CHAPTER 5

TEST OF PROGRAM

In the chapter 5, MATSEL-VPEX program in selecting mold materials for injection molds making is tested on PC computer to illustrate how this program can serve those objectives in materials selection. MATSEL- VPEX provides consultation in form of either text or graphic interface mode. To communicate with MATSEL in graphic interface , the user should have VGA display and mouse to use this demonstration rule base properly.

5.1 Strating MATSEL-VPEX

MATSEL program is started on the text-mode-interface environment.

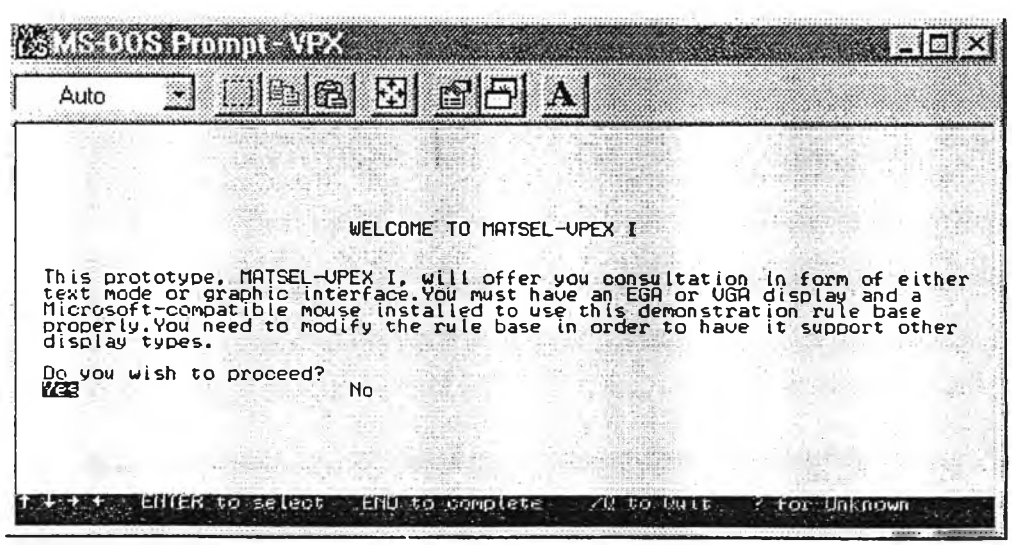

Figure 5-1 Starting MATSEL -VPEX Program

5.2 Introduction & Main Menu Program

In the main menu programe, introduction of MATSEL is provided with the chioce of level of knowledge aquisition from system. Introduction and main menu program of MATSEL is illustrate in Figure 5.2 . According to the introduction of MATSEL, MATSEL - VPEX is created on the expert system's shell.

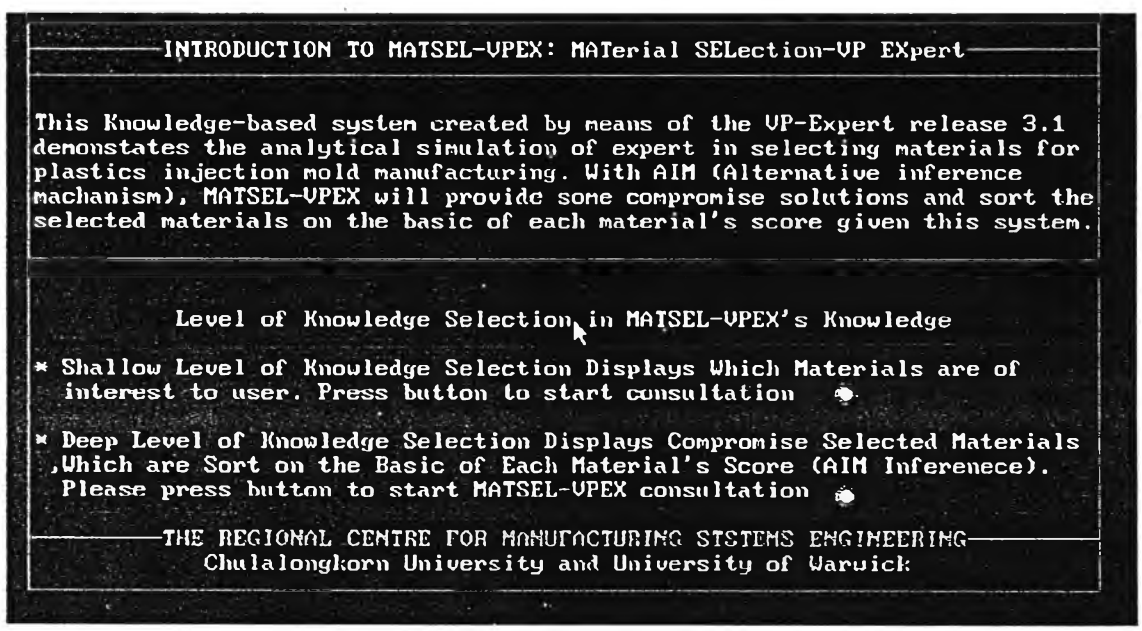

Figure 5.2 MATSEL's Introduction and main menu program

MATSEL system is able to provide user information about mold making materials in both of level of shallow reasoning and level of deep reasoning knowledge. The level of shallow reasoning knowledge offers the information of mold materials by using of the classification of materials into class, subclass 1, subclass 2 and finally object. This knowledge-based organizations are depicted in figure 4.4.1 - figure 4.4.1-3.

The level of deep chaining knowledge is used to serve the system' user, who can identify what the final properties of injection mold are and offer that information through replying the question, afterward, MATSEL-VPEX will offer the compromise solution.

5.3 The MATSEL- VPEX 's Level of Shallow Reasoning

As stated before, MATSEL-VPEX classifies all information in database to serve the system's user to select according to their interest following the scope of class, subclass 1, subclass2, .., object.. The Level of shallow knowledge chaining for this knowledge system is shown as follows:

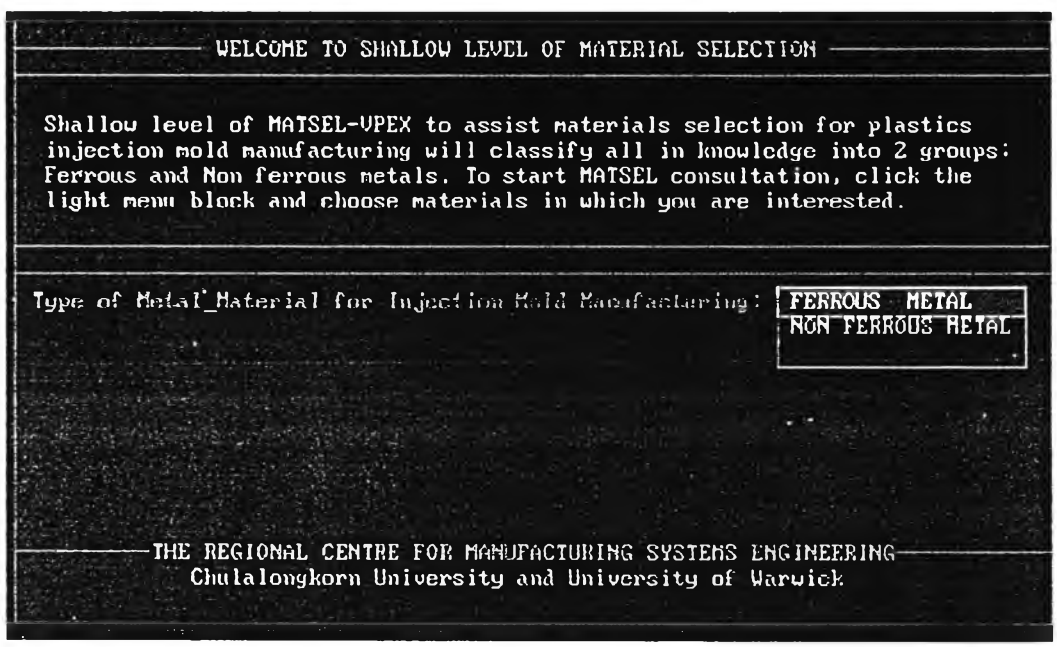

Figure 5.3 The MATSEL- VPEX's Level of Shallow Reasoning

Note that materials for injection mold manufacturing can be classified into 2 main class: Ferrous and Non Ferrous Metal. To start this level, the user with microsoft - compatible mouse can click through the light menu box and select type of metal materials for mold making as in the figure 5.3.

Whenever, the light menu are click, the rule base that embedded in the knowledge base of MATSEL is active throughout the rule base. According to figure 5.3, ferrous metal is clicked to choose. The following result are in the figure 5.4 and 5.5

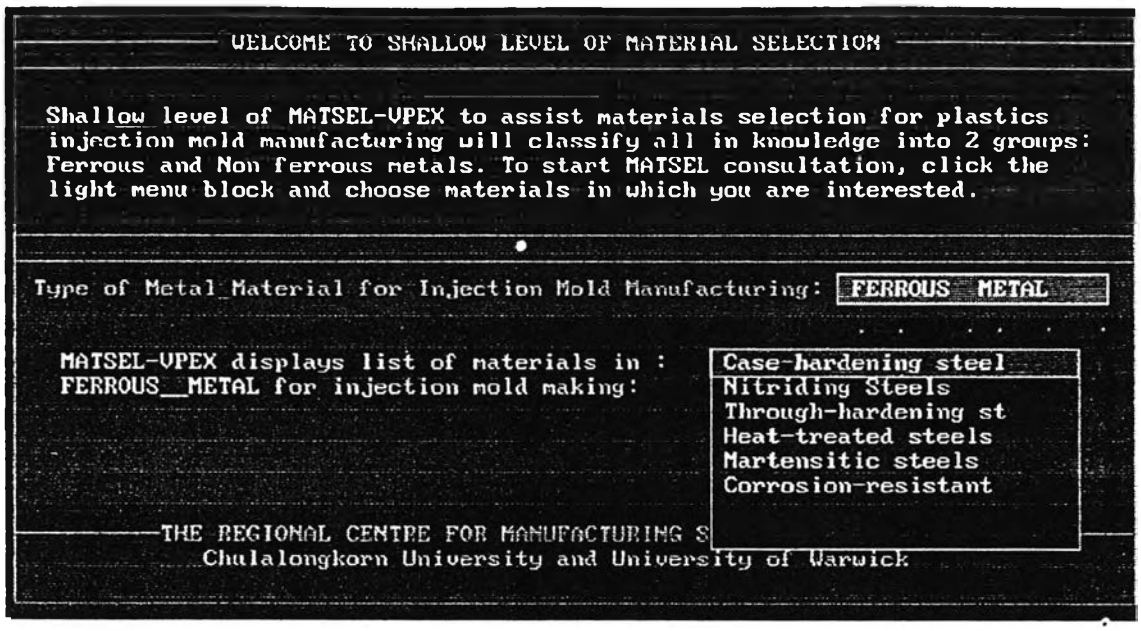

Figure 5.4 MATSEL-VPEX displays list of materials in Ferrous Metal

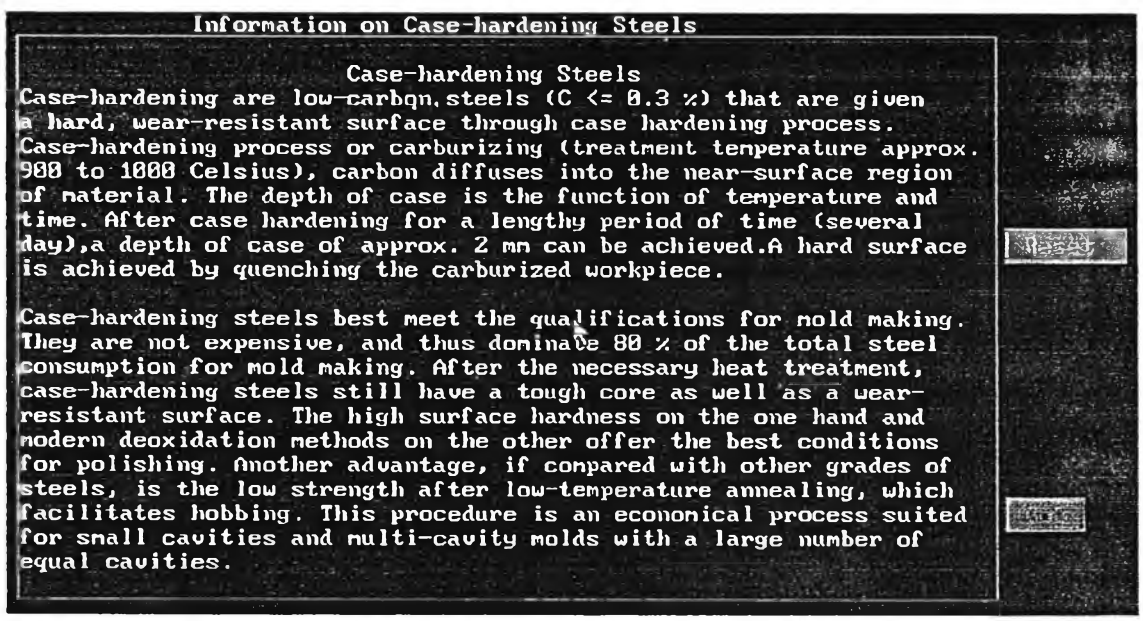

Figure 5.5 MATSEL-VPEX displays the brief introduction for Case-hardening Steels

Notice that after MATSEL-VPEX displays the brief introduction for Case-hardening steels, it offers the reset button to return the consultation to starting the MATSEL- VPEX's Level of Shallow Reasoning in figure 5.3 again. This may benefit to the user by using MATSEL-VPEX as the engineering information provider of materials for injection mold making.

However if the user need to know more detail on each case-hardening steel grade, which is defined in the object and its properties, the users can click the GO button to acquire those they need. The more details on each case-hardening steel grade illustrated by MATSEL consultation is depicted in the Fig. 5.6

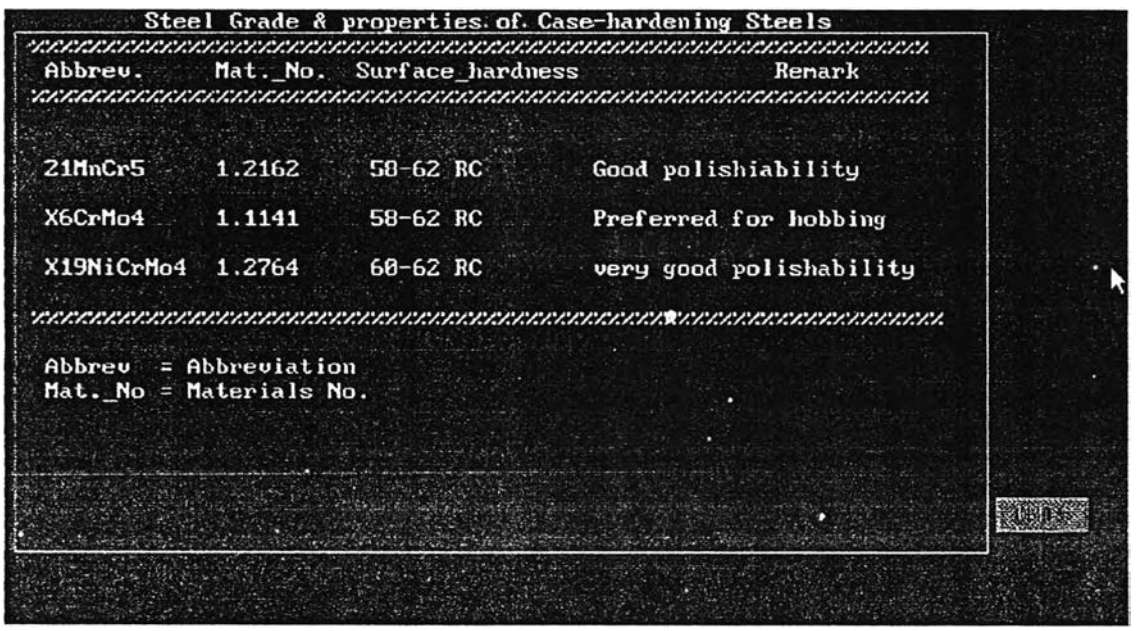

Figure 5.6 Properties of Case-hardening

5.4 The MATSEL- VPEX 's Level of Deep Reasoning

The level of deep reasoning knowledge always comprises the stage of questions. The system's user is questioned to identify which materials properties are of interested to the user. If any materials do not meet the user's requirements, they are eliminated. That is the first material selection process.

The second stage of materials selection process relates significantly with ranking the properties desired by weighing the user's specification to arrive at some balanced compromise solution and then, sorting the selected mold making materials on each material' s score over the range of materials properties.

5.4.1 The Inquiry Stage of MATSEL-VPEX

The purpose of the MATSEL-VPEX 's inquiry stage is to classify what the system 's user need and interpret those user 's specification into MATSEL-VPEX' inference engine. Therefore, In the stage of inquiry for MATSEL, the user are assigned with questions from MATSEL-VPEX. To enhance the understand to the MATSEL-VPEX 's operation in the inquiry stage, all step of this stage are illustrated and explained as follows:

MATSEL-VPEX question 1:

" Does the molding plastics component need to use reinforcement in form of mineral filler or the form of gas? "

Choices: Yes , No,

This question from MATSEL-VPEX is intend to know the operating environment for the injection whether the injection mold operates under environment that it is risk to wear out or not.

If the user answer Yes, MATSEL will identify the first group of materials that can service injection mold under high-wear environment. In contrast, if No is the user's answer, the group of materials that can serve injection mold under high-wear environment is eliminated.

MATSEL-VPEX question 2:

" Will the injection mold surface expose to the intensive acid environment such as in PVC processing environment ? "

Choice: YES No

The question No 2 is intended to know whether the injection mold operating in the high corrosive environment or not.

If the user answer Yes, MATSEL will identify the first group of materials that can service injection mold under high-corrosive environment. In contrast, if No is the user's answer, the group of materials that can serve injection mold under high-corrosive environment is eliminated.

MATSEL-VPEX question 3:

" What is the highest temperature that injection mold will expose the melting polymer? Please give your answer in degree °C.

Answer: Identifying by the system's user

The question No 2 is intended to know whether molding operating temperature of injection mold is more than 250 degree °C or not.

If the molding temperature is over the 250 °C, the mold making materials for high temperature environment are selected by MATSEL to serve this requirements. In contrast, those materials that is mentioned will be eliminated.

Question 1-3 is used to classify mold making by the specific use of that group of materials.; any materials which fail to meet the user's specification are eliminated. Question 4-6 is inquire the numerical specification that will involve in the process of ranking materials by weighing the user's requirement in the next stage.

Question 4 Identifying tensile strength for mold materials in MATSEL by using of choice as follows

Choice:

- Low tensile strength	$\geq$ 440	MPa
- Medium tensile strength	450 - 750	MPa
- High tensile strength	750 -1100	MPa
- Very high tensile strength	$\leq$ 1200	Mpa

Question 5 Identifying hardness for mold materials in MATSEL by using following choices.

Choice:

- Low surface hardness	> 56	Rockwell C
- Medium surface hardness	56-60	Rockwell C
- High surface hardness	< 60	Rockwell C

Question 6 Identifying thermal conductivity for mold materials in MATSEL by using following

Choice:

- Low thermal conductivity	$\geq$ 600	BTU/hr F
- Medium thermal conductivity	600-900	BTU/hr F
- High thermal conductivity	$\leq$ 1000	BTU/hr F

5.4.2 The Weighing Stage of MATSEL-VPEX

The weighing stage of MATSEL-VPEX is required the system's user defines the weight of importance for each specification of injection mold identified as follows:

- Thermal conductivity
- Wear resistance
- Corrosion Resistance
- Tensile Strength
- Hardness

Afterward, MATSEL will provide the compromise solution by using Alternative Inference Mechanism (AIM) to assist materials selection for mold manufacturing in term of compromise numerical score.

5.5 Case Study for Validation of MATSEL-VPEX Program

The stage of Validation is one of crucial stage in testing the credibility of developed system. Because MATSEL is created to assist materials selection for injection making practice. In the process of validation, the technical information in real time practice relating with both injection mold materials and product molded are required.

5.5.1 Molded Product Selection

The product was selected from I.N Precision Co., Ltd, a one of injection mold manufacturer in Thailand is bottle carrier. The factory provided the technical information of product and production capacity of injection mold made is also supplied by I.N Precision as follows:

Additives:	Color
Production Capacity:	800,000 Pieces
Materials for mold plastics part:	polyethylene (HDPE)

5.5.2 The Main Characteristics Supplied for Analysis with MATSEL-VPEX

The main parameters extracted from the I.N Precision's documents for analysis are summarized as follows: (Source [13]: I.N Precision Co., Ltd's manuals.)

Injection time:	12 (S)
Inner melt temperature:	193 (^{o}C)
Mold temperature:	67 (^{o}C)
Plastic material:	HDPE
Mold material:	P20 steel

Notice that I.N Precision select P20 to make this injection mold. So , MATSEL VPEX model will use this result to validate the program.

5.5.3 MATSEL-VPEX Validation

Starting program, MATSEL VPEX will show this screen to user the three question.

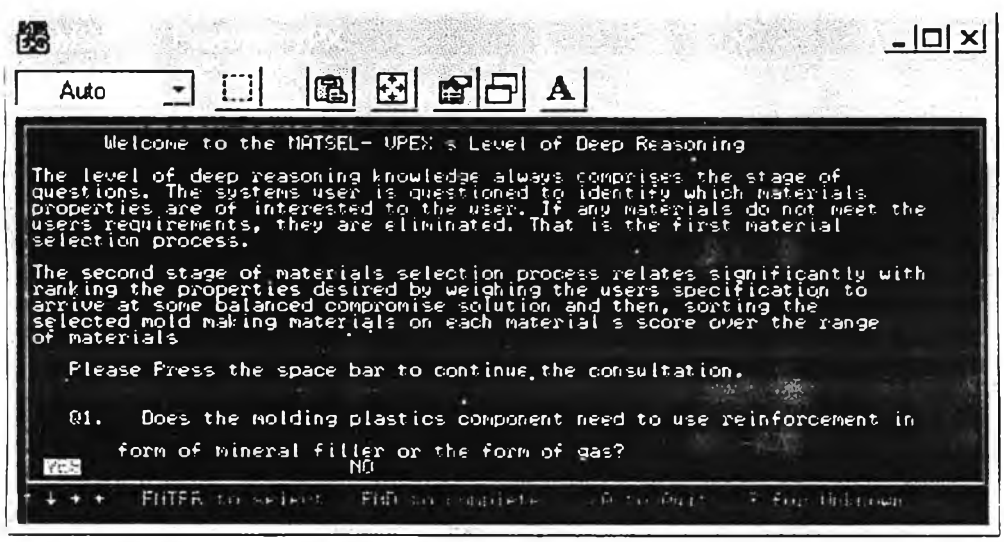

Figure 5.5.3 Displaying the validation of MATSEL-VPEX

MATSEL –VPEX starts the consultation to ask user the following questions:

MATSEL Question1:- (Source of Expertise : gathering from human experts)

" Does the molding plastics component need to use reinforcement in various forms of mineral filler or the form of gas? "

Choices: Yes , No,

According to technical information of HPDC, It is no need to add reinforce in form of mineral fillers or the form of gas. Thus, the user should select "NO". Thus, the group of materials that have high wear resistant is eliminated.

MATSEL-VPEX question 2:- (Source of Expertise : gathering from human experts)

" Will the injection mold surface expose to the intensive acid environment such as in PVC processing environment ? "

Choice: YES No

The question No 2 is intended to know whether the injection mold operating in the high corrosive environment or not. HDPE don't need to use the materials that can protect high acid environment. So, the answer should be "No"

MATSEL will identify the first group of materials that can service injection mold under high-corrosive environment and finally, MATSEL skips its search from this group.

MATSEL-VPEX question 3:- (Source of Expertise : gathering from human experts)

" What is the highest temperature that injection mold will expose the melting polymer? Please give your answer in degree °C.

Answer: Identifying by the system's user

The question No 3 is intended to know whether molding operating temperature of injection mold is more than 250 degree °C or not. According to table C-2 in Appendix C, melting point of HDPE is 210 °C , and inner melting temperature in mold is 190 C which is less than 250 °C . The materials used for high temperature environment such as beryllium-copper alloy will eliminated from MATSEL's search.

If the molding temperature is over the 250 °C, the mold making materials for high temperature environment are selected by MATSEL to serve this requirements. In contrast, those materials that are mentioned will be eliminated.

According to three first questions developed by using the source of expertise from human experts, MATSEL need to translate the answer of queries into the rules utilized to find out and classify the group of materials ,and finally eliminating those groups that are able to reach the system's user 's specifications.

Therefore, the rule for translating question simulating expert 's expertise are need to create. MATSEL-VPEX's source code for classifying group in rule of system are shown as follows:

Source Code of MATSEL-VPEX for Classifying groups of materials

```
RULE 0_ Group_of_Materials_D1
IF      REINFORCED = YES AND  <..... The answer to question 1 is :"YES"
        CORROSIVE = YES AND   <..... The answer to question 2 is :"YES"
        HIGH_TEMP = YES       <..... The answer to question 3 is :"YES"
THEN    DEEP1 = D1;           <..... Set VP-Expert variable to search
                                     in the group of materials D1
RULE 1_ Group_of_Materials_D2
IF      REINFORCED = YES AND
        CORROSIVE = YES AND
        HIGH_TEMP = NO
THEN    DEEP1 = D2;
RULE 2_ Group_of_Materials_D3
IF      REINFORCED = YES AND  <..... The answer to question 1 is :"YES"
        CORROSIVE = NO AND    <..... The answer to question 2 is :"NO"
        HIGH_TEMP = YES       <.....The answer to question 3 is :"YES"
        THEN  DEEP1 = D3;     <..... Set VP-Expert variable to search
                                     in the group of materials D3
```

RULE 3_ Group_of_Materials_D4

IF REINFORCED = YES AND ◄..... The answer to question 1 is :"YES

CORROSIVE = NO AND ◄..... The answer to question 2 is :"NO"

HIGH_TEMP = NO ◄..... The answer to question 3 is :"NO"

THEN DEEP1 = D4 ; ◄..... Set VP-Expert variable to search in the group of materials D4

RULE 4_ Group_of_Materials_D5

IF REINFORCED = NO AND

CORROSIVE = YES AND

HIGH_TEMP = NO

THEN DEEP1 = D5;

RULE 5_ Group_of_Materials_D6

IF REINFORCED = NO AND ◄..... The answer to question 1 is :"NO"

CORROSIVE = NO AND ◄..... The answer to question 2 is :"NO"

HIGH_TEMP = YES ◄..... The answer to question 3 is :"YES"

THEN DEEP1 = D6; ◄..... Set VP-Expert variable to search in the group of materials D1

RULE 6_ Group_of_Materials_D7

IF REINFORCED = NO AND

CORROSIVE = YES AND

HIGH_TEMP = YES

THEN DEEP1 = D7;

RULE 7_ Group_of_Materials_D8

IF	REINFORCED = NO AND	◄.....	The answer to question 1 is :"NO"
	CORROSIVE = NO AND	◄.....	The answer to question 2 is :"NO"
	HIGH_TEMP = NO	◄.....	The answer to question 3 is :"NO"
THEN	DEEP1 = D8;	◄.....	Set VP-Expert variable to search in the group of materials D8

Referring to the question simulation for validating MATSEL-VPEX system, the answer in question 1 is :"NO", the answer to question 2 is :"NO", and the answer to question 3 is :"NO". Hence, mechanism of MATSEL-VPEX will translate the system's user's answer by using the rule 7_Group_of_Materials_D8.

Whenever the most of conditions in the rule 7 are achieved, VP-Expert variable in the MATSEL-VPEX are set ,and MATSEL inference engine will start searching the injection mold making materials in this group, Materials_D8, which are able to serve the high wear, high corrosion, and high temperature condition. The example of materials that are classified in this group are in German code. Due to technological properties. These steel can also be substituted for the other steels of these groups.

Referring to Stoeckhert [9]. AISI-SAE type P20 or German code 40 CrMnMo7 is adequate for normal stresses of wear, and normal corrosion resistance, and is also moderate for operating under the normal operating temperature. Thus, AISI P20 are also classified into this groups. As mentioned earlier, however, this group of materials are consisted of other steels that can also be substituted for AISI P20. MATSEL is required to select and recommend the suitable materials for injection mold making. The identifying technical properties of materials and the second stage of materials selection process related significantly with ranking the properties desired are needed.

Afterward, the next stage in 4- 6 the mold design specification are defined in the MATSEL VPEX as follows:

Hardness is less than 56 RC (36- 40 RC Prehardened),

Tensile Strength is defined more than 1200 MPa,

Thermal conductivity is defined between 600-900BTU /hr °F

Note Expertise in question 4-6 is gathering and summarized to create the knowledge base from both sources of expertise defined : the related written literature and human experts.

After the system's user specify the range of specific properties for materials used to manufacturing, MATSEL will translate that specific properties into point of action value to each material in specific group for that properties. Each range of properties has the different point scores for action value in AIM's equation in equation 1.

Total score for mold material i = $\prod$ { [(weight(j) - mid_point_1) x (action (i,j) - mid_point_2)] + Scale_var} ..... [1]

Scale_var = Minimum value to assure that total weight is positive

weight (j) = weighing score's user for property j

action (i,j) = action value to material I for property j

mid_point_1 = average value of weight (j)

mid_point_2 = average value of action (i,j)

After the user is complete to specify the range of properties desired, MATSEL will provide the second stage of material selection by weighing the requirement desired by customer in the topic as follows:

- Thermal conductivity
- Wear resistant
- Corrosion resistant
- tensile strength
- Hardness

The score of the user's requirement weighed for properties will be kept in weigh (I) depending on the properties, which are stated above. For example, the weigh (1) for property of thermal conductivity. Afterward, the use of alternative inference mechanism (AIM) will provide the total score for each materials. For the case of validation, AISI P20 or 40 CrMnMo7and other steels(54 NiCrMoV6, and 47CrMo4) are not significantly different.

5.5.4 Conclusion of Validation case

MATSEL will search the rest of materials after the large three groups: high wear resistant steel, high corrosion steel, and high temperature materials are eliminated. Thus ,AISI P20 which is not in those can be found by the use of MATSEL. However, the specification of mold must be defined exactly, so that the correct material is P20, the stage of weighing is very important, because if the user is not clear in specification. The result may be deviated. This problem may be corrected by the use of the wide range of expert query simulation especially in manufacturing processes aspect such as polishability, and machineability.