Research Journal of Applied Sciences, Engineering and Technology 6(13): 2489-2494, 2013
DOI:10.19026/rjaset.6.3727
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: December 26, 2012 Accepted: February 01, 2013 Published: August 05, 2013

Research Article

A Method for Automatic Thread Demoulding Using Step Motor and Servo Motor with Synchronization between the Two Systems in Injection Mould

[1]Guo-Wei Chang and [2]Jun-Min Yang
[1]Mechanical and Electrical Engineering Department, Shunde Polytechnic University, Foshan, Guangdong Province, 528300 China
[2]School of Foreign Languages of Science, Central South University, Changsha, Hunan Province, 410083 China

Abstract: This study offers a method applied in injection mould with automatic thread demoulding by using servo control and the combination of mechanical structures. In injection moulding, using hydraulic motor to drive gears and cores with thread for automatically taking plastic-injected parts with thread off from the cores is a common method for thread demoulding. The thread demoulding is completed by two movements. One of them is realized by the rotation of the threaded cores driven by hydraulic motor; the other is to stop the injected plastic part from turning and meanwhile push it out by a pushing plate. The pushing plate is usually driven by springs which give forces that vary with the distance the plate travels. Because of this, the displacement of the pushing plate might be different from that of displacement of the core thread goes along the core axis. Thus the parts moulded may be damaged at the thread area on the part when the automatic thread demoulding is proceeding. This technique needs much to be improved hereon in injection moulding. In this study, the author brings up a solution that the hydraulic motor is replaced by a step motor and the pushing plate is driven by a servo motor. And there is a programmable logic controller to synchronize the two movements driven by the motors. Through the improvement the mechanism is substantially enhanced compared with the spring-driven pushing demoulding system.

Keywords: Injection mould, programmable logic control, servo motor, synchronization, thread demoulding, zero drifting

INTRODUCTION

In the electrical appliance, automobile and other industries, the parts with thread in the plastic-injection are involved. But the general problems existing in the testing and producing of the injection mould are as follows: At home and abroad, to produce such plastic-injected parts, the automatic thread demoulding technology applied are all the traditional pure mechanical ones, which generally have the problem that the speed of the thread taking-off mechanism and the speed of the pushing -out are not completely consistent, causing thread of the injected parts to be scratched, so as to make the quality of products unstable, high rate of waste products, low rate of the utilization of the materials and so on. A lot of efforts have been made by the enterprises at home and abroad to solve this problem without much progress. For example, in 2011, Midea Moulding Company applied the Korean moulding technology, which still mainly followed the way of the mechanical mechanism, to produce the automatic thread taking-off mould for a Korean Company, but it turned out to a failure in application.

The disadvantage of the traditional thread demoulding system that uses spring as the driving force for the pushing plate: In plastic injection moulding, using hydraulic motor to drive a gear and to automatically take a plastic-injected part with thread off from the threaded core is a usual method in this field (Chang *et al*., 2008). The portion of the mould body to execute the task of taking off is similar to the related structures. The taking off of the part from the thread is achieved by two effects, shown in Fig. 1. The spring-driven pushing plate-4 is to keep the parts from rotating and to push out the parts. And the rotatable core-8 with thread turns and releases the injected threaded parts. However, this automatic thread-demoulding mechanism has a common problem in that the speed of the pushing plate-4 and the axial speed of the thread of the core-8 are inconsistent, causing damage to the plastic parts. In this commonly used automatic taking-off method, the pushing movement of the plate is achieved by the spring force. Because the spring forces change with the distance the plate travels and lack reliability, the reliability of this spring-driven thread demoulding mechanism is also insufficient, especially when there is

Corresponding Author: Guo-Wei Chang, Mechanical and Electrical Engineering Department, Shunde Polytechnic University, Foshan, Guangdong Province, 528300 China, Tel.: 86 13006770281

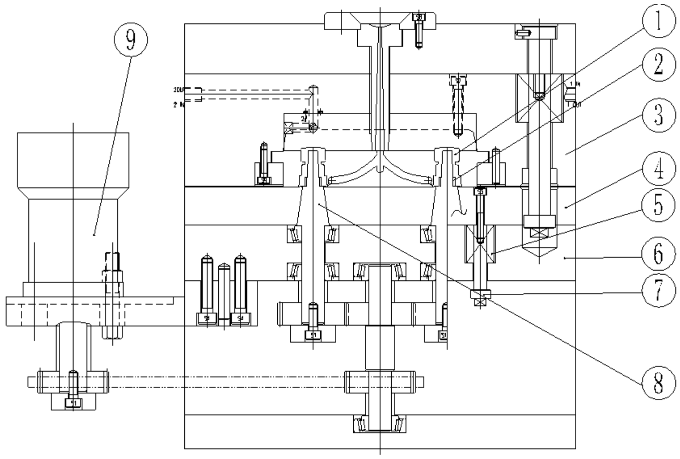

Fig. 1: Hydraulic motors and spring-driven automatic thread demoulding system

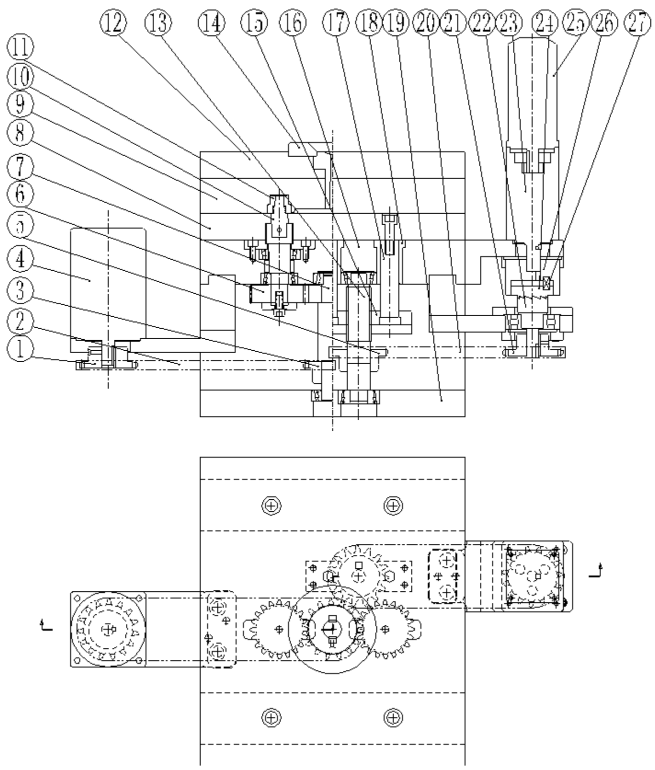

Fig. 2: The step motor and servo motor synchronization system for automatic thread demoulding

a longer thread on the part. At the beginning of the pushing, the initial spring force is so large that the thread may be over dragged and damaged. At the end of the pushing, the pushing force is inadequate and the pushing plate is likely to be separated from the part. As a result, the separation of the plate makes the threaded part possible to turn, which disables the threaded part to be released from the core. Therefore it may be difficult to make qualified products. 1. plastic part, 2. part screw, 3. fixed die plate, 4. pushing plate, 5. springs, 6. moving die plate, 7. position limit bar, 8.threaded core, 9. hydraulic motor.

The composition of the system after improving: The improved automatic servo synchronization thread demoulding system is shown in Fig. 2 (Chang *et al*., 2010).

The screw turning out system proceeds as follows: step motor-4 drives sprocket-1; sprocket-1 drives chain-2; chain-2 drives gear-3; gear-3 drives shaft-7; shaft-7 drives the gear on it and then drives the gear-6; and gear-6 drives threaded core-10.

The synchronous servo pushing-plate system proceeds as follows: servo motor-25 drives planetary gear reducer-23; the reducer-23 drives gear ratchet sleeve-26; ratchet sleeve-26 drives ratchet-24 to rotate; the ratchet-24 floats in the ratchet sleeve-26 and may move in axial direction in the sleeve, at the bottom of ratchet-24 there is 1 set of springs same as ratchet-spring-27 and the ratchet-24 engages with the bar-ratchet-22; the bar-ratchet-22 drives sprocket-d-21 to drive chain-b-20; sprocket chain-b-20 drives sprocket-c-5; sprocket-c-5 drives lead screw-13; screw-13 drives lead screw nut-15; screw nut-15 drives connecting rod-17; the connecting rod-17 passes through the guide sleeve-18 mounted on the moving die plate-16; the connecting rod-17 fastens with the pushing plate-8.

The advantages of the project: It is the first time to apply the servo mechanism using PLC control to the injection mould. The ingenuity of the project is in that the proper combination of the injection mould and the electronic control thoroughly solves the general problems existing in the injection mould. With the help of the electronic control, the application of this technology makes up for the disadvantage of the immutability of the pure mechanic structures and perfectly combines the two together so as to realize an essential promotion of the automatic thread demoulding system, thus fitting different thread pitches and different plastic work-piece materials, which breaks the limitation of the traditional thread demoulding mechanism and so makes a promising technology.

MATERIALS AND MATHODS

The improved design ideas: In the improved design mentioned above, the step motor is used to drive the screw turning out system, which is easier to control compared with a hydraulic motor; (Note: Fig. 2 and 3 are from the improved mould design, the numbers labeled to the parts in Fig. 1 are different from those in Fig. 2 and 3)

1. sprocket-a, 2. chain-a, 3. 2 sprocket-b, 4. step motor, 5. sprocket-c, 6. gear, 7. shaft, 8. pushing plate, 9. fixed die plate, 10. threaded core, 11. the plastic part 12. fixed die installing plate, 13. lead screw, 14. indicator ring, 15. lead screw nut, 16. moving die plate, 17. connecting bar, 18. connecting bar guide bushing, 19. moving die installing plate, 20. chain-b, 21. sprocket-d, 22. bar-ratchet, 23. planetary gear reducer, 24. ratchet, 25. servo motor, 26. ratchet sleeve, 27. ratchet-spring

In the synchronous servo pushing-plate system, behind the reducer there is a ratchet system added.

The ratchet drives the sprocket and consequently drives the lead screw. The lead screw nut is limited by the connecting rods which prevent it from rotating, so that the nut can only make axial movement and thus promote the pushing plate.

Thread demoulding of the plastic parts requires synchronization between the two systems. That is,

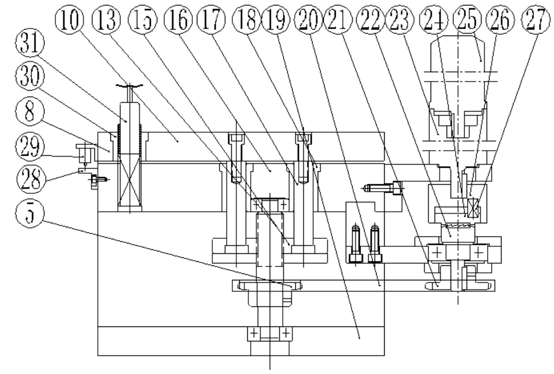

Fig. 3: More detailed section view of the synchronous servo pushing-plate system

when the screw turning out system is running to release the parts from the threaded cores, the synchronous servo pushing-plate system needs to push the parts and cover a distance equal to the axial distance the core thread goes. This action not only pushes the plate with the parts attached to it, keeping it from turning, but also works as an auxiliary pushing force to the parts. The synchronization between the two systems is achieved through the programmable logic controller. The left side of Fig. 2 expresses the section view of step motor driven screw turning out system; the right side expresses the section view of the synchronous servo pushing-plate system. Figure 3 shows the more detailed section view of the synchronous servo pushing-plate system.

Synchronization relationship calculations: According to Fig. 2, suppose that the moulded parts' thread pitch is P, the step motor rotating speed is Nst, servo motor rotating speed is Nse, R for the reducer ratio and Ps for lead screw pitch. According to step motor driving mechanism shown in Fig. 2, the sprocket drive ratio is 1:1; the gear transmission ratio is 1:1. So when the step motor rotates a circle, the moulded part is released the thread one circle.

That is, when the part goes a pitch value P distance, the pushing plate must also complete the displacement of Pt, therefore. $P_t = P$ (1) So there achieves the synchronization. Thus, the synchronous servo motor rotation is calculated as follows:

$$N_{se} = R \times \left(N_{st} \times P / P_s \right) \tag{2}$$

(Parts numbers before No. 27 has the same pointing as Fig. 2) 28. limit switch contactor, 29. limit switch, 30. moving die plate ball bearing bushing, 31. moving die plate ball bearing pin.

Control principle and components: Control system uses a programmable logic controller and a text editor component. It is required to control a step motor driven

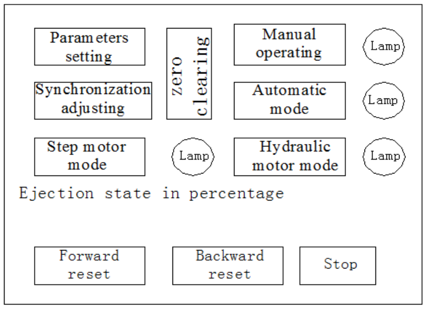

Fig. 4: The PLC control panel interface

system and a servo motor synchronous system at the same time. The programmable logic controller should have two-way high-speed pulse channels. The Mitsubishi FX-2N PLC was chosen as the controller. In the step motor driven system a checking transducer is added for detecting the rotation of the shaft connected to the threaded core for discrimination of synchronization.

After the servo and step systems are readily powered with electricity, the PLC processes the data, the customer's hypothesis parameters are set and the servo and step pulse numbers are computed. And then PLC sends out the servo ON signal, leading the servo system to the momentarily armed state and waiting for the injection moulding machine's ejection signal. Once it receives the injection moulding machine's ejection signal, PLC will send the pulse instructions simultaneously to the servo and step drivers. And by the calculation of position and speed according to the approaching switch detector signal, it adjusts the synchronization between the two systems, with the servo and step motors driving the threaded core and the pushing-plate arriving at expected positions synchronously.

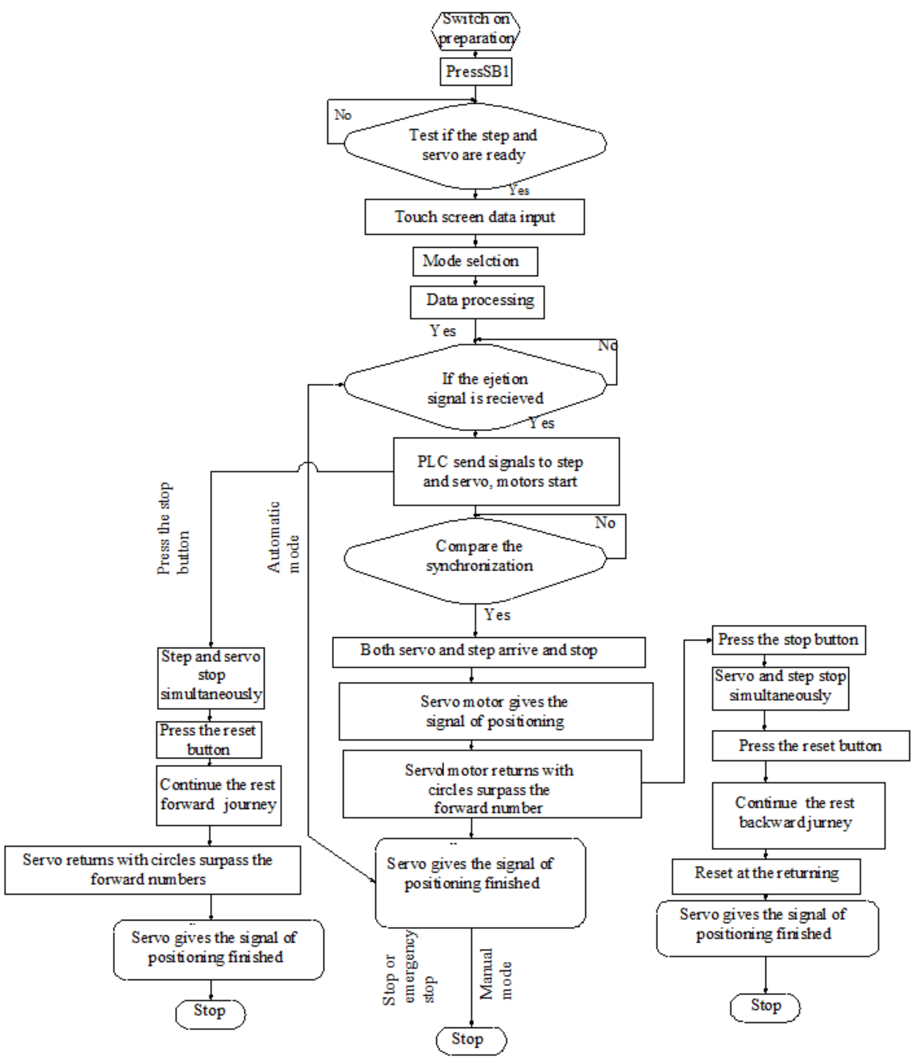

Fig. 5: Flow chart of the PLC control

If the parts' thread has the defect like contraction or over dragging, it can be amended on the site from the setting panel by adjusting the value of thread pitch P.

Considering that there are some small gaps in the actual mechanism, step motor and servo motor would start at the same time after receiving the signal theoretically, but in fact there is an interval between the real starting time of the core and the plate. So the control system needs to set up another a small time value as an adjusting value of Tw. By adjusting the value of Tw, we may adjust the time difference between the two systems' real starting time so as to achieve the best results.

The PLC control panel interface is shown in Fig. 4. When the actions begin, switch on the step motor first and then the servo motor and select the ejection mode. When the step motor ejection mode is selected, it is ready for the step motor to drive the threaded core to rotate. Then enter the parameter settings and enter the theoretical value of the part thread pitch, the pitch correction value and the length of thread along the axis. In the sub-settings such as the "advanced settings" of the parameter settings, enter the amount of the step motor subdivide value, the subdivide value of servo motor, the lead screw pitch and the lead screw pitch correction value. Then enter the synchronization adjusting interface, set the synchronization run time (i.e., the total time of ejection) and the servo motor in-advance time Tw. Then select manual or automatic mode. After these inputs, the system can begin to run. When the limit switch is turned on, the signal of which indicates the injection moulding machine starts to moves, the systems run to take the threaded part off the rotatable threaded core. At any position when the red button of the overall control is pressed, the system is stopped. Pressing the reset or reverse button may let the system run to the initial position.

In the control system, there are two parameters crucially simulating the actual injection moulding process. One is the part thread pitch correction value. This value can be adjusted in the actual injecting time, representing a variety of differences due to thermal expansion and contraction of parts where the actual pitch may differ from its theoretical pitch. The other is the in-advance time Tw to be adjusted for the servo motor. Because of the mechanical clearance itself, when the mechanical system starts the step motor, the servo system needs first to run in advance of 0.3-0.5 seconds to eliminate the mechanical clearance. Thus perfect demoulding of the thread can be achieved. Both parameters of the in-advance time and the pitch correction value are required to be adjusted at the same time when injection mould in testing.

PLC control system flow chart is as shown in Fig. 5.

RESULTS AND DISCUSSION

The zero drifting problem of the servo motor: There is a problem in resetting the pushing plate. Because the servo motor would drift from the zero point, when the servo motor rotates backward with the same revolutions as in the forward direction, the pushing plate-8 would not be settled to the original place. That is to say the plate would be inaccurately placed. If the drift were negative, the pushing plate-8 would contact with the moving die plate and the servo motor-25 would continue to rotate with a drift value from the zero point, but the pushing plate-8 at this time could not be moved any further. This would lead to a great mechanical internal force, resulting in a mechanical damage to the system. If the drift were positive, the pushing plate-8 and the moving die plate-16 would have a small gap between them. On the other hand, the pushing plate must stay close to the moving die plate before the injection begins, for a large clamping force should be withstood due to the pressure of the cavity after the start of the injection. And if there is a gap between the pushing plate-8 and the moving die plate-16, this gap is bound to be suppressed by the great clamping force, until the pushing plate and the moving die plate press against each other. In this case, the synchronous servo pushing-plate system is under mechanical deformation, which may mainly be represented by the deformation of the lead screw, possibly causing damage to the lead-screw-nut mechanical system.

The servo motor may have negative or positive zero drifting and zero drifting value may accumulates successively and unpredictably, which may cause the mechanical servo synchronization damage or fatigue damage.

The role of the ratchet system: Shown in Fig. 2 and 3, behind the servo motor and the reducer, the system is added a ratchet system (Chang and Xiang, 2011).

The total forward circles of the servo motor rotation number N1 = Nst can be set in the setting panel and the number N1 is determined by the part ejection or demoulding distance.

After completing the task of thread demoulding synchronization, servo motors rotates reversely and the pushing plate returns. The number of circles N2 that the servo motor returns is set larger than the number N1. That is, N2-N1 = δN, δN is intended to set in the system for the use of ratchet teeth. Since N2>N1, when the servo motor rotates reversely and the pushing plate has contacted with the moving die plate, the servo motor will continue to rotate δN turns, where δN is given a value about 3% of the total forward revolutions. When ratchet-24 is to force down the spring-27 at the bottom between the ratchet and ratchet sleeve, the ratchet-24 and bar-ratchet-22 start sliding until the servo motor stops. By this design, after each thread demoulding, the pushing plate can be guaranteed to return and stay close to the moving die plate tightly, without causing misplacement of the pushing plate and ensures the servo motor synchronous system to be reset at a stress-free condition.

After the servo motor synchronous system completes a mission of the demoulding and the pushing plate arrives at the current location noted as 0 point, the control system takes the current location as the next starting point of the servo motor rotation. The current location fits well because of the ratchet, so the system runs continuously in good security.

CONCLUSION

The system experiment device mentioned above has been successfully tested. By this method and idea of synchronization applied in injection moulding, when threaded cores are present and plastic parts automatic demoulding needed, many mechanical systems applicable to various specific situations could be put into practice.

NOMENCLATURE

Nse = Servo motor rotating speed defined in Eq. (2)
Nst = Step motor rotating speed defined in Eq. (2)
P = Moulded parts' thread pitch defined in Eq. (2)
Ps = Lead screw pitch defined in Eq. (2)
Pt = Displacement that the pushing plate must also complete according to the synchronization, defined in Eq. (1)
R = Reducer ratio defined in Eq. (2)
Tw = Servo motor in-advance starting time

REFERENCES

Chang, G.W., Z.M. Xu and Z.J. Hu, 2008. Design of servo-synchronous automatic thread stripping mechanism in injection mould. Die Mould Ind. China, 34(11): 45-48. (In Chinese)

Chang, G.W., B.Y. Xiang, J.J. Chen, Y.J. Liang and X.Y. Zhou, 2010. Improvement of servo-Synchronous automatic screw releasing mechanism of injection mould. Eng. Plast. Appl. China, 38(1): 69-72. (In Chinese)

Chang, G.W. and B.Y. Xiang, 2011. Servo-synchronous automatic screw releasing mechanism improving study in injection. Eng. Plast. Appl. China, 39(8): 69-71. (In Chinese)