paper and prove its advantages.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The author declares that there are no conflicts of interest.

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