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* See annex of J. Pamela et al, "Overview of Recent JET Results and Future Perspectives",
Fusion Energy 2002 (Proc. 19th IAEA Fusion Energy Conference, Lyon (2002)).

ABSTRACT

The paper describes the automatic generation of a JET 3D neutronics model from Data of Computer Aided Design (CAD) system for Monte Carlo (MC) Calculations. The applied method converts suitable CAD data into a representation appropriate for MC codes. The converted geometry is fully equivalent to the CAD geometry.

INTRODUCTION

Neutronics analyses of fusion devices are usually performed by the Monte Carlo method which enables the use of full and detailed 3D geometry models. The manual modeling of a complex geometry with a Monte Carlo code, as it is common practice, is a timeconsuming task. A more efficient way is to make use of available CAD geometry data for MC calculations. This can be achieved by converting the CAD data into a representation appropriate for MC codes. This requires beside an access to CAD data a suitable conversion algorithm. An implementation of an interface program for this purpose is currently under development. This paper describes the underlying method and the application of the interface program for the automatic generation of a JET 3D torus sector model for the MC code MCNP [2]. A CAD model of a JET torus sector (octant 3) consisting all significant components was pre-processed and converted into MCNP geometry. The conversion process reproduces fully the CAD geometry with moderate increase in the complexity.

1. METHOD

The underlying method is generic and does not depend on a specific CAD system or MC code. A suitable model is generated by a CAD system and is transfered through export of data via neutral file format to an interface program where conversion is performed. The need for conversion arises due to the difference in the representation schemes and is described in the following.

1.1. GEOMETRY REPRESENTATION AND CONVERSION

The geometry needed for MC particle transport is a decomposition of the problem space into a finite collection of disjoint regions (cells) of constant ray attenuation coefficient whose union is the problem space. It is usually represented as a boolean form of primitive solids or algebraic half-spaces. Such representations can be formalized as a semi-algebraic cell decomposition [1]. Currently, most commercial CAD systems use the boundary representation (B-rep) method to store geometric models of solids. A solid is assumed to be a compact and regular point set, whose boundary is composed of closed oriented manifolds of dimension up to 2 [1]. The difference in the representation schemes makes a conversion necessary. The approach we follow is to use the geometric and topological data of a B-rep solid from a CAD system and to construct its semi-algebraic representation as used in MC codes. The two main steps that are involved in this approach are: access to the data of a CAD system and the conversion process itself. Access to the data of a CAD system can be provided through export of data in neutral file format. Given a solid in boundary representation, it

can be shown that its semi-algebraic representation is computable. The algorithm which solves this problem is described in [1]. The conversion proceeds in two steps. After the traversal of B-rep data structure of a solid and extraction of boundary supports, the first step is to determine the definability of the solid by the available boundary support set. If this is not the case to enlarge the set so that definability is achieved. In the second step, a cell construction is performed by sign constant decomposition of the solid by the boundary supports.

1.2. INTERFACE PROGRAM

The interface program integrates a CAD kernel, a C++ GUI application framework, and the conversion algorithm. The CAD kernel provides core data structures, algorithms, and data exchange interfaces for neutral CAD files such as IGES and STEP. The GUI framework provides data structures for visualization and user operations. The conversion algorithm relies on the CAD kernel for its geometric and related computations. The implementation of the interface program is realized in a framework like library. The conversion algorithm and other capabilities for visualization, modeling, and data exchange are already implemented. The automatic generation of MCNP geometry representation is treated as data exchange operation.

2. APPLICATION TO JET TORUS SECTOR
2.1. MODEL PRE-PROCESSING

CAD design models are constructed mainly for visualization and manufacturing purposes and are often over detailed for the need of neutronics analysis. Hence, a preprocessing of design models is often necessary. Typically, the pre-processing task includes the analysis to identify and fix geometric and topological errors, detail suppression, and simplification of model by decomposition. The analysis is performed within the interface program. Including details such as blends, notches, fillets, protrusion, and chamfer may have insignificant effect on the neutronics analysis while severely complicating the geometry. Even after detail suppression the model may be still too complex and may require a further simplification by decomposition. Both detail suppression and simplification areperformed in the CAD system. Starting from design models, a suitable CAD model of JET torus sector (octant3) was generated with CATIA v.5. Detail suppression and simplification of model by decomposition were performed. Also most parts were constructed based upon free form surfaces, which can not be treated by the interface and MCNP. Therefore, they were replaced by algebraic surfaces. The final CAD model is shown in figure 1. The content of the model is summarized in Table 1. The model contains all major components such as vacuum vessel, mechanical structure, magnets, divertor, etc.

2.2. MODEL CONVERSION

Once a subtable CAD model is generated, it can usually be automatically converted. The conversion process does not introduce an approximation. Therefore the converted geometry is equivalent to

the original one. There is however a modest increase in the complexity of the model in terms of cells and defining surfaces. The converted MCNP models of the JET torus sector is shown in figure 2. Note that voids are not included in the model. The content is given in Table 1. The increase in the complexity of the MCNP model is modest. From a total of 80 solids, 210 sub-cells were produced. Sub-cells refer to product terms in a disjunctive normal form. After deletion of redundant faces, the number of surfaces is significantly reduced.

2.3. VALIDATION OF THE MODEL

The converted geometry is validated by comparing results of volume calculations by CATIA and MCNP. Since the CAD model does not describe the whole model, including void and contacts, as required by MCNP, the calculations were performed for single components. Complete MCNP models were generated for individual components located at their original potions in the torus. Table 2 displays volumes calculated by CATIA and MCNP. Note that MCNP calculates volumes stochastically. Hence the minor differences are due to statistical errors. As can be seen from the results, the volume property is well reproduced which confirms that the conversion process reproduces the CAD geometry properly.

CONCLUSION

This paper presents a method for a use of CAD data in MC codes. The method is implemented in an interface program. The application of the interface program for automatic generation of a JET neutronics model from CAD Data for MCNP is described. The generated geometry is fully equivalent to the CAD geometry which has been also affirmed by MCNP volume calculation of the converted geometry.

REFERENCES

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Contents of the CAD and MCNP model ot the JET torua sector					
	Number of solids / sub−cells	Plane	Number of surfaces		
			Cylinder	Cone	Torus
CAD	80	517	140	31	7
MCNP	210	1116	214	36	20

Table 1.

Volumes of components calculated by CATIA and MCNP.					
	Volume (m^3)			Volume (m^3)	
Components	CATIA	MCNP	Components	Cone	Torus
Coil D1	0.070	0.0685	I-Carrier	0.087	0.0862
Coil D2	0.083	0.0815	L.H.C.D	0.745	0.7435
Coil D3	0.097	0.0950	O-Carrier	0.113	0.1122
Coil D4	0.160	0.1572	Limiter	0.046	0.0440
Divertor	0.191	0.1893	RF Antenna	0.484	0.4703

Table 2.
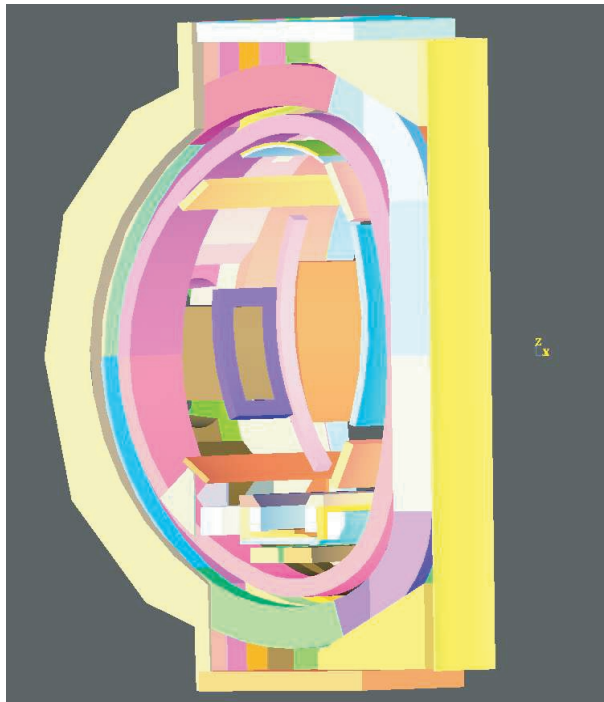
Figure 1: CAD model of JET torus sector.
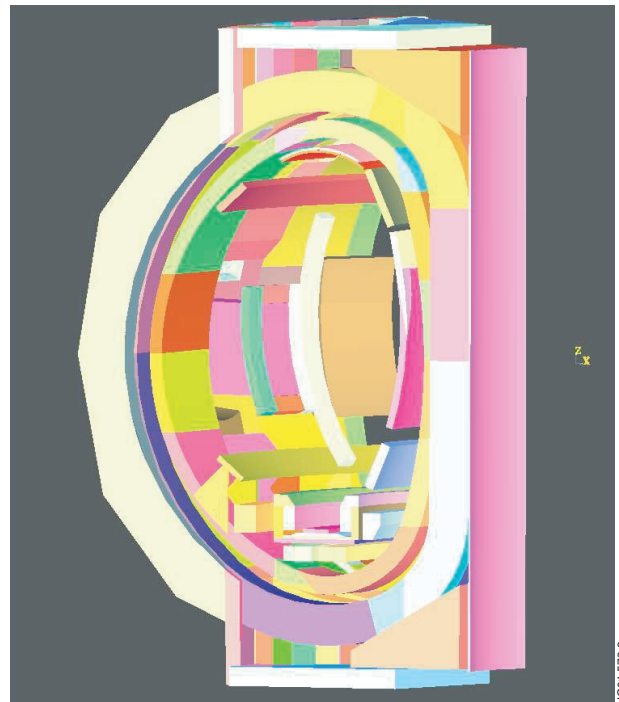
Figure 2: MCNP model of JET torus sector.