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AI-BASED AUTOMATED DESIGN SYSTEM FOR DEMONSTRATION FBR COMPONENTS

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ABSTRACT

In the structural design of FBR, many kinds of knowledge and information are required, and much manpower is spent to perform designing, however it is not always optimum design. The expert system is considered as one of useful tools to solve these difficulties. Authors has been developed an Al based computer system using an object-oriented approach. This paper describes the extension of this system to be applied to many complex structures in FBR. Some examples of application to several kinds of FBR structure are also presented.

1 INTRODUCTION

Structural design of FBR components is essentially complicated because numerical analyses are required due to dominant thermal stresses. Many kinds of knowledge and information should be transmitted in the design process between the engineers. In the conceptual design, iterative procedures are performed to obtain the satisfaction. Though much manpower is required in the conceptual design, it is not always optimum. Structural design of FBR involves difficulties not only of knowledge but of manpower and optimization.

The expert system is considered as one of useful tools to solve these difficulties in the FBR design. An AI-based computer system that can manage complex information flow had been developed by Yoshimura et al. [1] to be applied to the fusion first wall design. An object-oriented approach was employed in that system to represent design process.

Authors have modified that system to apply to the FBR design[2]. A new function was also developed in the previous work to obtain design windows, and the prototype system was adopted to the design of the reactor vessel wall. One of the severe portion in the reactor vessel is located near the sodium level. The main issue of this portion is the determination of the wall thickness and the heat transfer coefficient; a thick wall is preferred to prevent buckling due to seismic load but is not preferred due to severe thermal stresses, and lower heat coefficient is preferred to reduce thermal stresses but requires additional cost for construction. The expert system developed was successfully applied to this problem and interesting design windows were obtained.

The analysis model of the reactor vessel near sodium level has simple geometry of smooth cylinder, however there are many complex FBR structures. The advantage of an object-oriented AI system is to be extended to any problems. This paper describes the techniques to extend the prototype system and examples of application to FBR components which have structural discontinuity, specific portions or 3D geometry.

2 EXPANSION OF THE SYSTEM

2.1 Installation of MARC Code

In the system for the reactor vessel wall in the vicinity of the sodium level, a single purpose finite element analysis code "KINE"[3] was adopted. It can deal with thermal transient loads and mechanical loads for only two dimensional axisymmetric models. To improve the system so that it could serve as a versatile expert system with a wider range of analyzable structures, the "MARC"[4] code is installed. Empirical knowledges were stored into the knowledge base to generate input data of MARC.

2.2 Gathering Objects

According to the author's experiences on the conceptual design of FBR, designs of the main structural components require cooperative works of R&D staffs, designers, and structural analysts. Each group begins to work only when it has obtained all necessary informations. The work flow is not regular but dynamically depends on the state of design stages or conditions.

An AI-based computer program that represents the above group works with data flow procedure was developed by Yoshimura et al. [1] In that system, an object-oriented approach technique was applied. It consists of a drive engine and many objects. The engine is completely independent of the target of the design. This technique allows the expert system to deal with the group work that may vary depending on the conditions of structural components, load conditions and so on.

Gathered objects for the design of the hot-leg piping are shown in Fig. 1.

2.3 Rules for Design Change

The initial settings of a design may not satisfy the structural integrity criteria. It is necessary first to determine the design parameters for acceptable values.

Evaluation of such conditions depends on the degrees of stress, strain, and creep fatigue damage. They stand for margin from allowable values defined as

Margin = 100 x (1 - actual value/allowable value)··························(1)

Each margin should be positive for acceptance. If a margin is negative, it will be necessary in the next step of the design to change the values of the parameters to bring the conditions into the acceptable design range. Determination of the quantities of parameter's change follows the "if-then" rule with confidential values.

2.4 Interface

The EWS used here is a Sun Sparc Station 1+ with Xwindow system. A CRT view as shown in Fig. 2 is an example of the input screen after "login". The necessary items and other conditions may be selected on the input. They are written on "black board" and transferred to subsequent processes.

3 APPLICATION TO FBR COMPONENTS

3.1 Description of design objects

Three components were selected to show the availability of the AI system developed. The deadweight, internal pressure, seismic load and thermal transients were considered as a design load. Design conditions are normal, upset, emergency and fault conditions. Thermal transient analyses and elastic stress analyses were performed by using MARC code[3]. The structural integrity was evaluated according to the MONJU design guide line[4]. The material was modified type 316 stainless steel which has been developed for Japanese demonstration FBR material and allowable values were referred from tentative material database[5]. Outlines of three components are as follows.

(1) Y-piece junction of hot-leg piping

This example is chosen to show the the applicability of this system to the structural discontinuity, Y-piece is employed at the junction between hot-leg piping and outershell which connect piping to roof-slab to prevent a seismic motion of piping. The analysis model is shown in Fig. 3. The design parameters are the thickness of the piping and the radius of fillet at Y-piece. The most severe stress is thermal stress caused by temperature difference between sodium in the piping and that in the reactor vessel during thermal transients.

(2) Tube-sheet shroud of Intermediate Heat Exchanger (IHX)

This example is chosen to show the applicability of this system to the specific component. There are some difficulties to make a tube-sheet to axisymmetric model due to 3-D structure and boundary conditions. Then additional know-hows are required in designing of the specific component. Equivalent material properties of the tube-sheet are defined according to ASME Sec. III Appendix A-8000[6]. Analysis model is shown in Fig. 4. The thickness of the tube-sheet is 200mm and tube-sheet efficiency $\eta = 0.21$. The design parameter is the thickness of shroud, the radius of knuckle and radius of fillet. The most severe stress is thermal stress caused by temperature difference between primary sodium and secondary sodium.

(3) Hot-leg piping

This example is chosen to show the applicability of this system to a 3D model, The analysis model is shown in Fig. 5. The reverse U-type piping system is planned to be employed in Japanese demonstration FBR. The diameter of pipe is 38 inch, and the thickness of the pipe and the height of the outer shell which connect the piping to roof-slab to prevent a seismic motion of piping are design parameters. The most severe load is thermal expansion as well as seismic load.

3.2 Result and discussion

Design windows are obtained by this system as a result of iterative design. Design windows are drawn on graphics as shown in Figs. 6-8.

Figure 6 shows the design window for Y-piece junction of the hot-leg piping. Both upper bounds and lower bounds of the design parameters are settled by the experts of designing. A relatively wide window was obtained and current design values, thickness 16mm and radius 10mm, are located at the bottom-left position of the design window.

Figure 7 shows the design window for the tube-sheet shroud of IHX. As the design window can be searched only for two parameters, two kinds of the design window are obtained. Figure 7(a) shows the design window which was searched when the thickness is fixed to be 20 mm. Figure 7(b) shows the design window which was searched when the fillet is fixed to be 80 mm. Upper bounds of three parameters are decided by significant temperature deference between perforated and adjacent solid regions under the thermal transients. Lower bounds are decided by seismic and pressure loads.

Figure 8 shows the design window for the hot-leg piping. Both upper bounds and lower bounds of the design parameters are settled values by experts of designing. A wide window was obtained and current design values, thickness 16mm and height 5550mm, are located at the bottom-left position of the design window.

The design window makes it visually and easily to find the minimum cost design at the corner of the design window.

This system is good at the purpose of rapid search of the design window and getting a minimum cost design. But the decision of the final design for the high structural integrity needs evaluations of the margins. Therefore, a next development is some techniques that can evaluate the margin in the design window.

5 CONCLUDING REMARKS

An automatic design system with the design window search technique is presented in this study. Its effectiveness is clearly demonstrated through the design of some FBR's structural components.

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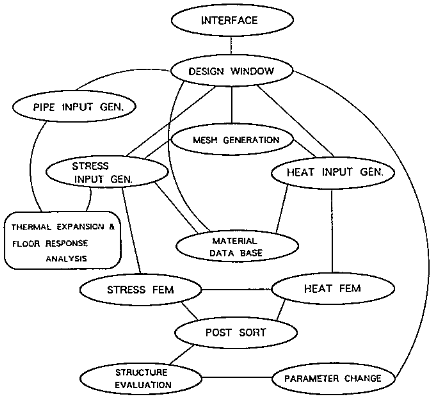


Fig. 1. Objects for Y-piece Design

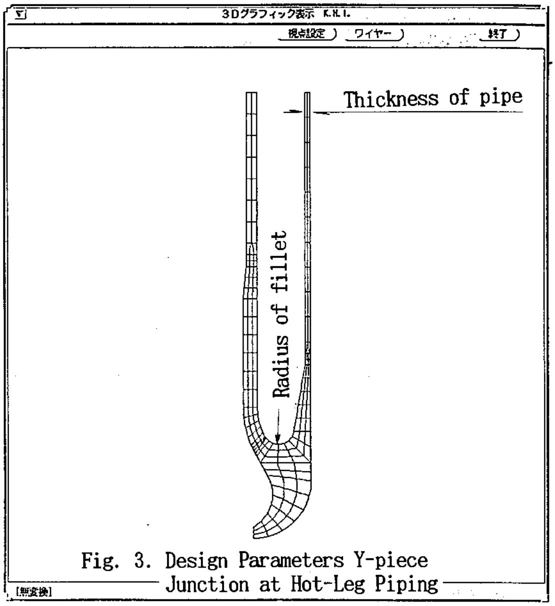


Fig. 3. Design Parameters Y-piece Junction at Hot-Leg Piping

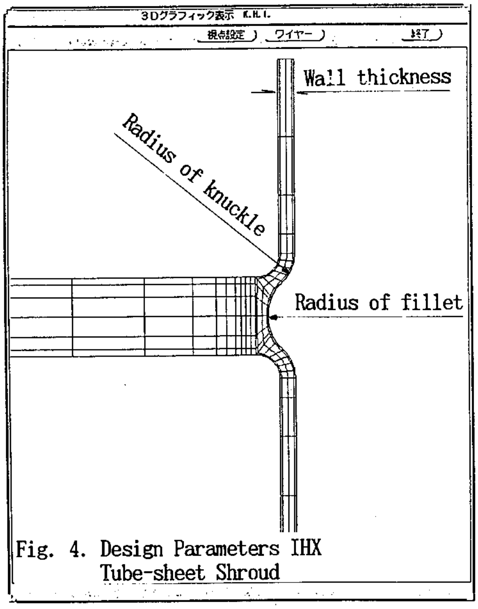


Fig. 4. Design Parameters IHX Tube-sheet Shroud

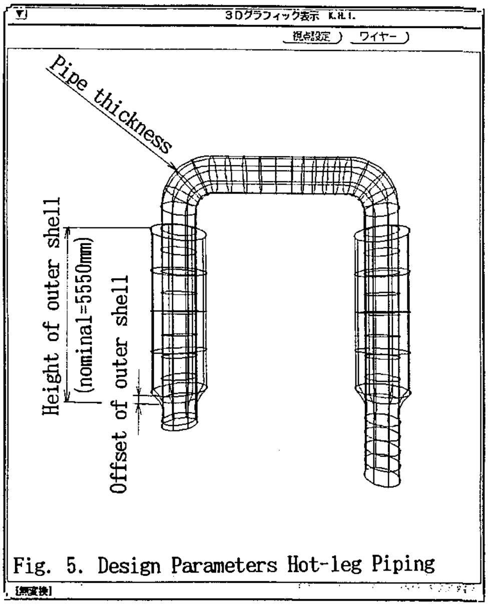
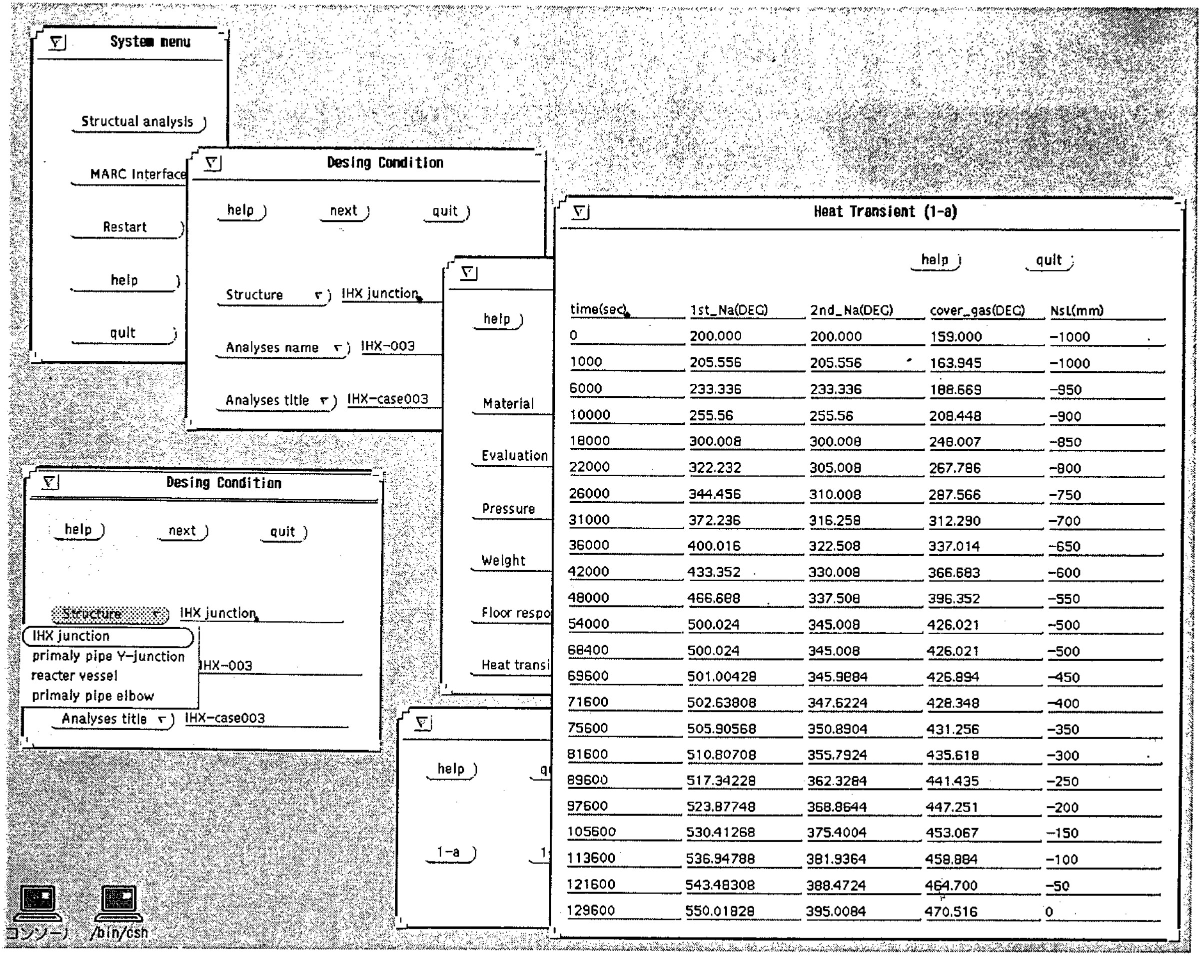


Fig. 5. Design Parameters Hot-leg Piping



time(sec)	1st_Na(DEG)	2nd_Na(DEG)	cover_gas(DEG)	NsL(mm)
0	200.000	200.000	159.000	-1000
1000	205.556	205.556	163.945	-1000
6000	233.336	233.336	188.669	-950
10000	255.56	255.56	208.448	-900
18000	300.008	300.008	248.007	-850
22000	322.232	305.008	267.786	-800
26000	344.456	310.008	287.566	-750
31000	372.236	316.258	312.290	-700
36000	400.016	322.508	337.014	-650
42000	433.352	330.008	366.683	-600
48000	466.688	337.508	396.352	-550
54000	500.024	345.008	426.021	-500
68400	500.024	345.008	426.021	-500
69600	501.00428	345.9884	426.894	-450
71600	502.63808	347.6224	428.348	-400
75600	505.90568	350.8904	431.256	-350
81600	510.80708	355.7924	435.618	-300
89600	517.34228	362.3284	441.435	-250
97600	523.87748	368.8644	447.251	-200
105600	530.41268	375.4004	453.067	-150
113600	536.94788	381.9364	458.884	-100
121600	543.48308	388.4724	464.700	-50
129600	550.01828	395.0084	470.516	0

Fig. 2. CRT View for Selection and Input Data

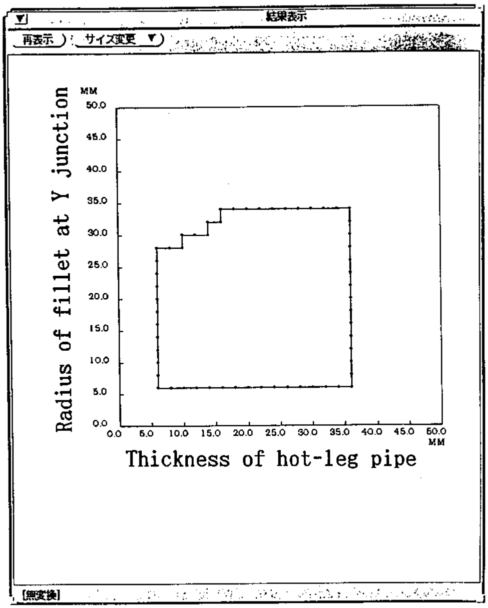


FIg. 6. Design Window Y-piece Junction

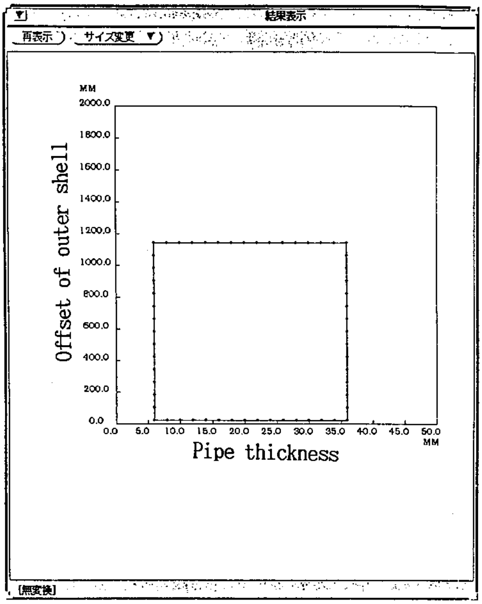
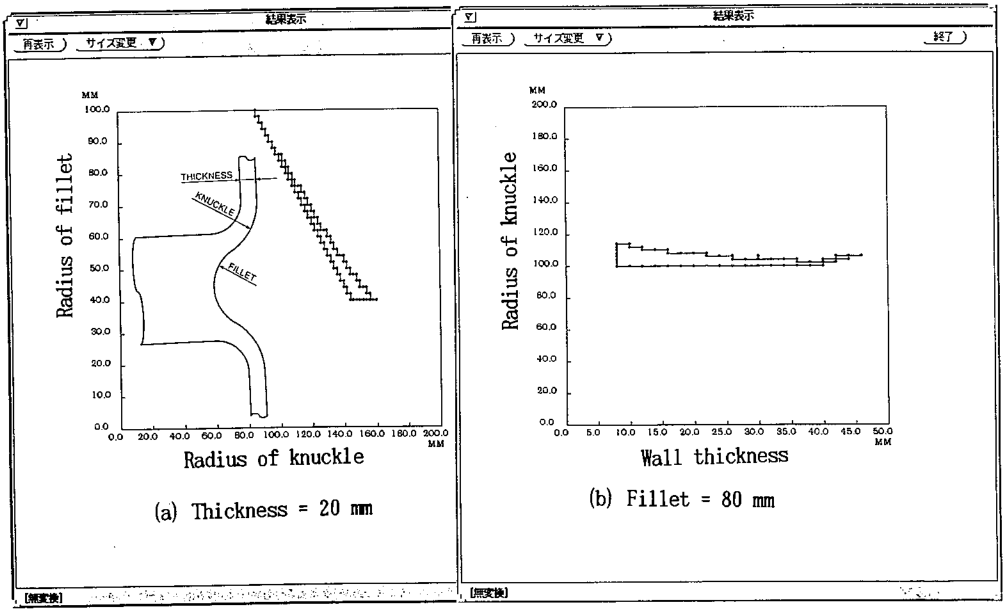


Fig. 8. Design Window for Hot-leg Piping



(a) Thickness = 20 mm

(b) Fillet = 80 mm

Fig. 7. Design Windows for IHX Shroud