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연삭가공 트러블 지식베이스 구축을 위한 지식획득과 데이타 베이스의 설계

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Knowledge Acquisition and Design for the Grinding Trouble Knowledge-Base

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ABSTRACT

연삭가공중에 발생하는 트러블의 인식과 처리는 공학적 원리에 입각한 방법과 현장 숙련기술자의 경험적 지식을 바탕으로한 방법이 있다. 그러나, 연삭가공은 관계되는 가공변수가 많아, 이들 상호간의 관계를 정량적으로 규명할 수 없어 대부분이 숙련자의 지식에 의존하는 것이 현실정이다.

본 논문은 이와같은 점에 착안하여 원통연삭을 대상으로 현장숙련자가 갖고 있는 경험적이고도 정성적인 지식의 효과적인 활용을 위해 계층분석으로 도입하여 이들이 갖고 있는 노하우를 정량화하고, 아울러 공학적원리를 가미한 연삭가공용 트러블 진단 · 처리시스템을 구축하였다. 또한 시스템 구성에 신뢰성을 높이기 위해 폴트 진단 모델을 도입하였다.

Key Words : Grinding Trouble-Shooting, Knowledge Acquisition, Qualitative Knowledge, Revised Fault Diagnostic Model, Analytic Hierachy Process

1. INTRODUCTION

Cognition and therapy of grinding trouble during the grinding process are classified into a measuring instrument depended upon engineering domain knowledge as well as an empirical method relied upon specialized knowledge and knowhow of a skilled hand. Especially, as a grinding operations is related with a large amount of functional parameter, trouble knowledge is mainly given by a skilled hand. But, it is actually difficult to utilize such a large amount of specialized knowledge obtained from a skilled hand. Furthermore, because the trouble therapy to grinding operations aren't not only exactly easy to control the quantitative method but also the trouble-shooting has been mainly relied on the knowledge of a skilled engineer.

Recent research[1-3] in trouble-shooting of

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machining process, especially with respect to diagnosis and therapy have emphasized the use of deep knowledge. Such work includes K. Mori and N. Kasashima's[2] research in monitoring and diagnostic system for cylindrical grinding using the sensor, and H. Nakazawa's[3] work on detecting the chatter vibration during the process. These trouble-shooting system are then integrated into a single point via a sensor that can draw on either diagnosing a paticular problem. However, despite the high quality work that has been done in this area, limitation for grinding trouble-shooting seems to hinder the wide application.

In this paper, thrapic method to the grinding trouble which makes the most of human expert that have been experienced on working area is presented, and the architecturing method for the grinding trouble knowledge-base adopted the revised fault diagnostic model[4] and acquisiting method for the grinding trouble knowledge utilized an analytic hierarchy process[5] about the chatter vibration and grinding burn are described.

Moverover, in order to deal with uncertain and qualitative grinding knowledge and to be useful of application and saving for knowledge-bse, in this system, grinding trouble knowledge is constructured hierarchically by classified into frame-based and rule-based model.

2. SYSTEM ARCHITECTURE

As shown in Fig. 1, in this system, inputing the kind of workpiece and required surface roughness, optimum grinding conditions[6] are established as follows: that is, grinding power will be permitted within the limits of maximum capacity, chatter vibration and burning are not occurred the trouble, and finished surface roughness is satisfied with specifications. Moreover, this system is treated that the grinding troubles are generally occurred in grinding process. Grinding operations is generally not only dealed with the qualitative and empirical data but also complicated inter-relationship of parameters. Therefore, it is necessary to design a useful trouble knowledge-base which includes with the uncertain and qualitative knowledge.

Therapy(control) of grinding troubles are carried out grinding trouble knowledgebase (GTKB) in our system. As the knowledge of grinding trouble is mainly included with uncertain and qualitative knowledge with fuzziness, it is necessary to convert the specialized domain knowledge. The revised fault diagnostic model is able to deal with qualitative and experient knowledge as if the skilled hands and/or specialist. Therefore, this model is the best approach which utilize the grinding diagnostic and therapic knowledge. And then, these trouble data are transformed into the production rule so as to utilize the database. But, it may be included with several problems such as an utilization of database and an inference time.

2.1 Revised fault diagnostic model

Fault(symptom) data to the grinding operations are designed on a semantic network which considered with the wokpiece and wheel surface status, spark state for burning, and sound pressure level for vibration, etc. Fig. 2 indicates the enquete result that obtained from a skilled hands(about 50 persons) and abolute value is the results that analyzed by AHP(Analytic Hierachy Process) obtained from a skilled hands which have been worked 15 years or more. Fault and symptom data are adopted in those parameters based on the enquete results. In Fig. 2, aspect ratio means

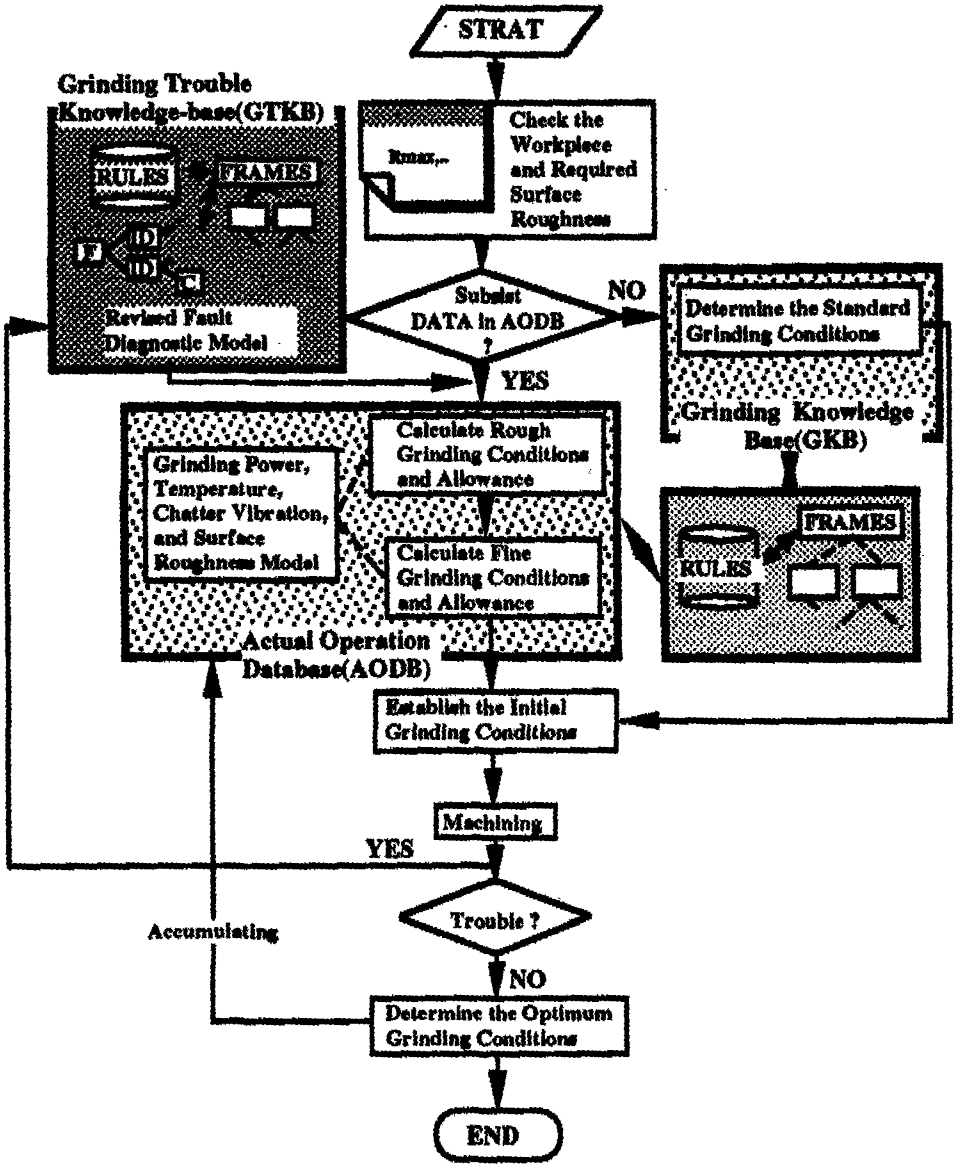

Fig. 1 Flow Diagram for the Establishment of Grinding Conditions and Trouble-Shooting

the ration for workpiece diameter vs. workpiece length.

Therefore, this model is possible to utilize the knowledge-base which compose of cause and symptom(fault) classified grinding trouble by the specialized knowledge that obtained from the qualitative and empirical knowledge of a skilled hand.

Firstly, in the architecture of trouble knowledge-base, a large amount of grinding trouble data are assembled in primitive node. But, it is actually difficult to utilize the

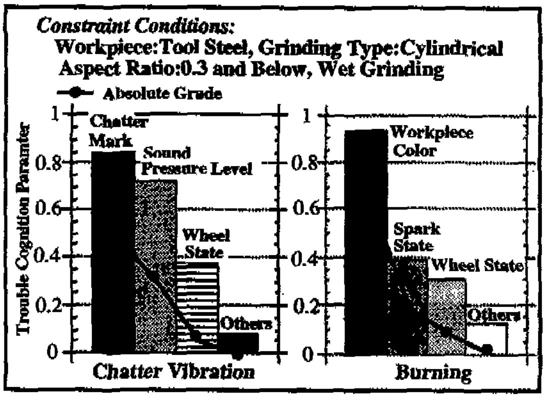

Fig. 2 Enquête Result about the Trouble Cognition Obtained from a Skilled Hands

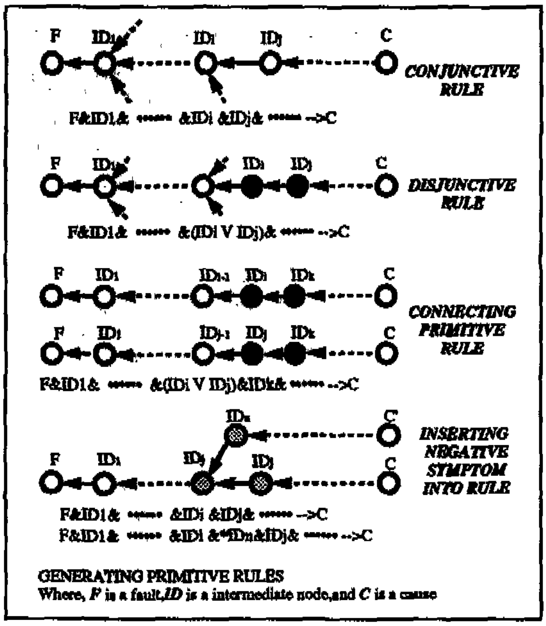

Fig. 3 Generating the Primitive Rules Refined from Qualitative Knowledge

grinding trouble data for all those information. Because the grinding operations is composed of too many parameters and deal with qualitative and uncertain knowledge as well as the compilation of inter-relationship for those parameter. In general, a skilled operators are determined to have a several patterns when have occurred the trouble. Therefore,

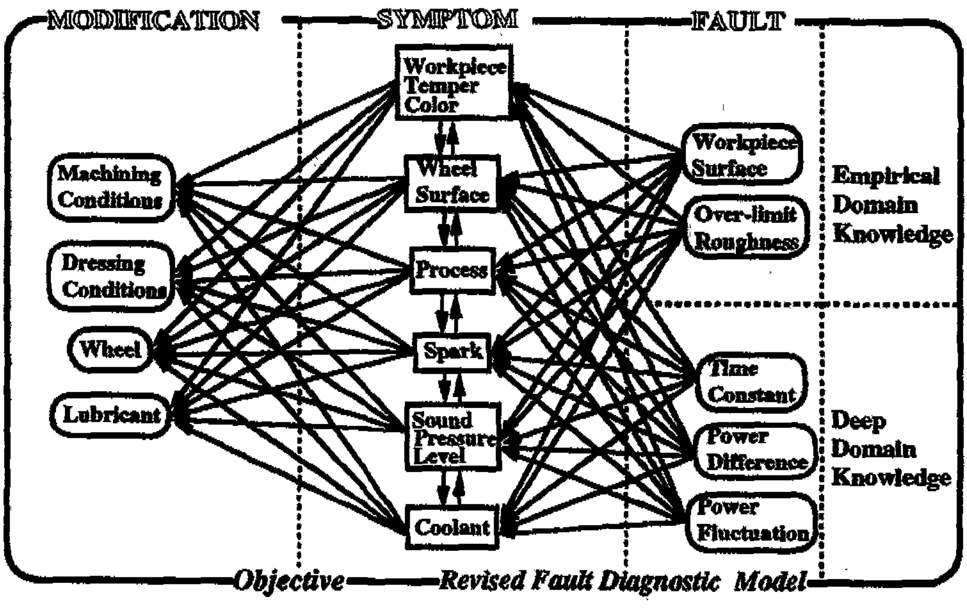

Fig. 4 Conceptual Architecture for Trouble-shooting about the Grinding Operations

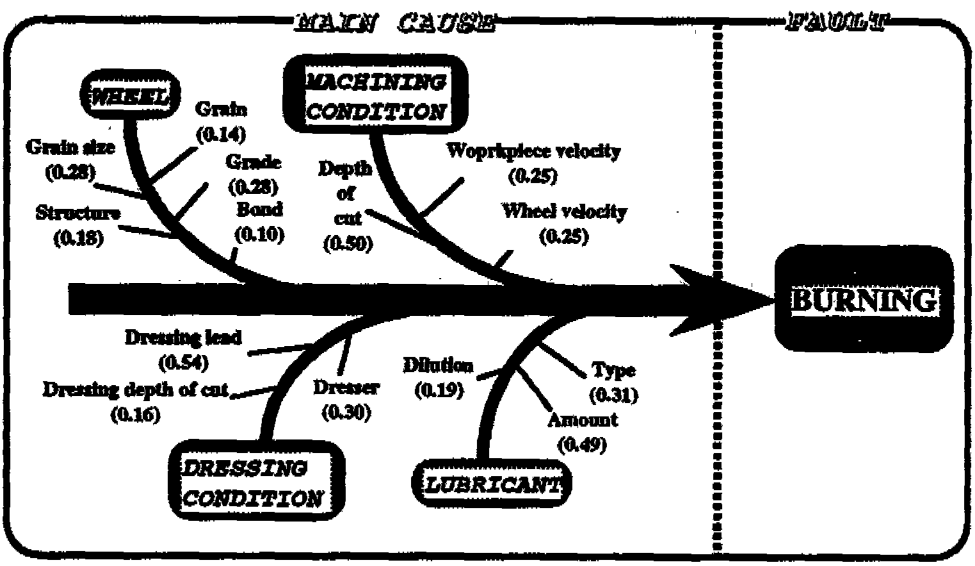

Fig. 5 Grinding Burn Effected by Parameter Grade Analyzed by Analytic Hiearchy Process

we make plans to carry out structure of trouble-shooting look a like skilled hand.

Fig. 3 indicates the refined rules for the acquisition of grinding knowledge-base, and Fig. 4 indicates the basic concept to the architecture of symptom and therapy. Symptom is divided into several grade. For instance, finished surface state are classified with [good/ bad] according to surface roughness, workpiece temper color are [high/ middle/ low] according to the burn grade, and modification of parameter is divided into two type: that is, wheel is modified to [up/down]and conditions(wheel velocity, workpiece velocity, wheel depth of cut) are controlled to [NH/NS/PH /PS], etc. Where, NH and NS mean highly and a little decreasing, and PH and PS mean highly and a little increasing, respecitively.

Fig. 5 and 6 show the result for the cause and modification parameter to the grinding burn obtained from a skilled hands(about 50 persons) and absolute value is the results that analyzed by AHP obtained from a skilled hands which have been worked 15 years or more. As the comparision of between cause and therapy parameter on trouble weight are differentiated. This means that the establishment of grinding condition should be considered seriously with cause relationship and the trouble therapy(control) should take a cautious the therapy relationship according to a skilled hand's knowledge and purpose.

2.2 Knowledge Acquisition

We are necessary as possible as to obtain the trouble knowledge that have objective data when it makes for production rule. Expert system must be made the best of qualitative and empirical knowledge which obtained from a skilled hand. If we applicate the AHP for the knowledge classification, it is possible to compose a grinding trouble knowledge-base including the objective and flexibility. Specialized knowledge determined from AHP, so called nodes are classified by the weight, is selected by the more important nodes than

Table 1 An Example of LISP Program

```
# (rule 1)
 (relation (?fault s1 s2 s3)
 (frame (fault ?f abnormal surface t) ))
 (frame (symptom ?s1 (temper_color t) ))
 (frame (symptom ?s2 (loading of wheel t) ))
 (frame (symptom ?s3 (suitable to the
                  amount of coolnat t) ))
 -->
 (create kind of trouble (kind ?k))
 (call rule-set rule 2)
# (rule 2)
 (not (frame (symptom ?? (grain size ?) ))
 <--
 (not (frame (symptom ?) ))
 (-->
 (call (format t "~%  wheel depth of cut ?"))
 (call (format t "~%  grain size ?"))
 (bind ?x number-read) ))
 -->
 (create rule-set 3)
# (rule 3)
 (goal (frame (modification ??) ))
 (frame* (grinding_conditions ?
          (grain size ?x! (>80 ?x46) ))
 -->
 (create modification (modification grade-1) )
# (rule 4)
  (frame (modification ?grinding_trouble
          (modification_parameter ?) ))
 -->
 (bind ?x (modification (modification
                  ?grinding_trouble) ))
 (bind ?message (rule_addstring "main cause
          considered with trouble are" ?x "))
 (call (display_result (list """""" ?message) ))
 (call (print 'modification_of_parameter,
     "please, decrease a little the wheel depth of
   cut or increase a little the workpiece
                  velocity in the first place"))
```

other. Therefore, each nodes are able to divide into several patterns by means of the analytic hierarchy process.

For example, Fig. 5 shows the causal relationship for the burn occurring the grinding process, and table 1 lists in the data for obtaining the weight by analytic hierarchy process.

3. STRUCTURE OF KNOWLEDGE-BASE

3.1 Structure of Trouble Knowledge-Base

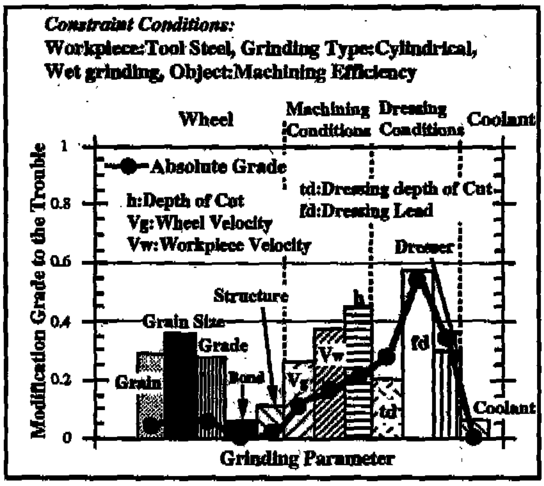

Fig. 6 Enqûete Result to the Modification Grade Obtained from a Skilled Hands

In this system, symptom(fault) is classfied into surface state of workpiece and wheel, sound pressure level, spark state, and surface roughness, etc. In the case of burn, symptoms utilize the surface temper color according to burn grade, loading and glazing state of wheel surface, melting state of chip formation(dry cut), spark state on grinding, amount of coolant, and required surface roughness. On the other hand, chatter vibration adopts the chatter mark appeared workpiece surface, falling state of wheel, sound pressure level under grinding, and workpiece surface roughness as shown in Fig. 6.

Fig. 7 indicates the semantic network for the fault diagnostic system to the grinding conditions. In this figure, symbols mean as follows; S is symptom, ID is intermediate node, C is cause. Burning derived from grinding conditions can be criminate to two parts. The one is grinding burn has no sooner ginding than it occurred. In this case, the main cause is the wheel depth of cut derived by the over-loading. On the other hand, it has occurred on a slow tempo during the process-

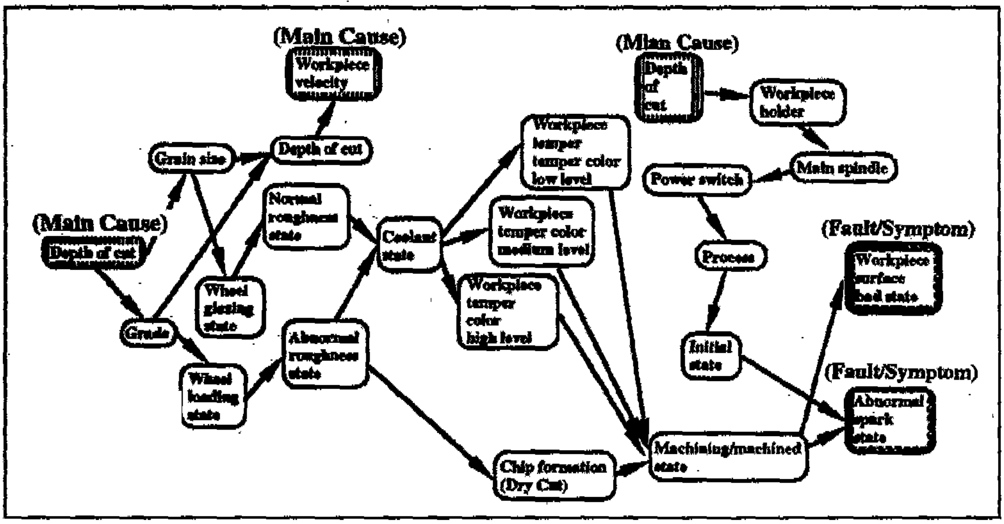

Fig. 7 Conceptual Revised Falut Diagnostic Architecture to the Machining Conditions according to Burning.

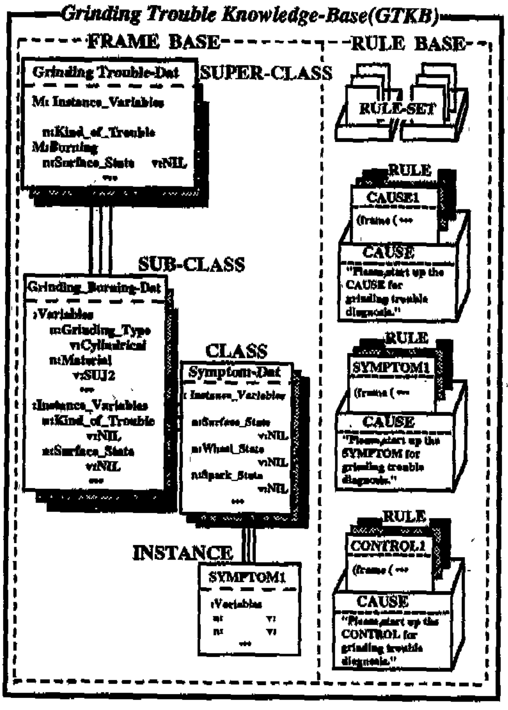

Fig. 8 Architecture of Grinding Trouble Knowledge-base and Inter-relationship at Trouble-shooting

For example, spark under grinding are extremely outstanding, we are firstly pay attention to the workpiece surface state, and then we may detect the grade of temper color appeared on workpiece surface. Therfore, we are able to draw out the main cause among the several parameters. Moverover, in our system, so as to constructure the production rules, it is, firstly, necessary to compose of semantic network based on the grinding trouble knowledge.

Furthermore, this system has a adoption and/or rejection method when makes a production rule. And, the selected node, as shown in Fig. 7 is finally accumulated in the knowledge-base converted into the production rule. Modification parameter adopted trouble data are not only acquired from the papers,[7-11] but also the interview of a skilled hand which experienced on the working shop.

Fig. 8 indicates the architecutre of the grinding trouble knowledge-base for trouble-

Table 2 Analysis Result by the AHP for the Grinding Burn

Weel	Grain	Grain size	Grade	Structure	Bond	Weight
Grain	1	1/2	1/2	1/2	2	0.14
Grain size	2	1	2	2	2	0.28
Grade	2	1/2	1	2	2	0.28
Structure	2	1/2	1/2	1	2	0.18
Bond	1/2	1/2	1/2	1/2	1	0.10

shooting based on the rule-based model and the frame-based model. Grinding trouble knowledge-base is composed of cause, symptom, and control coping with the inter-relationship.

Table 1 lists the IF~THEN production rule which structured by the revised fault diagnostic model and the example of LISP program so as to grinding trouble-shooting. Computer language utilize the common LISP. As listed in table 1, the rule number[#1/#2] are diagnosis program and the rule number [#3/#4]are the therapy program in order to modify the grinding condition.

In the table 1, S and f mean symptom and fault, respectively. Also, rule-set is the rule that assembles the inter-relationship, "display-result" and "rule-addstring"are the global function based on the LISP program.

3.2 Basic Concept for the Therapy

If we are able to offer the quantitative value to user, it is the best method as a control system. But, it is actually difficult to offer the quantitative data to a large amount of grinding knowledge. Because grinding operations is related with too many parameters and complete the inter-relationship in each parameter. Therefore, it is not easy to detect the trbouble cause exactly. Moreover, if the modification of the grinding trouble can not be offerred very well, on the contray, it may have a poor structure of the trouble knowledege. Therefore, we took steps to carry out a flexible trouble-shooting architecure based on knowledge of a skilled hands.

Therapy of trouble, in this system, is divided into two types: that is, wheel depth of cut, wheel velocity, and workpice velocity are classified into [PH/PS/NS/NH] and wheel components are [up/down].

Fig. 9 indicates the trouble diagnostic and/or therapy for the grinding burn. For example, if the workpiece is SUJ2(workpiece) and required surface roughness(R_{max}) is 5㎛, production rule indicates the rule number 5 shown in Fig. 9, "*If* workpiece surface temper-color is yellow type, wheel is the WA60ImV, amount of coolant with soluble is plenty, wheel surface is loading, grinding type is cylindrical, and the aspect ratio(workpiece diameter/workpiece length) is the within the range of 0.3 ***THEN*** main cause may be wheel depth of cut", ***THEREFORE***, "Decreasing a

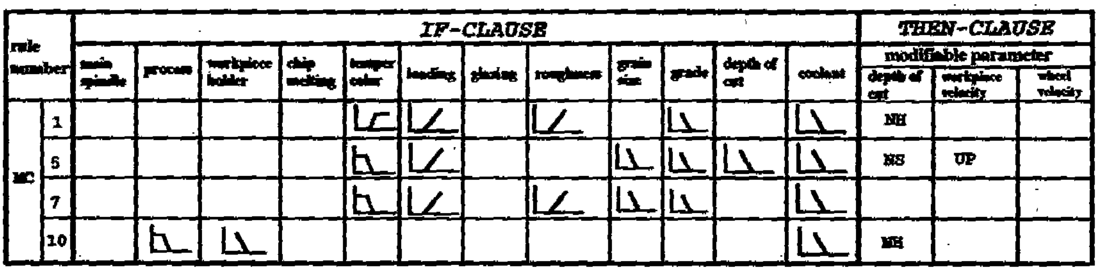

Fig. 9 An Example of Production Rules Refined by Skilled Hands to the Burn

little the wheel dept of cut(NS) or increasing a little the workpiece velocity (PS) in the first place".

4. AN EXAMPLE OF IMPLEMENTATION

Trouble knowledge-base is structured of fault(symptom) and therapy(control) frame. The diagnosis and/or therapy system are perforemed by the inter-relationship role not only class but also instance frame.

Moreover, Knowledge-base in designed on a grinding trouble-shooting system utilized by the frame-based and rule-based knowledge. And also, the inference engine of trouble diagnosis and/or therapy are performed when matched the input constraints of the *IF-CLAUSE*, that is, between the procedural data of frame-based and the ruleset of rule-based knowledge as shown in Fig. 8. And also, this system adopts the three patterns for inference engine, that is, for example, forward chaining rule, the rule number [#1], backward chaining rule, the rule number [#2], and hybrid chaining rule, the rule number [#3] as listed in table 1. Fig. 10 shows an example of implementation result to the chatter mark on workpiece.

In this system, flow step for the diagnosis and/or therapy of grinding trouble-shooting are as follows:

(1) Occurring the trouble, rulesets of the rule-based knowledge are accessed by dianostic message which transferred from procedural method within the frame-based knowledge.

(2) If the IF-CLAUSE constraints are all matched, firstly, forward chaining rule is excuted from the rulesets, but if it is not matched, creating the goal. In the backwark chaining rule, between the head and the same frame conditions are subsisted, it is carried out the matching of the IF-CLAUSE.

(3) The rules are competed, this system selects the rule according to priority determined by analytic herarchy process, and THEN-CLAUSE access the action. If the same weight of rulesets are subsisted with multiple, it is selected to the new-borned rule.

(4) If the IF-CLAUSE are satisfied for all constraints, this system is excuted by the

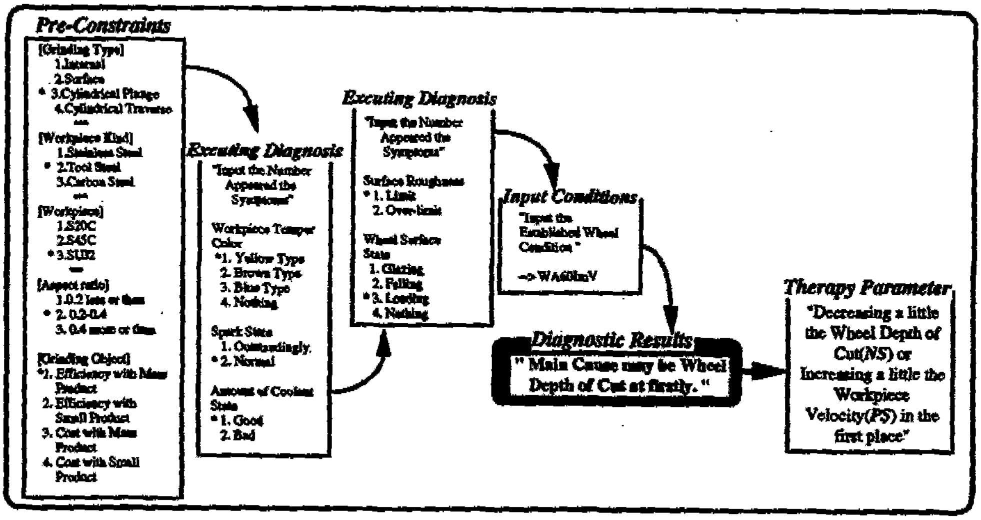

Fig. 10 Flow Diagram and Implementation for the Grinding Trouble-Shooting

action from the THEN-CLAUSE.

5. CONCLUSIONS

This system is construred to the grinding trouble-shooting system utilized by the revised fault diagnostic model. In this system, diagnostic/therapic knowledge analyzed by AHP are designed on a semantic network according to grade. Moreover, in this system, in order to make the best use of expert's knowledge, knowledge acquisition is partially utilized by analysis hierarcy process and architecture of trouble knowledge-base is deviced by revised fault diagnostic model. Therefore, this system can not only effectively make the best of knowledge-base and may flexibly correspond with the grinding trouble including knowledge of a skilled hand but also can give adequate advices to the user.

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