Research on the Big Data-based Product Quality Data Package Construction and Application

Bingquan Chen
Reliability Data Center, Key Laboratory of Industrial Equipment Quality Big Data, MIIT
The 5th Electronics Research Institute, MIIT
Guangzhou, China
E-mail: chenbq@ceprei.com

Guojian Nie
Reliability Data Center, Key Laboratory of Industrial Equipment Quality Big Data, MIIT
The 5th Electronics Research Institute, MIIT
Guangzhou, China
E-mail: niegj@ceprei.com

Shixin Jiang
Reliability Data Center, Key Laboratory of Industrial Equipment Quality Big Data, MIIT
The 5th Electronics Research Institute, MIIT
Guangzhou, China
E-mail: jiangshixinwh@163.com

Ning Hu
Reliability Data Center, Key Laboratory of Industrial Equipment Quality Big Data, MIIT
The 5th Electronics Research Institute, MIIT
Guangzhou, China
E-mail: huning@ceprei.com

Abstract: In the new environment of intelligent manufacturing, enterprise quality data has increased exponentially. How to manage, utilize, mine and analyze quality data has become a key issue in modern quality management. This article expands the definition of the product quality data package in the intelligent manufacturing environment, and proposes a big data-based product quality data package construction and management solution, gives a quality data fusion method based on business decision, outlines the application of quality data package. Finally, a chip manufacturing company was used to verify the feasibility of the product quality data package construction and management plan.

Key words: quality data package, big data, intelligent manufacturing, data fusion

I. INTRODUCTION

The product data package was first proposed by International Aerospace Corporation. It refers to a collection of product-related data, specifications, tables, etc., which will later be included in one of the important contents of product quality assurance work. The ECSS-Q-ST-20C proposed by the European Space Agency for Standardization Cooperation (ECSS) clarified the scope of the data package, including the data collection of product design, manufacturing, assembly, and testing[1]. The US military standards MIL-Q-9858A and MIL-I-45208A required further refinement, including the initial quality plan, engineering specifications, drawing samples and changes, measurement, test equipment, contractor inspection equipment use, procurement phase control, production processing and manufacturing, product inspection and testing, handling, storage and delivery, unqualified products, statistical quality control analysis, etc[2]. In China, data packets have been researched and applied mainly in the aerospace field: Huang Jiangang built a quality and reliability data package management system based on a distributed collaborative working environment[3]; Aiming at the two problems of unclear centralized management of electronic product data packages and lack of information system support, Liu Xuyi put forward the working ideas of data package standardization and information management platform[4]; Yao Ruifang gave a product data package management system plan from product data package planning, data collection, data management, data analysis and application, etc.[5]. With the application of the Internet of Things and big data in industrial manufacturing, many new opportunities have been brought about in terms of computing power, data acquisition, mining and analysis. This work studies how to develop quality data package construction, management and application in a new manufacturing environment, and has formed a typical application.

II. RESEARCH ON PRODUCT QUALITY DATA PACKAGE IN NEW MANUFACTURING ENVIRONMENT

A. Analysis of characteristics of product quality data package

With the goal of quality optimization and improvement, using the new generation of information technology and quality engineering technology along all stages of the product life cycle. Build product quality data packages based on big data, including product design, process, testing and inspection, quality improvement and comprehensive management documents and supporting data(photos, videos etc.), relevant documents and materials for use and assembly after the product is delivered. Compared with the traditional quality data package, it has greatly improved in terms of function, scope, content, data quality, etc. See Table 1 for details.

Table 1 Comparative analysis table

item	traditional data package	bigdata-based quality data package
function	As a basis for confirming that the product meets the requirements, it is mostly used for product acceptance and review	As the basis for product process control, quality improvement, data-driven quality optimization and organizational quality management capability improvement
scope	A collection of relevant data at one or more stages of the product realization process	While covering the entire life cycle of enterprise design, production, use, etc., focus on quality and extend it to suppliers and downstream users

item	traditional data package	bigdata-based quality data package
content and format	Design schemes and reports based on documents (WORD, PDF); list reports based on electronic forms and other multimedia files as supplementary materials, with a low degree of data structure	Strengthen the structured characterization of data (such as the feature label of unstructured data), and increase the production of real-time data
data acquisition means	Rely on design, production and other experts to manually organize, and some support single point information system export	Support real-time data collection based on data acquisition capabilities, strong correlation data integration and strong mechanism business analysis based on industrial software
consistency, completeness	It is usually the final record of key nodes, which is easier to keep consistent; but the data compatibility of each link lacks technical guarantee means	Technical means such as data governance and master data management can ensure the consistency and unique source of data; however, massive real-time data also faces the challenges of consistency, integrity, and correlation mining and analysis
traceability	Support the traceability of the results of quality and reliability work items (simulation, analysis, review, testing, etc.) in the product development process	Support the extension of traceability to the industrial chain, including suppliers, downstream users, etc.; improve the precision of traceability, including processing technology, smart product usage monitoring, etc.[6]

B. Research on the business process of product quality data package construction

This work takes typical discrete manufacturing as the research object. Based on the quality-related data foundation of industrial software systems such as ERP, PDM/PLM, MES, SCADA, etc., a business process for constructing product quality data packages in a new manufacturing environment is proposed. This process integrates the product development process, information technology and industry versatility requirements, and integrates the advanced product quality planning (APQP) process. As shown in Figure 1.

The quality data package includes traditional quality data such as basic product structure data, design and process key characteristics data, and final state functional performance; also includes industrial mechanism models, quality big data mining analysis models, and real-time operation data of production processes and smart products.

III. RESEARCH ON PRODUCT QUALITY DATA PACKAGE MANAGEMENT AND APPLICATION

A. Design of integrated management platform for quality data package

Based on the new manufacturing digital environment, considering the dimensions of IT technology, industrial technology, DT technology, etc., this paper designs a quality data integrated management platform for intelligent manufacturing, as shown in Figure 2. Based on the platform, the unified management and distribution of quality data can be realized, and the construction and application of quality analysis algorithm models can be used to support product quality assurance with objective records while mining the decision-making knowledge contained in the quality data.
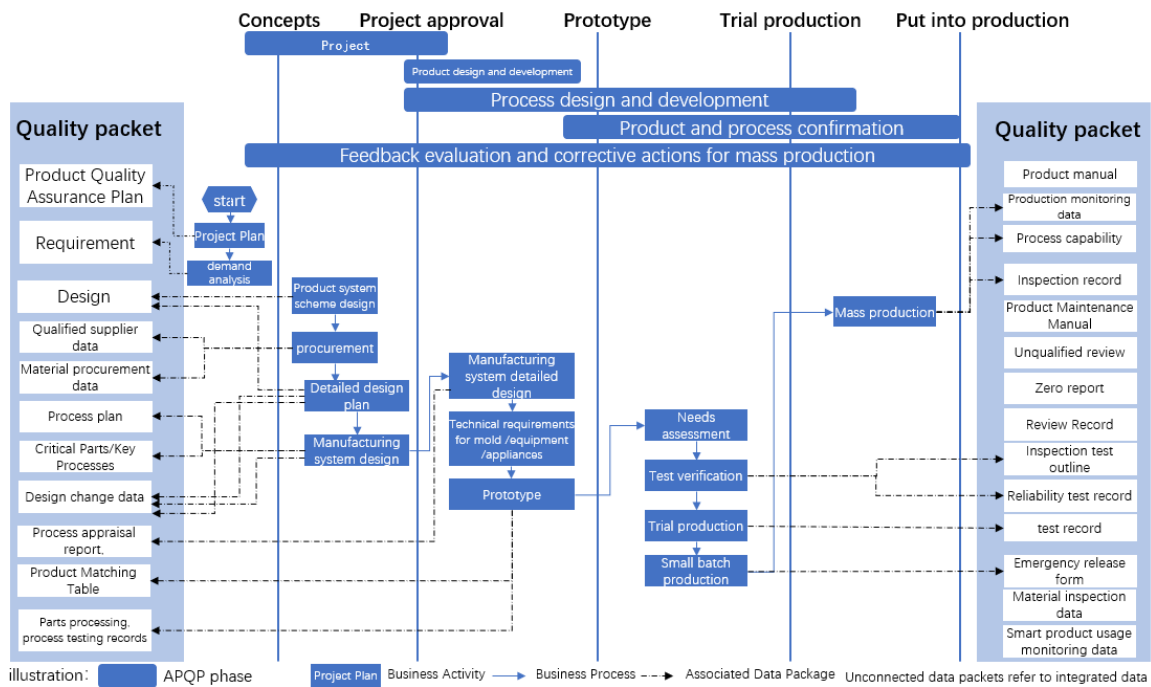

Figure 1 Quality data package business process

Master data management: Design data integration architecture around quality business requirements and establish mechanisms for master data creation and change. Specific functions include coding management, data resource catalog, master data model management, master data integration, data interface management, etc.. The master data synchronization between the quality data integration platform and various industrial software systems can be realized.
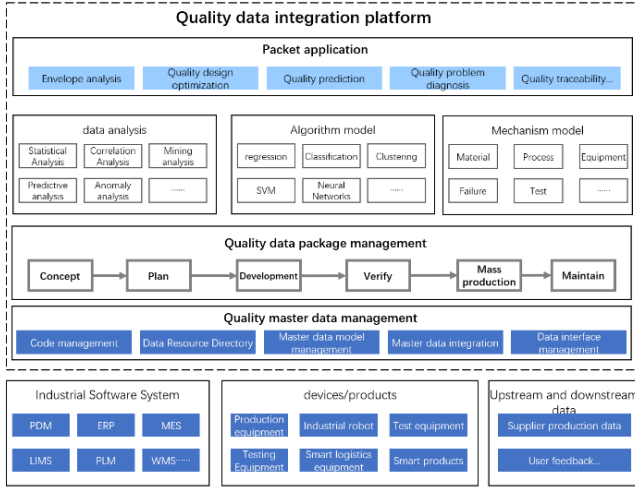

Figure 2 Quality data integration platform architecture design

Quality data package management: including structured, semi-structured, unstructured and other multi-source heterogeneous and high-dimensional data management.

Data analysis: providing basic statistics, mining, forecasting, anomaly analysis. It also supports the construction of business models such as scenario analysis and forecasting for specific industries.

Algorithm model: integrates multiple algorithm models such as machine learning and deep learning, including regression, clustering, neural network, SVM, etc.

Mechanism model: integrates key raw materials, complex processes, important production equipment, testing and other industrial mechanism models, and promotes the application of quality big data based on business interpretation.

Data packet application: It not only supports traditional envelope analysis, but also includes data-driven quality design optimization, quality prediction, traceability and other applications. Specific to the industry or scenario, including product pass rate, statistical process capability trend analysis and prediction, and equipment fault diagnosis and prediction, product and key component traceability, and key process parameter control and optimization.

B. Quality data fusion

The data in the whole process of product development is characterized by high-dimensional, multi-modal, and strong correlation. How to mine the relevance of data, extract valuable information, and provide a basis for decision-making for quality, data fusion is a work that must be carried out. This work proposes a data fusion method for business decision-making based on data characteristics for quality business decision-making scenarios, as shown in Figure 3.
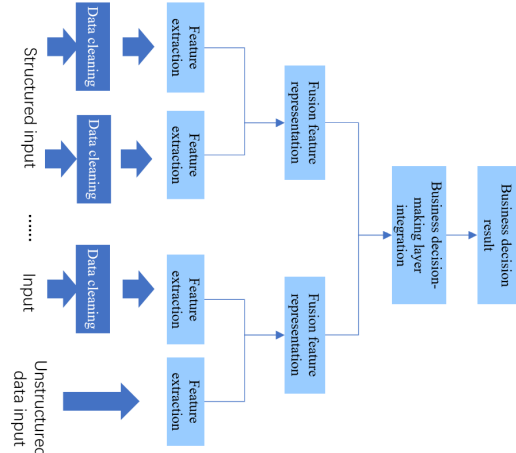

Figure 3 Business-oriented decision fusion

For specific decision-making scenarios such as process capability and production equipment fault diagnosis, starting from specific decision-making business issues, clean the collected data related to business issues; Then use fast Fourier transform, wavelet analysis, deep learning and other methods to extract features. For text data, select TF-IDF, Word2vec and other algorithms for feature extraction. And then carry out the mapping of features and business features, and use operations such as association and analysis to obtain business-based fusion feature representations, which are sent to the business decision-making layer; Finally, decision-making is made through Bayesian theory, neural network, expert system and other intelligent fusion algorithms to assist business development.

C. Quality master data management

Quality master data management is to establish quality business-related data management mechanisms under the framework of enterprise master data management; Based on the company's basic master data and operational master data, quality master data could be built by inheriting quality-related data, removing irrelevant data, adding quality-related data and codes, as shown in Figure 4. Quality master data management integrates the core data that needs to be shared in related business systems, standardizes them, and then distributes them to data package applications in the form of services.
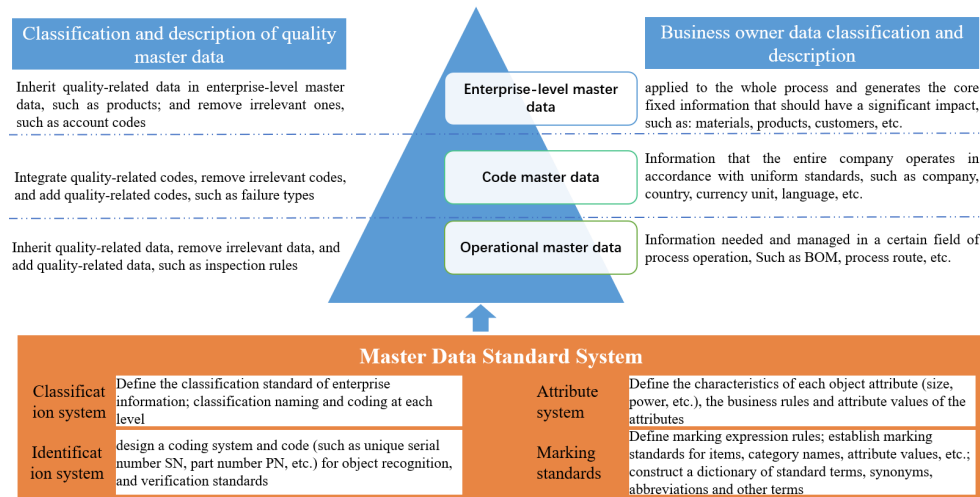
Figure 4 Quality master data construction reference frame

Under the reference frame, quality data resource catalogs can be quickly sorted out. Develop functional modules such as coding management, data resource catalog management, master data model management, and data interface management based on the company's IT architecture. Provide standard and unified data for data analysis of product life cycle quality activities, such as technical review, material quality management, closed-loop fault management, process quality control, product repair processing, etc., accomplishing master data with each business information system Synchronizing.

D. Quality data packet application

(1) Envelope analysis

Based on the quality data package, especially the characteristic quantities related to the characterization quality and failure, it supports the development of envelope analysis of incoming materials, semi-finished products, finished products, etc[7]. It can compare and analyze the range encompassed by data related to incoming materials, test results, key attributes of incoming materials, finished product-related tests, processing process data, product characteristics, etc., to find weaknesses in design or process to optimize Consistency of processing quality, product straight-through rate, etc.

(2) Quality prediction

The quality data package under the new manufacturing environment includes real-time processing and operating data, such as product design characteristics, process characteristics, inspection data, and monitoring data of production equipment or smart product operation. It can support applications such as machine learning and deep learning-based process quality consistency prediction, product quality prediction, failure prediction of key production equipment, and maintenance decision-making.

(3) Quality traceability based on data package

All data related to product quality can be traced back to the project plan number, product design plan, review record, process plan, inspection record, etc. It can assist the quality problem handling in the whole process of product development, including problem location, failure mechanism analysis, failure closed loop, experience solidification, feedback design, etc.

IV. QUALITY DATA PACKAGE APPLICATION PRACTICE

Construction of product quality data package

This work carried out the construction and application of quality data package in a chip manufacturing company. Taking the development process of a certain type of diode as an example, a quality data package was constructed according to the APQP control program implementation process. The data package covers program design, process design, procurement, processing, environmental testing, quality testing, warehousing and delivery, etc.; as well as specific dicing, core loading, pressure welding, forming, electroplating, rib cutting, packaging and other processes. Part of the data package list is shown in Table 2.

Table 2 List of quality data packages for a certain type of diode (partial)

No	APQP	data package	Remark
1	Project establishment stage	Technology Agreement	for the agreed product quality requirements
2		Product task book	Clarify product quality goals, including yield, PPK, cost, etc.
3		Product special features list	Key features such as constant drain-source withstand voltage and avalanche tolerance
4	Product design and development	Design task book	Product preliminary design plan
5		FMEA and checklist	PFMEA report and checklist
6		New facility assessment and determination	Evaluation and determination of new equipment, measuring tools, and testing requirements
7		Design	Including product frame, package, shape, etc.
8		Supplier samples and PPAP	Supplier samples and related control documents
9		Prototype Manufacturing CP	prototype manufacturing control plan based on FMEA
10		Prototype trial production and test verification plan	
11		technology file	Prototype production process file
12		Prototype production	Including core loading, pressure

No	APQP	data package	Remark
		and inspection records	welding, forming, testing, etc.
13		Product design verification	Resistance to welding heat, alternating damp heat, electrical performance test report, test data
14		Design verification	Transition stage review
15		Design changes	including engineering changes
16		Design of new measuring equipment	
17		Product process flow chart	
18		Pilot production CP	Control plan
19		MSA Analysis Plan	
20		Initial process capability	Process capability analysis record
21	Product and process confirmation (process)	Product trial production	Trial production key process monitoring
22		Measurement system evaluation	Repeatability and reproducibility data analysis
23		Production approval documents	
24		Production CP	Control plan
25		Product quality tracking card	
26	Feedback evaluation and corrective measures	Analysis of variation in mass production process	Product mass production process variation monitoring data, SPC analysis, etc.
27		Equipment management records	Key equipment operation monitoring data
28	Mass production (after-sales)	Mass production quality inspection	Quality inspection data such as process and finished products
29		customer feedback	demand and quality issues reported during the use phase

A. Construction and application of quality data package integration platform

An integrated enterprise quality data package management platform has been built, which connects ERP, PDM, MES information systems and production equipment, according to the four major links of supplier management, manufacturing process (production), reliability testing, and after-sales. Carry out quality data package management. The platform architecture is shown in the figure 5.
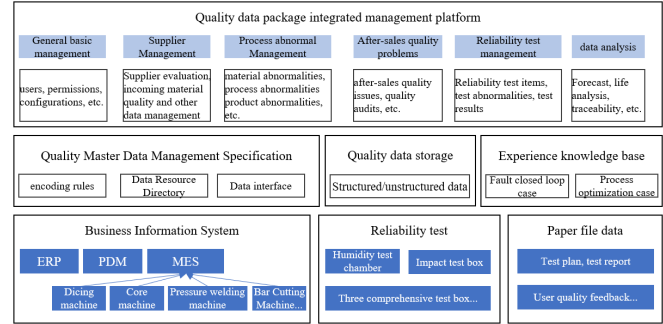

Figure 5 An enterprise quality data package integrated management platform

Comprehensively sort out and analyze ERP, PDM, MES (including the function of connecting equipment) and other systems and file data foundations, preliminary establishment of quality master data management specifications including coding, resource catalogs, interfaces, etc. It developed the enterprise quality data package management platform, including general basic management, supplier management, support abnormal closed-loop management, after-sales quality problems, reliability test management, data analysis and other functional modules. The system interface is shown in the figure 6.
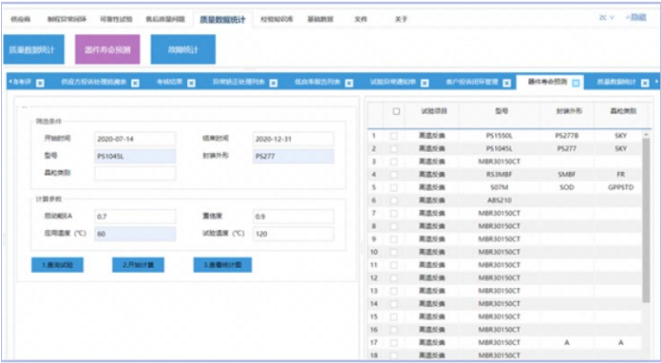

Figure 6 A system for quality data package management

The quality data package integrated management platform, the quality data of various information systems have been integrated, and the heterogeneous, professional, and massive quality data package has been constructed, supporting the efficient coordination of quality work in all aspects of the company's incoming materials, manufacturing process, and after-sales. With comprehensive data covering project plan numbers, product design plans, review records, process plans, inspection records, etc., support enterprise quality problem tracing and quality problem handling, greatly shorten the closed-loop cycle of quality problems, and provide for problem location, failure mechanism analysis, feedback design, etc. Provide detailed data support. At the same time, a knowledge base of corporate experience was formed and fed back to relevant design and production departments to improve product design. After nearly two years of implementation, the product defect rate dropped by 25%.

V. CONCLUSION

The new manufacturing environment driven by information technology has expanded the scope of quality data packages. Based on the theoretical basis of the quality and reliability data package in the aerospace field, considering the actual quality management requirements and application of industrial enterprises, this work proposes a new category of quality data package in the intelligent manufacturing environment, and studies the quality data package based on big data. The application of management and intelligence has been verified in typical industries, providing a reference for the improvement of product quality in the majority of manufacturing industries and the improvement of organizational quality management capabilities.

R<small>EFERENCES</small>

[1] ECSS.ECSS-Q-ST-20C Space product Assurance: Quality Assurance[S]. Europe: ECSS, 2013.

[2] Li jing Research on Maturity Evaluation Based on Product Data Package [J]

[3] Huang jiangang, Zhao qingsong, Zhang yingbing Construction and management of electronic model product quality and reliability data package Quality and reliability 2010.

[4] Liu xuyi Thoughts and Methods of Reliability Data Package Information Management [J] Aerospace standardization 2012 Issue 1 41-42.

[5] Yao ruifang, Zou wei, Tong yiqun, Su caihong, Song pan, Thinking on the Application of Product Data Package Management System in Model Shanghai Aerospace 2020 Issue S2 Volume 37, 73-75.

[6] National Manufacturing Power Construction Strategy Advisory Committee Strategic Consulting Center of Chinese Academy of Engineering Smart manufacturing Beijing Electronics Industry Press, 2016.

[7] Jing quan, Li jingyuan, Hu yun，Exploration and practice of data envelopment analysis methods for product success [J] Quality and reliability Issue 4, 2014:48-49.