CACAO – A Computer-Assisted Integrated System for Design of PWR Fuel Assemblies

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SUMMARY

An initial prototype for a computer-assisted integrated mechanical design system was presented in 1986. This paper focused on the objectives of such a system as illustrated by an intentionally straightforward example (Leroux-86).

After the first prototype tests, the data base conceptual scheme has moved towards a broader-based, more user-friendly system. This new presentation therefore centers on its guiding principles and on the final architecture of the system.

1. SYSTEM OBJECTIVES

The task of the designer consists in designing a product for a specific function. This activity leads him to analyze many interactive phenomena covering a wide range of disciplines and techniques. This involves collecting a large amount of data and applying to them a certain number of physical and mathematical laws or design rules. This approach allows the designer to meet the functional requirements which served as a basis for the system under design and to respect the related operating criteria. The interaction of these factors corresponds to the design process and makes it possible to determine and optimize the chosen technological solution in relation to the various aspects of design.

The mechanical design of a pressurized water reactor core calls for the use of a variety of design techniques. A large number of functional requirements and integrity criteria must be met in the process.

FRAMATOME Fuel Division, which designs and markets fuel elements and reactivity control components for PWR's, has accordingly undertaken to develop a computer-assisted integrated mechanical design system: CACAO (Fuel Assembly Computer-Assisted Design).

The objectives of this system are both management of the entire body of fuel assembly and reactivity control component mechanical design data and the creation and management of data applications for verifying and substantiating product design.
"Data" is understood to mean all the qualitative or quantitative elements needed by the designer to carry out his job, i.e. not only the geometrical features of a component used in the design of a mechanical system (as-built dimensions) but also its material including its characteristics and any other necessary information. "Application" is understood to mean the processing of data to reach a suitable technological solution. This may involve both complex calculations and straightforward operations such as verification of geometrical compatibility.

2. GENERAL DESCRIPTION OF SYSTEM

The single datum is the keystone of the CACAO system. If n data are collected to design and justify a mechanical system, these data must firstly be defined and characterized and secondly be organized or structured in relation both to the real or physical world and to the theoretical or logical world. This organization is illustrated in figure 1 which shows the three main blocks used to characterize data, describe the mechanical system and its environment and analyse design validity.

The description block needs further development—the data used by the designer are divided up into two sets: one describes the mechanical system being designed and which has to be acted upon, the other corresponds to the constraints imposed at the boundaries of the system (geometrical interface, for example) or of its range of activities. Finally, to avoid redundancy in the mechanical systems base, materials data are specifically handled in the materials base. The data base is built by means of a navigational or network-type management system.

The base relationship is of the type 1→n, in which a head node is connected to a limb node (father-son relationship). When a relationship of the type m→n has to be used, it is carried out by means of two 1→n relationships and one relay node. These relay nodes are also used as pivots for connections between several relationships. The conceptual scheme of the base is shown in figure 2; it features 32 nodes and 53 relationships.

In the following data base description, the nodes are identified by their number with the subscript [n], the relationships by (→ n) for 1→n relationships and by (m ↔ n) for m→n relationships.

Nodes [6], [11], [15] and [20] are blocks of information texts which constitute an on-line aid for users. Nodes [4] and [5] respectively group together the types of users (base master, consultations etc...) and the identification of the related users (→ 3). They manage and control access to the system.

These nodes and their associated relationships will not be referred to in the description below.
3. CHARACTERIZATION OF A DATUM

Any mechanical datum is characterized by a structure with associated quantities and units.

The data definition base [4] is used to input into the system, as required, structures [3] (nominal-tolerance, fly-specks, polynomials etc..) characterized by a label, the number of numeric values, the mark dimension and the label of a screen grid for clearly displaying the meaning of the numeric values.

It is also used to input quantities [1] (length, stress, temperature...) and to combine them (→ 2) with corresponding units [2] (meters, Pascals, degree Celsius etc...). Datum acquisition is then by definition of the attributes for identifying it (label, reference...) and by characterizing the datum by associating it with a structure (→ 9) then, depending on the structure, suitable quantities (→ 13, → 14, → 15) and units (→ 10, → 11, → 12). An example is shown in figure 3.
4. ENVIRONMENT DATA BASE

This part of the base is defined by simply compiling a list of environments [12] (900 MW reactors, 1300 MW reactors...), together with a list of headings [13] corresponding to interfacing disciplines (thermal-hydraulics, neutronics...) or to physical interfaces (reactor internals, control rods etc...).

Each environment-type of environment combination (35 <-> 36) can then be combined (- 37) with a set of data [14] as defined in paragraph 3.

5. MATERIALS DATA BASE

The materials data base consists of a list of materials [10] (Zircaloy 4, Inconel 718...). It is based on the following three notions : the characteristic [7] (yield strength, thermal expansion coefficient etc...) with its unit (-> 18), its type [8] (or production mode : uniaxial tensile testing, burst testing...) and its kind [9] which specifies its status relative to the design activities (statutory value, specified minimum, best-estimate value...).

It is then possible to combine [26] (-> 25) with each pre-defined triplet (-> 17), (-> 19), (-> 20) a set of data with different structures.

6. MECHANICAL SYSTEM DATA BASE

This base is used to compile a list of mechanical systems or groups of mechanical elements [16] (Fuel Assembly, Rod Cluster Control Assemblies,...) and to determine the mechanical elements [19] in each group. These elements (fuel rod, top nozzle...) are themselves components or sub-systems (set of several components).

The mechanical system is thus described according to a hierarchical breakdown [29] (28 <-> 29). It is then possible to combine a data set with any one of the elements of this description.

In order to streamline the description process for a mechanical system, the items of this description are classified into two groups : specific items [17] which are sub-systems or components whose type may be single or repetitive in the description (cladding, end plug...) and standard items [18] which are components (possibly sub-systems) having a sufficient level of standardization to be linked to a set of standard data (fastening screws, helical spring...). The latter cannot be broken down.

An item of a mechanical system is thus defined by its group (26 <-> 27), its type (-> 30) or (-> 31) or its label.

It can also be linked to its material (32 <-> 33).

7. DESIGN BASE

To calculate the design base, it is first necessary to draw up a list of functional requirements [24], which are met by verifying quantifiable criteria [23] (-> 46). These criteria are verified by applications [22] (-> 47), i.e. computer programs which generate a set of output data from a set of input data.

For a group (-> 44), an environment (-> 45) and an application (-> 48), it is possible to compile a list of data [21] by selecting them (49 <-> 50) from those previously defined in the other bases.
The datum may therefore be either internal, in which case the application will define the value, or external, in which case the designer will define the value.

The data file corresponding to the selected list is generated by CACAO; the application accesses these data by means of a Data Internal Management System. After the calculations have been performed, CACAO rereads the data file and carries out any necessary data modifications in the base (internal data).

8. CONCLUSIONS

With the CACAO system, it is now possible to manage all the items involved in justification of mechanical system design. The designer can at any time make an input of any kind: new component, new material, new datum, new criterion... Consultation is done readily, by running through the composition of the structure, by viewing a datum or by selecting a material then one of its characteristics.

For a given datum, it can identify the dependent criteria verifications and the associated applications. CACAO is a means of generating and developing an all-purpose knowledge base within the mechanical design scope.

REFERENCES
