Research on Civil Aircraft Structural Strength Material Performance Database Based on SpringBoot

Minmin He¹* and Shengli Lv²

¹School of Software, Northwestern Polytechnical University, Xi'an, Shaanxi, China
²Science and Technology of UAV Laboratory, Northwestern Polytechnical University, Xi'an, Shaanxi, China

*Corresponding author email: suruomo@mail.nwpu.edu.cn

Abstract. According to various materials used in civil aircraft structural strength analysis, and applying software engineering ideas and object-oriented programming methods, a set of civil aircraft structural strength material performance database system based on SpringBoot was developed. The scope of the material library management and the input data standards are initially defined, through the analysis of civil aircraft material data, the metal, composite materials and layup data are classified and managed respectively. The material library used for finite element calculation and strength inspection also provides the export function of Nastran material card, it has a certain reference value for highly-managed civil aircraft depots, and can achieve work collaboration and improve work efficiency.

1. Introduction

Civil aircraft structural design is a highly complex and knowledge-intensive activity. Among them, the choice of materials is an important part of the design [1], and the materials and material properties of civil aircraft are a large and complex system. The correct and rapid selection requires high knowledge and experience of designers. It is very important to ensure the rapid, correct and reasonable selection of materials in the out-of-tolerance disposal.

With the popularization of information technology and knowledge engineering technology in domestic aviation enterprises, more and more enterprises have begun to study or have implemented methods of using knowledge engineering technology to assist engineering work. Applying the ideas and information methods of the knowledge base to the selection process of civil aircraft materials [2], the classification, performance characteristics, selection criteria and regulations, and design experience of materials are expressed through association, aggregation, organization, and structure Generate knowledge and store it in database to form engineering knowledge base. This assists designers in the rapid and accurate selection of material properties, which greatly improves design efficiency and design quality.

The knowledge of material properties of civil aircraft used in this study comes from all common standards for aeronautical materials, material specifications, internal selection catalogs and design guides, aircraft design manuals, existing specifications and designer experience, and aircraft designers need to refer to the recommended experts, through this practical system based on SpringBoot effectively manages the existing material library data and implements functions such as Nastran material card export [3], which improves the collaboration efficiency of related personnel.
2. Material Library Data Requirements

2.1. Material Properties Selection Principle
Input files, such as MMPDS, provide tensile Young's modulus and compressed Young's modulus of materials. The Young's modulus used for finite element modeling needs to be minimized or averaged according to the relevant modeling specifications. The limit is taken as the material B reference and the L direction. Under the conditions of meeting the above benchmarks, the smallest $F_{tu}$ (tensile limit), $F_{ty}$ (tensile yield), and $F_{cy}$ (compressive yield) under different wool sizes are selected, and the screening and preliminary determination are used for verification, and the conditions are noted. $E$ (elongation), thermal expansion coefficient, wool size. More accurate material limit values are obtained manually by the user.

During the R & D phase\(^4\), materials that strictly meet the input standards cannot be obtained. Replacement materials can be used for temporary treatment based on the conservative principle to meet the requirements of strength design. The material library should clearly label these methods and prompt users to obtain formal data before obtaining evidence.

The above materials selection principles are applicable to the whole machine finite element modeling and batch strength check based on SIAP. It does not preclude strength engineers from using more accurate material property data in local finite element or inventory calculations, combining the specific characteristics of the problem.

2.2. Input Data Format
The data of the material property database are mainly derived from MMPDS and material test reports and material performance evaluation test reports that comply with the COMAC material procurement specifications. The data will be imported from the existing material database and can be carried out according to the special requirements of some data in this project.

The data format of typical metal materials and conforming materials is shown in Table 1 below, where the material number MATID is the uniform material card number defined in the modeling specification.

| Mat Name | MAT ID | E | Ec | $\mu$ | $\rho$ | $F_{tu}$ | $F_{ty}$ | $F_{cy}$ | E | A | Wool Size | Material Specification |
|----------|--------|---|----|------|-------|---------|---------|---------|---|---|-----------|------------------------|

The composite material description includes material name, material grade, tensile elastic modulus, compressive elastic modulus, Poisson's ratio, shear modulus, density, material specifications that meet COMAC requirements, and applicable temperature. The data format of the composite material is shown in Table 2 below.

| Mat Name | $E_{1t}$ | $E_{2t}$ | $E_{1c}$ | $E_{2c}$ | $\mu_{12}$ | $G_{12}$ | $\rho$ | A | Temperature conditions | Material Specification |
|----------|---------|---------|---------|---------|-----------|---------|------|---|-------------------|---------------------|

The data format of the standard layer library is shown in Table 3 below, where MATID is the standard number of orthotropic materials in the standard material library.

| LID | T | PLY1 | PLY2 | PLY3 | PLY4 | PLY5 | PLY6 | ....... |
2.3. Export Data Format
The material library will output a NASTRAN card corresponding to the material, that is, a .bdf file according to the finite element modeling requirements and the NASTARN material card data format. The output content and format standards of metal and composite materials are shown in Tables 4 and 5.

### Table 4. Metal Material Export Data Format.

| MAT1 | MID | E   | G   | NU  | RHO | A   | TREF | GE  |
|------|-----|-----|-----|-----|-----|-----|------|-----|
|      |     | ST  | SC  | SS  | MCSID | -   | -    | -   |

among them:
- **MID**—Material identification number, determined according to the management rules of the metal material library label (integer> 0);
- **E**—elastic modulus, which is output by the material library. The tensile Young's modulus, the compressed Young's modulus, or the tensile and compression average processing are selected as appropriate (real number>= 0.0 or blank);
- **G**—Shear modulus, output by the material library (real number>= 0.0 or blank);
- **NU**—Poisson's ratio, output by the material library (-0.1 <real number <= 0.5 or blank);
- **RHO**—mass density, output by the material library (real number);
- **A**—Thermal expansion coefficient, output by the material library (real number);
- **TREF**—reference temperature when calculating temperature load, or temperature-dependent thermal expansion coefficient, static analysis is generally not defined (real number: when item A is formulated, default value = 0.0);
- **GE**—damping coefficient of structural element, generally not defined for static analysis (real number);
- **ST**, **SC**, **SS**-stress limits for tensile, compression and shear, output from the material library (real numbers);
- **MCSID**—The identification number of the material coordinate system. The global coordinate system management is generally not defined (integer>= 0 or blank).

### Table 5. Composite Material Export Data Format.

| MAT8 | MID | E1  | E2  | NU12 | G12 | G1Z | G2Z | RHO |
|------|-----|-----|-----|------|-----|-----|-----|-----|
|      |     | A1  | A2  | TREF | X1  | X2  |     |     |
|      |     | GE  | F12 | STRN | -   | -   | S   | -   |

among them:
- **MID**—Material identification number, determined according to the management rules of the composite material library label (integer> 0);
- **E1**—longitudinal elastic modulus, output by the material library (real number);
- **E2**—transverse elastic modulus, output by the material library (real number);
- **NU12**—Poisson's ratio, output by material library (real number);
- **G12**—in-plane shear modulus, output by the material library (real number>= 0.0);
- **G1Z**—shear modulus of 1Z plane, generally not defined (real number> 0.0 or blank);
- **G2Z**—2Z plane shear modulus, generally undefined (real number> 0.0 or blank);
- **RHO**—mass density, output by the material library (real number);
- **Ai**—The thermal expansion coefficient in the i direction, which is output by the material library (real number);
- **TREF**—reference temperature, output by the material library (real number);
- **Xt**, **Xc**—Respective allowable stress or strain during longitudinal stretching and compression, respectively, because the single layer material is not checked, it is not defined (real number> 0.0);
Yt, Yc——Respective allowable stress or strain during transverse stretching and compression, respectively, because the single layer material is not checked, it is not defined (real number> 0.0); S——Allowable in-plane shear stress or strain, because the single-layer material is not checked, it is not defined (real number> 0.0); GE——structural damping coefficient, static analysis is generally not defined (real number); F12——Interaction value in Tsai-Wu theory, not defined here (real number); STRN——The stress (or strain) identification code required by the maximum strain theory. If STRN = 1.0, then Xt, Xc, Yt, Yc and the input strain value; if STRN is blank, it is the stress value, which is not defined here.

The standard layup library requires the format of the output PCOMP card as shown in Table 6 below:

Table 6. Layup Material Export Data Format

| PCOMP | PID  | ZO  | NSM | SB   | FT   | TREF | CE   | LAM |
|-------|------|-----|-----|------|------|------|------|-----|
|       | MID1 | T1  | THETA1 | SOUT1 | MID2 | T2  | THETA2 | SOUT2 |
|       | MID3 | T3  | THETA3 | SOUT3 | ........... | - | - | - |

3. Civil Aircraft Structural Strength and Material Performance Algorithm

3.1. Card Format

According to the requirements of the NASTRAN material card format, the .bdf file is output. The file includes five parts and three qualifiers. The specific file format requirements are as follows:

- NASTRAN statement (optional): mainly used to modify some operating parameters, such as: working memory status, data block size, data block parameters, etc. File management statements (optional): mainly used to initialize the database and FORTRAN files

- Execution control statement (required):
  1) Main function: specify the type of solution for performing the job analysis
  2) Other general functions:
     1) Optional ID statement to identify the job
     2) Optional TIME statement, set the maximum time limit for job execution
     3) End with the CEND qualifier

- Situation control instructions (required):
  1) Specify and control the output requirements of the analysis results (that is, the output requirements of force, stress, and displacement)
  2) Manage a set of model data inputs
  3) Define analysis sub-cases (such as applying multiple sets of loads in a job), select loads and boundary conditions
  4) After the execution control section, but before the model data section

- Model data set (required):
  1) After the situation control section, start with the qualifier "BEGIN BULK"
  2) Contains all data describing the finite element model: geometry, coordinate system, finite element, element properties, loads, boundary conditions, and material property model data records can be arranged in any order, but the last one must be the qualifier "ENDDATA"

3.2. Other Format Requirements

1. NASTRAN statement, file management section, execution control section, and situation control section use free-form model data sections in any of three formats
2. Each input data record (card) of the NASTRAN model data segment contains ten fields
3. The first field is filled with the feature name of the model data card (such as GRID, CBAR, MAT1, etc.)
4. The second to ninth fields contain data input information for model data records (cards).
5. Do not fill in the data in the first cross field, and prepare for continuing the information recording (card)

3.3. Program Implementation

This software is a web project based on the SpringBoot framework[5]. The system is a B / S structure[6]. Its operating environment is divided into web client, server and database server. Software design is based on the software requirements specification, designing the overall structure of the software system according to the functions determined in the requirements analysis stage, dividing the functional modules, determining the implementation algorithm of each module, and writing specific code to form a specific software design plan[7]. The specific research plan of the software is shown in Figure 1.

![Software specific research plan](image)

**Figure 1.** Software specific research plan.

4. Conclusion

Through the analysis and arrangement of existing material library data, the scope of material library management and input data standards, material performance selection principles, and output data standards were defined. The civil aircraft structural strength material performance database software based on SpringBoot was developed to initially meet the basic requirements. However, there are still not enough material data and insufficient types of materials, which will be improved in the next version.

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