DEVELOPMENT OF AUTONOMOUS DISTRIBUTED MANUFACTURING SYSTEMS (ADIMS) CONCEPT AND EXAMPLE OF IT'S APPLICATION IN THE CASTING INDUSTRY

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Abstract

This research deals with the development of Autonomous Distributed Manufacturing Systems (ADiMS) Concept and an example of its application in the casting industry. ADiMS is a manufacturing system concept developed to increase the flexibility of the system. In ADiMS, each of the manufacturing system elements (holon) had been modelled as an intelligent element with the result that each element had capability to manage information, communicate each other, and to make decision. The whole manufacturing problems are solved by each element and coordination among them. In the modelling at the developed application software, UML (Unified Modelling Language) was used, where each element of manufacturing system was modelled as a class as in the Object Oriented Programming (OOP) concept. As a case study, the development of the concept analysis and application software to manage casting industry, that has a piston ring as its main product, was carried out. The application software that had been developed, that still in a proto type stage, has five main functions that are an order management system, Quality Assurance, Warehouse management, Jig & Fixture Storage Area management, and Sand Casting Area management functions. Inside each function, there are several objects that working together with coordination among each others. The application showed that all main functions can make communication through the database server. The developed application that discussed at this research has a client - server technology. The same web-based system with the n-tier technology is still in the development stage now.

***Keywords**: Manufacturing Systems, application software, casting industry, autonomous holon*

1. Introduction

ADiMS concept has been developed and has been a trial-run through a simulation step and followed by an implementation step at job shop type industries. Management of the job shop type industry is the most complicated compare with the other type of manufacturing industries, such as flow shop and batch type industries. At this research, a short review will be carried out to the characteristic of the ADiMS concept that will be implemented into the flow shop and batch type industry. A piston ring casting industry will be used as a case study. That industry has a sand casting area to produce casting raw material based on a batch production, and also has a machining area to machine casting parts to be a final product based on a flow shop production.

At the previous development, modelling of ADiMS was performed based on the OOP (Object-Oriented Paradigm) as a modelling tool. Programming language used in the development was chosen the language that could support the OOP concept, such as C++, Delphi, etc. As an increasing demand to the application that must be able to be run on the computer network, there is a requirement to develop the web-based application of ADiMS. A modelling step also needs more discipline sequences and it to be possible to be realized with supporting of UML (Unified Modelling Language). There are several technologies that can be used in the development of web-based application software. This research develops web-based ADiMS application base on a client - server technology.

The developed prototype software will be planned to apply at the casting industries. It has five main functions that are order, Quality Assurance, Warehouse, Jig & Fixture Storage Area, and Sand Casting Area management functions. Each function has several objects that working together with coordination among each others. All main functions to be designed can make communication through the database server. The developed application will use a client - server technology as a platform.

2. Autonomous distributed manufacturing systems

The concept of Autonomous Distributed Manufacturing System (ADiMS) is proposed to realize flexibility in production. As an overview, the concept of ADiMS is summarized with the following three characteristics [3].

a) Autonomous
   ADiMS consist of autonomous production components where each of them can monitor condition, decide what to do the next, and how to control itself. The autonomous functions of individual components are considered from the logical view point. All the components in the manufacturing system, such as the machine tools, machining area, workpiece, and operators, can be the autonomous components from the logical point of view. In other words, all the components in the manufacturing systems share the decisions making functions of the production control in the logical and virtual model of the manufacturing system.

b) Task Distribution
   In ADiMS there is no global function that allocates jobs to machines on a shop floor. Instead of top-down scheduling, production components solve the manufacturing problems with bottom-up approach. Parts or assemblies that want to schedule their processes choose the production components with their own criterions. On the contrary, the production components choose the processes of parts or assemblies that able to be carried out base on their own criterions also.

c) Coordination
   Conflict of interests may appear consequently of the bottom-up approach. Production equipment can select a suitable operation and decide the starting and finishing time of operation. On the other hand, each lot of parts can also select and decide a schedule of operation relating with their processes. Some negotiation mechanism is therefore needed to coordinate the decisions of all production components. So the harmonization condition among the production components can be achieved.

After a review for application of ADiMS to the broader scope of manufacturing areas, there was a need to add the new characteristic to each autonomous component that is a holonic characteristic [1]. Every autonomous component can be modelled as a holon. At the ADiMS concept holon can be defined as a part of manufacturing system that has an autonomy to process (to transform, to move, and to store) part or information, or to stop a process. Holon can be a part of the other bigger holon and at the same time as a holarchy of the other smaller holons. Therefore a manufacturing system at a certain company can be modelled as a big holon with the other smaller holons as representation of areas inside the company, such as sand casting, machining, warehouse area etc. that can make coordination each other to achieve a certain goal. A collection of several holons that can make interaction each other, such as holon of sand casting area, machining area, and final inspection area, to achieve a certain goal called as a holarchy as shown at Fig. 1.

The word holon came from Greek's word, holos, which means entirely and a suffix, on, which means part-of. This word was introduced first time by Coestler, A. at his book: The Ghost in the Machine [2].

3. Modelling Stage

At the manufacturing system, the high level automation of production elements is usually equipped with controller (CNC) that can make calculation and decision making that be needed to control that production element, even though, there are production elements that are do not be equipped with CNC, such as workpiece, tools, etc. With the existing of a rapid progress in the computation technology, so there is a high possibility to develop an ADiMS architecture model in form of computer software. Therefore the first step that has to be done in order to realize the ADiMS concept is modelling. Modelling as shown at Fig. 2 is carried out by development of model software for each production element, or autonomous holon, with the result that in the computer software there are virtual object of the real production element.

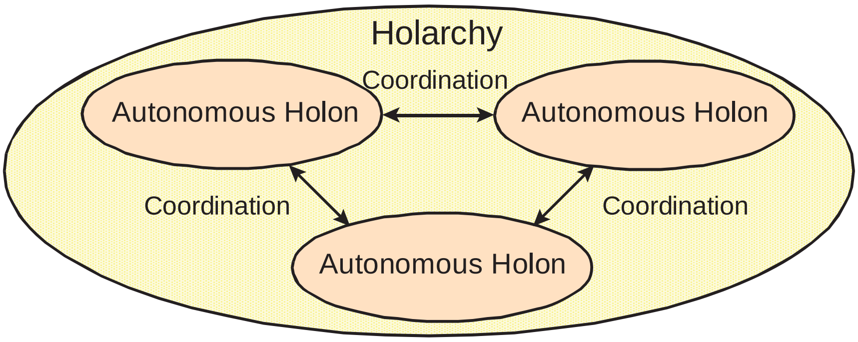

Fig. 1. Production element model as an autonomous holon

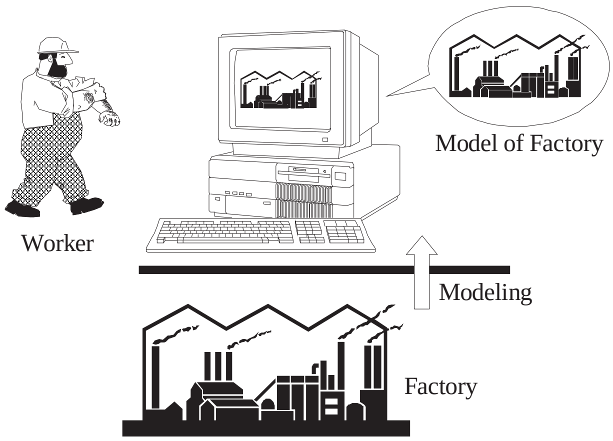

Fig. 2. Manufacturing system modelling

At ADiMS, the allocations of jobs inside the manufacturing system are fixed base on communication among model of the production element which is conceptually called as an autonomous holon. The autonomous characteristic that is possessed by production element model will make the manufacturing system still flexible toward disturbances or unpredicted events. [4]

Modelling of casting industry that contains final inspection, machining, jig & fixture, and sand casting areas are shown at Fig. 3. Casting industry model at this research was assumed consisted of four autonomous holon members and one holarchy holon that is a holon of casting industry itself.

4. Modelling sequence

UML modelling tools have given detail guidance in the modelling step. Although there are several steps which are able to be skipped. This is belonging to the complexity of the developed system. Modelling activities are divided into four steps. Those are a need analysis, modelling analysis, implementation overview, and deployment overview stages.

The modelling goal is to develop a model which will be used as a platform in the development of ADiMS software. In order to make the discussion to be focused, then the modelling activity will focus on the modelling of autonomous holon of a warehouse. Modelling steps of the other holons are the same with modelling steps of warehouse holon.

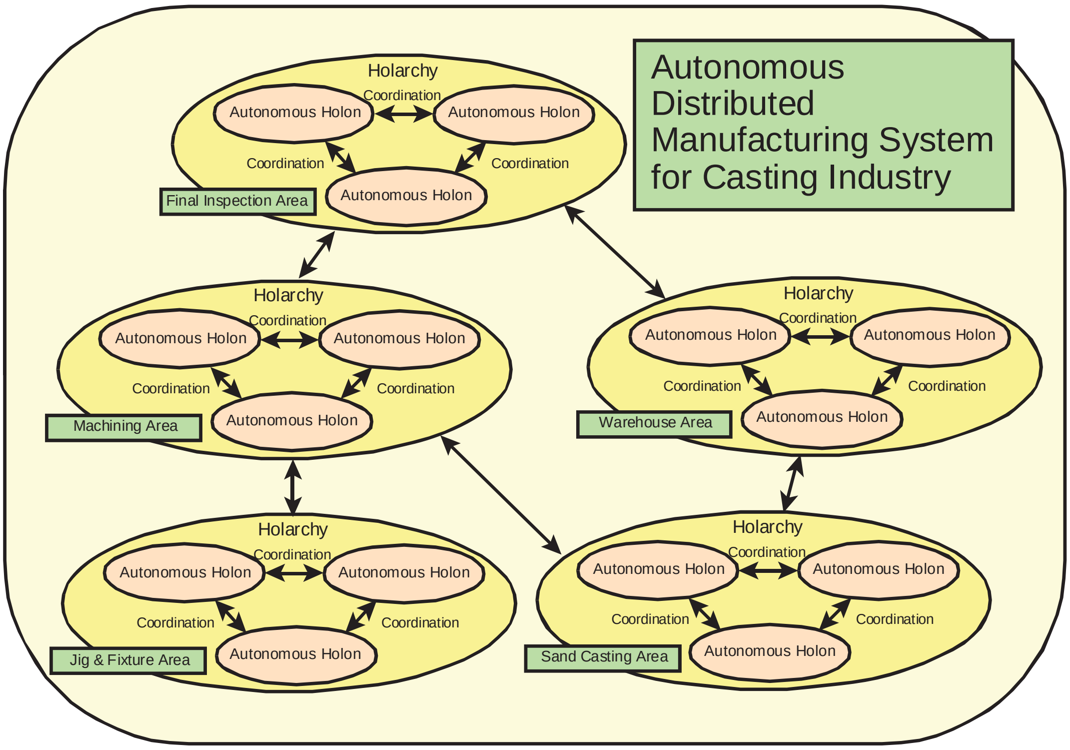

Fig. 3. Model of autonomous distributed manufacturing system for casting industry

4.1. Need analysis

The first step in modelling activities is to carry out analysis about needs that must be covered in the developed software. In the warehouse holon, the need can be formalized as follow:

1. Warehouse holon is developed to fulfil the warehouse operator's requirement in order to manage objects inside the warehouse,
2. Warehouse operators able to create, update, and delete about inside warehouse objects information,
3. At the virtual layer, warehouse holon able make interaction with other holons. It means that in an application layer, warehouse information must ably to make an interconnection with other area's information,
4. Warehouse holon able to give information about the amount and value of the asset that stored inside the warehouse,
5. Warehouse application can be run on the computer network with use a server as database layer,
6. Warehouse application can monitor raw materials, casting products, and final products, then all information can be extracted every time.

4.2. Modelling Analysis

Next step in modelling after need analysis is modelling analysis which is divided into several sub steps as explained after this.

Business Modelling

Business model constitute existing organization mapping in simple form. It can help to make clear the problems in the software development. Business model consists of business actor, business use-case, and business object models.

A business actor explains the business role to be performed by someone or something inside those business activities. A business actor at this system can be shown at Fig. 4. Personnel business actors are warehouses, QA (quality assurance), machining, sand molding, and foundry employees. The last two are employees at the sand casting area. Be sides in form of personnel an actor can exist as an information system or application. Business actors which have information system form are raw material system, semi finish goods system, and finish goods system.

Business use case constitutes an action business sequence that produces something able to be observed from a business actor. Business use case at the warehouse module is divided into four packages that are sand, melting, machining, and final inspection packages. Business use case for a casting unit at sand area is shown at Fig. 5.

Business object modelling was used to explain the realization of business actor modelling and business use case modelling. Fig. 6 shows business object model that are existing in a warehouse module.

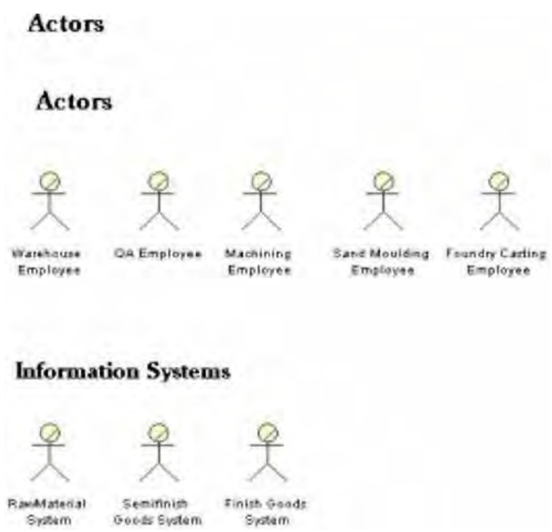

Fig. 4. Business actor modelling

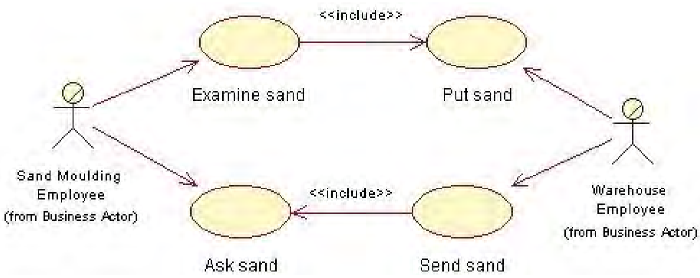

Fig. 5. Business use-case for sand mould manufacturer

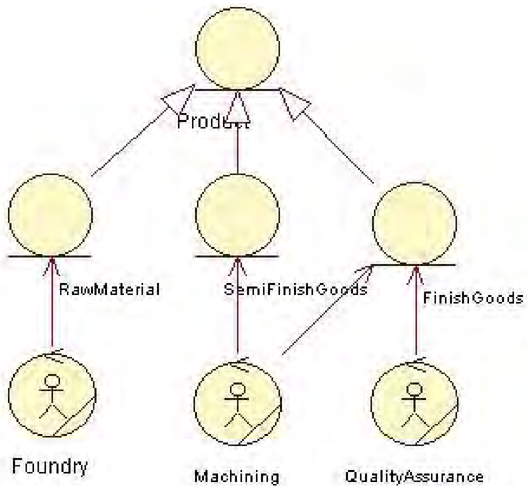

Fig. 6. Business object model for warehouse Use Case Modelling

At the use case modelling step, a software system for supporting a business model that had developed at a business modelling step will be developed. The Use case model constitutes a general overview of the system that indicates all of the business use case and business actor. The use case model at this system is divided into three parts, such as RM (Raw Material) handling system, SFG (Semi Finish Goods) handling system, and FG (Finish Goods) handling system. Fig. 7 shows an example of a use case model that is a RM handling system.

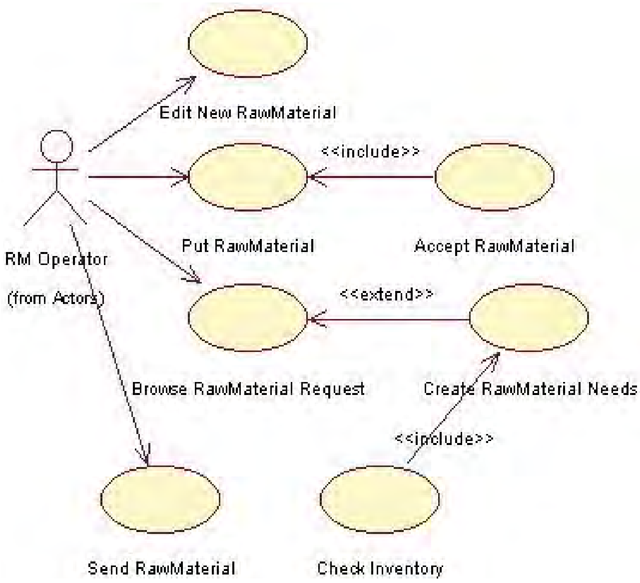

Fig. 7. Use case diagram for RM handling system

Model Analysis

Model analysis constitutes a general overview of the system that is shown in the form that nears with an application of software. The goal of model analysis is developing preliminary mapping of characteristics that are required at the inside system element/holon modelling. Model analysis shows a general overview of the system according to functional aspect.

Model analysis has relation with the development of three kinds of diagrams that are class diagram, sequence diagram, and collaboration diagrams. From the last two diagrams can be chosen one because all of them are giving the same or equivalent information. An example of a class diagram for a Raw Material handling system is shown at Fig. 8.

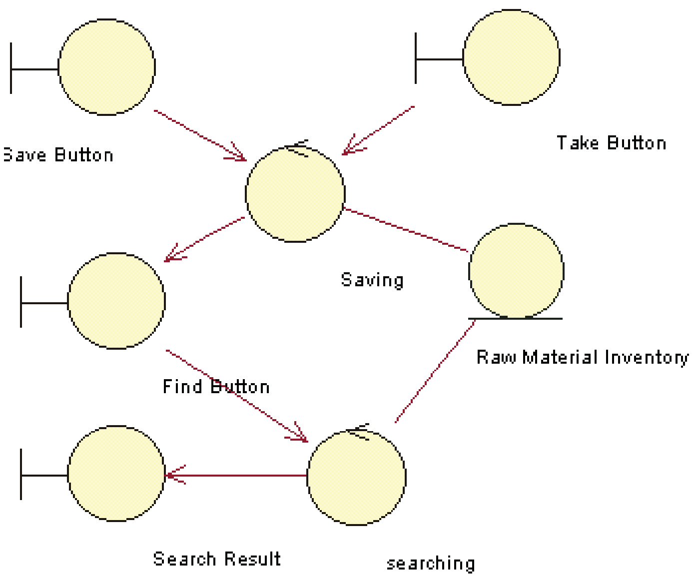

Fig. 8. Class diagram for raw material handling system realization

Model Design

Modelling at the design stage illustrates a system abstraction nearly to the source code. At this stage, class has been decided its programming language, attribute, and function/operation/methods. It will be useful for mapping the model into the source code. Fig. 9 shows an example of a class diagram that has been completed with attributes at each class.

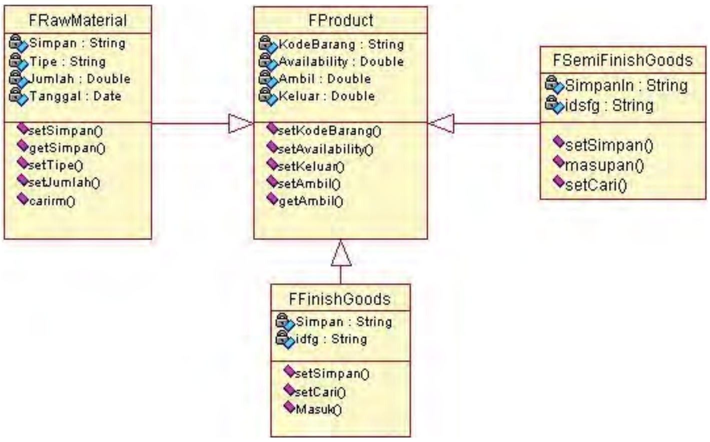

Fig. 9. Class diagram for implemented into source code

4.3. Realization Overview

At this stage, a component diagram that illustrates simple abstraction of software is developed. Figure 10 shows that a warehouse unit and others units' application software has interconnection through a common database server.

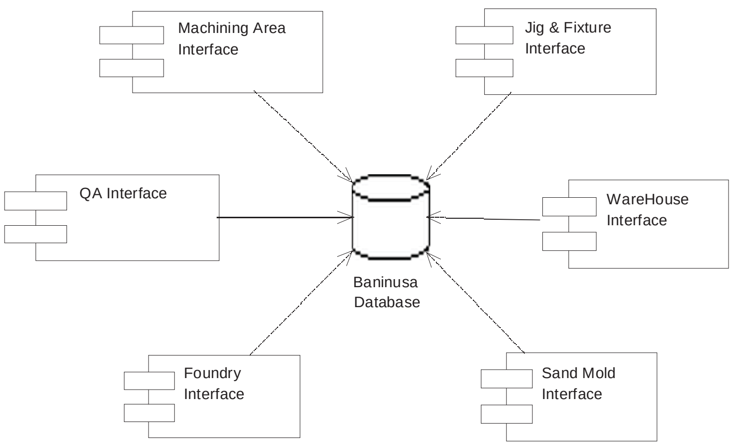

Fig. 10. Component diagram of units in casting industry

4.4. Deployment Overview

This stage shows a part of hardware that must be installed in order that developed software system can give a good function. Figure 11 shows the hardware that is installed at a warehouse, hardware for other production units, and a database server for supporting communication among existing production units.

5. Prototype of Software

All application software modules that are needed by a casting industry have been developed. One of the application windows is shown at Fig. 12. That figure shows a main window of Jig & Fixture Module, preparing for machining area employees, that consists of Work Calendar,

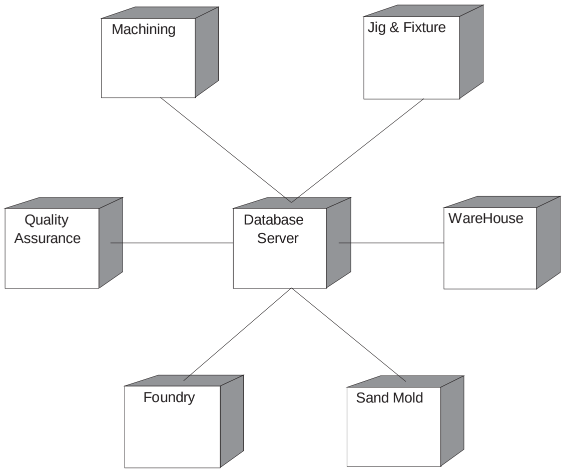

Fig. 11. Deployment Diagram of Hardware at Units that will be Connected with Database Server

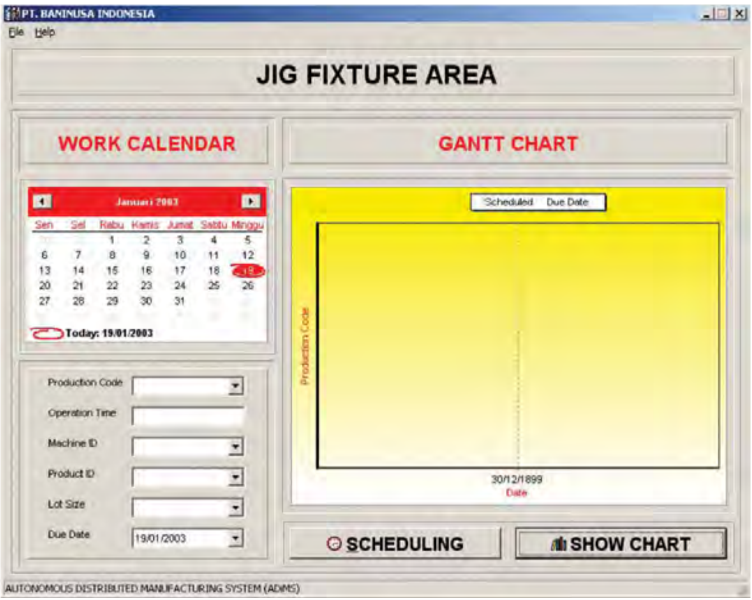

Fig. 12. User Interface of Jig & Fixture Area

Gantt Chart, Scheduling Button, Show Chart Button, and inputting fields demanded by machining area. That inputting information consists of jig & fixture specification such as production code, operation time, machine id, product id, lot size, and machining due date.

6. Conclusion

The prototype application software for casting industry has been developed. The application has been developed based on ADiMS concept, used UML as a modelling procedure, and used a client - server technology as a plat form of technology. Several modules that had been developed can make communication each other through a common database server.

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References

[1] Bagus, A., Martawirya, Y. Y., Chandra, L., *Modelling of Painting Area Based on Holonic Manufacturing System Concept*, Proceeding of Seminar Nasional Tahunan Teknik Mesin (SNTTM 7), pp. S16 1-8, Manado 2008.

[2] Koestler, A., *The Ghost in The Machine*, Arkana, London 1967.

[3] Martawirya, Y. Y., *Autonomous Distributed Manufacturing Systems I: Concept Development and Its Implementation in Flow Shop (Repetitive) Manufacturing Type Industry*, Lecture Note, Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, pp. 19-33, Bandung 2009.

[4] Martawirya, Y. Y., Setyadi, R., Fahruri, I., *Autonomous Distributed Manufacturing Systems: Development of Rescheduling Function*, Proceeding of Seminar Sistem Produksi 4, Bandung, 1999.