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A METHODOLOGY OF STRUCTURAL ANALYSIS FOR NUCLEAR POWER PLANT SIZE OF ASSEMBLY

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ABSTRACT

The quakeproof analysis for an assembly structure such as a nuclear power plant should not be cal culated as a piece of structure as existed structural analyses as do so, because of heterogeneity of each part in the functionality, which relates to the boundary condition. It has been well used the sp ring-mass model, supper element method, and substructure method to analyze an entire structure t aking in account of the heterogeneity and computational efficiency. As well known that nuclear po wer plant consists of over ten million detailed parts, it takes lots of computational resources such a s memory, disk space, and computational power to carry out its analysis. Even only 1 MB memory and disk per a part would lead to at least 100 GB up to 10 TB total memory and disk requirements for the total model assembled all the parts. In order to achieve the assembly structure analysis, it i s to give an efficient performance method, a treatable data handling method, and taking account th e heterogeneity of each part in the functionality. The proposed method is to treat a power plant size assembly with its components. The components are handled by one by one to reduce the size of d ata at a operation, and to concern heterogeneity of each part. The computation is carried out on gri d computing since any single computer can not calculate the size of assembly at this time. A nume rical experiment was carried out using actual nuclear power plant of JAEA, and successfully obtai ned the result.

Key Words: Assemble structure, Structural analysis, Finite element analysis, Grid computing, High performance computing

1. INTRODUCTION

It is proposed a methodology of structural analysis for nuclear plant size of assembled structures to estimate (1) the behavior by taking account of heterogeneity condition in assembly structures, (2) what could be happened among the connected parts, and (3) the multi dynamic behaviors in assembly. A part of the first approach is introduced in this paper so named FIESTA, Finite Element Structural Analysis for Assembly for structural analysis of nuclear power plant size of assembly. FIESTA is executed on the computers connected with networking in continuous processing space [1]such as grid computing environment to distribute the computational load by giving each part data to distributed parallel computers [2][3][4][5]. The verification was carried out for JAEA(Japan Atomic Energy Agency)'s High Temperature Thermal Reactor (HTTR) plant data [6], which consist of approximately 2000 functional parts. The objected finite element model is 250 million tetrahedrons in 20 GB memory space. The result data was successfully obtained with 2.3TB disk space. The chronicle data are visualized by developing a parallel support toolkit on the grid computing environment [7].

A methodology of structural analysis for assembly by taking account of heterogeneous condition is to treat the assembly by parts. To solve the complex structure, each part should be analyzed under heterogeneous condition, otherwise, part needs to be solved under each own necessary condition. For connected parts, parts may be connected by fasten bolts, means giving certain loads and constraints, to be solved in assembly. In order to manage heterogeneity condition in assembled structures, the method needs to treat the structure as part by part. The assembly is treated to provide boundary condition data for its parts. By preparing the input data one by one for analysis, and gathering ones, the complex object is easily generated and practically solved in distributed circumstance. FIESTA computes each part data in parallel computing, one by one, on the distributed computers to concerns functionality of part. Each part solved in distributed computers gathers to be assembling as a structure. It is introduced a mesh connection algorithm for different mesh density among parts, since part-wised mesh generation was carried out. Five algorithms are selected and modified for FIESTA. They are based on well known technology as penalty method, free mesh method, Lagrange method, h-method, r-method, and h- & r-method.

The grid computing environment used in FIESTA's verification is so-named AEGIS, Atomic Energy Grid Infrastructure, which was based on ITBL [4], Information Technology Based Laboratory conducted by MEXT, Ministry of Education, Cultures, Sports, Science and Technology of Japan as one of the national project, e-Japan. ITBL is operated as an national grid infrastructure with over one thousand users from 72 organization of academic, institutional, industrial sections with 12 super computers manufactured by Cray, Fujitsu, Hitachi, HP, IBM, NEC, and SGI, since May, 2000. The reason why ITBL was ready to operated at the start of the p roject is that ITBL's grid computing functions were utilized the STA, Seamless Thinking Aid [2]. AEGIS is a grid computing environment of JAEA, which connects super computers located in multiple sites, such as Altix3700 by SGI, PrimePower by Fujitsu, SX-6 by NEC, pS-690 by IBM, SR8000 by Hitachi, and so on. AEGIS perfectly features grid function such as MPI tool, RPC tool, scheduling, PSE, video meeting, file sharing and so on.

2. CONCEPTUAL DESIGN OF STRUCTURAL ANALYSIS FOR NUCLEAR POWER PLANT SIZE OF ASSEMBLY STRUCTURE

In any design and production, it is necessary to carry out experimental process, testify process and quality assurance process. It has been started in 1950's that the design and manufacturing pro cesses are computerized to automate them most likely to improve their efficiency [8]. In order to improve the quality of designing and manufacturing, a concept of CAD/CAM/CAE/CIM have been proposed with the idea of introducing information technology such as computational science and engineering to the conventional design methodology. The idea of the digital space science and engineering is based on the way of CAD/CAM/CAE/CIM, but it is emphasized on very large scale integrated computational analysis. The digital space science and engineering is to utilize experimental facilities in computational space, so named digital experimental facilities.

2.1. Digital Space Science and Engineering

The digital space science and engineering is to emulate and simulate the objective experiment in real size under actual condition, operational circumstance, and chronicle. Also, the natural circumstance such as temperature, earthquake, and so on, are concerned for the behavior of facilities in use, but not the research issues in the digital space science and engineering, which are to be introduced by earth researchers and their related. The digital space science and engineering is implemented on the grid computing environment, AEGIS by utilizing the information technology environment of AEGIS such as functional complex of data sharing, visualization, data-mining, problem solving environment, etc., as illustrated in Figure 1. Examples of the digital space science and engineering environment are vibration table and critical experiment facility in digital space.

In order to accomplish the digital space science and engineering environment, the synchronicity is required to AEGIS under its functional complex. Although the delay is always happened in communication, on calculation, at saving in the actual processing, but the I/O condition must synchronize among functions that mean not scheduling, but the management and controlling of application's requirement, which is required to grid computing processing. It is inquired for the computer environment of the digital space science and engineering to reserve on going calculated data and recall the calculated data when the application requests. Since the application must know what data is now sleeping and to be awaken, it needed to have a permission to talk among modules. This kind of management and controlling function should be provided as an application interface of the computer environment for the digital space science and engineering.

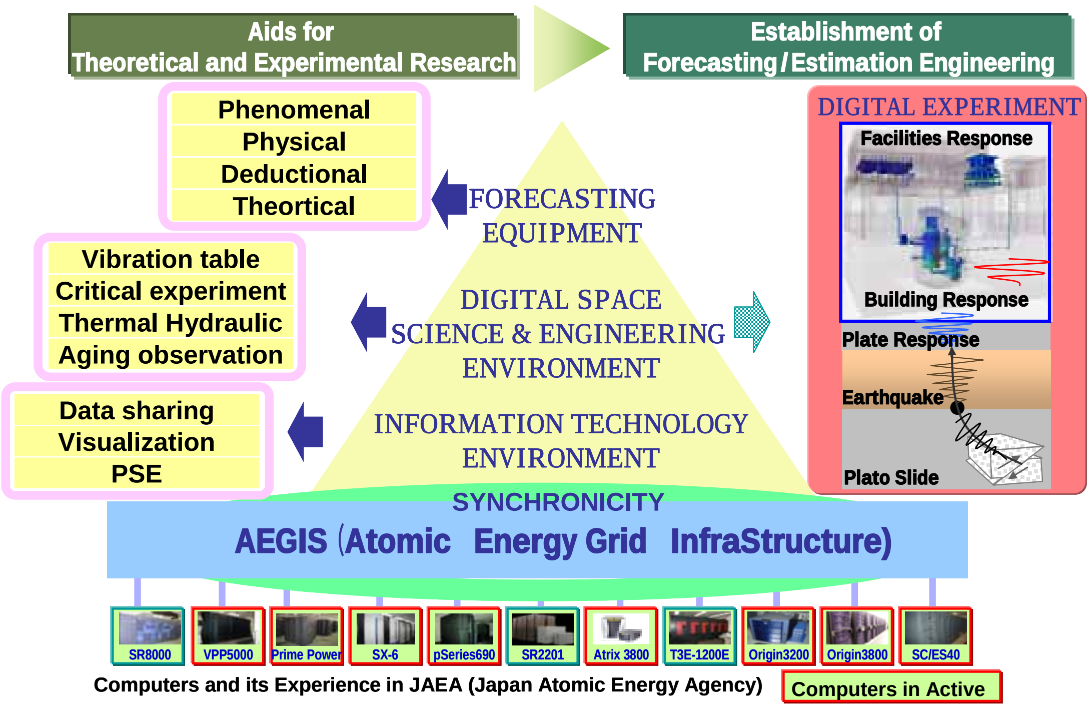
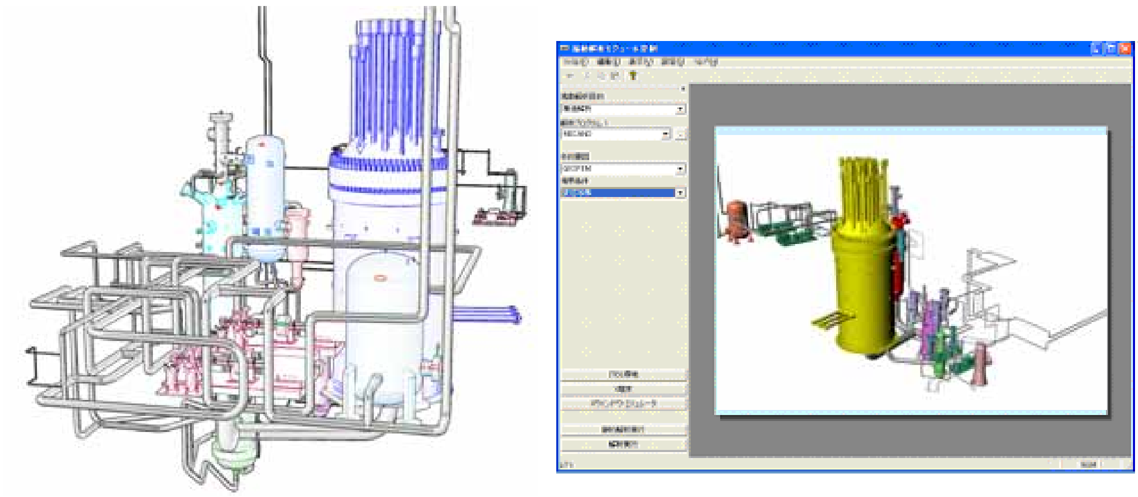


Figure 1. Digital space science and engineering

2.2. Digital Vibration Table for Nuclear Power Plant

Digital vibration table for a nuclear power plant is one of digital experimental facilities, and shakes the entire digital plant to evaluate the quake-proof structure [9]. The Figure 1 of right side pictures HTTR system in its building was shaken by an earthquake. Every part of HTTR is digitalized like Figure 2, and the controller panel to operate the digital vibration table defines the parameter necessary, which are type of earthquake, operational conditions, assembly parts, and analysis method. The digital vibration table requires to compute actual size of plants under actual condition, operational circumstance, and natural circumstance with any kind of earthquake, chronically.



(1) Digitalized Plant, HTTR **(2) Control Panels of Vibration Table**

Figure 2. Digital Vibration Table for Nuclear Power Plant

3. SPECIFIC DESCRIPTION OF STRUCTURAL ANALYSIS FOR NUCLEAR POWER PLANT SIZE OF ASSEMBLY STRUCTURE

ASA(pronounced as ‘A-Sir’, is a name of folk dance in southern island of Japan, Okinawa), Assembled Structure Analysis is a conceptual method applied to the digital vibration table for nuclear power plant. The ASA system’s configuration is imaged in Figure 3. In order to implement the digital vibration table for nuclear power plant, it is necessary to utilize many emulation and simulation method. Indeed, as it is shown in Figure 2 on control panel of a nuclear power plant, its components are gathered to be give functions like most mechanical products are the assembly structures. Except very simple products, no products are consisted of only a part; otherwise products are composed by parts and not uniform structure.

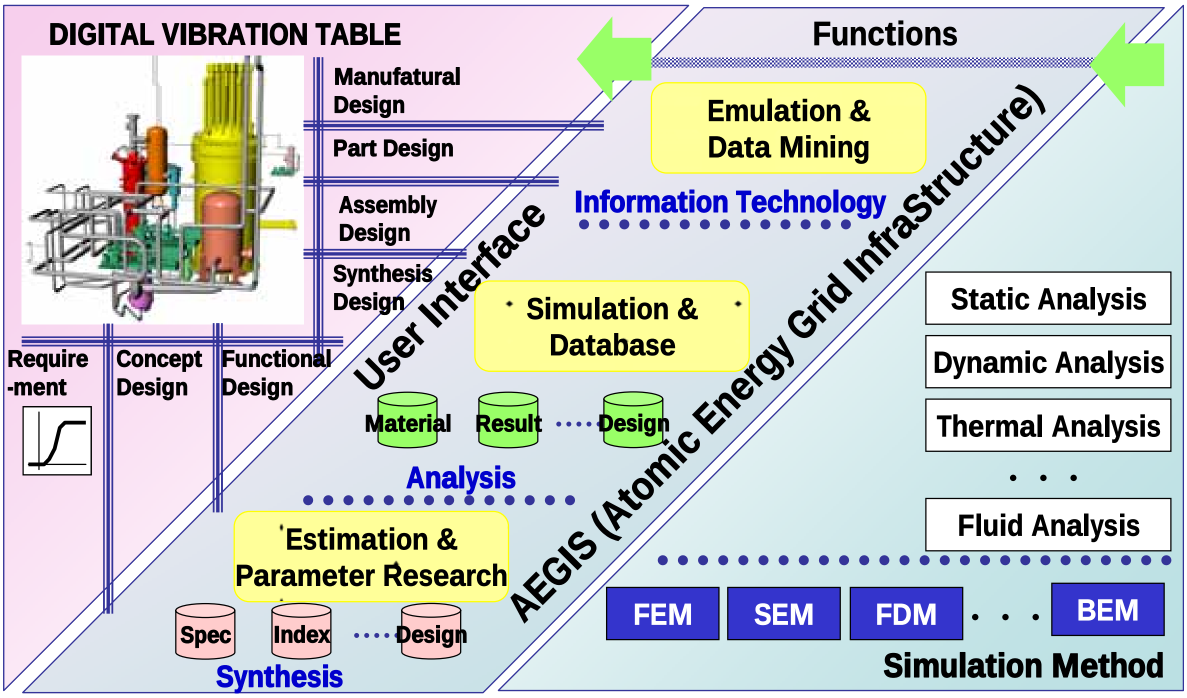


Figure 3. Design by ASA : Assembled Structure Analysis System

It has been modeled an assembly structure as uniform structure to analyze by Finite Element Analysis (herein after abbreviates as FEA) [10], and it gave a reliable understanding to the behavior in macroscopic view point. The assembly structural analysis considers the structural behavior in detail, and to give boundary conditions when a part is needed to analyze. Figure 4 shows an example of assembled structure analysis, which tells the differences the stress distribution whether the uniform analysis or assembly analysis. ASA performs one to other analysis by translating the calculation result to other’s input. A coupling analysis among parts is one of way to achieve assembly analysis. ASA is the main function of digital vibration table, and the table utilizes any simulation method useful to satisfy the requirement. The first step of implementation in ASA method is to realize FIESTA.

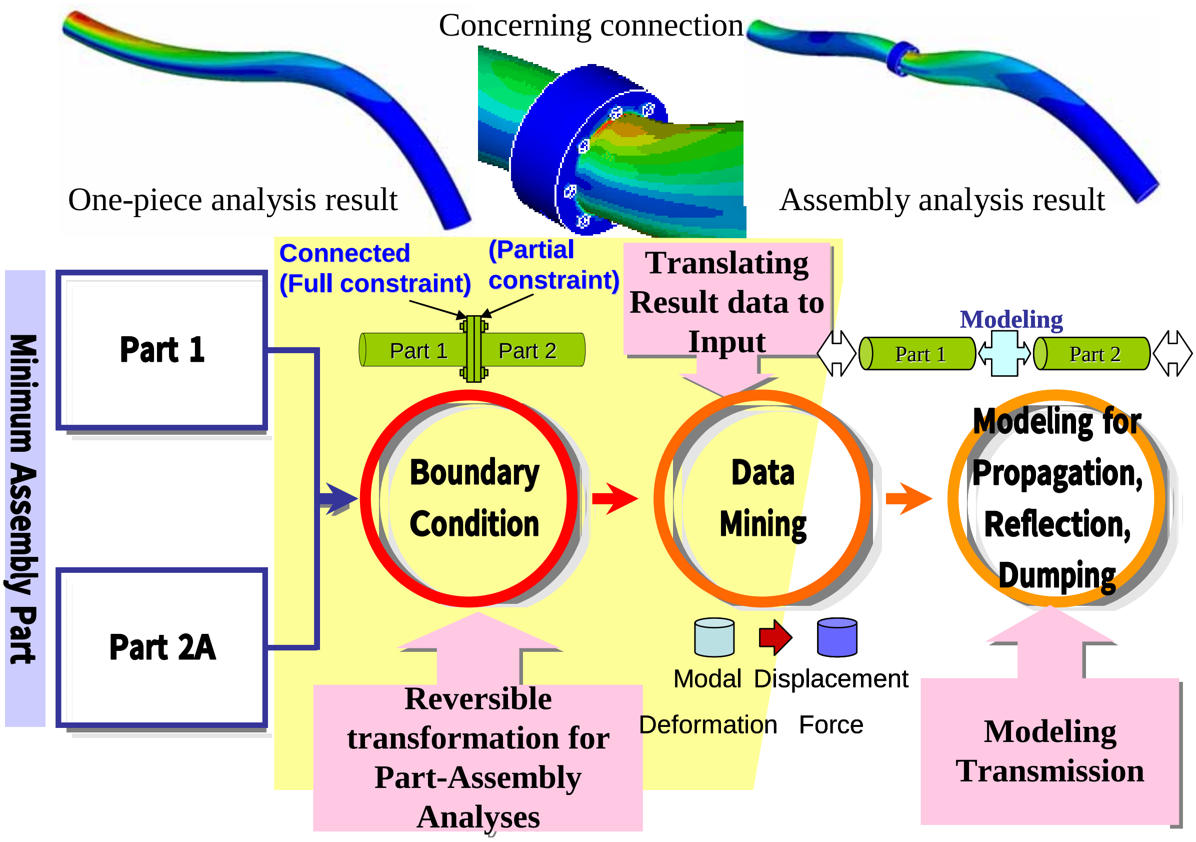


Figure 4. An Example of Assembled Structure Analysis

3.1. FIESTA: Finite Element Structural Analysis for Assembly

FIESTA [11] has two steps to accomplish its functionality. FIESTA is going forward to previous part analysis to synthesis analysis. The first aim of FIEST is to prove the assembly analysis by the part connection. In Figure 5, three parts are connected in a simple beam structure, though in this case there is no need to analyze as an assembly. Three parts modeling gives an easy operation and creation of input data preparation for an analysis. The second aim is to show why assembly is necessary for the synthesis. The right side picture of Figure 5 shows three parts has each objective such as static, elasto-plastic, and response analysis. In order to analyze three kinds of analysis, otherwise letting three meaningful, the boundary condition for the analysis of the product must be given by the design specification, which is described by the requirement of the product. The designer and analyst put assumptions to translate the requirement and specification to the boundary condition. FIESTA aims to introduce the boundary condition for each part by analyzing the entire, assembly.

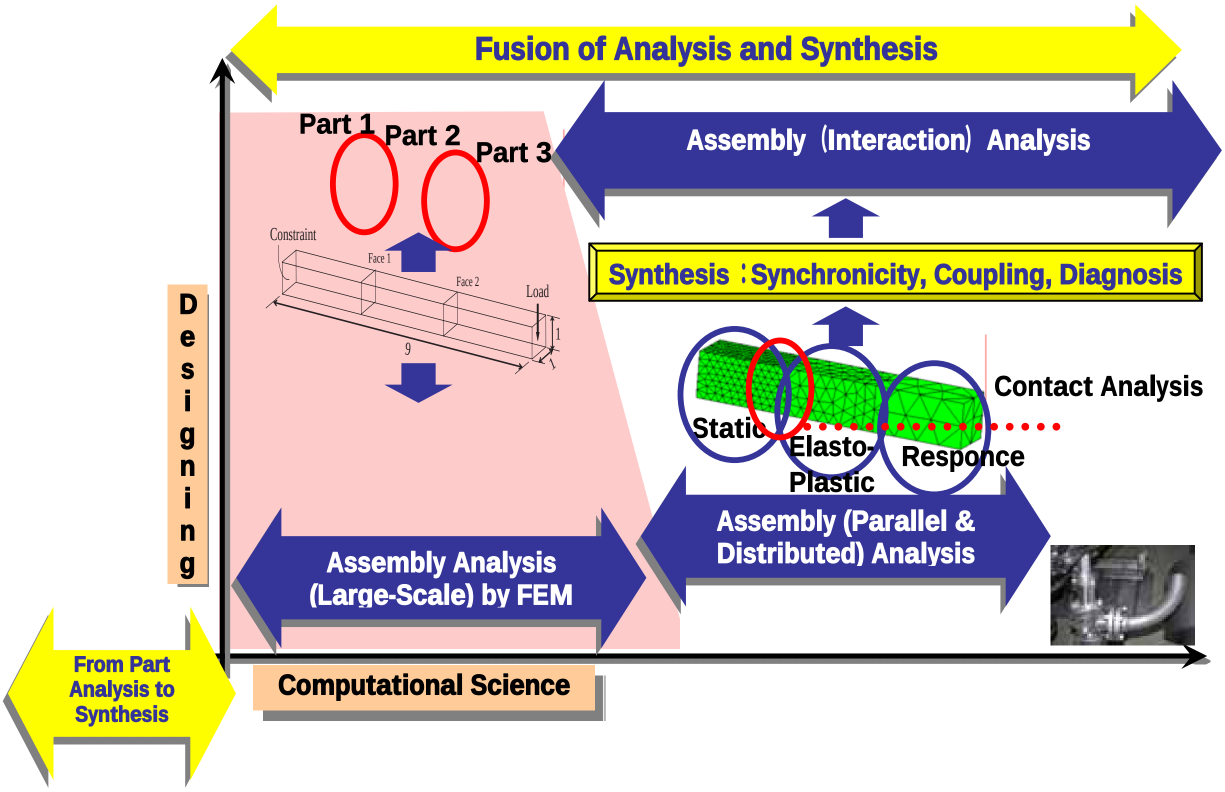


Figure 5. Two Objectives of FIESTA's Achievement

Figure 6 gives a comparison among uniform and assembly structural analysis. The advantage in handling data for preparation and evaluation is for assembly method, but the interconnection among parts in assembly is not recognized. The methodology of the interconnection among parts in assembly is introduced to the next section.

FIESTA proceeds the distributed computing and parallel computing as shown in Figure 7. The part data is prepared individually with neglecting adjustment between the part boundaries, but the mesh density of a part is generated with design intention. Every part of mesh data is gathers to determine the share boundaries among parts, and parts data are distinguished in shared boundary nodes and elements, and parts own data. The own part data are treated by domain decomposed method to process in parallel computing. For the distributed computing, each part data is placed on the grid computing environment by taking into account of the computer resources, load balance in computers, size of part data, and size of shared boundaries data.

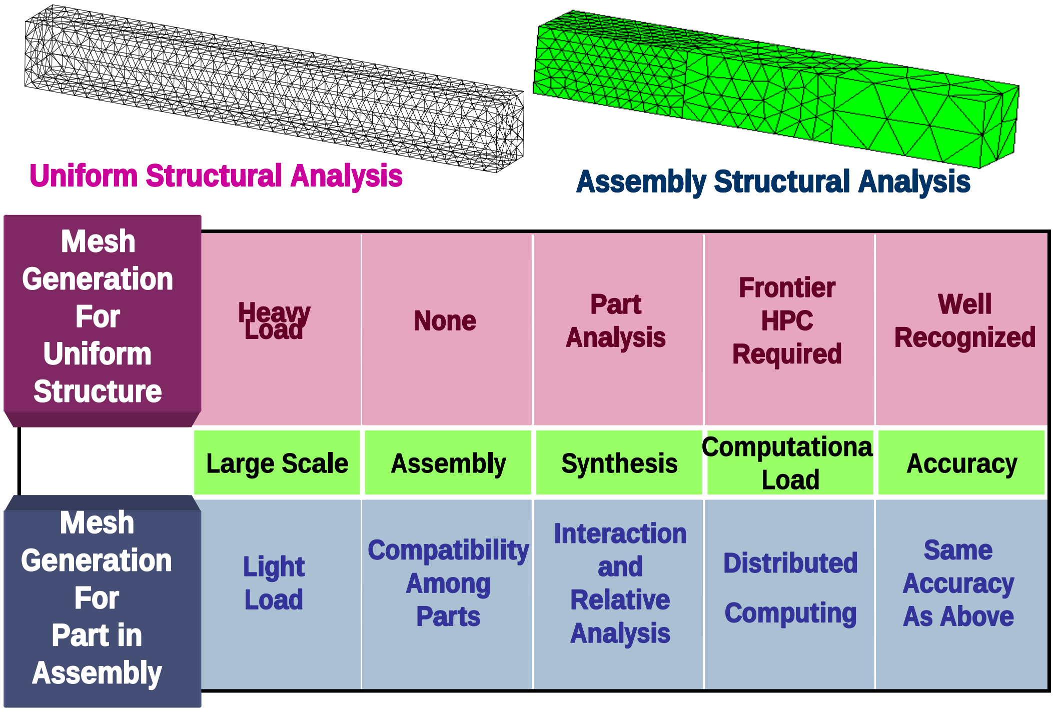


Figure 6. Comparison of Uniform Vs. Assembly Analysis

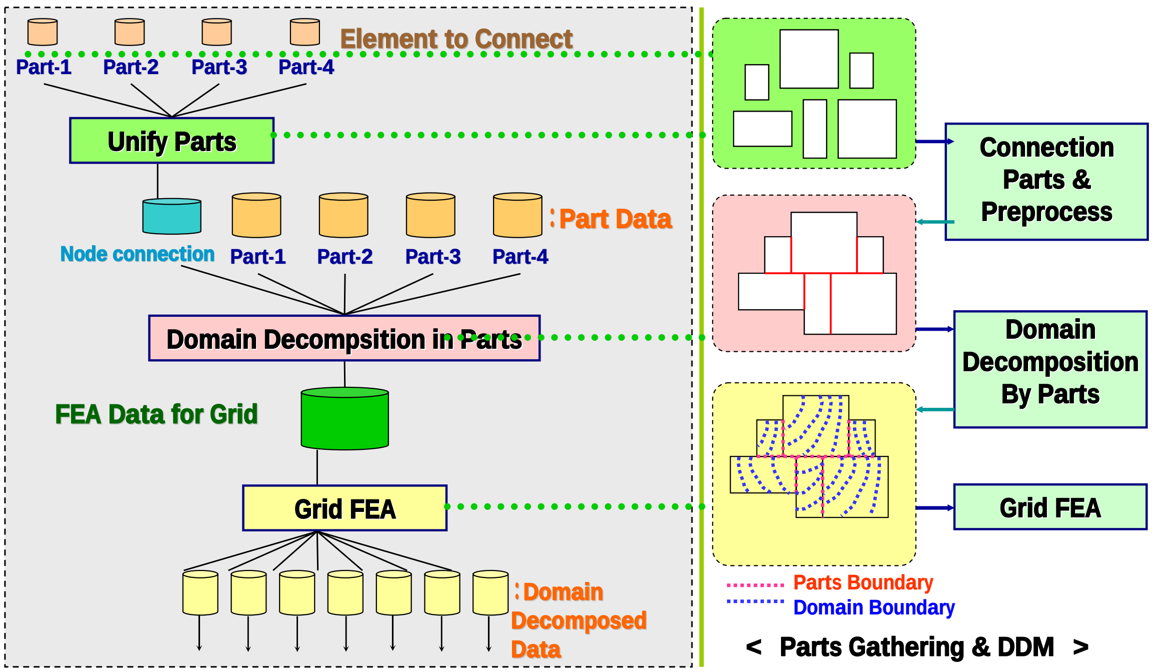


Figure7. Procedure of Assembly Analysis in FIESTA

3.2. Part interconnection

At the first aim of FIESTA, FIESTA computes each part data of an assembly in parallel computing, one by one, on the distributed computers to concerns functionality of part. Each part solved in distributed computers gathers to be assembling as a structure. It is introduced a mesh connection algorithm for different mesh size among parts, since part-wised mesh generation was carried out. Five algorithms are selected and modified for FIESTA. They are based on well known technology as penalty method, free mesh method, lagrange method, h-method, r-method, and h- & r-method as listed in Figure 7. In FIESTA, free mesh method is recommended if same accuracy is wished as same as the uniform structural analysis, since free mesh method is said to prove non-dependable for mesh generation, which means accuracy is well conditioned [12]. The penalty method was first applied to the part connection with obtaining practical result, but computational efficiency for plant size of large scale calculation.

In assembly of FIESTA, the part connection is investigated with the penalty method, because of its conditioning of mesh connection. It ought to be conditioned at the interface of connection part whether loosen, infinitesimally sliding, or bending. The connection by the penalty method is in the second aim of assembly analysis of FIESTA.

		Parallel & Distributed Computing	Efficiency	Operation	Inter-Action concerning
	Uniform Analysis	△	○	○	−
Assembly Analysis	Penalty	○	△	△	○
	Iteration	△	△	○	△
	Lagurange	○	△	△	△
	Mesh Free	△	○	○	△
	Interpolation (h, r, h-r)	○	○	○	○

Figure8. Interconnection Method Among Parts

4. A PROTOTYPE EXPERIMENT OF STRUCTURAL ANALYSIS FOR NUCLEAR POWER PLANT SIZE OF ASSEMBLY STRUCTURE

HTTR is digitalized with every part to be assembled entire plant. Figure illustrates a list of parts.

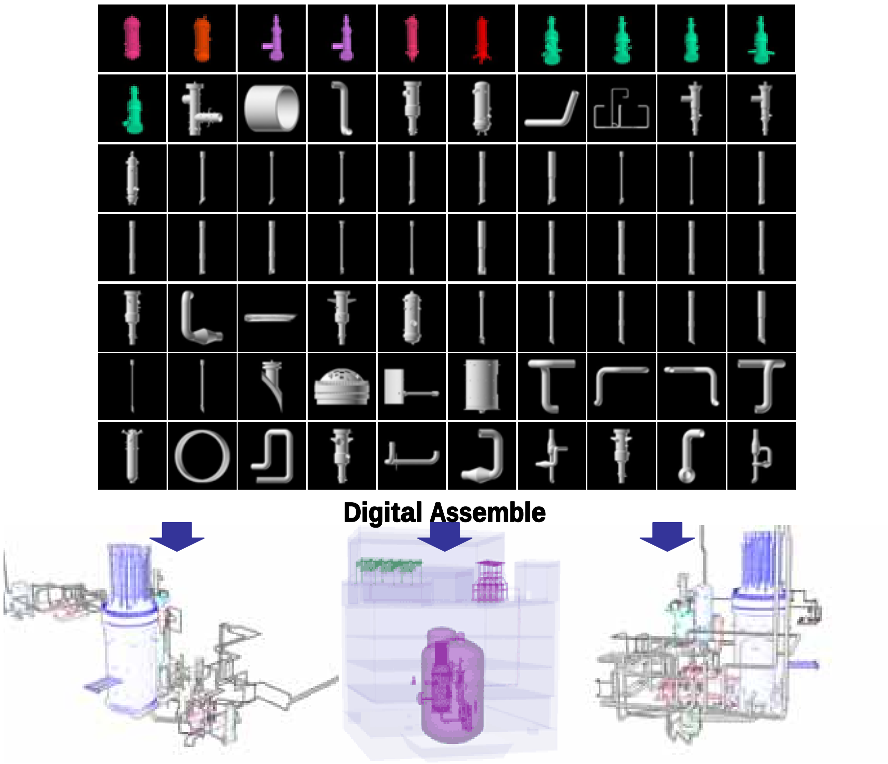


Figure 9. Digital Vibration Table for Nuclear Power Plant

The experiment was carried out simple ones can be referred by theory to actual plant size data. Figure 11 and 12 shows the result of two cases of typical plant size data. One is by a statically, and other is dynamic simulation. Both actual models are calculated and examined.

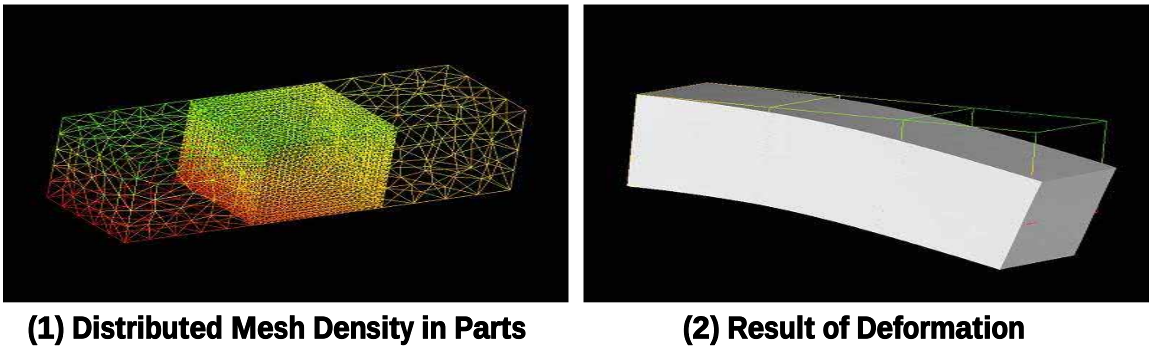


Figure 10. Validation Example of Part Connection in Assembly

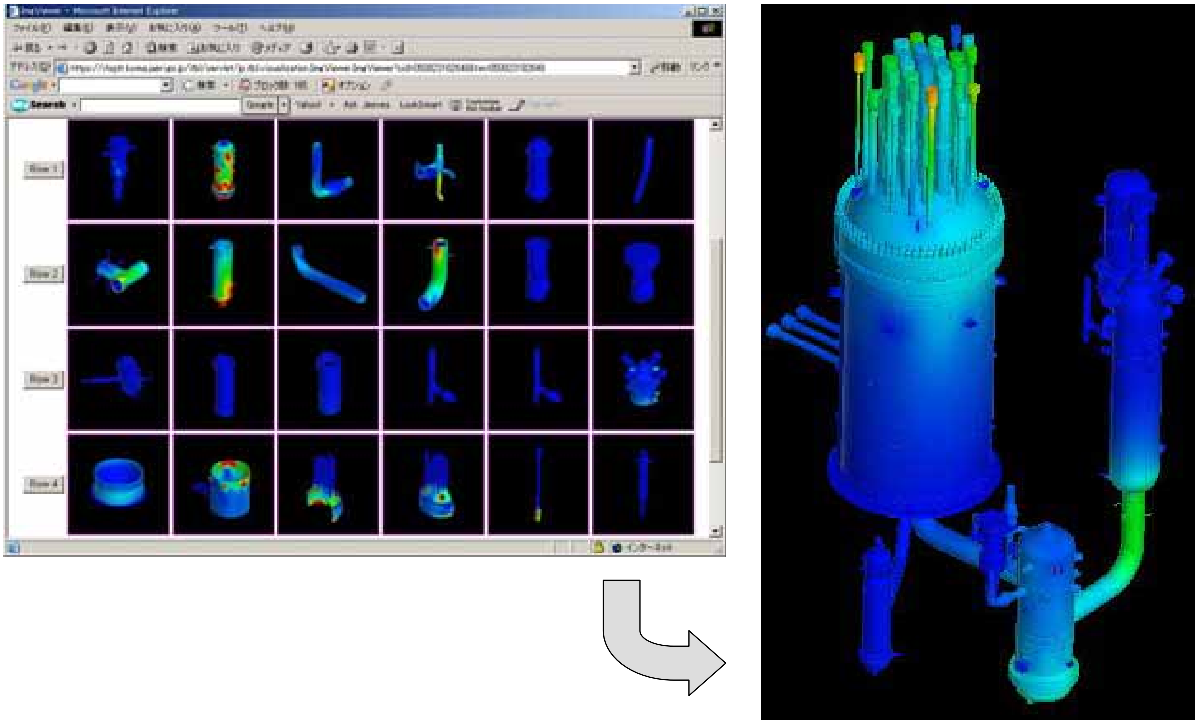


Figure 11. Static Analysis for Assembly Structure

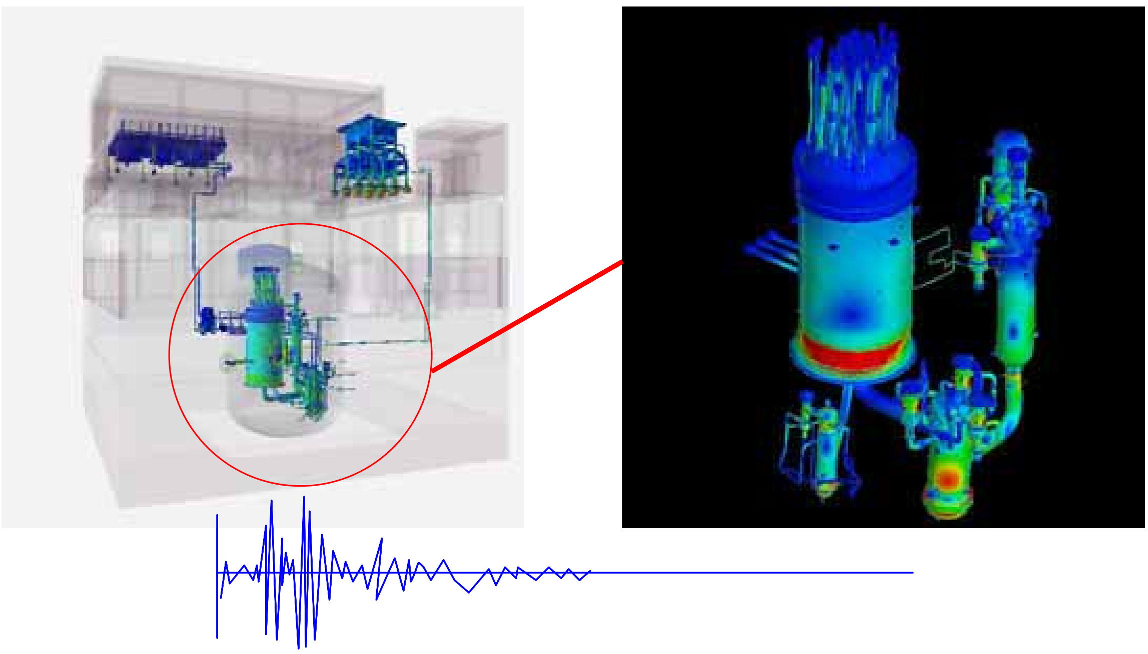


Figure 12. Dynamic Analysis for Assembly Structure

5. CONCLUSIONS

A concept of Assemble Structural Analysis (ASA) is introduced to the digital vibration table for nuclear power plant as a part of digital space science and engineering. As one of a methodology of ASA to analyze assembly structure, Finite Element Structural Analysis for Assembly (FIEST A) is proposed to analyze the structural behavior of nuclear power plant. The methodology of FI ESTA has introduced the way it implements and it demonstrated with numerical experiments to function. FIESTA proved the part connection computing can be calculated with same accuracy as finite element analysis for uniform structure. FIESTA proceeds on grid computing environment, AEGIS (Atomic Energy Grid Infrasturucture), and gave a requirement to improve its efficiency.

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