Research on Dynamic Rescheduling Program Base on Improved Contract Net Protocol

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***Abstract*— Dynamic rescheduling of workshop production management, with the feature of combinatorial computation complexity, is an important and difficult research area, and be of significant importance for the dynamic scheduling problem. An improved Contract Net Protocol (CNP) with the global two-way, Multi-Agent System (MAS) based communication model, which incorporated the local autonomy of working mutually in consultation by negotiation, is presented in this paper. Furthermore, the simulation results in dynamic scheduling accompanying with its perturbation show that the proposed model and the algorithm are effective to the dynamic scheduling problem in manufacturing system.**

***Index Terms*—MAS, Agent, dynamic scheduling, Contract Net Protocol**

I. INTRODUCTION

Present industrial system forward in the direction of large complex dynamic changes, Traditional industrial systems and technology in a number of key issues are serious challenges. Efficient and practical method which is used in scheduling and optimization technology is a key to plant productivity [1]. Assume that the traditional process with a clear schedule and a fixed processing time, while the actual processing, there are many uncertain factors, for example, changes in processing time, product demand, delivery, equipment failure, resources and production processes. The dynamic interference of these factors make the original dynamic scheduling can not be implemented successfully. The rescheduling is occurring in the course of events and uncertain response to other changes, which is based on the state of the system time for the next cycle of program activities; therefore it has a very high search value [2].

Job shop scheduling is a NP-hard problem, Church LK [3] studied the rescheduling driven based on cyclical time and the two rounds of re-scheduling-driven methods. Jian Fang [4] designed the Ministry of Information under full dynamic scheduling model rolling horizon procedure, and then had analyzed and evaluated. Sanjay V [5] processed the way to absorb the random failure of the disturbance proposed by the appropriate method of inserting idle time. Kim [6] proposed a flexible production environment which can handle processing of planning and shop scheduling symbiotic genetic algorithm. D.Petrovic [7] used the fuzzy method to study the re-scheduling of the start. Cheng [8] proposed scheduling based on genetic algorithm concept of real-time response. Wang Hui [9] put the uncertainty of the impact of events designed as a set of random changes in the time period. Goncalves [10] proposed a hybrid genetic algorithm for shop scheduling. Wong [11] designed a device based on the production of multi-Agent system.

Based Agent which has a high degree of autonomy, in this paper, a group of self-government body (Agent) was used to solve the effective coordination between the complex and dynamic rescheduling problem, and Agent in the process of scheduling, we use consultation and collaboration between scheduling, therefore have a higher real-time [12]. This is the same need in the dynamic shop scheduling. So this paper from the Agent communication mechanism of individual multi-Agent cooperative mechanisms and MAS's system of institutions to start; combine the re-scheduling problem of dynamic workshop is described in detail. Propose a global two-way dispatch, local self-improvement contract net protocol negotiation and simulate, then confirm its effectiveness.

II. MAS-BASED MODEL RESCHEDULING

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In dynamic shop scheduling environment, job shop problem can be described as: In a processing unit or system, n jobs need to be processed on m machines, every job J_i ($1 \le i \le n$) has n_i process O_{ij} ($1 \le i \le n$, $1 \le j \le n_i$)

need to processing, Set machine tool with a collection of M, Then each process O_{ij} either by the concentration of machine tools M_{ij} can be processed in a machine, where $M_{ij} \subseteq M$. If $M_{ij} = M$, the scheduling problem is a completely flexible scheduling problem; if $M_{ij} \subset M$, it is a local scheduling problem with flexible [13].

Re-scheduling operation set is a machine failure occurs, all machines need to re-scheduling of the operation on the set. Rescheduling operation set is essentially a set of variables constraint satisfaction problem.

As rescheduling model is the corresponding evolution of the initial scheduling model, so the initial problem modeling available:

$$\min \max\{c_{is} \mid i \in I\}$$

$$\text{S.t. } s_{ij+1} \ge s_{ij+1} + p_{ij},\ i \in I, J \in \{1,...,s-1\} \quad (1)$$

$$(m_{i_1 j} \ne m_{i_2 j}) \vee (s_{i_1 j} \ge c_{i_1 j} \vee s_{i_2 j} \ge c_{i_2 j}) \quad (2)$$

$$i_1, i_2 \in I, i_1 \ne i_2, j \in J \quad (3)$$

$$c_{ij} = s_{ij} + p_{ij},\ i \in I, j \in J \quad (4)$$

$$s_{i_1} \ge 0, s_{ij} \ge \sum_{k=1}^{j-1} p_{ik}, i \in I, j \in \{2,...,s\} \quad (5)$$

$$m_{ij} \in R_j = \{r_{j1},...r_{jl_j} \mid j \in J\}, i \in I \quad (6)$$

i means workpiece number and $i \in I = \{1,...,n\}$, j means level number and $j \in J = \{1,...,s\}$, r_{jl} means the machine number, s_{ij} means the start time of initial scheduling, m_{ij} means the start machine, p_{ij} means the processing time of the operate workpiece.

In the above model, (1) shows the optimization goal of the scheduling problem is minimum of $C_{\max}$.

(2) shows the operation of the timing constraints, it is said that the workpiece after the end of the previous stage to begin the next stage of processing tasks.(3)shows that If the two jobs processed on the same machine, then the can not doing at the same time.(4)shows processing the workpiece can not be interrupted after starting.(5)and(6)shows operation started variable time and the variable range of processing machinery.

Then it supposes the machine $r_{j_d l_d}$ disruptions at the time $[t_b, t_e]$,so the initial scheduling begins to have a change in t_b ,and the initial scheduling will change to the dynamic rescheduling,

$$\max f = \frac{\sum_{i \in I}\sum_{j \in J} w_{ij}\delta 1_{ij}}{\sum_{i \in I}\sum_{j \in J} w_{ij}} + \frac{\sum_{i \in I}\sum_{j \in J} v_{ij}\delta 2_{ij}}{\sum_{i \in I}\sum_{j \in J} v_{ij}} \quad (7)$$

$$\text{S.t. } (m_{i_1 j} \ne m_{i_2 j}) \vee (s_{i_1 j} \ge c_{i_1 j} \vee s_{i_2 j} \ge c_{i_2 j})$$

$$i_1, i_2 \in I, i_1 \ne i_2, j \in J$$

$$c_{ij} = s_{ij} + p_{ij},\ i \in I, j \in J$$

$$m_{ij} \in R_j = \{r_{j_1},...r_{jl_j} \mid j \in J\}, i \in I$$

$$(m'_{ij} \ne r_{j_d l_d}) \vee (s'_{ij} \ge t_e), i \in I, j \in J \quad (8)$$

$$s'_{ij} \ge t_b, i \in I, j \in J \quad (9)$$

(7) shows the scheduling programs to maximize the time before and after adjustment arrangement and the total weight assigned to the similarity machine. $\delta 1_{ij}$ shows rescheduling operation of The similarity of the timing with workpiece o_{ij}.

$$\delta 1_{ij} = \frac{\max\{\min\{c'_{ij}, c_{ij}\} - \max\{s'_{ij}, s_{ij}\}, 0\}}{p_{ij}}$$

$\delta 2_{ij}$ shows the dynamic rescheduling with Before and after the operation of the dynamic rescheduling to assign the similarity in the workpiece o_{ij}.

$$\delta 2_{ij} = \begin{cases} 1, m'_{ij} \in M_{ij}; \\ 0, other \end{cases}$$

(8) shows the new constraints of mechanical failures,(9)shows the beginning of the operation of the new range of variable start time. o_{ij} means the stage j of workpiece i, w_{ij}, v_{ij} mean operating weight of the workpiece and the machine time consistency of weight respectively, s'_{ij} means the operating parts of the starting time in rescheduling, m'_{ij} means the machine of operating workpiece in rescheduling.

For the rescheduling problem, the structure of Agent can be expressed as: Agent= $def < Id, Goal, Act, Rule, L >$.

Agent Id is the identifier which, different Id in different Agent. Re-scheduling of the workshop can be the Agent of Id from 1 corresponds to the location of the machine in the list. The Agent can be used to express as ag_i which Id is i.

Goal is the Agent of the goal, the goal is that the Agent inserts after the current job is still making the current optimal or near optimal job queue. The goal can be expressed as $Goal_i = (C^i_{\max}, J^i_1 \to J^i_2 ... \to J^i_{ni})$, where $\{J^i_1, J^i_2 ... J^i_{ni}\}$ is the machine M_i currently operating the current sort order queue $J^i_1 \to J^i_2 ... \to J^i_{ni}$ and set. $J^i_1 \to J^i_2 ... \to J^i_{ni}$ is the priority of the current sequence set on the machine or near optimal order. $C^i_{\max}$ is the optimal value of the machine M_i or similar to the corresponding optimal value.

Act can be said to the action set, in the form on behalf of the Agent $Act = \{act_1, act_2 ..... act_n\}$ can be to complete the operation. Each Agent has a communication, collaboration features.

Rule represents Agent on behalf of Agent cooperation with other rule sets, In this paper we use the modified contract net protocol .

L is the Agent communication language, different Agent use the languages to communicate with L, In this paper the rules based on FIPA ACL language.

III. DYNAMIC SCHEDULING SYSTEM SASED ON MAS MODEL

A.Functional Design Agent

Traditional rescheduling is generally aided by the manual or has operations in accordance with certain re-

allocation algorithm [14]. This paper uses the MAS-based intelligent scheduling system Agent mainly through collaboration between the nature of making intelligent machines, in order to achieve the automation of job re-scheduling and optimization. The basic structure of improved contract net model is unchanged, by the Management Agent, Resource Agent, Supervision Agent and Work piece Agent composition.

Management Agent (MA) Management Agent is the core of the scheduling system, mainly responsible for evaluating and scheduling the task which mandate outside received. Specific tasks include the host information and the degree of emergency. Then put the information submit to the Resource Agent. Management Agent and other Agents' relationship are shown in Fig.1.

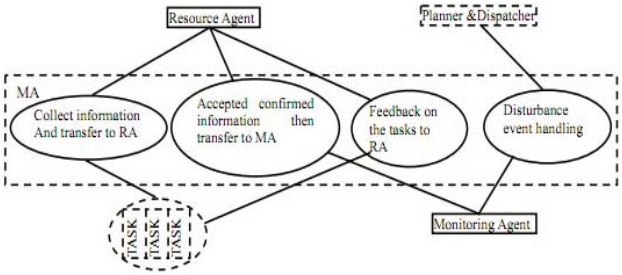

Figure1. Description of Management Agent

Resource Agent (RA) Resource Agent is responsible for receiving and processing plant outside production tasks and in accordance with the current processing capacity, to determine whether to perform the task workshop. In the decomposition of tasks, each Equipment Agent releases to the tender, accordance with the rules of the agreement to form processing program, and then reports to the Supervision Agent, to obtain feedback on the various parts after the Agent is responsible for scheduling production. Resource Agent internal schematic is shown in Fig. 2.

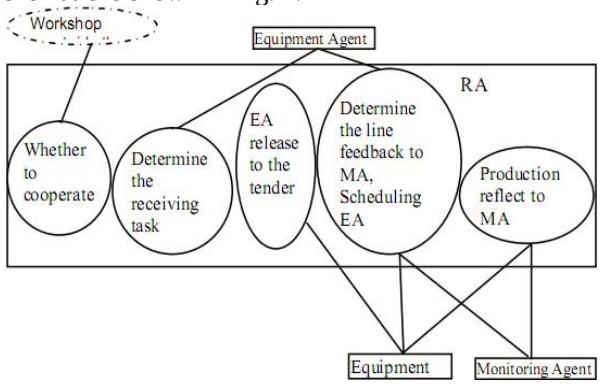

Figure2. Resource Agent internal schematic.

Supervision Agent(SA) Supervision Agent mainly reports on alternative production plan of Management Agent for a simulation, then selects processing route back to the Management Agent to comply specifically. And the Supervision Agent mainly is responsible for the supervision of Agent equipment failure, the addition of new equipment and the arrival of other emergency tasks. Fig. 3 shows the internal schematic.

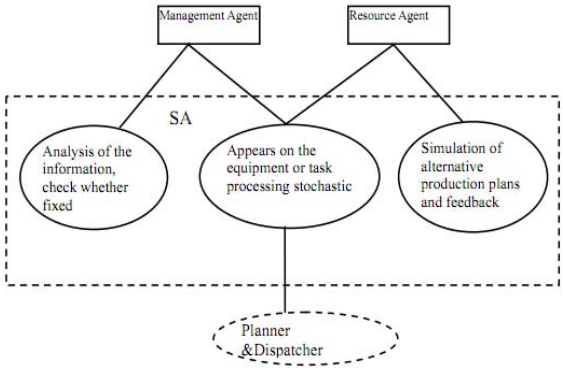

Figure3. Supervision Agent internal schematic.

Equipment Agent (EA) Actually it can be considered as a manufacturing unit. Each Agent self-management of each piece of unit, responsible for the appropriate operation management, equipment, command transfer and information collection. Equipment Agent receives the information after Resource Agent, products equipment on their assessment of the corresponding， then decide whether to tender. According to the equipment cases it makes a corresponding quote if tender, feedback on whether the production capacity to the Resources Agent to complete the task. Internal schematic shows in Fig. 4.

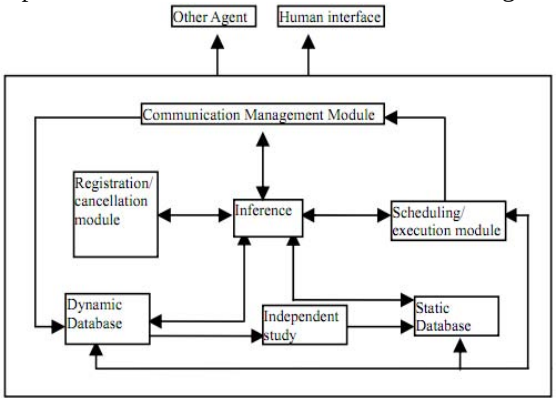

Figure4. Equipment Agent Internal Schematic.

Then, the Management Agent send a message to Workpiece Agent with the communication primitives sample can be expressed as:

:Sender(managerAgent@abc:1099/jade)
:Receiver(Equipment@abc:1099/jade)
:Ontology AMS-ontology
:Protocol FIPA-contract-net
:Language FIFA-KQML
:Content "((Issue (taskid(01),surface Type(plane),machining Type(drilling),number(8),tolerance(geometic Tol:02dimensional tol:01roughness:02), deadline(2010.12.01/21:10)))"

Resources Agent releases from the processing of waiting tasks, select processing tasks in sequence, according to the form of tender to manufacture parts of the process for the Workpiece Agent with issuing the request, the communication primitives can be expressed as:

(
CFP

:Sender(Agent-identifier:name resource@abc:abc:1099/jade)
:Receiver(Agent-identifier:name equipment@abc:abc:1099/jade)
:Content(action issues:issuebook:taskli\task01:working procedure\01\)
:task ready time"2010-12-01 21:20"
:surface roughness 4:dimensional tolerance time\"60"\:deadline\"2010-12-01 21:20"\)
:Reply-with CFP1
:in Reply-with PROPOSE1
:Language FIPA-KQML
:Ontology scheduling ontology
:Protocol fipa-contract-net
)

According to their capacity and status of the request, Workpiece Agent is in a given period of time which gives the proposed tender. Agent for the tender parts request primitives can be expressed as:

(
PROPOSE
:Sender(Agent-identifier:name equipment@abc:1099/jade)
:Receiver(Agent-identifier:name resource@abc:1099/jade)
:Content"((action(bidbook(bidbook :finishtime\2010-12-01\21:30\)):cost:10:equipment (Agent-identifier:name equipment@abc:1099/jade)))"
:Reply-with CFP1
:in Reply-with PROPOSE1
:Language FIPA-KQML
:Ontology scheduling ontology
:Protocol fipa-contract-net
)

B.The contract net protocol based on the improved process of rescheduling

In the planed internal allocation model, Management Agent generates the appropriate contract under the task order, the final bidding through the contract net protocol mechanism to determine the distribution relationship [15]. But by given the efficiency of consultation and workshop frequent dynamic scheduling, to improve efficiency, the global scheduling use a two-way consultation mechanism. The workshop is no longer accepted management's bidding information passively. It can take the initiative to inform the Management Agent on free time, and to have rescheduling with Resource Agent and Equipment Agent. Shorten the time required for scheduling. Resource Agent is no longer the same time with the broadcast model of unconditional tender information published to the workshop, they test whether Agent scheduling applications have been submitted firstly, and then bidding between these application workshops, it means Invitation to bid model. Through this two-way consultation mechanism, the system is greatly reduced communication, negotiation efficiency also improved. It is shown in Fig.5.

In this paper, Scheduling in the local autonomous negotiation strategy is used. It focuses primarily on a single operating part of the consultation process. Management Agent access to the task, the state machine select Agent in a particular queue. By the time they run the task initiated by notice to select the appropriate Agent to negotiate on its mandate. If access to the task at the same time, the launch of negotiations on a random selection. When the machine authorization of the Agent and executes for the task, the machine first notify the current Management Agent has completed the task, and then update their state, while awaiting transfer to the next stage of the job queue. On the other hand, work piece Agent change them idle.

Reschedule for emergency orders： Due to market dynamics, new orders appear frequently. at that time the Resource Agent running in the system, first use the conventional approach to internal Management Agent to launch negotiation, if it can not find the time for new entrants to the scheduling order, then Resource Agent release some of the production plan, while the delivery of these orders guarantee to be completed before delivery, the scheduling of the Resource Agent released until the successful operation of emergency orders, which the released orders will reschedule after the emergency scheduling. The flow chart is shown on the left of Fig6.

Failure of the machine: For the failure of the machine, immediately terminate the operation, and then issue a notice in need of repair, the Equipment Agent timely processing the state feedback to the Resource Agent, Resource Agent records the current processing situation, the task then to be processed back and see if there are other Agent can instead of the Equipment Agent, if you can replace, then the task will be distributed back out; if not, the task is to re-bid, re-scheduling. The flow chart is shown in middle of Fig. 6.

For other exceptions: such as the shortage of raw materials, the task can not be completed in the near future, Management Agent will recover the corresponding tasks, so ahead of the back scheduling, the unfinished task will schedule again after the input processing conditions. Thus, the autonomy of local consultation can be well on the impact of the whole system on the strategy eliminating rescheduling. The flow chart is shown on right of Fig.6.

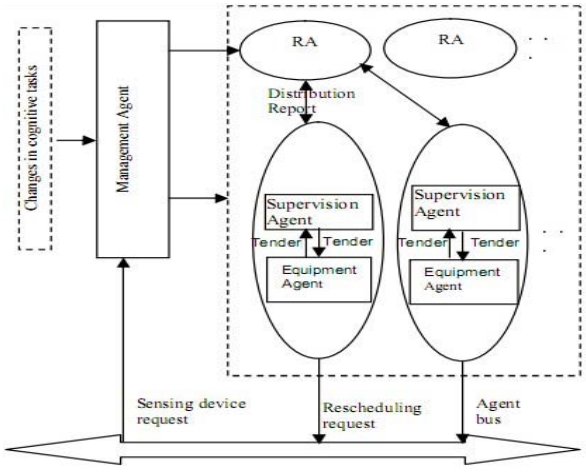

Figure5. Dynamic Scheduling Model Based on Multi Agent.

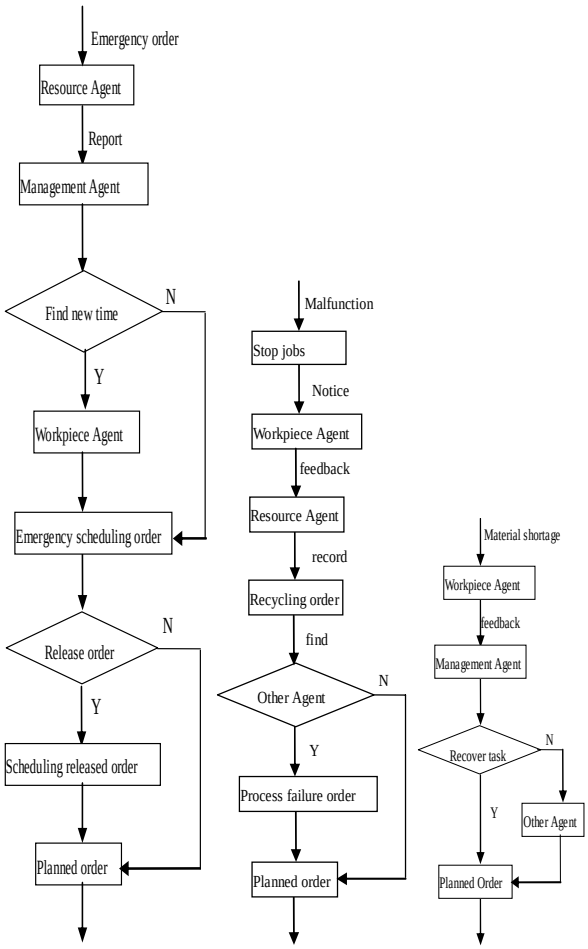

Figure6. Dynamic scheduling flow chart

IV. BASIC SCHEDULING ALGORITHMS IN AGENT

The dynamic re-scheduling based on MAS composes of local scheduling by a multi-stage process. The local scheduling of each stage is carried out based on CNP model, the basic algorithm is as follows:

Step 1 Scheduling information received from the outside world after the initial Management Agent release price PR_i. It can be defined: $PR_i = (t_i | T_a / B_a / M_a)$

t_i Means that other Agent where the deadline to respond T_a means that the time required to complete the task constraints, B_a means space constraints, M_a means material constraints.

Then for emergency insertion of the work piece, once the original work piece delay, the delay time should to be as short as possible, so the time constraint can be expressed as:

$$T_a = \min[(T_s + t_i), (T_d + T_p)] \quad (10)$$

S.t. $c_{ik} - p_{ik} + M(1 - a_{ihk}) \geq c_{ih}$,
$i = 1,2,...n; h,k = 1,2,...m$
$c_{jk} - c_{ik} + M(1 - x_{ijk}) \geq p_{jk}$,
$i, j = 1,2,...n; k = 1,2,...m$
$c_{ik} \geq 0$,
$i = 1,2,...n; k = 1,2,...m$
x_{ijk} =0 or 1,
$i, j = 1,2,...n; k = 1,2,...m$

In which (10) indicates time constraints. T_s means the time that Management Agent make the initial offer, T_d means the latest time that jobs end, T_p means the average of extend operating time, which c_{ik} and p_{ik} mean that the finished time and the processing time of work piece i and machine k. a_{ihk} and x_{ijk} are coefficient and the indicator variable indicating.

Step 2 Equipment Agent tender offer are given counter offer, Equipment Agent first assess their own parts to meet the resource constraints, and then give counter offer $PR_j = (a_j | T_c, M_c)$, a_j means the commitment wait time, T_c means the first beginning time that is produced by the Equipment Agent which after assess, if the Equipment Agent do not meet T_a , B_a , M_a ,or occupied by either the state constraints, then give up bidding. If T_c is idle, then the Equipment Agent initiate to Resource Agent for counter-bids which is in the idle time scheduling, to save the scheduling time.

Step 3 Resource Agent assesses the counter offer and then authorize. Management Agent evaluates all bids which returned, according to the formula: $\min[(T_c + T_p), M_c]$ .Select the best Equipment Agent to authorize, that is, considering the earliest start time of the Equipment Agent, the workpiece capacity and efficiency.

Step 4 Perform an operation process. The Equipment Agent authorizes to perform job tasks, in the process of failure may occur. If normal, while the Management Agent of total consumption statistics, and then back to the Equipment Agent. If failure occurs, report to the Supervision Agent, to stop the operation and into the fault repair process of negotiation.

V. SIMULATION RESULTS

For example, to a machine shop, considering the equipment of 5parts, 4processes and 8machines; the workshop is to complete planning, milling, turning, drilling and other processes. There are two multi-functional machines: two different specifications of the plan and two specifications different lathe, a milling machine and a multi-function machine tool. Relationship between process machines is shown in Table I(in the table, 1 indicates that the machine can complete the process, 0 not).Process sets of the workpiece are shown in Table II. The processing time is shown in Table III. Consider two cases, one piece of the delivery is not particularly tense situation, is set to FIFO scheduling the delivery of products under the rules of the average processing cycle, the other is a more intense delivery time, that is 1:1.2. MAS proposed methods will be used in the FIFO rules and EDD rules performance comparison, the simulation results are shown in Table IV.

TABLE I.
RELATIONSHIP BETWEEN THE MACHINE AND PROCESS

Machine / Process	A(Planer1)	B(Planer2)	C(Milling)	D(Lathe1)	E(Lathe2)	F(Multifunction)	G(Lathe)	H(Multifunction)
P_1	1	1	0	1	0	1	1	0
P_2	0	0	1	0	0	0	0	1
P_3	0	0	0	1	1	0	1	0
P_4	0	0	1	0	0	1	1	0

TABLE II.
EQUIPMENT AND PROCESS

Piece ID number	1 procedure	2 procedure	3 procedure	4 procedure
j_1	Plane(id:1)	Milling (id:2)	Diamond (id:4)	Car (id:3)
j_2	Car (id:3)	Diamond (id:4)	Milling (id:2)	Plane (id:1)
j_3	Milling (id:2)	Plane (id:1)	Car (id:3)	Diamond (id:4)
j_4	Diamond (id:4)	Plane (id:1)	Milling (id:2)	Car (id:3)
j_5	Milling (id:2)	Diamond (id:4)	Plane (id:1)	Car (id:3)

TABLE III.
PROCEDURE PROCESSING TIME

Machine / ID	Plane			Milling		Car		Diamond	
	A	B	C	C	G	D	E	F	H
j_1	3	4	6	10	8	2	3	5	9
j_2	7	8	8	5	6	6	7	6	4
j_3	2	3	3	3	5	4	5	3	3
j_4	8	9	9	2	7	11	12	7	7
j_5	3	5	6	5	3	5	6	8	6

TABLE IV.
MODEL SIMULATION RESULTS

Production Line Status	Scheduling rules	Time delivery/%								Weighted average delay/h							
		A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
General	FIFO	49	48	51	57	50	50	50	51	21	18	18	16	16	20	15	16
	EDD	46	54	55	61	65	50	52	68								
	MAS	85	91	94	88	90	84	93	80	3	3	1	1	8	7	9	8
Emergency	FIFO	0	0	0	0	0	0	0	0	55	84	65	59	71	65	84	74
	MAS	100	94	85	89	98	89	92	94	5	7	5	3	10	6	8	6

TABLE V.
EQUIPMENT FAILURE MODEL SIMULATION

Production Line Status	Scheduling rules	Time delivery /%								Weighted average delay /h							
		A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
General Failure	FIFO	55	58	51	55	54	59	50	49	41	20	15	17	19	21	19	20
	MAS	96	92	92	95	90	95	99	94	6	8	3	3	7	6	4	5
Emergency Failure	FIFO	0	0	0	0	0	0	0	0	35	33	24	32	29	16	31	121
	MAS	99	94	88	89	98	89	92	94	8	6	6	11	11	8	7	8

As can be seen from the table IV, Fig.7 and Fig.8(G-FIFO means General FIFO;G-EDD means General EDD;G-MAS means General MAS;E-FIFO means Emergency FIFO;E-MAS means Emergency MAS;G-F-FIFO means General Failure FIFO;G-F-MAS means General Failure MAS;E-F-FIFO means Emergency Failure FIFO;E-F-MAS means Emergency Failure MAS), using the proposed consultation mechanism from this paper, for reducing the weighted average delay in delivery of products, improve product time delivery, has an extremely effective results.

For the problem of equipment failure, assuming a daily equipment failure 12h, simulation time for one month, the same as the other set, FIFO is not processed on equipment failure, MAS consultation mechanism with self-processing, simulation statistics are shown in Table V, Fig.9 and Fig. 10.

Fault simulation shows that the proposed consultation mechanism of local autonomy which reduce equipment failures better impact on the production line.

In the normal fault and the fault of the emergency, were increased on-time delivery rate, and reduce the average weighted delay.

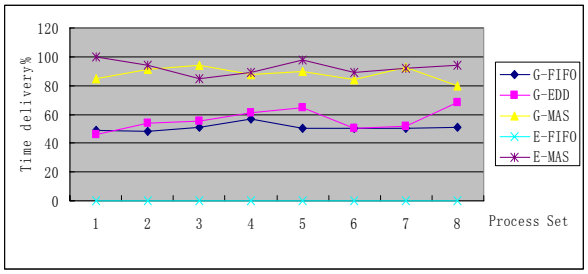

Figure7. Time Delivery Comparison In Normal State

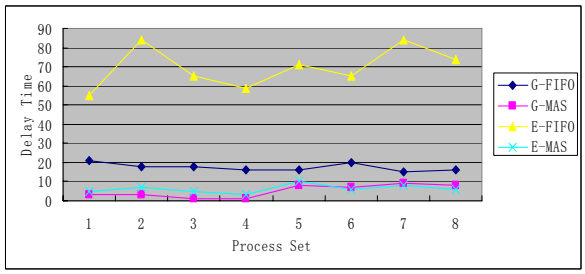

Figure8. Delay Time Comparison In Normal State

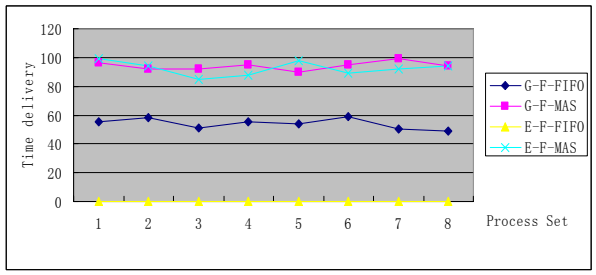

Figure9. Time Delivery Comparison In Failure Model

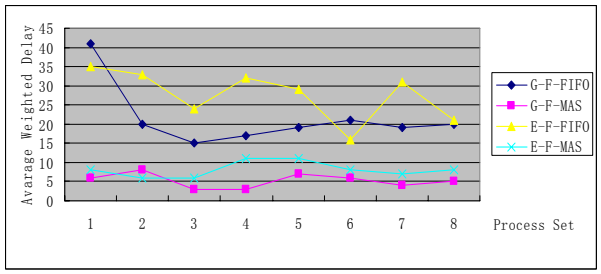

Figure10. Average Weighted Delay In Failure Model

VI. CONCLUSIONS

Dynamic rescheduling problem is widely used in modern production plant. In this paper, it is the first time that the improved Contract Net Protocol from MAS is used into the rescheduling of the workshop environment, to provide a new way of solving the problem in this area. Then give full consideration to the workshop production of the machine failure and repair process of scheduling, the complex dynamic rescheduling process is divided into corresponding independent Agent and interactive process. The technology extends the behavior of the fault and related considerations. The problem of mechanical failure was simulated to prove the validity of the model based on MAS system simultaneously.

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