Implementation of the KNGR Class Library Based on the GPM and Semantic Networks for Co-design

Kwangjong Cho[1] and Chancook Park[1]

[1]Institute for Advanced Engineering, Korea, kjcho@iae.re.kr, parkck@iae.re.kr

ABSTRACT

With the competition between companies becomes fiercer, it is necessary that several designers who are usually geometrically distributed, need cooperative work in design for an efficient design. In particular, a nuclear power plant is so complex, and these co-design environments were positively required. In this paper, to support co-design common data model, which has geometry and non-geometry data model, was developed based on semantic networks. That is the Korean Next Generation Reactor (KNGR) class library. The subject of data model is the Reactor Coolant System (RCS) in the KNGR. The KNGR class library was completed using XML through an analysis of the KNGR Information Management System (IMS) – Engineering Database (EDB) and the Generic Product Model (GPM) class library. When the KNGR class library was made, we considered a structural representation of plant and differences between the Pressurized-Water Reactor (PWR) and the Boiling-Water Reactor (BWR).

Keywords: STEP, GPM, class library, PWR, co-design

1. INTRODUCTION

Recently, as the competition between companies becomes fiercer, a short lead time to market, a high quality level and a fast response to the market demands have become the main success factors in a product market. With advances of computer technologies, many product development life-cycle processes have been automated by the introduction of computer-based systems, such as Computer-Aided Design (CAD), Computer-Aided Process Planning (CAPP), Computer-Aided Manufacturing (CAM), and so on. When a complex product was designed, it is separated into several design components. Then it is necessary that several designers who are usually geometrically distributed, have to co-design. When a product is composed of many parts and components, designers often have limited knowledge and information to accomplish product design tasks. So designers have to receive the design information of them from parts supplier. If requirements of product design were changed, data exchanges were occurred frequently and need more cooperative work in design. But, despite of the investment in recently years, both in small and in large enterprises, the market still presents a lack of IT tools able to support co-design in particular at a suitable cost.

In today's co-design environments, a product data model and standardization of data model for an efficiently cooperative work in design is a core factor. And a standard data model for geometry and non-geometry representation of product is needed in co-design activities using several kinds of CAD software. Particularly when several engineering companies are participated in designing nuclear power plant, a standard data model between them is needed. International Standardization Organization supports ISO 10303, which is called STEP (STandard for the Exchange of Product model data), for exchanges of product data. This is not the standard data model for co-design. So this paper indicates the standard data model based on semantic network model, that includes geometry and non-geometry data model, for a cooperative work in design of nuclear power plant. And the GPM (Generic Product Model) is a core model of suggested common data model.

2. RELATED WORKS

A computerized co-design system can be generally grouped into the two categories, not considering network environment, security, etc. Those are the process-centered co-design and the product data-centered co-design. The former is managing the design process and workflow of designing product. The latter is the management of product data which is information and knowledge of product. That is supplied to engineering designer for co-design at appropriate time [2].

2.1 The Process-centered Co-design

Yuliang, Li developed the process-oriented intelligent collaborative product design system, based on the Analysis-Synthesis-Evaluation (ASE) design paradigm, the CORBA (the Common Object Request Broker Architecture) standards and mobile agents [14]. And Y. Jin suggests ActivePROCESS (Active PROcess-driven Collaborative Engineering Support System) prototype system, composed of the process model APM (Active Process Model) that captures both high level and low level activity dependencies and an agent network that monitors process execution and facilitates coordination among engineers [13]. G.Q. Huang proposes the web application that is highly expected to provide an adequate information infrastructure to support the collaboration between work-centres geographically distributed over time [3]. And to improve the collaborative design productivity, S.C.Y. Lu suggests methodology for analyzing collaborative design process and conflict based on a new Socio-Technical design framework that can identify the interdependencies among design tasks [8].

2.2 The Product Data-centered Co-design

Franca Giannini devised the Product Manager module that manages decomposed components, which were reusable parts by means of the product family and project template concepts [2]. At a University of Calgary, a design database modeling system was developed for supporting concurrent design based on the Function-Behavior-Form design modeling approach introduced by the NIST Design Repository Project. This system is modeled by primitives called features, such as design features and manufacturing features [12]. D. Xue suggests CE-DDRM (Concurrent Engineering-oriented Design Database Representation Model) that is defined as concepts and behaviors of different design database modeling components, including entities, properties, relationship, tasks, and specifications at meta-class level [1]. And W.C. Regli devised a digital library to support computer-aided collaborative design. The engineering design knowledge repository is an effort to collect and archive public domain engineering data for use by researchers and engineering professionals [11].

This paper defines the geometry and non-geometry data model of product for supporting product data-centered co-design. And these data model was modeled at both a meta-class level and an individual object level, relationships between classes are represented by a semantic network. In this paper, the modeling object is nuclear power plant. So the International Standard related to a plant information representation was analyzed. And to represent product data for co-design, the class library was created.

3. THE INTERNATIONAL STANDARD DATA MODEL FOR CO-DESIGN

When a cooperative work in design is done, in product data-centered co-design the common data structure is needed. Until recent years, these data structure is dependent on cooperative design system. When a very large and complex plant was designed such as nuclear power plant, several CAD softwares were often used. For example, the AUTOCAD in Autodesk Inc., the Pro/ENGINEER in Parametric Technology Corporation and the Microstation/Plantspace in Bentley Systems Inc. were used in plant design field. And varieties of CAD software result in several kinds of CAD file format. Though only CAD software was used, different CAD file format could be formed because of different installation environments of the CAD software.

A variety of CAD file format needs to be integrated into a common data model, when we do cooperative work in design and use the CAD files as information for constructing, operating and maintaining a plant. By these needs, a neutral file format that includes the structure of geometry and non-geometry product data was required.

There are several industrial data standard, such as ISO 10303(STEP), ISO 15926 etc., for modeling geometry and non-geometry data of plant. In the beginning, the STEP supported data exchange for a CAD data. But nowadays it supports the structure that enable to sharing product data. Specially, International Standards related to power plant are STEP AP 221, AP 227, AP 231 and STEPlib [9]. ISO 15926, that is the data model for offshore plants in initial stage, tries to apply to diverse plant fields, such as chemistry plant, process plant etc [5, 6]. And the GPM is based on GDM (Generic Data Model) like ISO 15926, it is more flexible and scalable than ISO 15926, as a result of a remarkably simple Core Model, that is a higher ARM (Application Reference Model) of a ARM in STEP. It can be easily extended to the data model for not only design stage of a power plant, but also construction, maintenance and demolishment stage of power plant. In this paper, in advantage of easily work that is a modification of the data model, we decided to select GPM and modeled a nuclear power plant based on it for co-design.

Fig. 1 describes the exchange data between several CAD systems and operation/ maintenance system based on standard data library that includes geometry and non –geometry product data model. We can save, retrieve and view the data in data repository, that contains standard data structures and instance data, through the CAD translators between a few CAD systems. And an operation and a maintenance system, such as the ERP system or the local legacy system, can be utilized through the interface.

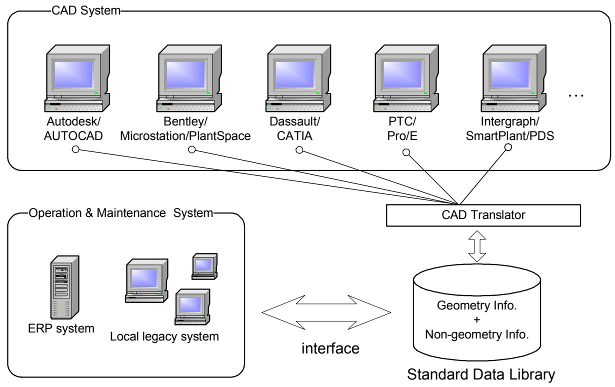

Fig. 1. Co-design environment using standard data library

4. IMPLEMENTATION OF KNGR CLASS LIBRARY FOR CO-DESIGN

The object of implementation is the APR (Advanced Power Reactor)-1400, that is a type of the PWR, the KNGR. A detail subject is the RCS, which is a primary loop of nuclear power plant. The process of implementation is as follows. First, we analyze the EDB of Nuclear Steam Supply System (NSSS) in the IMS of APR-1400 to comprehend the structure and the component of a nuclear power plant. Second, we analyze the GPM class library. Finally, we create new KNGR class library for the APR-1400 using semantic networks and the GPM.

4.1 Analysis of the KNGR IMS-EDB

The KNGR IMS-EDB consists of analysis parts and physical component parts. And physical component parts are composed of the RCS, Main Steam and Feed Water System (MSMF), Reactor Vessel Internals (RVI), Steam Generator (SG), Discrete Indication & Alarm System (DIAS), Data Processing System (DPS), and so on [7]. The category of this paper is the RCS. Because RCS generally includes MSMF and SG, total objects of this paper are the RCS, MSMF and SG. Fig. 2 depicts RCS that is composed of a reactor, a pressurizer, pumps, steam generators and pipes.

The physical parts of the RCS define a component entity as a root entity. Both the mechanical/process equipment entity and the electrical equipment entity were inherited by the component entity. Attributes of the component entity are common attributes that all entities have. Tab. 1 shows the number of entities, attributes in the KNGR IMS-EDB.

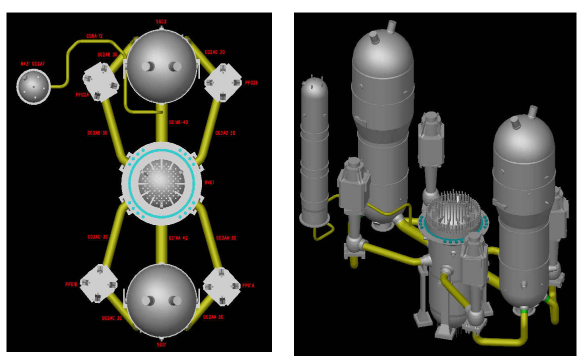

Fig. 2. RCS in the KNGR

	Entity	Attribute	Relationship	Inheritance
Number	427	3089	522	25

Tab. 1. Feature of the KNGR IMS-EDB

To analyze entities and attributes for a reactor, a pressurizer, pumps, steam generators and piping system, we drew an Entity-Relationship Diagram (ERD) of KNGR IMS-EDB through reverse engineering. As a result of reverse engineering, we could get hold of 147 entities in the RCS. Fig. 3 is a part of the ERD of RCS, includes main entities: component entity (CMP in Fig. 3), mechanical/process equipment entity (MECH EQP in Fig. 3) and electrical equipment entity (ELEC EQUIP in Fig. 3) and so on.

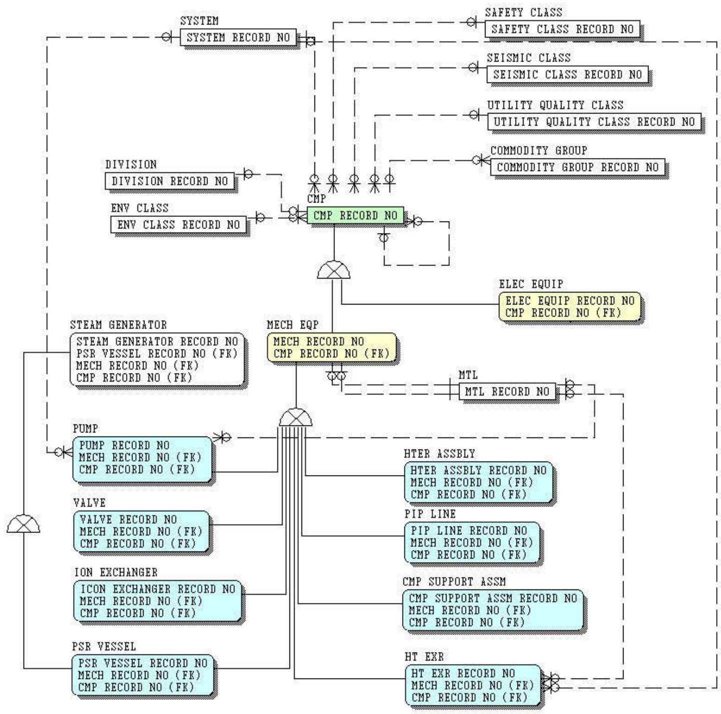

Fig. 3. Partial ERD of the RCS in the KNGR IMS-EDB

In the KNGR IMS-EDB, a nuclear power plant was managed per unit, which is composed of a few systems. And a system consists of a few mechanical/process equipments and electrical equipments. Mechanical/process equipments were classified into HTER assembly, pressure vessel, heat exchange, turbine, pipe line, ION exchange, component support assembly and pump. And there is a motor in the electrical equipments.

4.2 Analysis of GPM Class Library

The GPM class library was development in Japan, based on GPM core model, which is a semantic network model [4, 10]. The subject of GPM class library was a nuclear power plant of the BWR type. The GPM class library is composed of two object libraries. The one is a class object library. The other is an association object library. First the former is grouped into 31 genres according to role of class object. Each genre has independence and correlation between them. And there are two types of class object for representing geometry and non-geometry data of product. As typical cases, Location_base_definition, Presentation, Topology and Geometry genre are related to representing geometry data. The others are related to representation non-geometry data. A structural representation of the GPM class library for a plant configuration management is founded on that of STEP AP 227. But it has distinctive features that are different from that of STEP AP 227. In the GPM class library, the Plant_item is defined as the most basic element, like in STEP AP 227. In STEP AP 227, the plant_system is composed of several plant_items [Fig. 4]. But the system unit, in GPM class library, is formed of a few plant_items and/of unit_segments. The system_unit is a part of plant_system. For example, a line, a piping line, a control line, a duct line, and so on. The unit_segment is a part of a system_unit. For a pipe, a system_unit is assigned to a piping class, and unit_segment is assigned to the different condition within the same piping class.

There are several association objects that represent the relationship between classes in GPM class library. Primarly is_assembled_from, is_classified_as, is_place_on, possess, is_repersented_by, has_property_of, is_qualified_as, is_connected_to etc. are used.

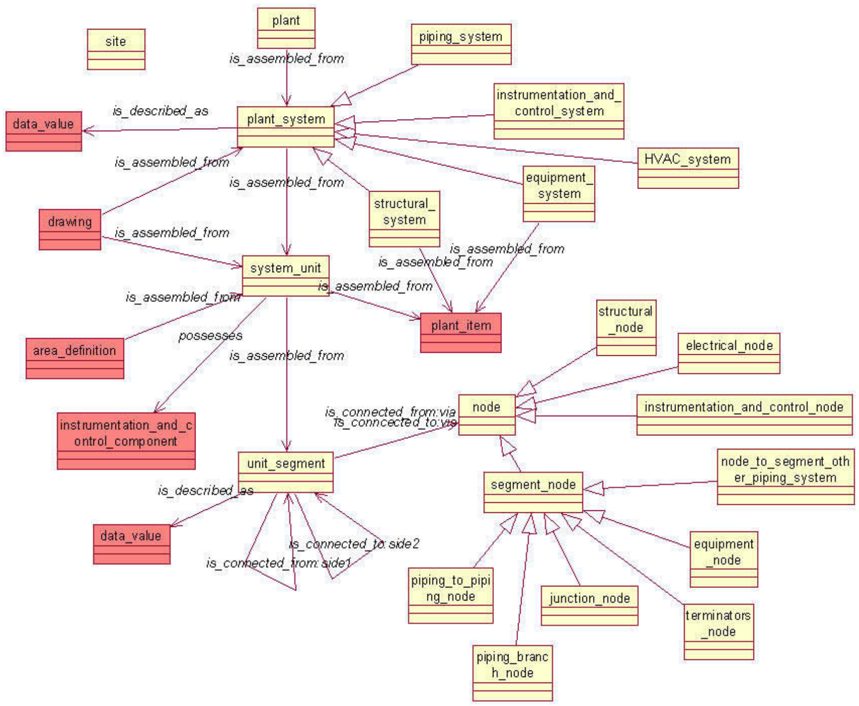

Fig. 4. A structural representation of the GPM class library

4.3 Implementation of KNGR Class Library

The GPM class library is different from the KNGR class library that will be developed, because of different reactor type. So we developed class library based on GPM class library, with an analysis of difference between two types of nuclear power plant. We consider a structural representation of nuclear power plant and different reactor type. And we created the KNGR class library based on these analysis result using XML tools.

The title should be in 12-point Souvenir Lt BT bold. It should be no longer than one line, two if it is absolutely necessary. No abbreviations are allowed unless they are well known, e.g. NURBS, STL or IGES. Author names may be listed in any order, each given a superscript representing the author's affiliation. Each author requires only an affiliation, e.g. University or company, and an e-mail address. No mailing address, phone and fax numbers are allowed.

4.3.1 Structural Representation of Nuclear Power Plant

There are some differences for a structural representation of nuclear power plant between the KNGR IMS-EDB and the GPM class library. Tab. 2 is a mapping table between the GPM class library and the KNGR IMS-EDB, viewed at a structural representation of plant. The plant_item in the GPM class library is equivalent to the component of the KNGR IMS-EDB.

And the plant_system in the GPM class library corresponds to system in the KNGR IMS-EDB. In the KNGR IMS-EDB, system level representation is simply system. But in GPM class library, there are a variety of plant_systems which are piping_system, structural_system, instrumentation_and_control_system, electrical_system, equipment_system, HVAC_system, according to different function of system. Because the KNGR was aiming to manage equipment data related to design phase in a lifecycle of a nuclear power plant, most objects are modeled to equipment. Not so much as, piping components inherited from the mechanical/process equipment. On the other hand, the GPM class library has more detail structures, such as system_unit and unit_segment.

Class objects related to the geometry representation that are derived from STEP part 40-49, are existed in GPM class library, but not in KNGR IMS-EDB.

GPM class library	KNGR IMS-EDB
plant	unit
plant_system	system
plant_item	component
system_unit	component
unit_segment	-

Tab. 2. Mapping table between the GPM class library and the KNGR IMS-EDB for the structural representation of plant.

4.3.2 Reactor Type

The PWR utilize two coolant loops with an intermediate heat exchanger (steam generator) the reactor core heats the primary reactor coolant (water) at which point it flows to the steam generator. After transferring its heat to the secondary water in the steam generator, the temperature of the primary coolant is reduced. The reactor coolant is then circulated by a pump back to the reactor core. The reactor coolant is kept at a pressure of about 2200 psia which prevents the primary coolant form boiling. The secondary water, which receives the transferred heat, is changed to steam that is piped to the turbine. The BWR utilize a single coolant loop and therefore boil water in the reactor core. The produced steam is sent directly to turbine. Like above explanation, we seized the difference between the PWR and the BWR. A main difference is that the steam generator is existed in the PWR but not existed in the BWR. And types of reactor, pump, condenser etc. are different. When we create class library, we considered these features.

4.3.3 Implementation of KNGR Class Library

Because the KNGR IMS-EDB doesn't have detail structural representation of plant, we decided to accept the structural representation in the GPM class library, that is, based on STEP AP 227. And we redefined attributes of the plant_item in GPM class library, with analyzing attributes of component entity in KNGR IMS-EDB. We made class library for main equipments in KNGR IMS-EDB. At this time, we take distinguishing features of PWR type into consideration. Fig. 5 depicts class diagram for main equipment class in class library. We could confirm steam generator added below the static_equipment-vessel-pressure_vessel class in Fig. 5.

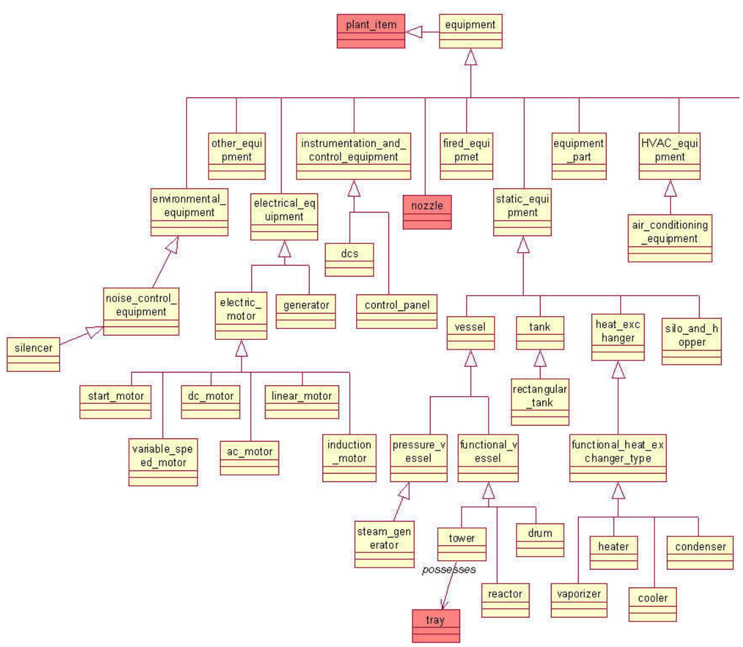

Fig. 5. Equipment class library

In this project, XML is used to create the KNGR class library. XML is very flexible development tool and suitable for object-based modeling. And XML has the advantage of modeling a semantic network. We use the XMLspy, which is

the XML editor tool, to produce the KNGR class library on the XML Schema in Fig. 6. Fig. 6 is a kind of view supported by the XMLspy to present XML Schema that defines the structure and the syntax of the KNGR class library.
The root node in XML Schema is the ClassDefinition. And there is the Classes element which describes a class grouped into genre. A class is defined as the class element and composed of Definition, Reference, Resource, replace and Association element. In the KNGR class library, two class libraries were defined. The one is the class object library to define a class object based on XML Schema in Fig. 6. The other is the association object library to define an association object based on association XML Schema. The Instance object is defined through the class object library and association object library.

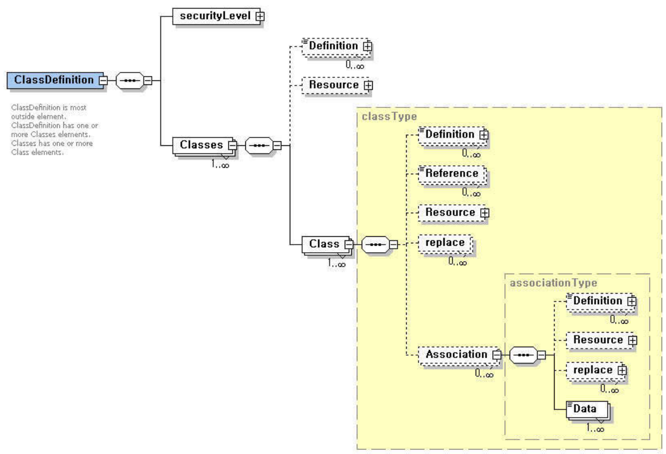

Fig. 6. XML Schema of the KNGR class library

Fig. 7 depicts XML instance of the steam generator class object. In Fig. 7, the steam generator is connected to "pressure_vessel" class object through "is_classified_as" association object. And attributes of the steam generator are represented by "has_property_of" association object. The "qualifier" attribute in association element describes the characteristic or constraint of "property" attribute. After the KNGR class library was completed, it was exported to the Oracle 8i database.

5. CONCLUSION

This paper has presented the KNGR class library, which has geometry and non-geometry data model based on semantic networks, to support co-design between engineering design companies. The KNGR class library was completed through an analysis of the KNGR IMS-EDB and the GPM class library. And we considered a structural representation of plant and differences between the PWR and the BWR.
The KNGR class library is so flexible that it can be extended other field. That is, we can easily create the KNGR class library for construction, operation and maintenance of plant without modifying the core model of that. Our research will be conducted on it.

6. ACKNOWLEDGMENT

This research project is primarily supported by Electric Power Industry Technology Evaluation & Planing.

7. REFERENCES

[1] D. Xue, H. Yang, "A concurrent engineering-oriented design database representation model", Computer-Aided Design, 2004, pp. 947-965
[2] Franca Giannini, Marina Monti, Domenico Biondi, Flavio Bonfatti, Paola Daniela Monari, "A modeling tool for the management of product data in a co-design environment", Computer-Aided Design, 2002, pp. 1063-1073
[3] G.Q. Huang, K.L. Mak, "Web-integrated manufacturing: recent developments and emerging issues, International", Journal of Computer Integrated Manufacturing, 2001, pp. 3-13
[4] http://openknow.com/vipnet/, IMS-VIPNET, Open Knowledge
[5] ISO 15926-1: provides an overview of ISO 15926.

[6] ISO 15926-2: specifies a generic, conceptual data model that supports representation of all life-cycle aspects of a process plant.

[7] KNGR NSSS EDB DEEP SLICE development report, Korea Hydro & Nuclear Power Co., 1997

[8] S.C.Y. Lu, J. Cai, W. Burkett, F. Udwadia, “A methodology for collaborative design process and conflict analysis”, Annals of CIRP, 2000, pp. 69-73

[9] Sharon J. Kemmerer, STEP the Grand Experience, NIST, 1999

[10] T. Yoon, Y.Oota, Y. Naka, T. Yoshinaga, K. Shibao, M. Igoshi, K. Matsushima, T. Suzuki, “Knowledge Fusion among the Virtual Production Enterprises within the Technology Information Infrastructure Environment”, 2002.

[11] W.C. Regli, V.A. Cicirello, “Managing digital libararies for computer-aided design”, Computer-Aided Design, 2000, pp. 119-132

[12] Xue D, Yadav S, Norrie DH., “Knowledge base and database representation for intelligent concurrent design”, Computer-Aided Design, 1999, pp. 131-145

[13] Y. Jin, L. Zhao, A. Raghunath, “ActiveProcess: a process-driven and agent-based approach to supporting collaborative engineering”, Proceedings 1999 ASME Design Engineering Technical Conferences, Las Vegas, 1999, NV, 12-16

[14] Yuliang Li, Xinyu Shao, Peigen Li, Qiong Liu, “Design and implementation of a process-oriented intelligent collaborative product design system”, Computer in Industry, 2004, pp. 205-229


```xml
<Class id="steam_generator" security="public">
  <Definition>The physically global features of the steam generator
  peculiar to the general pressure vessel feature</Definition>
  <Reference>KNGR IMS EDB</Reference>
  <Association name="is_classified_as" security="public">
    <Data role="classifier">pressure_vessel</Data>
  </Association>
  <Association name="has_property_of" security="public">
    <Definition name="the global dimensions of the steam generator
    secondary side"/>
    <replace association="secondary_side_dimensions" flag="true">
      <remove role="qualifier"/>
      <remove role="property"/>
    </replace>
    <Data role="qualifier" security="public">secondary_side</Data>
    <Data role="property" security="public">dimensions</Data>
    <Data role="data" security="public">data_value</Data>
  </Association>
  <Association name="has_property_of" security="public">
    <Definition name="the surface area of the steam generator secondary
    side exposed to secondary fluid"/>
    <replace association="secondary_side_secondary_fluid_surface_area"
    flag="true">
      <remove role="qualifier"/>
      <remove role="property"/>
    </replace>
    <Data role="qualifier" security="public">secondary_side</Data>
    <Data role="qualifier" security="public">secondary_fluid</Data>
    <Data role="property" security="public">surface_area</Data>
    <Data role="data" security="public">data_value</Data>
  </Association>
  <Association name="has_property_of" security="public">
    <Definition name="the average wall thickness of the base metal for
    the steam generator secondary side"/>
    <replace association="secondary
    side_base_metal_average_wall_thickness" flag="true">
      <remove role="qualifier"/>
      <remove role="property"/>
    </replace>
```

Fig. 7. XML instance of steam