THE DEVELOPMENT OF AN ALGORITHM OF ADAPTIVE DISCRETE PID CONTROL FOR THE EXTRUDER BASED ON A MICROCONTROLLER

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Introduction

It is supplied in a printer in a form of filament (figure 1).The most reasonable way of creating models is printing them out of ABS plastic. Nowadays, 3D printing gains the popularity and practical applicability.

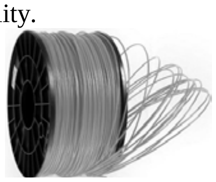

Figure 1. Form of filament

The technology of plastic fiber production assumes the adherence of diameter (1.7 mm) with the accuracy of 30 mcm. The plants (extruders) that can provide the given value are expensive. The created model of an extruder is shown as a model in figure 2.

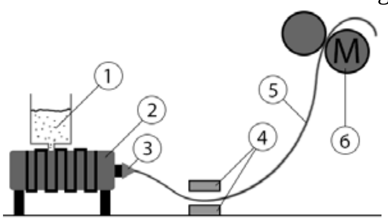

Figure 2. The model of extruder

where
1 – Bunker;
2 – Extruder;
3 – Nozzle;
4 – Transducers;
5 – Filament;
6 – Motor.

The crushed plastic is piled up to a special bunker (1) where it is heated up to the special temperature. The soft plastic is pressed out through the nozzle (3) as a filament (5) with a certain diameter by the screw rotating. After that the fiber (5) extends through the position transducers (4) by the gravity method. Depending on the sensor reading (4) it is needed to control the motor rotating frequency (6). It is necessary to solve the following problems of controlling this SAC loop:

- The continuously adjustable frequency of a motor rotating (without working in fits and starts);
- The optimal speed search of broaching (due to the non-linear speed of plastic supplying from the extruder;
- The warning system support (the plastic break etc.).

At the moment the motor rotating frequency control is implemented with the help of relay automation. The use of such implementation involves only a partial solution to the tasks. For example, there is a probability of plastic break because of the motor impulse control. Also, the diameter reduction is possible because of the fiber extension due to the stretching mechanism spurts.

Nowadays it is possible to reach the accuracy of 30 mcm on the functional plant but with the material over-expenditure, raising the question of profitability of the ABS fiber production. The developed algorithm may solve the presented problems absolutely. It is based on the classical PID loop control and supposes the adaptive discrete control. The scheme of the classical PID loop control is shown in figure 3.

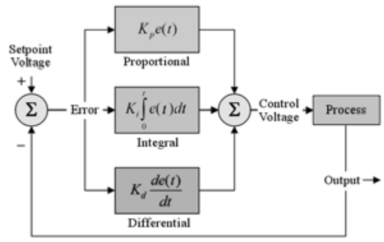

Figure 3. The classical scheme of the PID control loop

The control influence is formed depending on the sensor (or sensors) feedback. It includes proportional, integral and differential components depending on the error value (the difference between a set point and a real value). The quality of processes depends on the respective factors selection (1).

$$u(t) = P + I + D = k_p e(t) + k_i \int_0^t e(\tau)d\tau + k_d \frac{de(t)}{dt} \quad (1)$$

It is obvious that a classical PID controller assumes the continuous (analog) signal using. Moreover it does not support the control influence adaptation. The main task is the software and hardware complex for control speed of motor (pulling fiber) developing that allows avoiding jerks with the increasing speed, automatically selecting the optimal feeding speed.

Algorithm

The flow chart of a suggested algorithm is shown in figure 4. When reading from the lowest sensor will reach the SETPOINT the motor speed will increased according PID control algorithm. Before the highest SETPOINT2 activation the algorithm of slowly breaking will be activated. Then the data for adaptive speed function will be saved and calculated.

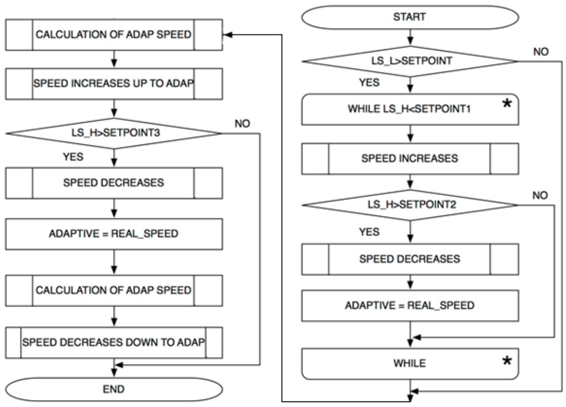

Figure 4. Flow chart

The calculated data will be transformed to the motor speed and translated to the engine. The motor will normally work at adaptive speed but if the highest sensor is activated at SETPOINT3 the adaptive speed will be recalculated.

In general the adaptive function may be presented as the following formula (2):

$$u_{t+1}(t) = \lim_{x \to t} \sum_{x=i-1}^{x=i} \frac{u_x}{2} \pm k_p e(t_{t-1}) + k_i \int_0^{t-1} e(\tau)d\tau + k_d \frac{de(t_{t-1})}{dt} \quad (2)$$

The choice of sum or difference shows depends on the motor speed trend.

Hardware

To solve the pointed problems completely it was decided to use a micro controller (instead of relay automation), transistors and 2 opt switches (to provide a feedback). MOSFET transistor was used as a controllable key because it can supply preselected performance of the pulse width modulation (PWM) of the control influence sent by a micro controller. The schematic diagram of logic key is shown in figure 5. The three-wire sensors connection scheme (figure 6) was used for fine-tuning.

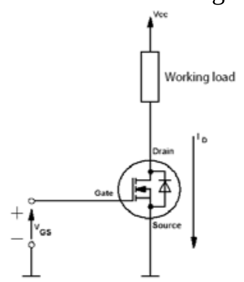

Figure 5. Schematic diagram

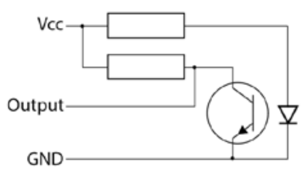

Figure 6. The three-wire sensors connection scheme

For implementation of the developed algorithm the position of opt switches was chosen (figure 7). This solution allows the better control of the fiber position in the space. Also the 3D model of a holder was developed in the special software (Autodesk Inventor) and was printed with the help of a 3D-printer (figure 8).

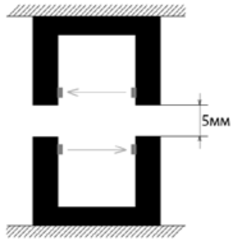

Figure 7. The position of opt switches

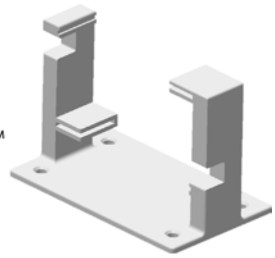

Figure 8. Model of holder

The proposed solution is based on a microcontroller ATmega2560, which is capable of 16 MHz PWM.

Results

According to the algorithm the graphs of transients are presented in figure 9. The research has given the following result (figure 10).

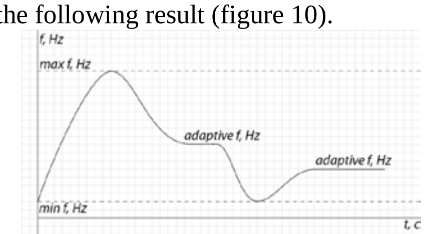

Figure 9. The graph of transient according to the algorithm

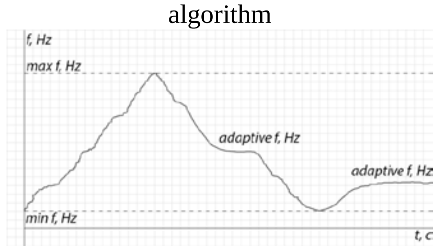

Figure 10. The real graph of transient.

According to the schedules of the transition process there is an ever-increasing and deceleration rotational speed of the broaching mechanism. Also, the algorithm provides the stable output for adaptive speed, which was calculated by a microcontroller using the trend process.

Conclusion

The described hardware and software solution has been tested and is successfully used in the ABS plastic fibers production in the upgraded unit. The solved problems:

- The smooth change of the engine speed (the pull mechanism) at the expense of transistor switches, PWM and the proposed algorithm.
- The optimal speed converting in the course of unit working is automatically selected.
- The emergencies were minimized because of the jolting pulling of fiber absence.

References

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2. Users Guide to Autodesk Inventor by Rajat K. Daftuar, Purdue University School of Electrical Engineering