http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 10 (11): 2034-2043, 2011
ISSN 1812-5638 / DOI: 10.3923/itj.2011.2034.2043

Research on Technology System and Key Technologies of Configuration Identification for Product Lifecycle

[1]Gu Qiao-Xiang, [1]Xiao Ying, [2]Qi Guo-Ning and [3]Su Shao-Hui
[1]Quality and Safety College, China Jiliang University, China
[2]Institute of Manufacturing Engineering, Zhejiang University, China
[3]School of Mechanical Engineering, Hangzhou Dianzi University, China

Abstract: In order to ensured the accuracy, uniqueness, integrity and traceability of the configuration items in the product lifecycle which were product configuration model, main models of parts, custom products and the instances of the parts. The technology system of configuration identification for product lifecycle was proposed and its key technologies were researched, such as the modeling technologies based on the meta-data, product configuration model based on ECA rules and Tabular Layouts of Article Characteristic (TLAC) and version of control based on the directed acyclic graph. It takes the three-series industrial steam turbine for example and also validates the key technologies configuration identification for product lifecycle.

Key words: Product lifecycle, configuration identification, data model, configuration design

INTRODUCTION

Because of the diversification of customer requirement and the severe situation of market competition, the enterprise must establish the integrated system which integrates the design, manufacturing and management to manage the product in its life cycle. It can shorten the design time of new products, produced the production which meet customer needs the best, which in the shortest possible time and using the most effective methods.

As one of key technologies of product lifecycle management, the configuration management is a management discipline which using the technologies and management tools to manage the development, design, manufacturing, management and sales service phase of the product. Its research content includes configuration identification, configuration control, configuration history and configuration audit (Saynisch and Burgers, 1997; NASA, 1995; ISO 10007, 2003). The configuration identification is base of configuration management. It is process which to choose, name and describe the configuration items. In present, the research on configuration management was almost for the software products (Burgess *et al*., 2003), another research objects were rarely involved, such as complex mechanical and electrical products (Hua-Zhang and Ming-Shu, 2001; Biao *et al*., 2008; Xiao-Fei, 2007). And the research were covered the phase of design for product, other phase were rarely was covered. In addition, the operability of the relevant standards were poor which on the configuration management. It was guidance documents in practical application (Burgess *et al*., 2003). However, the configuration management for the product lifecycle is a discipline which the practical is strong. So it needs a theoretical system and some key technologies to support it.

According to the research status of the configuration management and requirement on product data model in product lifecycle management, study presented the technology system of configuration identification for product lifecycle and studied the key technologies, such as the modeling technologies for product family, configuration design technology and version of control technology.

THE TECHNOLOGY SYSTEM OF CONFIGURATION IDENTIFICATION FOR PRODUCT LIFECYCLE

The target of configuration identification for product lifecycle is to insure the accuracy, uniqueness, integrity and traceability of the configuration items in the product lifecycle. In order to achieve these goals, it needs some key technologies to support. The study propose the technology system of configuration identification for product lifecycle, it includes the object layer, the method layer and technology layer. The object layer is answer the questions, such as what is the configuration identification for product lifecycle? What is the target? The method

Corresponding Author: Gu Qiao-Xiang, Quality and Safety College,China Jiliang University, China

layer is discussing the way of configuration identification for product lifecycle. The technology layer is discussing how to support the way of configuration identification for product lifecycle to achieve (Fig. 1).

Because the objects of configuration identification in the product lifecycle must include all configuration items in product family lifecycle, it needs to further consider of identification the product configuration model, main models of parts which besides single product. And it needs three steps to complete which are product family modeling, product configuration and version of management.

According to the market information and technological progress, the roles of product family modeling were developed product family, determined the main model of parts which assembled it and described the product configuration model. All these were the base of the product configuration management.

Using the product configuration model, the roles of configuration design was design the custom product which satisfied the custom needs.

In order to ensure the traceability of the configuration items in the product lifecycle, the version management was control the result which generated in the phase of the product family modeling and the configuration design.

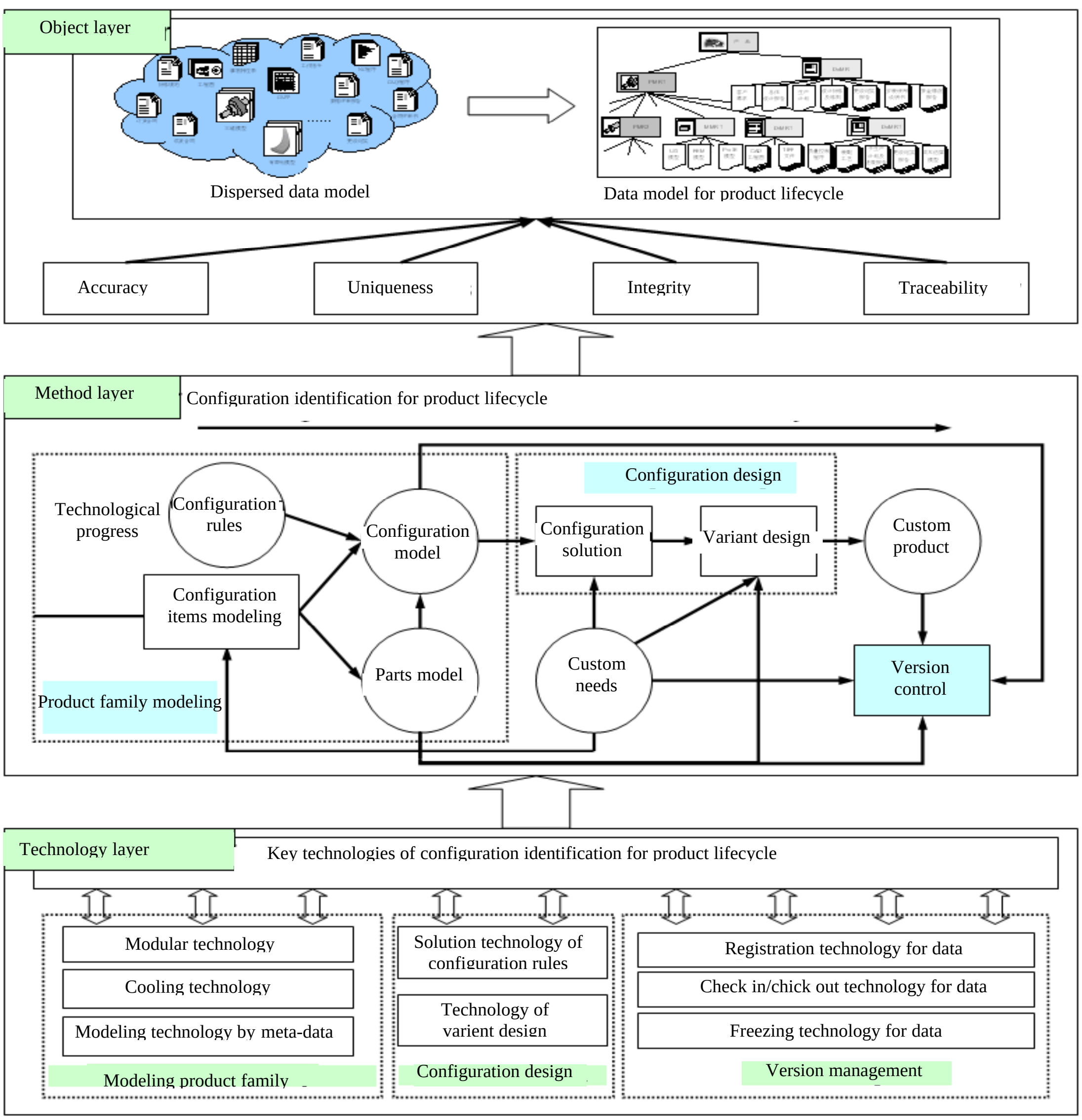

Fig. 1: The technology system of configuration identification for product lifecycle

THE KEY TECHNOLOGIES OF CONFIGURATION IDENTIFICATION FOR PRODUCT LIFECYCLE

Modeling technologies for product family: Modeling for product family is the base of the product configuration identification for product lifecycle. Product family is composed of product which its function, structure and process are similarity. The data models for the product family include the product configuration model, the main model and main document for parts. In the process of modeling for product family, we must divide the product into the modular which on the base of standardization and normalization. It can get the parts of product family. We can use the TLAC to establish the main model for parts which it is easy to variant design; Secondly, we need use the effective coding system to classify and code these parts main model; Finally, we can using these parts to construe the product configuration model.

Modularization technology: On the basis of overall analysis and research on customer needs, using the modularization technology, the designers developed an independent function module which can be used to assemble the complete product family. This module is the key to product configuration design and variant design. It can reduce the internal diversification of products and enhance the exterior diversification of products.

For example, under the direction of the principles of modularization, the rotor of the steam turbine can be divided into five sections in logic which are regulate, pre-sealing, through-flow, post-sealing and user sections (Fig. 2). With the exception of the through-flow section, the sections are designed for standardization modules which are in a numerical system. According to customer needs, the engineers design the model of the through-flow section. The designers can then choose the corresponding models from the series models of the others sections and assemble the rotor model quickly.

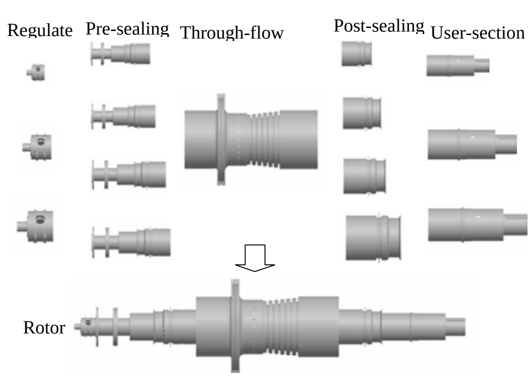

Fig. 2: The theory for module design the rotor of industrial steam turbine

Code technology for configuration item: Code for configuration item is the foundation and core in the configuration. It is to identify all the model, process and resource data for product in its lifecycle. It is the basic work to build a complete coding system for product configuration management. It will contribute to search and reuse the resource.

The code for configuration management of product lifecycle is composed of the classification code, identification code and view code (Fig. 3). These can be used in combination.

The classification code (TLAC code) is used to manage the part family in the product family. It can adopt the membership code or classification code. The identification code is unique in the life cycle of the parts and it adopts a sequential code.

Modeling technology for product lifecycle based on meta-data: The data model of the product lifecycle must cover the needs analysis, development, design, manufacturing, sales and service, recycling phase of the product family and the custom product, so it must included all the information (such as model data, process data and resource data, etc.) , which used by all application areas in its lifecycle. In practical application process, all the data were generated by different computer application system or manual, these were stored with different media (such as electronic documents, paper media and physical model, etc.) and in different locations. Further more, the formats of these was different (such as TIFF, IGES, DXF, STEP, etc.). So, in order to share and interoperate, it must describe these data consistently. The article used the modeling technologies which based on the meta-data to describe all the data in the product lifecycle as a whole (Fig. 4) and the data model will service for the needs of all phases and all departments in its' lifecycle.

The product data model for its lifecycle which based on meta-model, used the all kinds of object chains to build the product data model for its lifecycle as a whole (Qiao-Xiang *et al*., 2009). And the object chains were structure object chain, configuration object chain, model object chain, document object chain, draft object chain

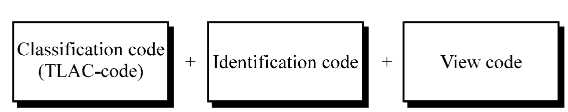

Fig. 3: The code for configuration management of product lifecycle

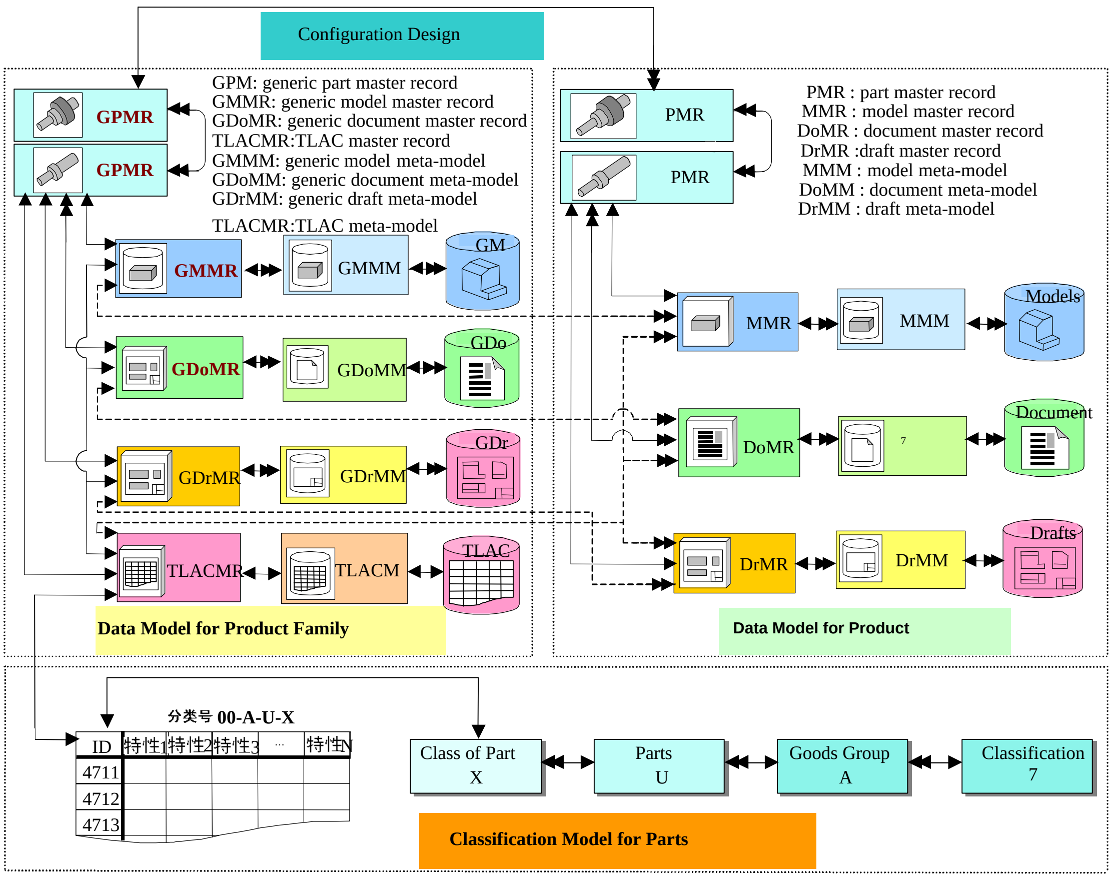

Fig. 4: Data model for product lifecycle based on meta-data

and TLAC object chain. Using the method can describe the product family, custom products, main models of parts and the instances of the parts completely. The structured product data model for its lifecycle can satisfied with the need of all departments in its lifecycle.

Product configuration design based on ECA rules and TLAC: Aimed at the characteristics of make-to-order and engineer-to-order product, the product configuration model was proposed, for which Event-Condition-Action (ECA) rules and Tabular Layouts of Article Characteristic (TLAC) were used. The structure of customization product could be generated through selection of indispensable modules and optional modules according to ECA rules; the individual product could be designed quickly using TLAC of the modules.

According to certain relations, the product can be composed of the module (sub module), part and characteristic element. Using the ECA rules and TLAC to building the product configuration model, the relations can be build in the TLAC of product level. The each line of the module which in the product configuration model, was express a variant instance of it. Every instance includes ID, configuration rules ID and ID for the instance of sub module. So in the process of configuration design, using the TLAC of product level and the instance ID of the module, part or shape elements, the technicians can design the custom product quickly.

Figure 5 is the product configuration model which based on the ECA rules and TLAC. In Fig. 5, the part 4 includes the shape element and configuration knowledge, its TLAC used the reference pointer to point the document of the configuration knowledge and TLAC of shape element. The TLAC of module 2 used the reference pointer to correlate the related configuration knowledge and TLAC of parts 1, parts 2 and parts 3. We can use the same way to handle the relationship between the modules and so on we will obtain the product configuration model.

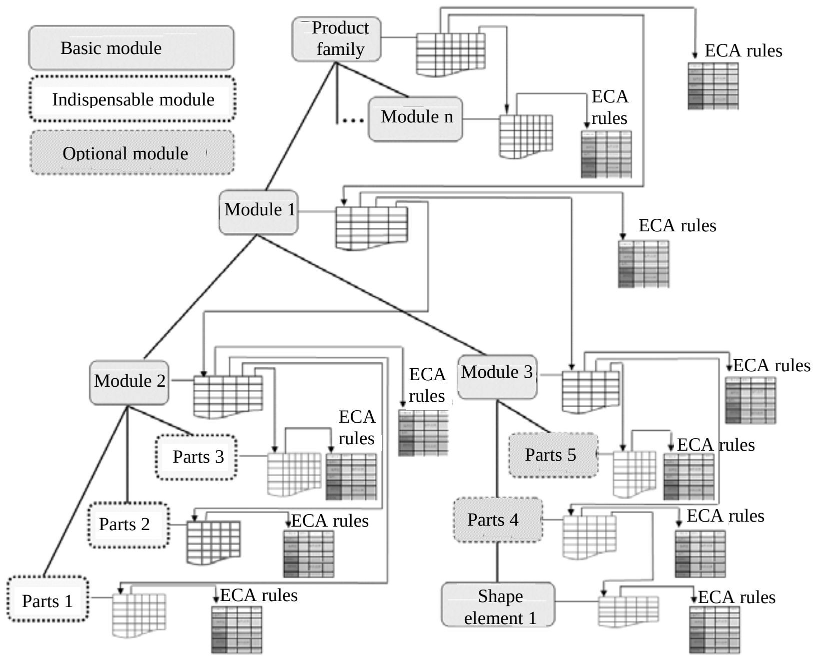

Fig. 5: Product configuration model based on ECA rules and TLAC

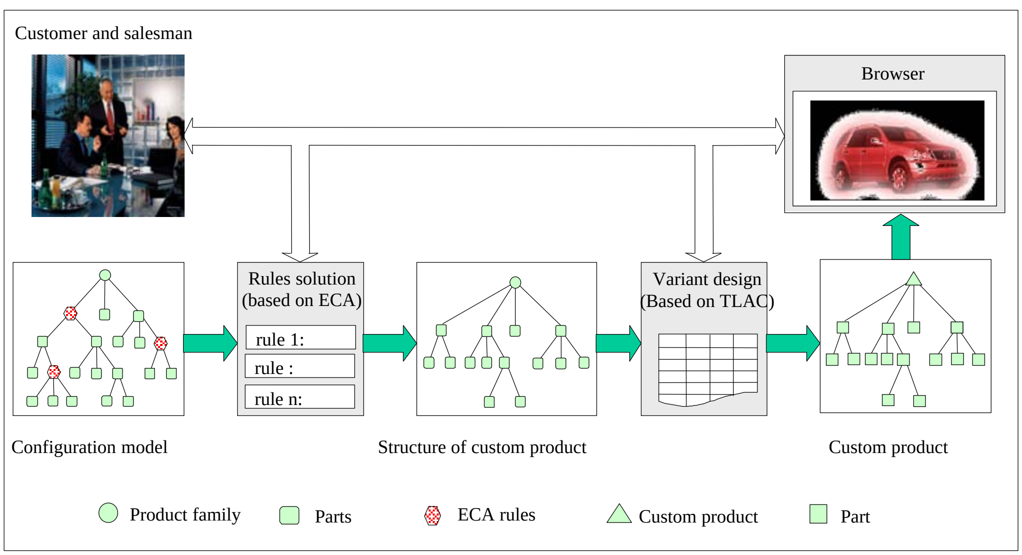

Fig. 6: Process of configuration solution based on ECA rules and TLAC

The core ideas of configuration design which based on the ECA rules and TLAC, are as follows: According to the requirements of the customer, designers choose the module (required modules and optional modules) in the configuration model by ECA rules and complete structural variants. Further, designers carry on variant design of the module in the custom product structure by TLAC and get the custom product which satisfied with the customer need. Because the hierarchy of component modules (includes basic modules, required modules and optional modules) have build in the configuration model which based on the ECA rules and TLAC, it will simplify the complexity of the solution of the configuration greatly (Fig. 6).

Version control technologies: In order to ensure traceability of the configuration items in the product lifecycle, we need to control its version effectively in its lifecycle. The basic ideas of version control in the product lifecycle are as follows: Firstly, according to some process, related personnel audit the data which produce by the phase of the product lifecycle and check in the Product Lifecycle Management System (PLMS) when the audit was passed; Further, it need some audit process to execute the check in/out about the data model; Finally, it need to be frozen when the product data model were disseminate to production department. The user can browse it and can not modify it.

Evolution of product data model based on the directed acyclic graph: In the production lifecycle, technicians will change the product family, parts, product and part and form different version. So it needs to manage the data model's version effectively and ensure the uniqueness and the traceability of these. Figure 7 describes the version evolution of product configuration model and custom product in the product lifecycle.

According to the evolution process of the version of production data model in Fig. 7, the article present to describe it using the directed acyclic graph, that is G = (V (G), E (G), φ (G)) and V (G) = $\{v_1, v_2,..., v_n\}$ (V (G)≠ϕ) describes the controlled data model, E (G) = $\{e_1, e_2,..., e_m\}$ is the collection of edge of G, $e_i = <v_j, v_t>$ shows that the controlled v_t was gotten by the evolution of v_j, φ (G): E→V×V was the correlation function which describe the reason of evolution.

It can use the formal structure matrix to describe the compose of the product family and custom product. For example, Fig. 8 describes an instance of the configuration model. In the configuration model, the parts main model A_4 is composed of A_1, A_3, A_7 and A_8, at the same time, the parts main model A_6 is assembled by A_2 and A_5. The constraint rule is R_1, by which A_4 builds father-son relationship with A_1 and A_3, also the constraint rule is R_3, by which A_4 builds father-son relationship with A_7 and A_8. Figure 9 describes the formal structure matrix for Fig. 8.

Through analysis the evolution process of product configuration model and the custom product, it can provide the theoretical basis for the storage, query, tracking and control version management model of data model in its lifecycle. And it is facilitate to manage and control the data model of product lifecycle effectively.

Registration technology for data model: In order to management the model data, process data and resource data in the lifecycle effectively, these must be register in controlled database for PLM and create the relationship between the business object and the data object. So it can make them in a controlled state.

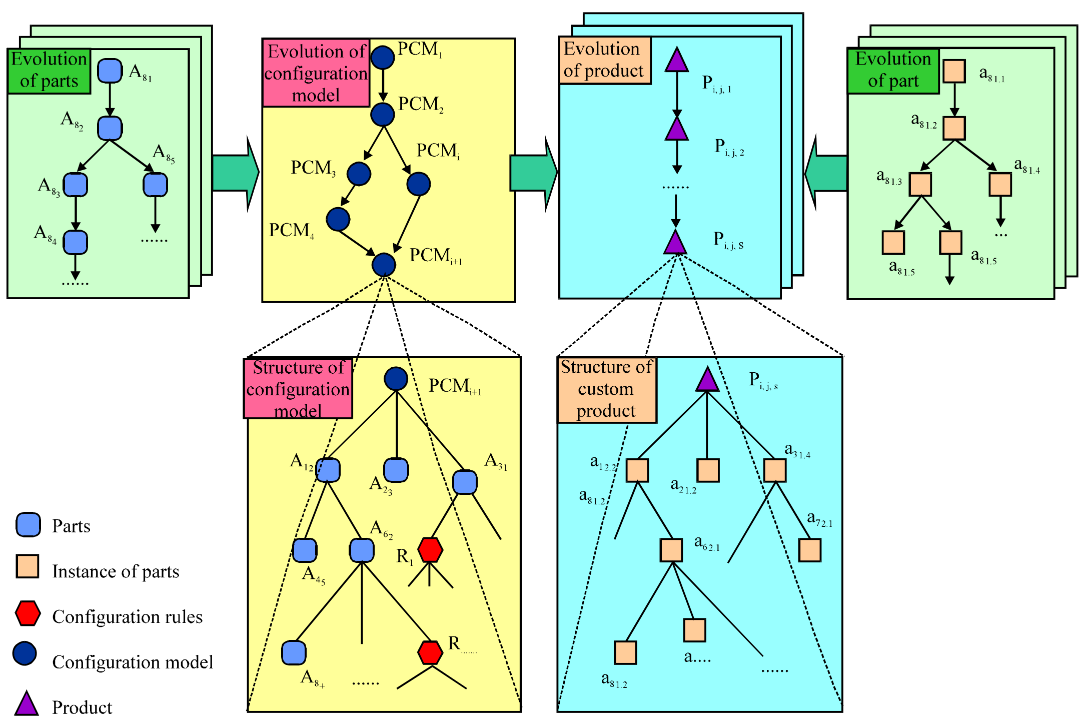

Fig. 7: Version evolution of product data model

By the integrated interface of PLM/CAx, the user can register the data in the PLMS. Next, the article will describe how to register the new CAD model in the PLMS (Fig. 10).

The first step, using the interface of PLM/CAD which integrated in the CAD system, the designers extract the new properties of CAD model (such as system type, creator and creation date, or so) to create the data exchange files and transport it to the PLMS.

The second step is to create the model object chains (PMR-MMR-MMM, Fig. 10). By transporting the data exchange files which was generated in the first step to the input interface in PLMS, designer can save the model file of CAD; The important properties about the business meta-model and data meta-model can return to the CAD model by data exchange files using the interface of PLM/CAD which were the code for CAD model, project ID, name, release phase, etc.

The third step, by the data exchange files created in the second step, the properties of business object and data object will be written to the attribute column of CAD model. And the data model will be saved in the storage location where the data meta-model assigned.

By the three steps, we will complete the registration of new CAD model in PLMS and create the object chain of CAD data model which is the object chain of PMR-MMR-MMM-CAD data model (Fig. 10).

Using the same way, the user could register the other CAx documents.

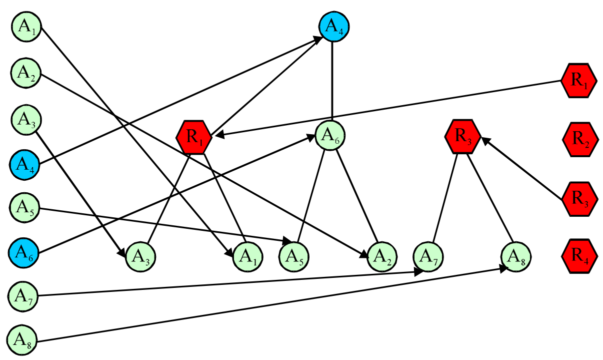

Fig. 8: Instance of configuration model for product

$$\begin{bmatrix} (1,R_1) & 0 & 0 & (-1,1,R_1) & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & (-1,1,\varphi) & 0 & 0 \\ 0 & 0 & (1,R_1) & (-1,1,R_1) & 0 & 0 & 0 & 0 \\ (1,-1,R_1) & 0 & (1,-1,R_1) & 1 & 0 & (1,-1,\varphi) & (1,-1,R_3) & (1,-1,R_3) \\ 0 & 0 & 0 & 0 & 1 & (-1,1,\varphi) & 0 & 0 \\ 0 & (1,-1,\varphi) & 0 & (-1,1,\varphi) & (1,\varphi) & 1 & 0 & 0 \\ 0 & 0 & 0 & (-1,1,R_3) & 0 & 0 & (1,R_3) & 0 \\ 0 & 0 & 0 & (-1,1,R_3) & 0 & 0 & 0 & (1,R_3) \end{bmatrix}$$

Fig. 9: Configuration model described formal structure matrix

Check-out and check-in technology for data model: Using the Check-out and Check-in, in PLMS, it can ensure to use a version of the product data in the project group in the status of conflict-free. That is to say, it will allow a user to write the meta-data and the file at the same time. Now, it will elaborate the theory about the Check-out and Check-in which takes the business object and the data object of the draft as example:

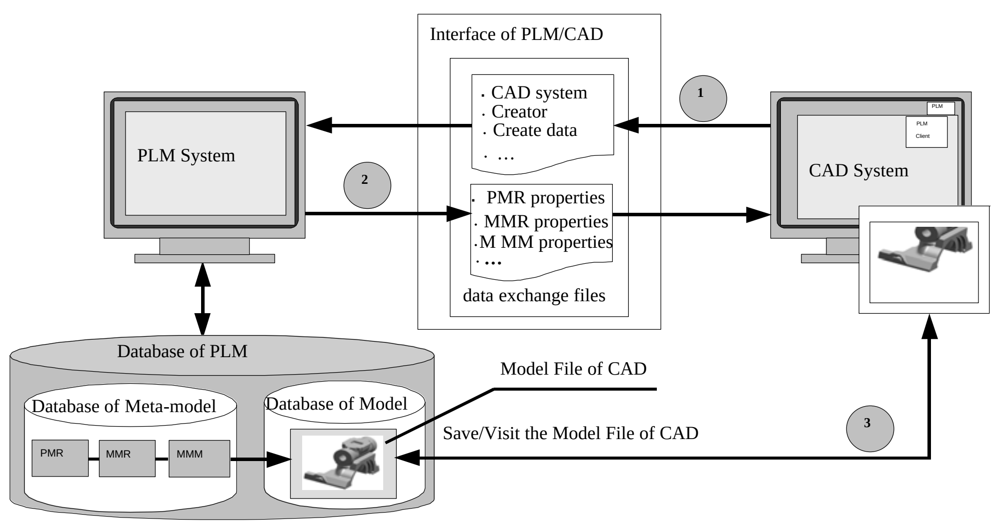

Fig. 10: Register the new CAD model in PLMS

- **Check-out technology for data model:** Using the operation of Check-out, designers can copy the object from a workspace to another workspace and the processing status of it will increase 1. After the operation, the PLMS will not allow writing about original version and only allow reading it. When Check-out the business object, user need to determine whether Check-out the related object at the same time. For example, the user check out the business meta-model, data meta-model and the data model of draft at the same time (Fig. 11). These will be copied from the PLM database to the user database. The processing status will be increased from 1 to 2 and the user is the owner of the copy. The PLMS will create the relation object automatically which between the object of Check-out and the original version of it

Using the same way, the user can Check-out the business meta-model without data-meta and data model.

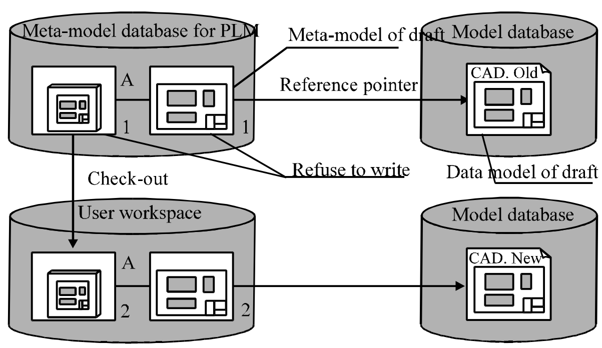

Fig. 11: Check-out the business meta-model DrMR (with data object draft)

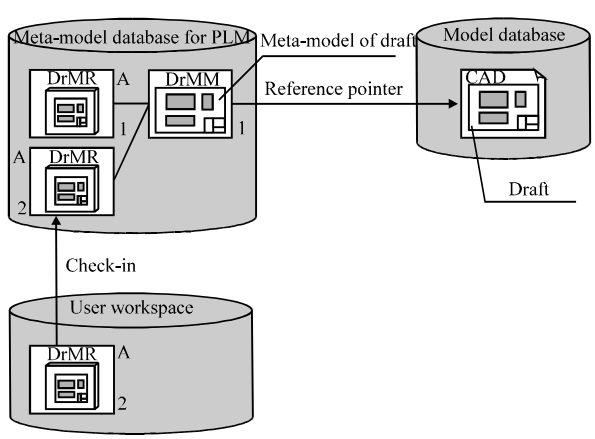

Fig. 12: Check-in the business meta-model DrMR (replace the original version)

Check-in technology for data model: When the business meta-model, data meta-model or data model will be checked in the PLMS, it can replace the original version and can also not replace the original version.

When designers check in the business meta-model which will not replace the original object. The new version will keep the relation with the original version. At the same time, the new version of business meta-model for draft will also keep the relation with meta-model for draft (Fig. 12).

Freezing technology for data model: In the product lifecycle, the model need to be frozen when the product data model were disseminate to production department. And, in this phase, the user can not change it. In order to ensure this, the PLMS provides the frozen function about the data model. The business object and the data object can receive a frozen mark and will be stored in the archive database. It guarantees that the system users can not check out a frozen object from the archive database.

CASE STUDY

The article takes the three-series industrial steam turbine produced by a company for example and also validates the key technologies configuration identification for product lifecycle by employing the smarteam platform that integrates self-developed TLAC management module.

Figure 13 provides interface of the model based on meta-model in the smarteam platform. It described the process of creation the meta-model of data and the process of creation the object chain of data.

Figure 14 provides the configuration model of three-series industrial steam turbine (cylinder). It described the module composition about the cylinder of three-series industrial steam turbine. The custom product could be designed quickly using it.

Figure 15 described configuration design for cylinder based on ECA rules and TLAC. Using the TLAC, technicians can design the customer cylinder and select the matched instance module according to combination rule of cylinder which were described by ECA.

After complete the configuration design and confirm the accuracy of it, the technicians can check it in the project on the smarteam by the integrated interface of PLM/CAD in CAD system (Fig. 16) and the data on customer product was in the controlled status.

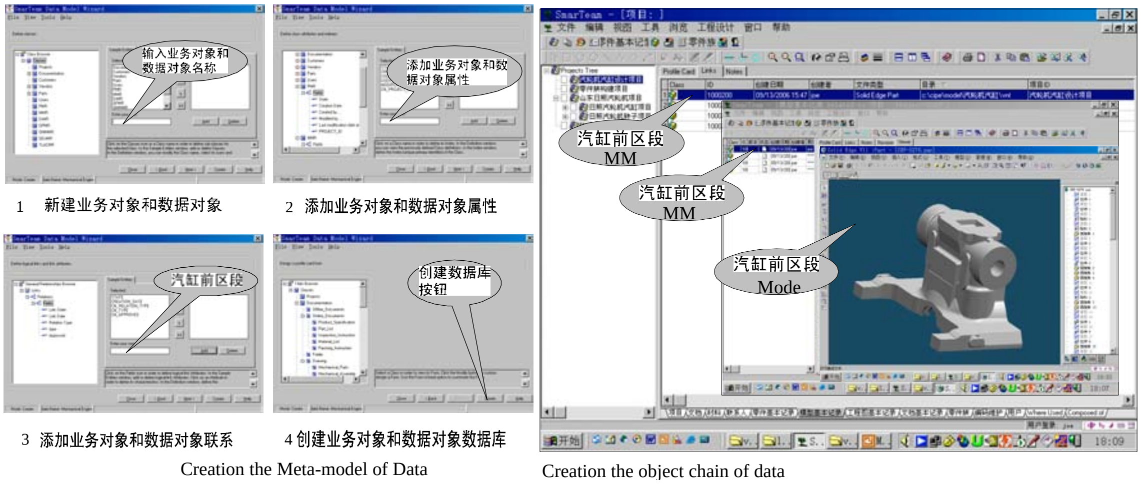

Fig. 13: Interface of the model based on meta-model

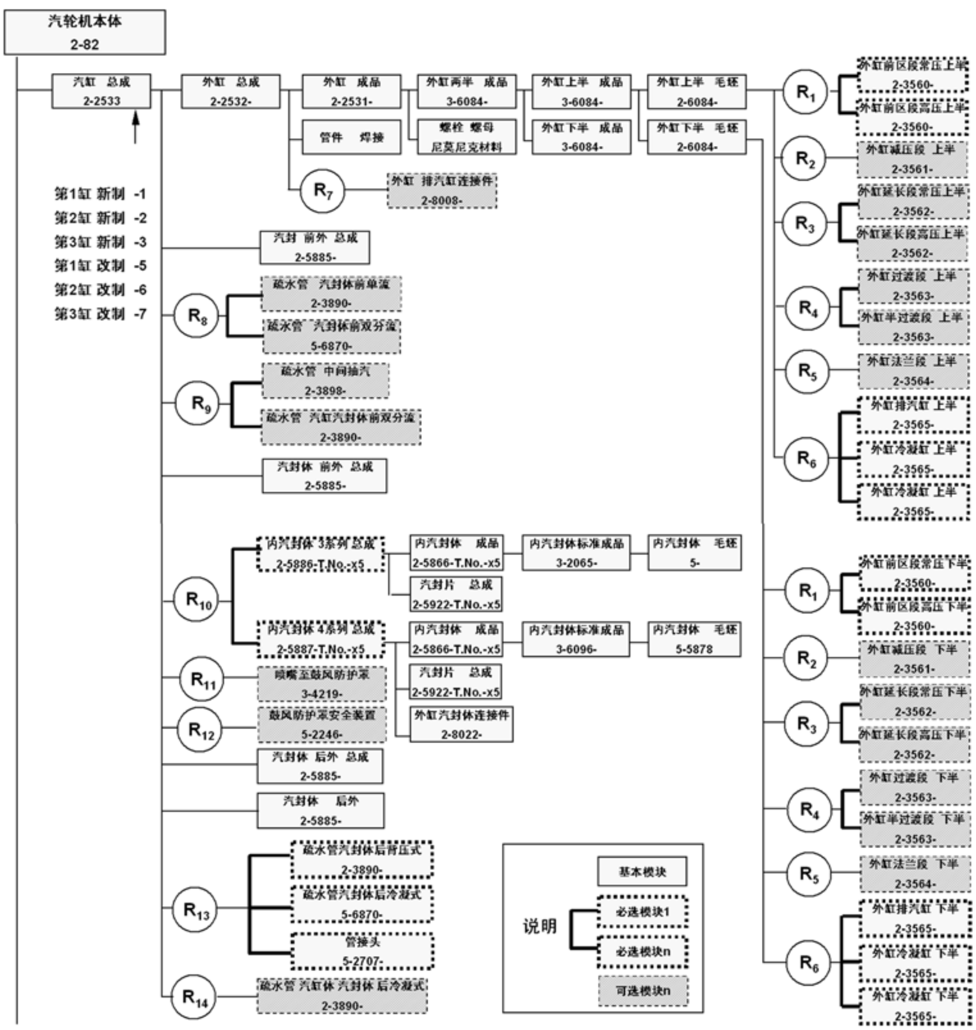

Fig. 14: Configuration model for three-series industrial steam turbine (cylinder)

Fig. 15: Configuration design for cylinder based on ECA rules and TLAC

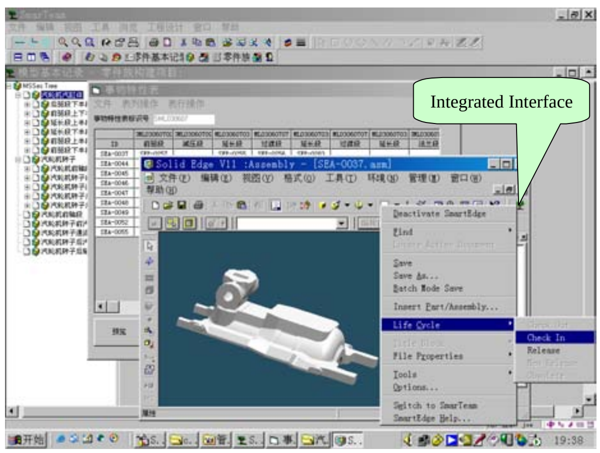

Fig. 16: Interface of instance check in

ACKNOWLEDGMENTS

This work was supported by Natural Science Foundation of Zhejiang Province (No.Y6090504) and Key Discipline of The Ocean Mechatronic Equipments Technology of Zhejiang Province.

REFERENCES

Biao, S., H. Xiao-Jian and D. Jia-Shi, 2008. Configuration management during the development of complex engineering system. Aeronaut. Manuf. Technol., 21: 82-88.

Burgess, F., K. Byrne and C. Kidd, 2003. Making project status visible in complex aerospace projects. Int. J. Project Manage., 21: 251-259.

Hua-Zhang, L. and L. Ming-Shu, 2001. Study of software configuration management systems based on ISO9000 and CMM. Comput. Sci., 28: 78-80.

ISO 10007, 2003. Quality management systems-Guidelines for configuration management. International Organization for Standardization. http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=36644.

NASA, 1995. Software configuration management guidebook. NASA-GB-9503. National Aeronautics and Space Administration, Washington, DC., USA. http://www.uml.org.cn/pzgl/pdf/cmgb.pdf.

Qiao-Xiang, G.U., J.I. Yang-Jian, Q.I. Guo-Ning and X. Ying, 2009. Data modeling technologies for complicated product in product lifecycle. J. Zhejiang Univ., 43: 1871-1877.

Saynisch, M. and H. Burgers, 1997. General aspects of Configuration Management (CM). Int. J. Project Manage., 15: 331-332.

Xiao-Fei, W., 2007. Settlement project about informization for configuration management of military equipment manufacturing. Comput. Syst. Appl., 43: 1871-1877.