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Manufacturing Message Specification (MMS) based Open Manufacturing System

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Manufacturing equipment should be integrated to construct a computer integrated manufacturing (CIM) environment, but several economical and technological difficulties may surface when heterogeneous systems are integrated into each other. Manufacturing message specification (MMS) can be effective in such case, but the problem is that MMS-related products are comparatively expensive and most existing manufacturing equipment does not support MMS. This study focused on developing a gateway suitable to a non-MMS-compatible CNC machine-tool, and on implementing an open system interconnection (OSI) upper layer on TCP/IP. The development system was applied to a cell controller by means of heterogeneous equipment under the CIM environment and to evaluate its interoperability and portability.

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1. Introduction

When machining cell is constructed using MMS service, the problem may be on how to effectively integrate the manufacturing equipment made by various vendors.[1,2] It may be more problematic if a machining cell is constructed using the existing manufacturing equipment. Up to not long ago, the functions of controllers have been analyzed and then one-to-one interface has been performed according to the analysis result in order to construct a machining cell through various manufacturing equipment. Fig. 1 shows this process. The process is advantageous in construction, but at the same time is disadvantageous in extensibility and portability. In addition, it was difficult to exchange information due to its hierarchical control structure.[3,4] To solve such problems, manufacturing automation Protocol (MAP) appeared since the 1980s.[5,6] As MMS introduced an object-oriented concept into the communication sector among manufacturing equipment, it was positioned on the top-level of MAP and was proposed as the standard of upper application layer messages and services. Afterwards, it was became ISO/IEC 9506 standard (ISO/IEC 9506-4, 1992) certified. MMS defines the standard of the exchange messages and services in application software tasks scattered on the network, as well as supports computer numerical control (CNC), robots and programmable logic controller (PLC). The communication protocols supporting MMS are being developed into MMS on Full MAP, MMS on Mini-MAP, MMS on Ethernet, MMS on transmission control protocol/Internet protocol (TCP/IP) and others. The MAP, based on OSI, has not come into wide use yet and also its marketability has been lowered due to its complexity. On that account, MMS has been researched so that it can be implemented on TCP/IP or Fieldbus. Several producers commercialized 'MMS on Ethernet' that uses the 3rd, the 4th, the

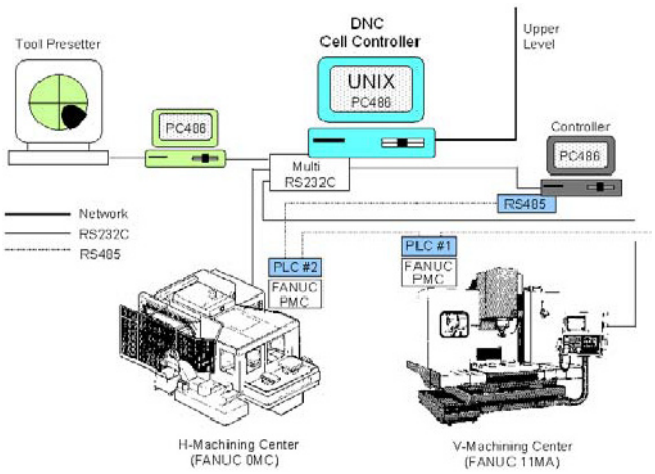


Fig. 1 Machining Cell with Heterogeneous CNC

5th and the 6th layer, out of OSI 7 layers, to OSI protocol, but the problem is that it is relatively expensive and also it is difficult to set up its respective environment and operation. In conclusion, MMS cannot be universally used when flexible manufacturing system (FMS) or CIM is constructed despite the fact that it was appointed according to the international standard. There are several reasons; firstly it is difficult to apply the protocol that configures the MMS applicable to the existing system and also MMS-supporting products are expensive. Secondly, most existing manufacturing equipment do not support MMS.[7,8] MMS protocol itself had been implemented on Ethernet, but it is so researched that it can be implemented on the TCP/IP protocol of the internet network and can be set in CNC and PLC in order to solve the aforementioned problems. There are several methods to map MMS into TCP/IP, but a standard was not established as yet. The MMS service, which can satisfy popularity and economical efficiency at the same as TCP/IP, should be developed as well as an intermediate technology, which can uses MMS standard by objectifying the existing equipment that are the same as gateways, should be researched in order that the characteristics of MMS such as interoperability and portability can be accounted for in cell environment. In line with this purpose, the CNC of the existing machine tools was researched so that it can be objectified by using a gateway that supports MMS service. This study attempted to apply 'MMS on TCP/IP', which matches MMS service to TCP/IP, to the machining cell controller taking into consideration popularity and economical efficiency. On this score, the CNC virtual manufacturing device (VMD) suitable to MMS standard was developed and applied to a gateway. An office LAN was used to the MMS service-based model cell by using two machine tools having heterogeneous controllers. The machining cell was tested on whether the cell controlling and monitoring are normally performed at the positions that are 20m and 1Km distant from heterogeneous controllers, respectively. As the result, many advantages were observed in portability, extensibility and data access.

2. MMS Characteristics Process

MMS is a standard of application service element in the 7th layer model of OSI designed to support programmable devices to exchange messages with each other in CIM environment. Specifically, MMS is to define services and protocols so that the control objects connected with the Host or manufacturing equipment that can be organically communicated with each other, in regards to a company-wide LAN. MMS, proposed as the standard of the top-level application layer message or service of MAP, has developed into MMS on Mini MAP, MMS on Ethernet/OSI, MMS on TCP/IP and others, based on the concept of object-oriented automatic communication. As MMS on Ethernet/OSI uses the layers between the third and the sixth to OSI protocol, OSI protocol has several problems with popularity, price, configuration and operation. Consequently, MMS on TCP/IP tends to be popular because it matches MMS service to the TCP/IP of which stability was verified through LANs and internet protocols. The Adaptation Layer and Compressed Stack are representative methods to implement MMS on TCP/IP. Most MMS on TCP/IP Vendors, such as SISCO, Marben, Cycle Software and others, adopt extensible Adaptation. However, compressed types are more advantageous in the environment that requires real-time response because its network configuration is simple and inexpensive. The adaptation type means putting RFC1006 Adaptation Layer between TCP/IP and Session Layer in order to drive OSI Session Layer and Presentation Layer on TCP/IP. The compressed type means using ISO/TC184/SC5/WG2 N578, which provides MMS protocol, on 2 Layer Stacks. Each type has its advantages and disadvantages, but it is considered that the compressed type may be universalized in view of long-term efficiency. The MMS on TCP/IP, adopted in this study, was implemented in consideration of the above-mentioned advantages and disadvantages. It seems to be similar to N578, but users are unrelated to it. It consistently provides API to users regardless of the subordinate protocols.

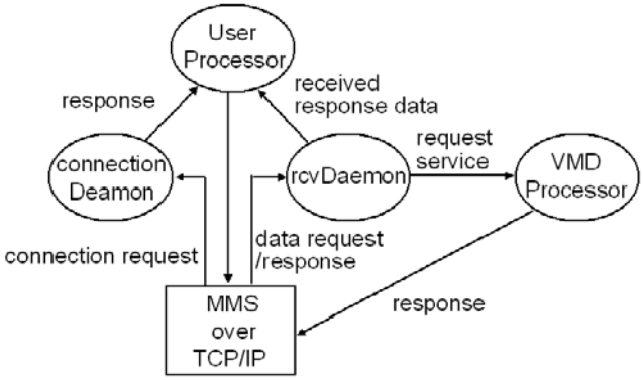


Fig. 2 Structure of Applied MMS

As shown in Fig. 2, the structure of MMS applied in this study consists of connection daemon playing a role in message transmission, receive daemon playing a role in processing received message, and application processor playing a role in managing clients and servers. In MMS, the control object and the manufacturing equipment designate CNC, Robot and PLC. Fig. 3 shows the concept. According to the figure, the client can use VMD with MMS service, and the server is a VMD application system. Likewise, VMD is a virtual manufacturing device of function and object, necessary for control and monitoring, are abstract. Fig. 4 shows the concept of MMS limited to CNC. A real machine can be controlled and monitored via VMD from the characteristic service called 'MMS'. On this note, MMS treats these manufacturing equipments as VMD by introducing an object-oriented programming concept. For this reason, specific equipment such as CNC, a robot, PLC and others should be clearly defined. The followings are functions of NC device-related MMS- client•server (CS) among the standards accompanied with MMS.

1) Defining the communication service of manufacturing message, necessary to apply NC devices
2) Defining NC models as application functions; Defining the connection between these functions and VMD

3) Providing the standard name to the specific object of NC
4) Defining NC application models and classes

VMD always remembers the status of real equipment on the basis of variables, domains and semaphores, and shows the related data at the request of a client. Likewise, it can control the real equipment on request.

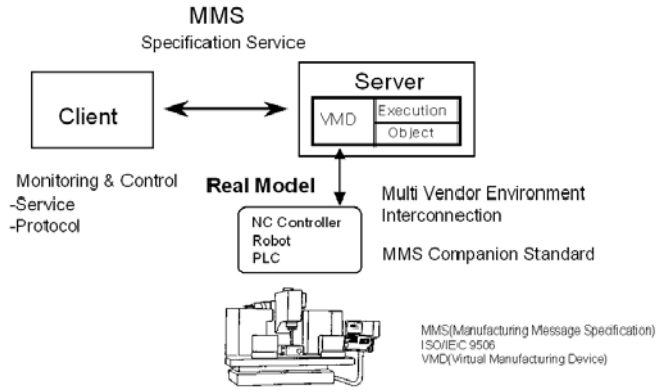


Fig. 3 Concept of MMS Implementation

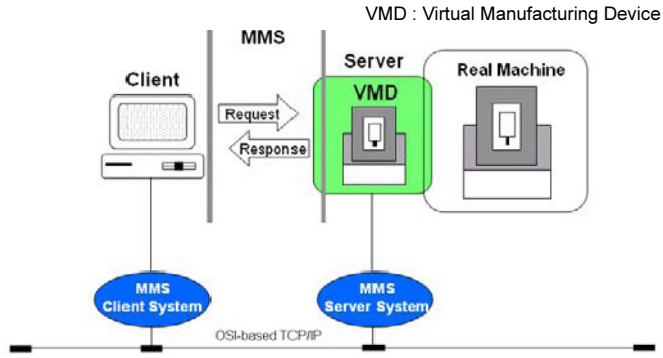


Fig. 4 Concept of VMD Implementation

3. MMS Environment Design

The communication layer is applied to serve MMS. It shows the system application hierarchy reconfigured to operate MMS under the situation that it is really applied to OSI 7 layers. There are application programs such as MMS and manufacturing message specification interface (MMSI) in application layers. MMSI is a standard API that uses MMS in application layer, and common mutual interface was set up in respect that MMS is being used. Synthetically, an application program was made out by using a standard API called 'MMS Interface'. Fig. 5 shows the MMS Client/Server system connecting MMS service with real equipment. The server and the client are connected with TCP/IP through standard network interface. In the MMS application program that is connected with MMSI, the server is more complicated. The application program in the server is constituted by a VMD module, protocol conversion module, device local mapping module and an equipment driver module. VMD module is a virtual model related with mechanical characteristics and functions, and device local mapping module is to control or monitor real equipment.

The machine tool, which is controlled by an open architecture controller (OAC, ex: PMAC, Delta Tau) and FANUC controller, was used to test the operation of MMS on TCP/IP. VMD server was configured to control and monitor real equipment, and a client was separately connected to TCP/IP base. The VML server, which controls and monitors the machining center based on programmable multi-axis controller (PMAC), was configured to test the operation of MMS on TCP/IP. Also, a client was separately connected with the TCP/IP-based LAN. The dynamic link library (DLL) typed middleware, which manages MMS Interface and Communication Socket Service Interface on multitasking Window, was set in the client and VMD server. Many middleware-leveled processes are necessary to operate MMS. Thus, the APIs provided from DII are used after the MMS service-related library was designated. The related APIs can be externally interfaced after they were appointed to be 'extern'.

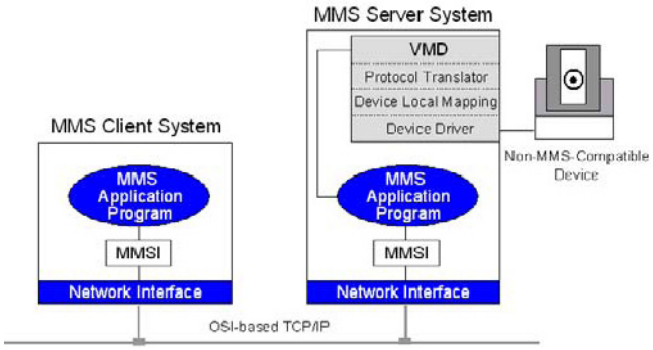


Fig. 5 MMS Client/Server System

4. Configuration of Open Machining Cell

If CIM environment is constructed by integrating manufacturing equipment distant from each other, RS485 and similar devices can be applied. However, distance, cost and communication reliability may be problematic. In this study, such problems were solved by using the existing TCP/IP network. To test MMS on TCP/IP operation, a machining cell was configured on KIMM model plant as shown in Fig. 6.

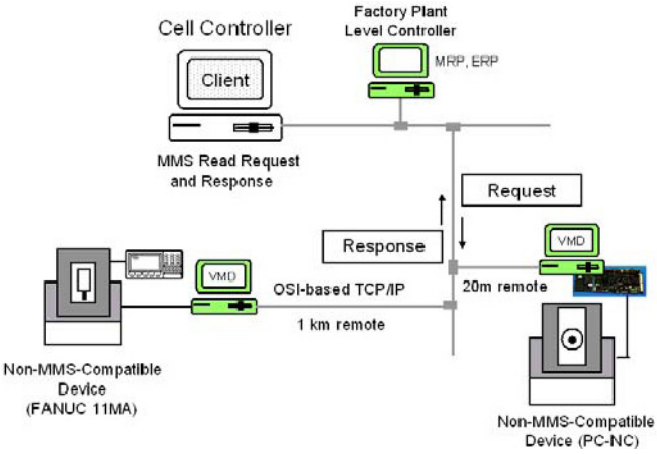


Fig. 6 OAC Machining Cell

FANUC 11MA and PC NC (non-MMS compatible devices) were put on the under part of the cell controller that takes orders from the server, which manages schedules and production control under CIM environment, and manages subordinate manufacturing equipment. In addition, VMD was also mounted. PC-NC is about 20m from the cell controller, and FANUC 11MA is 1Km distant. Remote model plants designate machine tools, coordinate measuring machine (CMM), automatic guide vehicle (AGV), automatic storage and retrieval system (ASRS), transfer machine, tool presetters and others, but this study focused only on the CNC machine tool. PLC board functioned as the interface layer between FANUC 11MA and VMD, and PMAC board functioned between PC-NC and VMD.

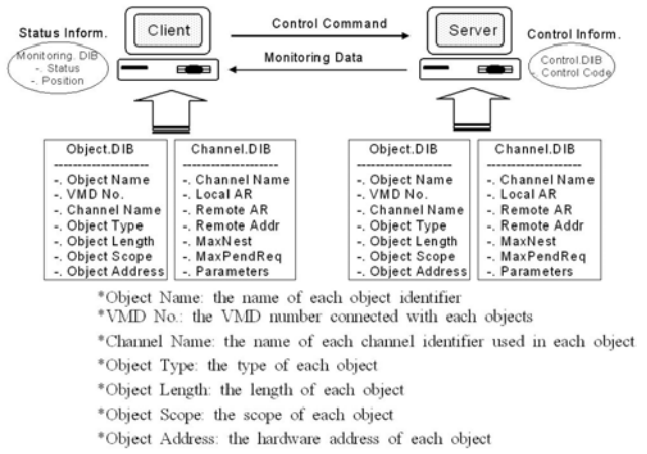
The VMD, based on the open control board, was implemented in the Window environment, and defined the object to configure the VMD recommended by ISO/IEC 9506-4. The VMD, set in the application process of MMS, is constituted by an executive function and finite variables.

5. Operating Test of Machining Cell

With regard to MMS operating test, a variable object and a program invocation object were defined. Initialization process is necessary to actually transmit messages between a client and a server, aimed at the defined objects. Fig. 7 shows the process. In view of information processing, the client and the server initialize each object and channel information through DIB file.

Table 1 Definition of Object Variable

Object	Variable	Attribute
Unnamed Variable Objects	N_PgmNo	Variable Name
	N_CurPosX	Variable Name
	N_CurPosY	Variable Name
	N_CurPosZ	Variable Name
	N_OpStatus	Variable Name
Program Invocation Objects	N_PgmSearch	Program Invocation name
	N_PgmUpload	Program Invocation name
	N_CycleStart	Program Invocation name
	N_CurPos	Program Invocation name
	N_Stop	Program Invocation name



*Object Name: the name of each object identifier
*VMD No.: the VMD number connected with each objects
*Channel Name: the name of each channel identifier used in each object
*Object Type: the type of each object
*Object Length: the length of each object
*Object Scope: the scope of each object
*Object Address: the hardware address of each object

Fig. 7 System Initialization Process of MMS Service

An object information file defines various and detailed information related with reciprocatable variables, and designates communicable channel names. The designated channel name defines the name of the host connectable with a channel information file and parameter. In succession, it should be initialized so that the APIs provided from MMSD II can be used; it is managed by the API 'MMS_Initialize( )', and all servers should perform the job before using MMS service such as 'link_variable', 'link_fact_ptr', 'get', 'put', 'PI' and others. After initialization, the function of a cell controller was tested under the CIM environment by means of the automatic plant shown in Fig. 8. In performing a function test, a program should be downloaded to each machine tool by the schedule made out above or the program in the controller should be called out. After program download, the machine tool should be started (Cycle Start) as shown in Fig. 9. Its motion status can be monitored at any time, and the positions of machine tools can be checked in case of need. The client transmits codes to the control information, such as 'Cycle Start' and 'Position Value', through interoperable object variables. VMD server performs the control function of the machining center, and after that it transmits 'Status Value' when needed. In this case, the motion status of the machine is monitored at regular intervals, and status information and present state information are monitored between the present positions of X, Y and Z-axis and job contents as shown in Fig. 10 and Table 2. After the job is completed as such, the result is sent out to the client. Such information is useful for the client to operate a simulator. Also, repetitive tests were performed to examine whether the start-stop

Fig. 8 Machining Cell on MMS Service

Fig. 9 Manufacturing by MMS Service Command

function of the machine tool works normally. Altogether, it took 1±0.05 seconds to receive the data requested from the cell controller functioning as the client to VMD server. In such case, the response time of equipment may be 0.5±0.03 second(s) if the client requests the start-stop function. Response time can be shortened further according to the specifications of the network card (Testable Condition: 10mbps) and network version. Test results are considered to be controlled in real-time from the viewpoint of Cell/Area in CIM reference models.

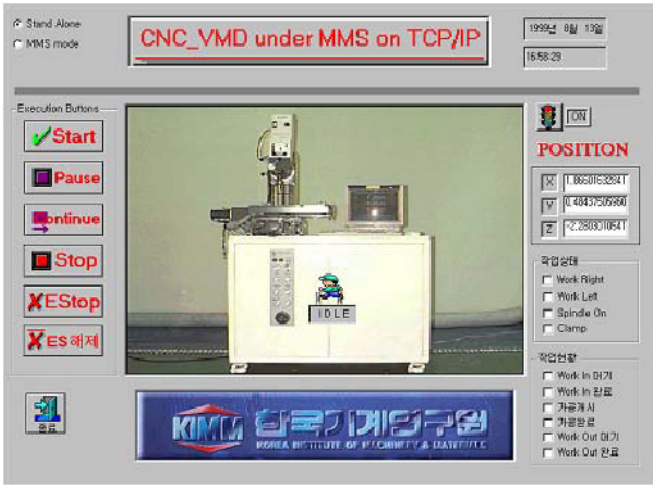


Fig. 10 Display of MMS VMD Server on OAC CNC

Table 2 Items example of Monitoring Data

Machine Status	Work Status
-. Working/Idle/Stop -. Machining On/Off -. Spindle On/Off -. Clamping On/Off	-. Work In Standby -. Work In Completion -. Machining Start -. Machining Completion -. Work Out Standby -. Work Out Completion

Through the operating test, we found that manufacturing equipment of machining cell was improved in availability. The time spent in waiting for collaborative manufacturing was reduced by approximately 30 percent according to the average of experimental results for over a year.

6. Conclusion

In this study, the network was constructed by using the MMS on TCP/IP that matched MMS service to the TCP/IP which is now in wide use. Also the machining cell was constructed by objectifying the non-MMS-compatible device in order so that the cable system, including the line change of machining cell, can be possible. In the system constructed as mentioned above, it was ascertained whether VMD is normally mounted on MMS on TCP/IP and whether MMS is normally operated. In consequence, the interoperability, which can solve the isolation of the automatic line configured by heterogeneous equipment, should be secured, while real-time remote control and monitoring was verified.

1) An open machining cell was constructed by using a machine tool based on CNC_VMD gateway.
2) MMS service can be adopted in more various applications by applying the MMS on TCP/IP coming into wide use.
3) The cell controller, developed in this study, can be flexible, interoperable, portable and extensible with respect to line change.

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