

자율 최적 성형 공정 시스템 개발

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A Concept of Self-Optimizing Forming System

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Abstract

Nowadays, a strategy of the self-optimizing machining process is an imperative approach to improve the product quality and increase productivity of manufacturing systems. This paper presents a concept of self-optimizing forming system that allows the forming system automatically to adjust the forming parameters online for guarantee the product quality and avoiding the machine stop. An intelligent monitoring system that has the functions of observation, evaluation and diagnostic is developed to evaluate the pully quality during forming process. Any abnormal variation of forming machining parameters could be detected and adjusted by an intelligent control system aiming to maintain the machining stability and the desired product quality. This approach is being practiced on the pully forming machine for evaluating the efficiency of the proposed strategy.

Key Words : Self-optimizing(자율 최적), Forming process(성형 공정), Online monitoring(온라인 모니터링), Intelligent control(지능 제어), Fuzzy Logic(퍼지 로직)

1. Introduction

Today, in a pully manufacturing system demands of making the high product quality and reducing the downtime are vital factors, it means the system must be required higher autonomous and intelligent. In order to satisfy these criteria, a concept of self-optimizing forming system is proposed as an imperative approach. This concept focuses to develop a self-optimizing control strategy based on the pully quality criteria. In the pully forming line⁽²⁾, the pully product quality

is depended on the forming parameters. Therefore, selection of the optimal forming parameters is very important during forming process. According to the conventional control system, the forming parameters were selected based on handbooks or operator's experience, and these parameters must be chosen with a redundant amount to compensate for disturbances during the forming. Even if the forming parameters were optimized off-line by some optimal algorithm, they cannot be online adjusted in the forming process due to disturbance changes^(3,4).

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In order to improve the quality of pulley products and reduce the downtime and forming costs, this paper presents a strategy of self-optimizing forming system, which is capable of diagnosing, evaluating and adjusting the forming parameters tracking the desired quality. This paper is organized as follows: section 2 describes the composition and working principle of forming system. Section 3 presents the strategy of self-optimizing forming process, and section 4 shows the evaluation method and the conclusion.

2. Composition and working principle of the pulley forming process

Pulley forming process uses the roll spinning technique which the pulley products are formed by the pressing of the rollers on the rotating work-piece⁽²⁾. The principle diagram of pulley forming process is shown in Fig.1. Work-piece is a circle sheet metal that is held between the die and the mandrel. The roller is mounted on the frame and enabled to rotate around its axis. It can be moved toward the mandrel through the handling of the cylinder. Pulley parts are formed by pressing the roller on the rotating work-piece. A period of the pulley forming process consists of many steps of the roll spinning depending on the product types.

During the pulley forming process, under the pressing of the rollers the work-piece is deformed following the shape of these roller faces. If the disturbances (vibration, roller wear, chatter, non-homogeneity material, mandrel speed changes) happen, the pulley product quality will be deteriorated. As a result, these products will be eliminated in the inspection stage. In order to maintain the pulley product quality, a self-optimizing forming strategy is proposed to handle the forming system which overcome these disturbances.

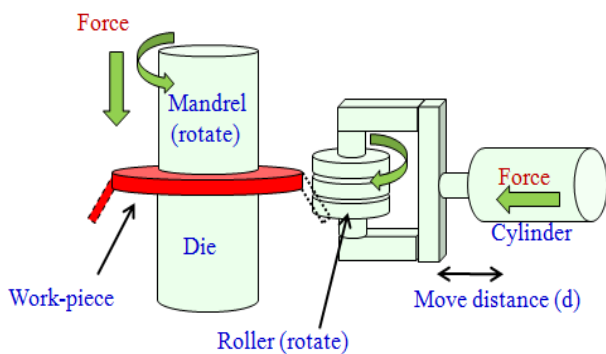


Fig. 1 Principle diagram of Pulley forming system

3. Developing a self-optimizing forming process

The pulley product quality is depended on the forming parameters such as roller wear, mandrel speed, pressing pressure of the cylinder. One of major impact upon the pulley product quality is the wear of rollers. If the roller wear is over the tolerance limit, it must be replaced to guarantee the product quality. Otherwise, if the wear of roller falls inside the specification limit, the distance between roller and workpiece should be adjusted appropriately by the handling the cylinder force. The major study goals in roller wear monitoring are to develop self-adjusting and integrated systems capable of monitoring under various working conditions with minimum operator supervision⁽¹⁾. Sequence of steps for developing a self-optimizing forming system is as follows: Step 1: Developing a inspection system to measure the forming process variables: the current situation of forming variables is determined through analyzing of the measured values from sensors. Step 2: Developing a monitoring system that uses to monitor onlinely the roller wear and the process variables and to evaluate whether the forming process variables are in good or bad of operating condition. Step 3: Proposing an optimized algorithm that is capable of search the optimal values for adjusting the roller parameters. Step 4: Generating a self-adapting control system to adjust the roller position such that the pulley product quality is guaranteed.

3.1 Developing a measurement system

The scheme of the monitoring and data acquisition system

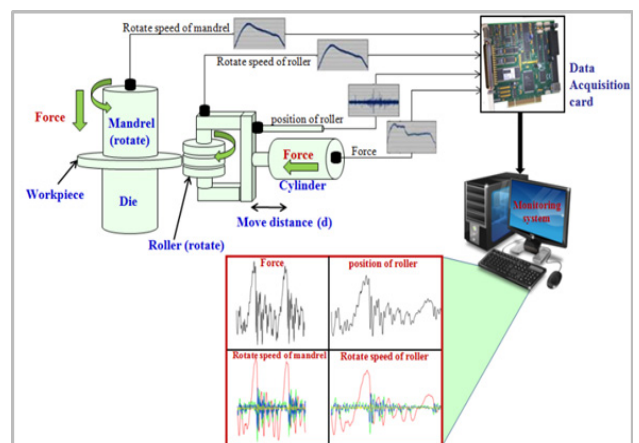


Fig. 2 Monitoring and data acquisition system scheme

is shown in Fig.2.

The measurement system includes the tachometers that use to measure the rotation speed of mandrel and rollers. The position sensors are used to determine the position of the rollers, and the dynamometer utilizes to measure the pressing force on the roller. These measured data from sensors are sent to the data acquisition card that has functions of A/D conversion, filtering, and feature extraction. These processed data are then sent to the computer for developing a monitoring system.

3.2. Strategy for developing a monitoring system

The roller wear monitoring diagram in forming process is shown in Fig.3. The purpose of automated roller wear monitoring in forming is to relate the process signals to the roller conditions, and detects or predicts the tool failure.

This monitoring system is composed of two components: a data acquisition subsystem and a decision making subsystem. The data acquisition subsystem consists of a signal measurement device (sensor) and a signal processing algorithm. When a forming operation is in the process, the sensor signals are then processed to extract forming features. These features can be used by the decision-making subsystem with the pattern recognition algorithms as dynamically collect raw machining signals (pressing force of roller, rotating speed of mandrel and roller, moving distance of roller, etc.). Those raw forming predict part quality to determine if any corrective action is necessary.

In order to develop a monitoring system for evaluating and diagnosing the roller wear, the fuzzy logic technology is applied in this study. The fuzzy logic seems to be a unique method of dealing with the physical process that has information uncertainty and vague. A fuzzy system consists

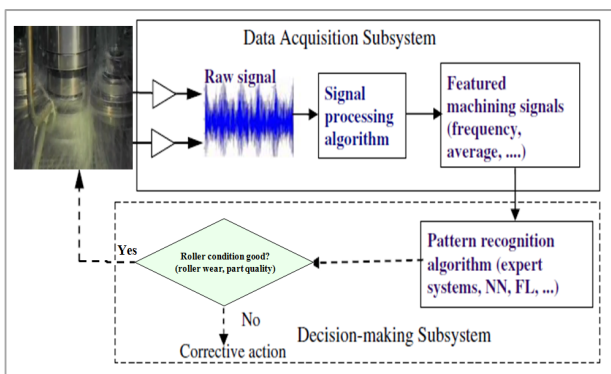


Fig. 3 Roller wear monitoring diagram of forming system

of four base components as: fuzzification, fuzzy inference, rule base and defuzzification⁽⁵⁾. The diagram of a fuzzy system is shown in Fig.4.

- Fuzzification: The purpose of fuzzification is to assign the measure values of the input variables to fuzzy set by the membership functions. Therefore, for individual input variables, the membership functions are assigned and the weight of the rule for membership functions is calculated. Several fuzzification methods are available, however, the triangular method is normal used. In this study, the triangular fuzzification method is chosen. For each input sensor data (speed of roller, speed of mandrel, moving distance of roller, pressing force on roller), the triangular membership functions with the linguistic values “small”, “medium” and “large” are used (as shown in Fig.5).

Where a_1 , a_2 , and a_3 are parameters to determine the positions of membership functions, as well as affect the shape of the membership functions. The fuzzy logic to derive the tool condition and fuzzification computes for each sensed input based on the above the membership functions. These values indicate the degree of the input that belongs to the “small”, “medium” and “large” linguistic terms.

- Knowledge base and Fuzzy inference: The purpose of fuzzy inference is to define the system behaviour by means of the rules “if...then” at the language level. The rules are generated based on human heuristic and the obtained data

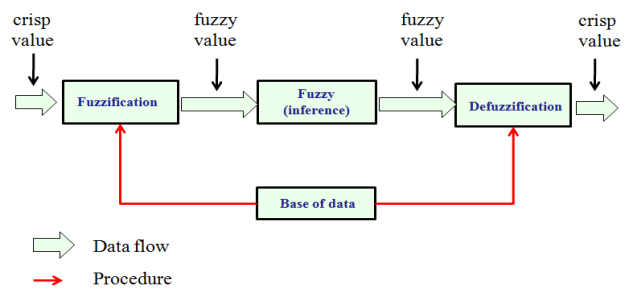


Fig. 4 Diagram of a fuzzy system

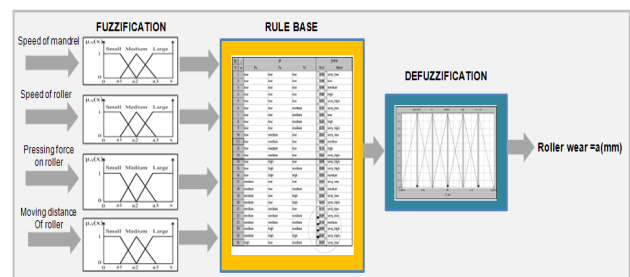


Fig. 5 Fuzzy logic algorithm for evaluating the roller wear

from experiments. The knowledge base is presented as a fuzzy relation or as a linguistic fuzzy rule base with membership functions as a database. For each rule, it is necessary to determine its weight. The result depends to a certain extent on a correct determination of the defined rules importance. The weight of these rules can be changed during optimization. The result of this process is a linguistic variable⁽⁵⁾.

- Defuzzification aims to express a crisp value from an inferred fuzzy control action of the given value from the resulting fuzzy set. There are two defuzzification methods, center of gravity method and maximum method. The center of gravity method is the calculating more complex, but the shape of the membership function is considered. Meanwhile, the maximum method is the calculating simple, but the shape of the function are not considered. Fuzzy logic algorithm for monitoring and evaluating the roller wear is shown in Fig.5.

3.3. Strategy for self-optimizing forming parameters

The main objective of forming operations on the forming machine is to achieve the forming products with low cost and high quality. In order to satisfy these objectives, the determination of optimal forming parameters such as speed of mandrel (v_1), speed of roller (v_2), moving distance of roller (d), and pressing force on roller (f) plays an important role for the product quality. Fig.6 shows the strategy for self-optimizing forming parameters.

In order to develop following this control strategy, firstly, the testing process is executed for each forming product, for example, the forming process of the double pulleys, in standard operating condition without disturbances. The experience results with the obtained parameters will be stored in the database for reference data.

In the actual operation, if the diagnostic result of roller wear in the monitoring system is fall within the specification limit, the new forming parameters should be generated newly to maintain the product quality. In the decision-making module, a fuzzy-neural controller is proposed to optimal and update new forming parameters and online self-adjusting the parameters during forming process. Neural network is well known as the ability of self-learning the complicated process. Meanwhile, the fuzzy logic has an advantage of reasoning based on knowledge. The Fuzzy-Neural combines the

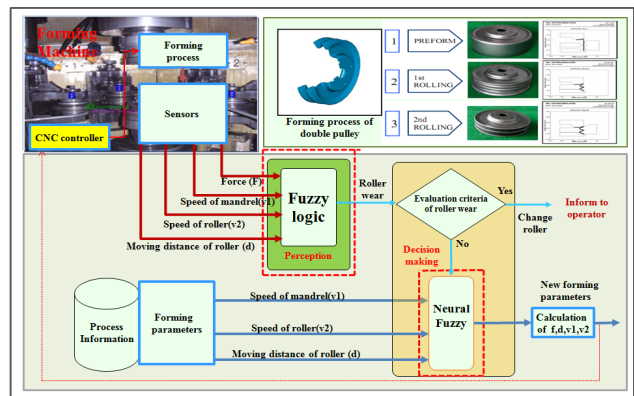


Fig. 6 Strategy for a self-optimizing forming parameter

advantages of fuzzy and neural system helping the forming system capable of adapting with the uncertainties. In this study, a neural network with the back propagation algorithm is used to learn and optimal the forming parameters, it means this algorithm optimizes the parameters of the input membership function shape of fuzzy logic system and the weight of controller outputs during the system operation. The optimal output parameters which were achieved from the fuzzy controller, is then sent to the CNC controller to adjust the moving distance of the rollers reasonably.

4. Evaluation and conclusion

In order to evaluate the efficiency of the proposed strategy, we make a survey on the conventional pulley forming process of KAPEC company. It assumed that, we delivered the sixty parts to this forming system, and setting the time operation is the sixty minutes. During forming process, due to the disturbances (roller wear, high oil temperature, low pressing force of the rollers, low speed of the mandrel, etc.) happen, the forming system has to be stopped for disturbances removing. As a result, the finished parts are 36 parts and the efficiency of the system is $\eta = 36/60=60\%$. Meanwhile, in the same testing condition for the self-optimizing forming system, with the functions of optimal and update new forming parameters and online self-adjusting the parameters during forming, the proposed system obtains the fifty four parts, and the efficiency is $\eta = 54/60=90\%$. These results show that the production efficiency of the proposed forming system is higher 30%. Fig.7 is the comparison between the conventional pulley forming system and the developed system.

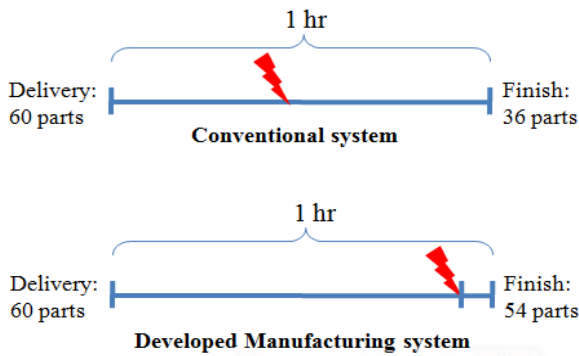


Fig. 7 Evaluation method



Fig. 8 The pulley forming system testbed in KAPEC company

In this paper, the strategy of the self-optimizing forming process was presented. The artificial intelligent algorithms such as fuzzy logic and neural network were proposed to apply to the forming system aiming to increase the autonomous, intelligent, self-learning and self-adapting with the uncertainty process. Through this proposed strategy the productivity and efficiency of the forming system will be increased, and the downtime and production cost will be reduced. This proposed strategy will be tested on the pulley forming line of the KAPEC company in the future. Fig.8 shows the pulley forming testbed in KAPEC company.

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