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AN ANALYSIS ON ENERGY CONSUMPTION OF INJECTION MOULDING PROCESS USING NEURAL NETWORK

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DECLARATION

I declare that this Choose an item. entitled "An Analysis On Energy Consumption Of Injection Moulding Process Using Neural Network" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (BMMW) with Honours.

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DEDICATION

This study is wholeheartedly dedicated to my beloved parents Haji Ahmad Siaman Bin Kasim and Hajah Naimah Binti Misran who have been a great inspiration and gave me strength to keep on moving forward on my studies, moral, spiritual, emotional and financial support.

And also not forgot to Ts. Mohd Faizal Bin Halim, my supervisor, who has supported me throughout the period of my study and without whom I would not have been able to accomplish my research project.

ABSTRACT

This paper presents a hybrid optimization method for optimizing the process parameters during injection moulding. This proposed method neural network to find the best parameter in injection moulding. A multi-objective optimization model is established to optimize the process parameters during injection moulding on the basis of Orthogonal experiment method, and neural network. Optimization goals and design variables (process parameters during injection moulding) are specified by the requirement of manufacture. A neural network model is developed to obtain the mathematical relationship between process parameters and the power value. The best parameter will find out after the experiments occured. A case study of a plastic article is presented. Clamp meter as well as clamp force during injection moulding are investigated as the optimization objectives. Mold temperature, melting temperature, packing pressure and cooling time are considered to be the design variables. The case study demonstrates that the proposed model neural network method can adjust the process parameters accurately and effectively to satisfy the demand of real manufacture.

ABSTRAK

Kertas kerja ini menyajikan kaedah optimasi hibrid untuk mengoptimumkan parameter proses semasa pembuatan cetakan suntikan. Kaedah yang dicadangkan ini menggunakan jaringan saraf untuk mencari parameter terbaik dalam pembuatan cetakan suntikan. Model optimasi multi-objektif ditubuhkan untuk mengoptimumkan parameter proses semasa pembuatan cetakan suntikan berdasarkan kaedah Eksperimen Orthogonal dan jaringan saraf. Matlamat optimasi dan pembolehubah reka bentuk (parameter proses semasa pembuatan cetakan suntikan) ditentukan oleh keperluan pembuatan. Model jaringan saraf dibangunkan untuk mendapatkan hubungan matematik di antara parameter proses dan nilai kuasa. Parameter terbaik akan ditemui selepas kejadian eksperimen. Kajian kes bagi produk plastik dikemukakan. Meter klem dan daya klem semasa pembuatan cetakan suntikan dikaji sebagai matlamat optimasi. Suhu cetakan, suhu cair, tekanan pengisi dan masa sejuk dianggap sebagai pembolehubah reka bentuk. Kajian kes ini menunjukkan bahawa model kaedah jaringan saraf yang dicadangkan boleh menyesuaikan parameter proses dengan tepat dan berkesan untuk memenuhi keperluan pembuatan sebenar.

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^{o}C	-	Degree
sec	-	Time in second
(% Injection Pressure)	-	MPa
rpm (%)	-	Revolution per miniute

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CHAPTER 1

INTRODUCTION

1.1 Background

Injection moulding tools today are often made up of many different parts that work together, including mechanical, electrical, air-powered and fluid-powered components. The design of the mold must ensure that it can work effectively in the manufacturing process, even if it is very complex. (Sahai & Verma, 2021). Injection moulding is the most widely used method for producing plastic components. Injection moulding may be used to create a wide range of items with varying sizes, complexity, and applications (Sahai & Verma, 2021). The injection moulding process necessitates the use of an injection moulding machine, raw plastic material, and a mould. In the injection moulding machine, the plastic is dissolved and then injected into the mould, where it cools and freezes (Sahai & Verma, 2021). This is a highly desired method in the manufacturing business because it can make complex-shape plastic goods with high dimensional precision and quick cycle times. Automobile industry, casings and housings of items such as computer monitors, mobile phones, and other devices with a thin shell characteristic are typical examples (Sahai & Verma, 2021).

1.2 Problem Statement

When compared to material and equipment expenses, energy usage during the injection moulding process is modest, according to some study. Despite the fact that injection moulding appears to be a low-energy process at first glance, its vast scale makes its influence quite important, and even little efficiency improvements can result in huge energy savings. In addition to having an impact on product manufacturing costs, energy consumption is a component of environmental effect and a crucial aspect of any overall sustainability strategy. Indeed, the majority of study into the environmental effects of manufacturing processes and systems has been on energy consumption patterns, with energy reduction being a key aspect in sustainable manufacturing.

1.3 Research Objective

The research for this main objective includes an analysis of the energy consumption of the injection moulding process using the BP Neural Network method, as well as an energy model that estimates energy consumption in the early stages of product design based on part material and geometry, as well as injection process specifications.

i. To minimize the amount of energy consumption by modifying machining parameters.

ii. To made an analysis on injection moulding process by using model Neural Network method.

iii. To validate the final result by identifying the best parameter.

1.4 Scope of Research

The scopes of this research are as follows:

- Conduct a thorough investigation of the injection moulding process and existing ways to modelling energy usage in this process.
- All experimental energy measurements, as well as processing settings, material, machine, and component parameters, were obtained.
- The models were run on the data from the experiments, and the results were compared to the energy consumption measurements.
- An Neural Network was chosen as the ultimate solution for modelling energy consumptions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter opens with a study of plastic materials, their use and effects on the environment. Journals, thesis, case studies, books, papers and other forms of electronic media are also employed in the study. Each source was chosen for its suitability to the study's goals (Umizhatul Najwa Binti Jamaludin, 2015). The next paragraph went through the details of plastic recycling including the restrictions on how recycled plastic may be used. Given that gear is a key topic that is relevant to plastic applications, the information on plastic gear will be extensively reviewed in the next paragraph. The injection moulding process is emphasized as a key emphasis to be studied in this study (Umizhatul Najwa Binti Jamaludin, 2015). An introduction to many plastic gear processing methods is offered, with the injection moulding process highlighted as a main focus to be examined in this study. Following the effects of material selection, mould and product form design as well as processing conditions on the quality of manufactured components were examined (Umizhatul Najwa Binti Jamaludin, 2015).

2.2 Injection Moulding Industry

Injection moulding is a common manufacturing procedure for making huge quantities of plastic components. As a result, retaining a competitive advantage in the injection moulding sector necessitates constant improvements in product quality consistency (Park et al., 2019). Artificial Neural Network, Genetic Algorithm, Iterative approach and simulation-based optimization techniques are being utilised to optimise the injection moulding process and get optimal processing conditions. Quality failure happens, however, owing to variance in moulding cycles (Park et al., 2019). Product quality is determined by the interaction of various factors such as method, material, and machine. The focus of this work is on real-time AI-based process parameter control in the injection moulding cycle (Park et al., 2019).

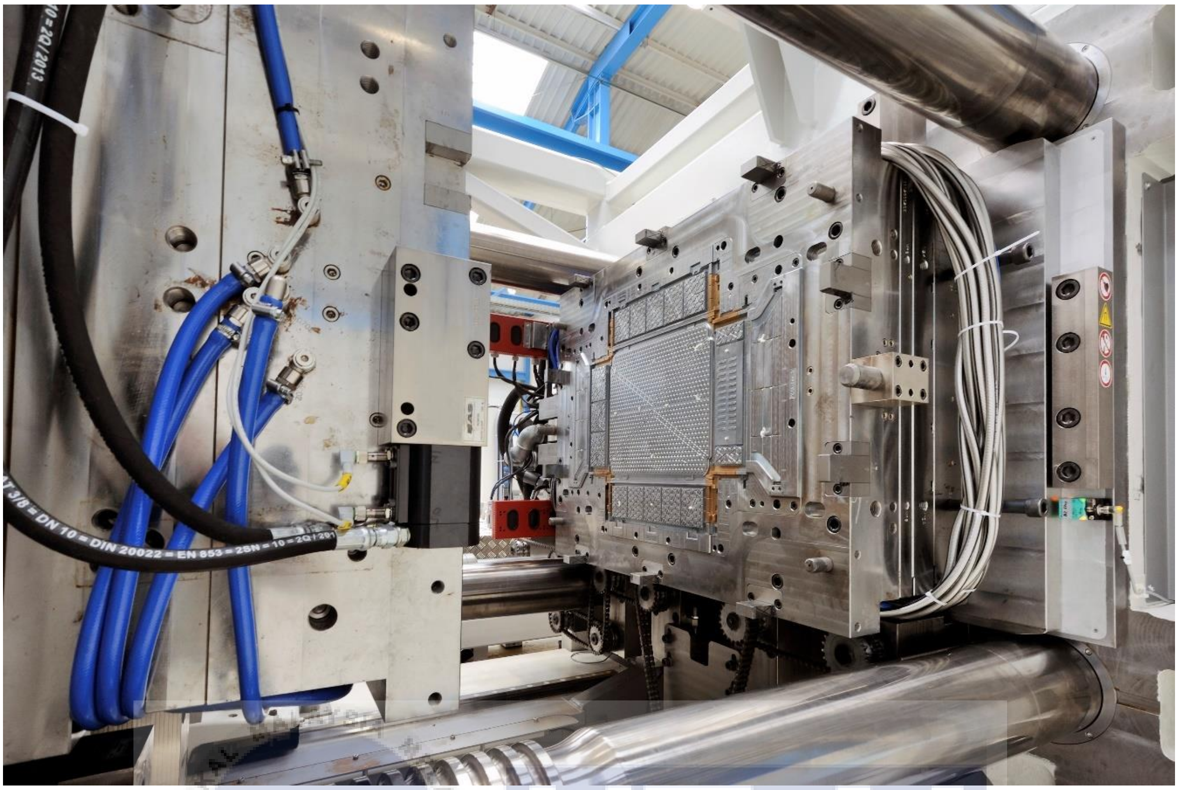

Figure 1 Plastic Injection Moulding Process

Plastic injection moulding (PIM) takes use of the formability of thermoplastic and thermosetting polymers to produce high-value-added precision products in a quick and cost-effective manner (Sadeghi, 2000). PIM is the largest polymer processing company with a product range ranging from micrometre accuracy precision pieces of the order of gramme mass to tens of kilogramme mouldings and has expanded significantly since the mid 1960s. In the recent decade, there has been a shift toward a greater understanding of quality and the need to accomplish it more consistently (Sadeghi, 2000). In this regard, intelligent planning and processing is one of the quantum steps ahead for this highly complicated multi-variable process in order to keep the product within defined quality boundaries, despite changes in raw materials or processing circumstances (Sadeghi, 2000).

Despite efforts by raw material suppliers to homogenise their products, the materials utilised and process operating factors are a major cause of variance in polymer flow behaviour and ultimate product quality. Shorter cycle times and thinner or more complicated components continue to raise the requirement for accurate quality control in PIM in this regard (Sadeghi, 2000). Operations that convey the product directly from the moulding machine to assembly stations challenge moulding optimization even further. To preserve the benefits of contemporary process technology, effective process planning and quality control are required (Sadeghi, 2000).

2.3 Issues of Injection Moulding

Injection moulding is a high-speed, automated method for producing unfilled or discontinuous-fiber-reinforced plastic components with extremely complicated shapes (Fan & Speight, 2017). The following are the four stages of a typical injection moulding process: (1) filling the relatively cool mould with the melt polymer; (2) packing more material into the mould under high pressure to compensate for volume contraction of the material as it cools; (3) cooling the material in the mould until it is sufficiently solid; and (4) ejection of the solidified product from the mold. (Fan & Speight, 2017).

Because the component is confined in-plane while in the mould, it develops stresses during solidification. The relaxation of these stresses induces immediate shrinkage in the moulded portion, which is frequently anisotropic and non-uniform. Additional shrinkage may occur during the cooling process following ejection. A degree of part warp will emerge from the anisotropic and non-uniform shrinking behavior. (Fan & Speight, 2017).

Figure 2 Common Injection Moulding Issues

2.4 Injection Molding Parameter

Injection moulding does not frequently employ the direct optimization approach. This strategy necessitates a sophisticated interaction of the simulation tool and the optimization code. This method has been utilised by a number of authors. Lam et al. presented a hybrid GA/gradient technique for optimising injection moulding settings (Dang, 2014). The GA method optimization strategy necessitates a large number of function evaluations or simulation cycles. When several computers operate at the same time, parallel computing can cut simulation time. Wu et al. used a distributed multi-population genetic algorithm, which is an improved genetic algorithm (Dang, 2014).

Injection moulding makes extensive use of metamodel-based optimization approaches. The usage of metamodel-based optimization approaches is dependent on the circumstances and the researchers' preferences. The following are some of the most prevalent optimization strategies for plastic injection moulding that have been documented in the literature (Dang, 2014).

2.4.1 Artificial neural network model

Because artificial neural network is a potent tool for forecasting high nonlinear responses via function approximation, neural network that replicates certain basic characteristics of human brain operation is an emerging method (Dang, 2014). Many writers have utilised artificial neural networks as a predictive model to illustrate the association between process parameters and quality index. The neural network predictor employing learning data retrieved by CAE analysis corresponds well with the experimental results, according to Kwak et al., Yarlagadda and Teck Khong, and Yarlagadda (Dang, 2014). The neural network model can reliably forecast product quality, according to Kenig et al., Mok and Kwong, Chen et al., and Altan, and this technique is a practical and efficient tool for quality criterion prediction (shrinkage, weight, or tensile strength). The process parameter optimization can be carried out based on this approximate relation (Dang, 2014).

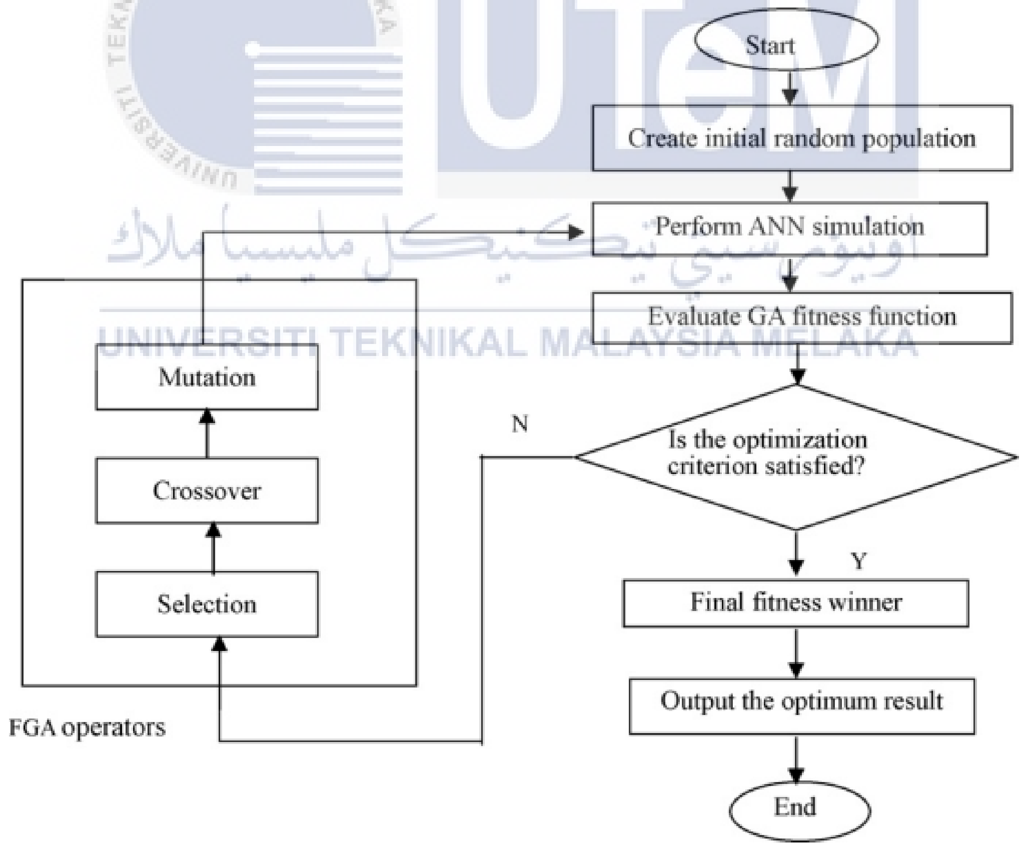

Figure 3 Flow Chart of Combining ANN/GA Optimization (Shen et al., 2007)

The usage of an ANN model in combination with a GA optimization approach is recommended. Shen et al. used a mix of artificial neural networks and the GA approach to optimise injection moulding process parameters (Dang, 2014). Chen et al. used soft computing with ANN and GA to optimise process parameters for multi-input multi-output (MIMO) and multi-input single-output (MISO) plastic injection moulding. Ozcelik and Erzurumlu used ANOVA, ANN, and GA to compare warpage optimization in plastic injection moulding. Other writers have utilised ANN and GA to enhance the quality of moulded parts by optimising process parameters in injection moulding. The majority of these authors came to the conclusion that combining ANN with GA is a sound technique (Dang, 2014). However, the majority of them failed to indicate how to choose the number of tests that would be utilised to train the ANN model. In most of these research, the number of input parameters ranges from four to six, however the number of experiments varies widely (from 27 to 252). It is obvious that if the number of trials is very big, the cost of simulation or actual experimentation will be exceedingly expensive (Dang, 2014).

2.5 Process Optimization

The goal of process optimization is to find the appropriate control variables for injection moulding within specified limits in order to have the greatest component quality. The fitness function employed in the process conditions optimization of injection moulding is based on the ANN model, and the process conditions are optimised using Genetic Algorithms (GA) in this research (Shen et al., 2007).

2.5.1 Genetic algorithms

An algorithms that are meant to imitate biological evolution principles in natural genetic systems. Genetic algorithm also known as stochastic sampling techniques can be used to address complex problems involving objective functions with 'poor' qualities such as multi-modality, discontinuity, non-differentiability, and so on (Shen et al., 2007). These algorithms retain and modify a population of solutions and use a'survival of the fittest' technique to look for superior ones. GAs tackle linear and nonlinear problems by utilising mutation, crossover, and selection operations on individuals in the population to explore all parts of the state space and exploit promising locations (Shen et al., 2007).

The employment of a GA necessitates the resolution of six key issues: chromosomal representation, selection function, reproduction function genetic operators, starting population creation, termination criteria and evaluation function (Shen et al., 2007).