The Multi-Varieties Small-Batch Gas Monitor Flexible Digital Job Shop Design and Integration Technology Research

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Abstract. With the large-scale construction of city gas pipeline, increasing natural gas pipeline leakage accident disasters caused by the gas monitor is an important on-line measurement instrument for the safety operation of the network of natural gas, which has the characteristics of multi-varieties, style complex, complex procedures, automatic production, low digital level by making multi-varieties small-batch gas monitor as the main the mode of production. In order to solve that the traditional digital manufacturing job shop cannot meet the modern multi-varieties and small-batch production of gas monitor manufacturing requirements, based on the complex production process of digital equipment, digital control, digital key technology, it proposes a gas monitor job shop solution based on intelligent manufacturing, construction of the implementation of the integrated framework and implementation activities of information flow model to realize the bottom equipment layer, design and manufacture of middle management and intelligent control layer. It has proved that multi-varieties small-batch of digital manufacturing job shop manufacturing process and development has a good application effect and can provide a reference model for the multi varieties small-batch manufacturing precision instruments in the production, greatly saving the production casting time cost, production cost and resource cost.

1. Introduction

Natural gas pipeline called “urban lifeline”- worked as a crucial public infrastructure in modern urban-brings natural gas to every corner in urban to improve the convenience for public and to support the urban general operation with the development of mass construction of city gas pipe network. However, the natural gas inside the pipeline has the characteristics of flammable and explosive, toxic, spread fast compared with other kinds of pipeline such as water supply, heat supply pipeline. In addition, as the gas detectors have the characteristics of variable-style, complex, fast changes and due to the variety of working principle, production technology and product structure, the production scale is changed from mass production to multi-variety and small-batch production mode which requires a high-improvement for the production quality. With the popularization and promotion of social safety and smart city, the current production mode cannot meet the multi-varietiesdemand and posts an urgent requirement to explore. and discover a new production mode to fulfill the manufacture demand of diversification and small-batch production.

In the current processing of manufacturing of “Industry 4.0”, on the basis of intellectualization digital network, the manufacture industry combined IOT and service network to make an intelligent manufacturing system which own the functions of perception, decision-making, control and execution
Currently, domestic and foreign scholars had done a lot of researches and engineering tests on the processing and manufacture of diversification and small-batch production. In 2001, SON Y J, WYSK R A put forward the method of automated building simulation model to solve the problem of real-time scheduling control in complex internal and external environment of job shop[4]. In 2002, ZH H Yu had studied on the similar process analysis method based on similar elements and the process similarity analysis application on statistical quality control [5]; In 2005, LEON V J made the components switching and posting time into shortest by modifying the group switching strategy element both similarity and tooling PCB geometric similarity[6]; In 2008, Y Gao had realized the visual monitoring technology of multidimensional vector points in job shop which solves bad real-time performance and small volume of monitoring under traditional production mode as well as the problem of information break from director layer to management layer due to real-time field response[7]. In 2006, S.Y.Nof G discovered control system with the characteristics of coordination, integration, integration, network and distributed decision support to solve the problem in automatic control of the production logistics system[8]; In 2006, Monostori L studied the random scheduling mode of the flexible manufacturing system[9]; In 2010, X L Wu had done research on the multi-varieties of small-batch scheduling algorithm of flexible job shop and proposed a multi-objective hybrid genetic algorithm to solve the assignment problem and process scheduling problem in flexible job shop[10]; In 2011, Obweger H proposed the state management framework based on ECA(E-Business Collaboration Architecture) which followed the default logic rule rule and matched the simple event collected by perceptual nodes to produce the new complex event[11]; In 2013, F Liu proposed to construct multi-varieties small-batch digital production job shop included digital manufacturing foundation support layer, business infrastructure software platform, data collection and information interaction platform, function layer and user interaction layer by doing research on the networking manufacturing course of multi-varieties small-batch production job shop[12].

Based on the analysis above, the production mode had transferred from traditional single species mass production mode to the multi-varieties small-batch production mode. Therefore, on the consideration of transition of the resource scheduling and processing mode, the traditional production cannot meet the demand of production requirements of modern enterprise. In the paper, on the basis of gas detector processing technology and manufacturing processes, it proposed a digital processing and manufacturing methods of multi-varieties small-batch gas monitor which adopted the distributed centralized control with component technology, to solve the problem of low degree of automation and to modify the resource scheduling mode in the processing production.

2. Processing Craft Procedure

2.1 Overall processing craft procedure
Combustible gas detector assembly is consisted of internal temperature and humidity sensor, methane sensor shell cover, air pump, trachea, probe, antenna and battery parts to complete the procedures of preassembly of combustible gas detector. Then complete machine assembly according to the predetermined assembly process and the assembly process is shown in figure 1.

2.2 Main Circuit board manufacturing procedure
Main circuit board which can be connected to and control each part of the sensors is key part of Combustible gas detector to realize the function of data acquisition, filtering and signal processing. The manufacturing procedure includes welding, inspection, testing, and three-proofing validations of the temperature & humidity sensor and main circuit board as shown in figure 2.

3 Digital assembly job shop technology framework
Multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop is on the direction of product production process, on the basis of production information for each stage to integrate equipment, product and manufacturing information into centralized control platform and
implement the product courses of processing, assembly and test. And the information of each stage is on the basis of professional database to do the process of instructions to send/receive information and also to share the information of each stage on the centralized unified database management platform.

Centralized control platform is based on the underlying hardware and software platform as the basement, the intermediate data standard format conversion process as key point to connect the Industrial Ethernet and all the production instructions and to do the preservation, processing [13], modeling and analysis courses by unifying the information distributed to each data information management servers. In addition, it realized the rapid information transmission and data sharing by constructing newly DNC(Distributed Numerical Control) network to improve the operation efficiency and reliability[14].

The centralized control system of multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop includes user layer, data layer, functional layer, network layer and execution layer as shown in figure 3.

The user layer of job shop is responsible for the staff of processing and constructing job in the job shop to manage the order, acceptance, plan and execution of production task and job shop visual dynamic monitoring task according to each duty.

The functional layer is to achieve the rapid path planning of the actuator in processing and assembling by calling underlying data structure and fast modeling data driven module. Therefore, it can finish the fast modelling course of plan issued product and send message to execution layer.

The data layer is to save the underlying information, upper layer information, plan task orders, and product information of production job shop and to provide an analysis of the data and information traceability queries for functional layer.

The execution layer is responsible for the production, processing and assembly of the combustible gas detector of the action of execution units to realize the operation of machining process by receiving the executed command complete fixed action.

The network layer is the crucial part for the digital job shop information transmission. It realizes the reliability of data transmission and designs the transmission of Ethernet ring structure.

![Figure 1. Combustible gas detector assembly process](image-url)
Figure 2. Main circuit processing technological process

Figure 3. Combustible gas detector digital job shop system structure

4. The construction of the digital job shop

4.1 Circular Industrial Ethernet Structures

Figure 4. Combustible gas detector system platform

Figure 5. The system function structure logic diagram
The main systems are the field bus control system, distributed control system and network control system in the current computer control. Among the systems, the NCS (Network Control System) is a system that uses form of feedback control system through the network and connects the controlled objects with the controller and the drive through a common network platform [15]. The network control system, worked as a typical spatial distributed system, has the advantages of easy information resource sharing, easy expansion, easy connection, high efficiency, easy maintenance, reliable performance and so on. In the paper, the redundant ring-like Industrial Ethernet control system made full use of the advantages of network control systems to realize the field control of multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop. The top layer of the system is the circular redundant Ethernet control system and bottom layer adopts the different fieldbus types of DCS system to realize structured control mode of “workstations - fieldbus - smart meters” as shown in figure 4.

4.2 The system function structure
The multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop adopts the C/S structure. The server and client communication, control software stay on the shop controller and station controller respectively. Each layers and centralized control platform send and receive two-direction information reciprocally to realize the different functional requirement. And it can be divided into four parts—the system management module, the production information management module, the equipment module and the dynamic monitoring module according to system functions.

The system management function realizes the system access management to different users to meet the demand of job shop condition order placement, receiving, task execution and supervision. And also, users in different permissions to the job shop information management are also different.

Production information management module is responsible for the implementation of production and material plan release, production scheduling, maintenance and management of production line, process flow and organizational scheme of processes. It also evaluates the gas detector quality and scheme adjustment to guarantee the production processing quality and the adjustment of equipment resources, schedule and to optimize production resources by using different types of expert knowledge bases.

The basement of visual production dynamic monitoring implementation is the real-time data acquisition of dynamic assembly job shop. It constructs the combustible gas detector assembly process model based on the working process, scheduling model based on the craft processing plan and the real-time monitoring model based on the dynamic assembly data to realize the function of visualization dynamic monitoring from production and processing to the assembly.

The system realizes the connectivity by defining the form of communication and interface data driven of production assembly equipment, the implementation of the data sharing by driving module, Win32 API function, survival and reading the XML file, dynamic data read between equipment and storages with numerical control equipment. The whole system function structure is shown in the figure 5.

5. Combustible gas detector tooling test

5.1 The overall design of processing job shop
Based on the research achievement of multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop, it designs the flexible digital manufacturing plant to solve the problem of controlling actual production progress, the low degree of visual monitoring process, the bad real-time performance, the collaborative weakness between processes and the adverse impact of unreasonable resource scheduling. The design effect is shown in the figure 6.

The multi-varieties small-batch combustible gas detector flexible digital manufacturing job shop includes detector assembly procedure in storehouse, the sensor assembly process, air tightness testing
process, drying equipment assembly process, the bottom shell component assembly, testing, and the whole machine assembly process and so on. After the completion of the cycle, it is expected to increase the delivery rate of the goods by 80%, decrease waste rejection rate by 10% and decrease the finished product inventory rate by more than 30%.

5.2 Combustible gas detector performance testing
To verify actual usage and quality problems of the combustible gas detector flexible digital machining manufacturing plants, it tests and verify processed products in the real field. The effect of measuring gas monitoring is shown in the figure 7 and that of the temperature and humidity monitoring is shown in the figure 8, 9.

6. Conclusion
(1) With the propositions of advanced manufacturing system such as the precision manufacturing, the intelligent manufacturing system, the distributed centralized control system, the concurrent engineering and the omnipotent manufacturing system, the modern manufacturing is developing towards the direction of digital, multiple, flexible manufacturing, integration and intelligence. It realizes the real-time dynamic tracing and collaborative applications of the material in the process of production, equipment, products and personnel to greatly save the production cost and manufacturing time.

(2) In this paper, for the current insufficient situations of the visual monitoring and scheduling ability of multi-varieties small-batch gas monitor processing job shops during work operating and on the basis of analysis of the international and domestic digital plant, it completes the combustible gas detector design and builds the flexible digital manufacture job shop with the system integration from the bottom up of equipment states and the integrity of the product information acquisition. It realizes the implement course of the manufacturing job shop production plan scheduling, the resource
optimization configuration and the visualization of dynamic monitoring during production and manufacturing. In addition, it solves the problem of the manufacturing information island, improves the quality of the products, reduces the production cost, shortens the normal cycle of the castings and improve the market fast response ability of the new product.

(3) The construction of the digital manufacturing job shop accumulates hardware and software implementation experience of multi-varieties small-batch gas monitor processing job shop. The implementation of the system satisfies the need of enterprise production and quality requirements as well as playing a positive role model in the application of digital manufacturing industry in the world.

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