

# Research on Modeling and Analysis of Energy Consumption Data in Forging Production Process

Xie Xu, Fei He<sup>\*</sup>, Yifei Tong and Ning Guo

Nanjing University of Science and Technology, Mechanical Engineering College, Jiangsu Nanjing 210094

<sup>\*</sup>Corresponding author

**Abstract**—According to the characteristics of forging production, it describes the forging production from the dimensions of forging products, forging equipment, process flow, quality management, mold management, production personnel management, and sorts out the data flow in the forging production process, which includes energy-saving factors, production constraints and production targets. Based on analyzing the energy consumption data of the forging production process, it establishes a energy consumption data model for energy-saving optimization, which provides a data foundation for MES real-time control of forging production and energy-saving scheduling, to achieve the goal of forging energy-saving.

**Keywords**—*forging production; data flow; energy consumption data; data model; MES; energy-saving scheduling*

## I. INTRODUCTION

In the mechanical manufacturing industry, forging has become an extremely important processing and production method with high production efficiency, high dimensional stability and good mechanical properties. However, the forging production process consumes a lot of energy. In order to realize the control function of the forging production process, analyze the key processes of forging production and construct the production process, especially the energy consumption data model, so as to realize the energy-saving control of the forging production process.

Domestic scholars have conducted a lot of research on production control and manufacturing modeling and analysis of production data. In order to achieve the goal of forging energy conservation, Jiang Mingming [1] established an energy-saving scheduling model for each process based on the key processes of forging, and studied the energy-saving scheduling algorithm. Yang Huifang [2] analyzed the equipment operation data, established the data analysis system of Xingshan iron ore equipment based on data warehouse technology, and realized data integration. Xu Zhen [3] introduced the content of product data management, and expounded the application method of product data model in product data management, in order to improve management efficiency. Zhao Zhiyu [4] established an industrial interconnected data model based on Petri nets. Liu Weijie et al [5] established a process-level data feature model, combined with an improved similar element analysis method, to evaluate the similarity of multi-level packaging description and manufacturing process of process data and apply it to production practice.

Foreign scholars also have many related studies. P. Valckenaers et al. [6] designed a self-disciplined manufacturing execution system by analyzing the manufacturing data of ant colony foraging behavior, enabling production control and predicting production trends. Y Seow [7] and Li Y [8] calculate and analyze the theoretical energy consumption, indirect energy consumption and auxiliary energy consumption of each process, and establish different levels of energy models in the manufacturing workshop.

The above references does not involve the study of energy consumption data in production. On the basis of fully considering the characteristics of forging production, it analyzes the energy consumption data in the forging production process, and constructs the energy consumption data model to provide data basis for energy-saving dispatching of forging production.

## II. MODELING ANALYSIS OF FORGING PRODUCTION DATA

Based on the basic requirements of energy-saving dispatching and MES control forging production, the forging production process is analyzed, and the data flow in the forging production process is sorted out. In order to effectively manage the forging production data and realize the energy-saving goal of forging production, proposes the "data-model-flow-management" method, which is based on the forging production data collection, from various dimensions. Forging production data, detailed analysis of production energy-saving factors, production constraints and production targets, the establishment of energy-oriented forging production data model, in order to achieve data interaction between production resources and production intelligent control.

## III. ANALYSIS OF ENERGY CONSUMPTION DATA IN FORGING PRODUCTION PROCESS

Further analyze the data flow in the forging production process [9], extract the energy consumption data of each dimension of forging production, and sort out the interaction relationship between the data, and build the energy consumption data model of the forging production process with the purpose of energy optimization.

### A. Forging Data Analysis

In the forging production process, due to the difference in forging characteristics, the state of the forging production process is different, which ultimately affects the furnace

scheduling and the selection of relevant process parameters. The analysis of forging energy consumption data and its effects are shown in Table 1.

TABLE I. FORGING ENERGY CONSUMPTION DATA

forging data	energy consumption factor	energy analysis
basic data	material	the initial forging temperature
	size, shape, quality, quantity	heating time, the order of loading
production process data	initial forging temperature, final forging temperature, ,	the choice of process parameters

B. Device Data Analysis

In the forging production process, forging equipment is the main energy consumption bearer, such as heating furnace, forging unit, grinding ring machine and so on. Detailed analysis of energy consumption data of forging equipment is shown in Table 2.

TABLE II. FORGING EQUIPMENT ENERGY CONSUMPTION DATA

device data	energy consumption factor	energy analysis
basic data	quantity, new factor, rated power	equipment allocation plan
operating state parameter	voltage, current, power, power,	power consumption
maintenance data	integrity rate, accident rate, maintenance period	productivity

C. Process Data Analysis

According to the forging process flow, the energy consumption data during the process execution is analyzed, as shown in Table 3.

TABLE III. PROCESS ENERGY CONSUMPTION DATA

process data	energy analysis
forging process attributes	process structure improvement
manufacturing environmental data	material supply chain improvement
technical conditions	finished product quality standard
device real-time data	matching equipment capabilities to production plans
NC control program	process improvement

D. Quality Data Analysis

Forgings are widely used in locomotives, ships, aviation and other fields. Their performance and accuracy are very high. The energy consumption factors in the analysis of forgings quality data are shown in Table 4.

TABLE IV. FORGING QUALITY ENERGY CONSUMPTION DATA

quality data	energy consumption factor
quality inspection data	surface quality, geometric size, mechanical properties
analytical data	number of defective products, pass rate, pass rate, repair rate
management data	cost loss, production lot size, inventory backlog, invalid work time

E. Mold Data Analysis

Die forging is a special process in forging production, and the tooling tool used is the mold. Different forgings need to match the corresponding mold, the type of the mold and the failure form affect the quality of the forging. The energy consumption data in the analysis of the mold data is shown in Table 5.

TABLE V. MOLD ENERGY CONSUMPTION DATA

mold data	energy consumption factor
basic data	material, structural strength, stiffness, surface hardness, surface roughness, machining accuracy
use data	claim and return cycle
maintenance data	integrity rate, wear rate, maintenance period and cost

F. Analysis of Production Personnel Data

Production personnel management is the interaction process between forging production information and personnel information in the forging production process, fine management of production personnel, and rational allocation of resources. The energy consumption factors in the analysis of forging production personnel data are shown in Table 6.

TABLE VI. FORGING PRODUCTION PERSONNEL ENERGY CONSUMPTION DATA

production personnel data	energy consumption factor
basic data	position, skill level
production process management data	process data, in process data
performance management data	capacity, working hours, planned completion rate

IV. CONSTRUCTION OF ENERGY CONSUMPTION DATA MODEL FOR FORGING PRODUCTION PROCESS

Through detailed analysis of energy consumption data of various dimensions of forging production, describe the characteristics of different forgings, different processes and different control requirements, and use MES flexible pipe to

control forging production, and finally achieve the goal of energy saving for forging production. Forging production data management effectively integrates forging data, equipment data, process data, quality data and other information, and cooperates with the use of MES functional modules. Based on the above energy consumption data analysis and energy saving requirements, based on the IDEF0 structured modeling theory, the energy consumption data model of the forging production process is established, as shown in Figure 1, which is described as follows: Input forging information, and implement production constraints with quality requirements and personnel management, use equipment information and mold information as production execution environment, support forging production process execution, and finally output finished product manufacturing information to complete MES pipe forging production process and optimize Forging process to achieve energy-saving forging.

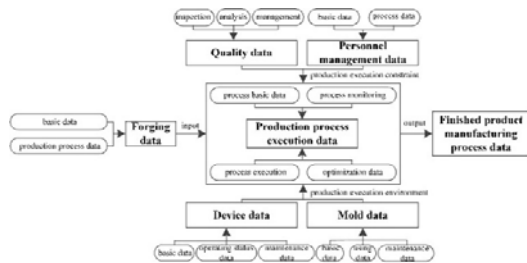


FIGURE 1. FORGING PRODUCTION PROCESS ENERGY COMSUMPTION DATA MODEL

V. CONCLUSION

Forging has a special manufacturing process, and its production process is a process in which production data are shared and interacted between production processes; forging production data is the basis for ensuring normal production operation, and production data management is the key to effective control of forging production in workshop-level MES systems. One of the technologies. Energy consumption data modeling provides the basis for energy-saving dispatching of forging production. Data integration management promotes informatization construction of forging enterprises, which is conducive to comprehensive intelligent control of forging production and energy-saving forging.

ACKNOWLEDGMENT

This research was financially supported by National Natural Science Foundation of China, "Modeling and Evaluation of Multi-source Energy Consumption Characteristics for Forging Production and System Energy-Saving Optimization Method" (51575280) and 2017 Intelligent Manufacturing Integrated Standardization and New Model Project "Intelligent Production of Key Components of Aero Engines and Gas Turbines"

REFERENCES

[1] Jiang Mingming. Research on energy-saving dispatching for forging production [D]. Nanjing University of Science and Technology, 2017.  
 [2] Yang Huifang. Design and implementation of data

analysis system for Xingshan Iron Ore Equipment in Shougang Mining [D]. Northeastern University, 2015.  
 [3] Xu Zhen. Product Data Model in Product Data Management [J]. Electronic Technology and Software Engineering, 2018 (03): 181.  
 [4] Zhao Zhiyu. Petri net modeling and analysis of industrial interconnected data [D]. University of Electronic Science and Technology, 2017.  
 [5] Liu Weijie, Ji Weixi, Zhang Chaoyang. Big Data Modeling Analysis Method for Intelligent Production Maintenance [J]. China Mechanical Engineering, 2019, 30 (02): 159-166.  
 [6] Valckenaersl P, Van Brusse H. Holonic Manufacturing Execution Systems [J]. Computers and Industrial Engineer, 2010 (62): 926-931.  
 [7] Y Seow, S Rahimifard. A framework for modeling energy consumption within manufacturing systems [J]. CIRP Journal of Manufacturing Science and Technology, 2011, 4: 258-264.  
 [8] Li Y, He Y, Wang Y, et al. A framework for characterizing energy consumption of machining manufacturing system [J]. International Journal of Production Research, 2014, 52 (2): 314-325.  
 [9] Zhou Yaqin, Wang Junliang, Bao Jinsong, Zhang Jie. Research on General Data Model of Intelligent Control of Knitting Production [J]. China Mechanical Engineering, 2019, 30(02): 143-148+219.