Development of the Aircraft Materials Selector Expert System

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Abstract

To comply to demand for a development requirement of aircraft design part, the expert system builds up standard knowledge-base based on presently maintained expert knowledge and experience in aircraft structure material selection. It also builds up database based on aircraft design open data, and standard calculation module used for present design and analysis method.

This system is developed using Visual Basic language. The expert system standardize aircraft structure material selection and can be applied to all type of elementary stage of aircraft structure design. It is working on Windows, which has a friendly interface and is convenient for debugging, maintenance and transplanting. Explanation of the structure and the function of the system was given in this paper.

Keywords:

Aircraft design; Expert system; Select Material

1. Introduction

Material engineering is the basis of aircraft development-production. Traditionally aircraft development-production process is done in serial manner. Five or six years are required for materials selecting analysis, determining technical-requirement of newly developed materials, developing and applying research of newly developed materials, and producing aircraft materials that already exist to process parts of the aircraft made from the materials.

Digitalization of aircraft design and manufacturing enabled 'concurrent engineering' of 'design and manufacturing unification' in aircraft development process and reduced the period of model development-production progress. Long period of material's development-production becomes an obstacle of manufacturing period and models' development-production. If we cannot solve this problem, it has an effect on 'design and manufacturing unification' and development-production of material. Accordingly, the aircraft materials selector expert system for material development, application research, structure design and manufacturing unification can re-develop materials and up to date methods of aircraft development and production. It has not only the advantage of reducing period of aircraft development-production, guaranteeing the quality of material, satisfying requirement level of the model but also it combines material development of the model with high technology.

This paper shows both theoretical and practical value in the prototype of the aircraft materials selector expert system by combining material select process with expert system.

2. Conceptual design of system

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The purpose of this system is emulating aircraft structure material select expert and engineer. Based on the requirements of the new model, it confirms what parts that are needed and which position it is going to be used. It demonstrates the capability of which type of material using plan can be chosen and new materials that can be used according to the environmental requirement. It can also show material's important original capability(physical capability, anti-corrosion, basic dynamic capability, fatigue capability, collapse capability etc.) and automatically create document related with design and production(material select list, material list and limited usable material list etc.).

2.1 Method and step of aircraft structure material selection

The methods for selecting aircraft material are by scientific research procedure which is generally as follow.

Step 1 : Based on the environmental requirement of parts, the required stress level in operation and kinds of load, it decides what kind of material and part is going to be used by considering static strength, fatigue stiffness, stress corrosion fatigue stiffness requirement.

Step 2 : It considers requirements of fatigue, damage tolerance and durability design in more detail and decides

cored material based on operating environment of parts, operating requirement and damage about flight safety risk level.

Step 3 : With the material selected, it finally select material after synthetic selection process, which thoroughly considers the requirements of the condition of design and capability of materials based on the use requirements of the aircraft and parts of the structure.

2.2 Conceptual design of system

An aircraft is constructed with the structure including wings, body, horizontal tail and landing gears assembled with skin, rib, beam stringer, corrugated substructure. Using accumulated empirical knowledge from practice, it can express a lot of detailed module separation of elements using knowledge from experience, rules and principles at material selection progress. Using a popular inference engine, it can infer with separating database that has another detail item as well.

2.3 Select HW/SW environment

The system organized aircraft material selection knowledge-base using relation database program 'Access'; including dictionary base, rule base, fact base. The expression method of knowledge frame using relation database does not only have a beneficial effect on working for the inference engine but also editing and managing the knowledge base and improving practicality of system.

The system program is an Object Oriented Programming(OOP) using Visual Basic, and for the OS a Windows environment is required to ensure proper working memory.

3. Realization of system structure

3.1 Knowledge-base design

3.1.1 Knowledge expression

Based on feature of material select experience, it can show knowledge with production rule. "IF ... THEN ...'structure of the production rule is similar to human language and conversation's natural formation, convenient to precision realization, coincidence validation, automatic correction and expansion of production rule. Furthermore, it is convenient to operate inference engine design.

3.1.2 Dictionary-base and rule-base design

Working database(Synthetic database) ; This database is the working space of saved original facts, interim results and final result. It infers whether the can be used or not, including its reliability. Fact is the index list of this database.

Dictionary-base ; This base is saves preconditions, conclusions and serial numbers of the rule-base. The fact it uses natural language, that is precondition or conclusion using natural language. Serial number of fact is index list of this database.

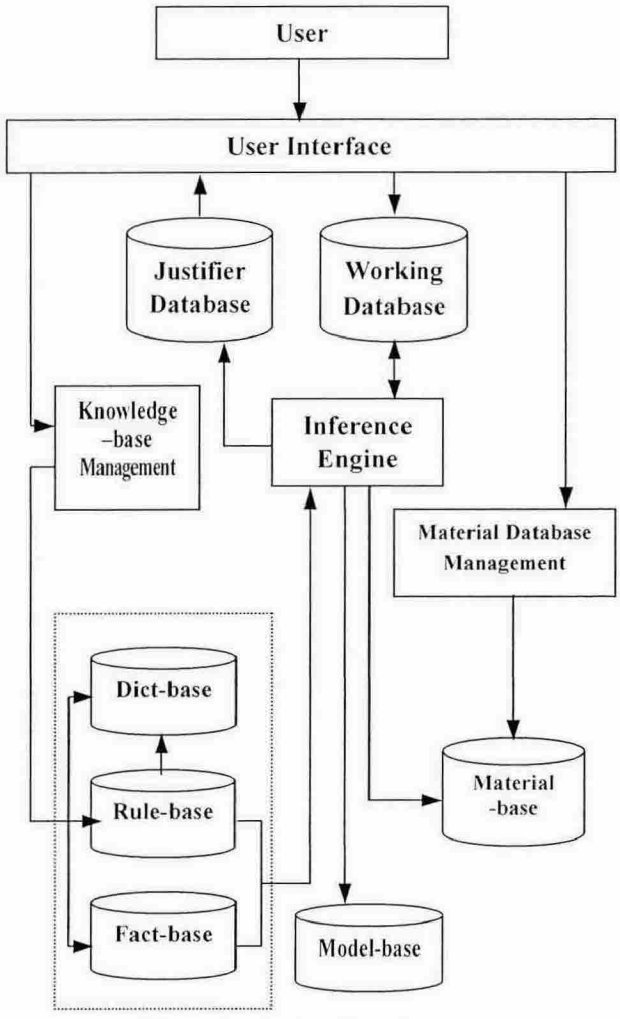

Figure 1 – System Structure

Precondition of rule database ; It saves the corresponding precondition with a rule. It includes the rule name, the serial number of fact and reliability of rules. Rule name and serial number of fact are the index list of this database.

Result of rule database; This saves the corresponding conclusion with a rule. It includes rule name, serial number of fact, reliability of a rule's precondition and reliability of a rule's conclusion. Rule name is the index list of this database.

Justifier database; This saves the result of inference process and the final result.

The result of rule database establishes relations with the precondition of rule database using the rule name. Precondition of rule database establish relations with dictionary base using serial number of fact.

3.1.3 Knowledge acquisition

Nona-automatic methods are used for acquiring knowledge and the knowledge acquisition engineer acquires knowledge using combination of the knowledge editor method. At the moment, it has no substantial material select

knowledge. So it needs collection and arrangement of knowledge using material of selecting knowledge. The experience of experts and the examples from several existing aircrafts should be collected and well arranged. In addition to knowledge acquisition through technical books or related literature, knowledge must be acquired by talking with experts and analyzing theories.

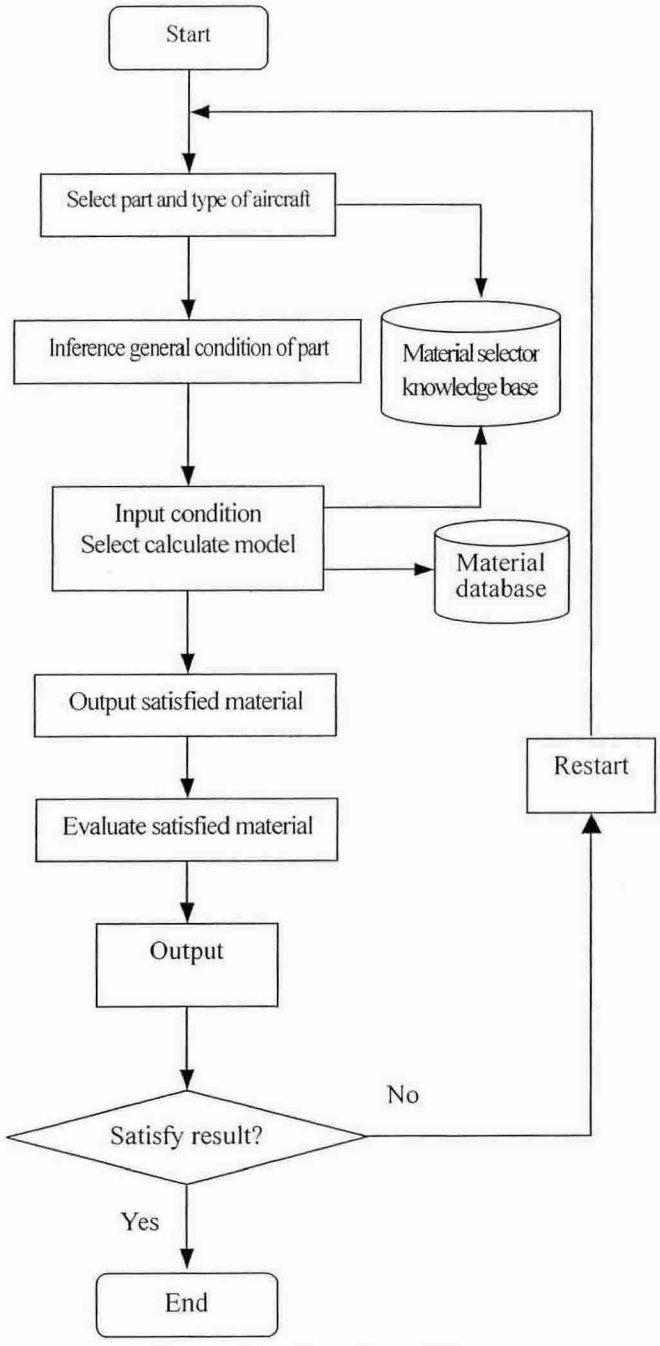

Figure 2 - The working flow chart of the system

3.2 Structure and realization of inference controller

3.2.1 Conflict resolution

A simple intuitional conflict resolution method was used for arranging several knowledge items with a fixed up priority order. Arranging method is as follow;

(1) Divide structure; dividing the structure of knowledge base based on each part of the aircraft and each of its dissimilarity, and selecting available knowledge among applicable knowledge base during search for problem root process.

(2) Arranging structure order of knowledge base; first, arranging every knowledge condition part's condition with fixed up priority order, and arranging available knowledge order with fixed up character order that included this sort condition.

(3) Arranging with CF; Existing two production rules are coincides, deciding preferentially use which production rule based on its CF.

3.2.2 Inference controlling

For inference in this system forward chaining method and in-depth preferentially searching method of available rule search were selected. The advantage of this is definiteness of inference and simplicity of the program.

The Serial number is the primary index list in the rule's precondition database. It can lead to rules and results related to some condition by using a rule name. It should also be noted that rule's precondition database correlates with serial numbers of fact and dictionary base. Some serial numbers of facts are expressed in natural language. SQL language and related techniques provides good methods for inference, which can infer more easily and raise efficiency.

3.3 Justifier mechanism

The justifier mechanism explains the inference route of a problem solving process of systems and the state of knowledge employment in knowledge-base. It also explains how it solved the problem. In this way, it guarantees consensus of solving process and the application justifier mechanism.

3.4 Establishing material database

Materials database mainly functions in storing data about the performances and price of metal materials such as steel, aluminum, titanium, etc. Each entry of record contains several fields. Each field has a corresponding serial number and it stores related data of each typical material, such as their names, sorts, varieties, state of heat treatment, and other performance indexes.

The System manages and maintains the database, such as adding, deleting, renewing and transferring data.

3.5 Calculation model-base

The calculation model-base saves analysis calculation model including fatigue life, stress corrosion calculation, remaining strength analysis and crack propagation

Using obtained result from experienced experts or material select examples, it judges injury degree of flight safety and offer calculation model of user select parts based on working environment of parts and working requirements.

3.6 Comprehensive decision-making method of material selecting

The rule in the rule-base is mainly applied in qualitative inference decision. It determines the names, sorts, varieties, and the state of heat treatment of the candidate material. When there is more than one candidate, further quantitative comparison is required to choose the most satisfactory material.

Liu Tingyao[9] once applied the fuzzy mathematics theory to do comprehensive assessment on the mechanical performance of aircraft material. His operation proved that this method was workable and that material performance can be differentiated according to the assessment. Therefore, this method can be applied in comprehensive decision-making method of material selecting, while the detailed working procedure will not be covered in this article.

The system offers the system user a weighted modulus that is extracted from several already existing aircraft examples of choosing materials combined with experts' experiences that are added to the knowledge-base.

Fig 2. shows the working flow chart of the system.

4. Conclusion

(1)An expert system prototype for aircraft structure material selecting has been developed. It includes a general inference engine and a set of material selecting knowledge bases. Knowledge is presented in generative-method and uncertain-inferential method is employed. The whole system runs efficiently following a clear procedure to ensure the obtained result has high reliability. The knowledge base can be further upgraded after its establishment.

(2) Complying to the sort of aircraft parts, the place these part to be used and the environmental requirement, the system can decide the material composition including already existing material and that material that needs to be developed. It also offers critical performance index that the material must possess, and automatically generate documentations for design and manufacture including a qualificatory material list and a list grading the material in terms of eligibility. Since comparative practical engineering model is employed, this system can basically meet the design requirement.

(3) The system running procedure is subject to technology and it is convenient to debug, maintain and upgrade it. Besides, the system can be run in Windows in which has a friendly interface.

(4) This is merely a prototype of the expert system, more work needs to be done on improving the database and knowledge base so that the system can be of greater use to aircraft material selecting.

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