An Automation of Fatigue Durability Analysis for Welded Bogie Frame Using System Integration Techniques

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Abstract: - A web based automation of fatigue durability analysis for a welded bogie frame of railway vehicle is realized with several kinds of system integration techniques. The macro program of I-DEAS, the APDL of ANSYS, and an in-house fatigue code are utilized for the parametric geometry modeling and automatic generation of finite element models, the static stress analysis, the fatigue durability analysis, respectively. A multi-agent based engineering framework is implemented on the JADE to integrate the overall process. All engineering programs are integrated by a XML based wrapper. A database to contain engineering data and web based user interfaces are also developed. A parametric study is carried out to take into account the effect of geometrical change of transom support brackets on its fatigue durability. Developed automation techniques reduce remarkably the time and costs required in the fatigue durability analysis.

Key-Words: - Fatigue durability analysis, Welded bogie frame, Automation, System integration, Multi-agent, Wrapper, Hot-spot stress,

1 Introduction

A bogie frame of railway vehicles plays an important role in sustaining the static load from the dead weight of a car body. Quasi-static loads occur periodically during curving and braking operations, and cyclic dynamic loads are caused by an irregular rail surface and relative movement of the attached equipment. Since the majority of the bogie frame is a welded structure which is very susceptible to the fatigue failure under such loads, a fatigue durability analysis to ensure the sufficient fatigue strength of its weldments is a relevant issue.

In practice, meanwhile, frequent geometric changes are required in early stages of the design process and the sharing of design parameters should be performed between sub tasks and in the overall process for the fatigue durability analysis. In spite of these necessities, these kinds of works can not be performed due to the lack of automation techniques for the required analysis.

In this paper, an automation of fatigue durability analysis for the weld bogie frame of railway vehicles is realized. The weld bogie frame is developed by the Korean Rotem Company, as shown in Fig.1. The parametric geometry modeling and automatic generation of finite element models, the static stress analysis, and the fatigue durability analysis are organized using the macro program of I-DEAS, the APDL of ANSYS, and a BFAP (Bogie Fatigue Analysis Program), respectively. The BFAP [1] is an in-house program using a nominal and hot-spot stress concept to assess the cumulative fatigue damage according to the UIC Code 615-4 [2]. After analyzing the conventional manual process as shown in Fig.2, a new automated process is proposed.

The multi-agent system (MAS) has shown many advantages to use distributed hardware and software resources. We had developed a multi-agent based engineering framework [3~4] with the National Research Council Canada's Integrated Manufacturing Technologies Institute (NRC-IMTI) and a new multi-layered framework to consider a function of multi-user and multi-job [5].

The multi-agent based engineering framework manages the overall process and integrates sub tasks composed of the fatigue durability analysis.

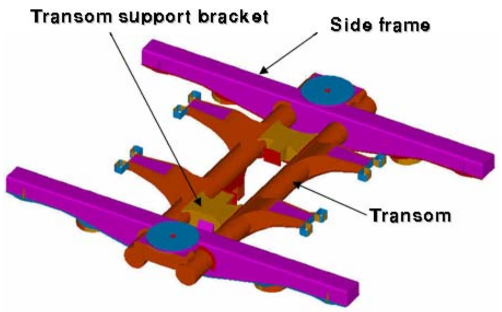

Fig.1. Welded bogie frame of railway vehicles.

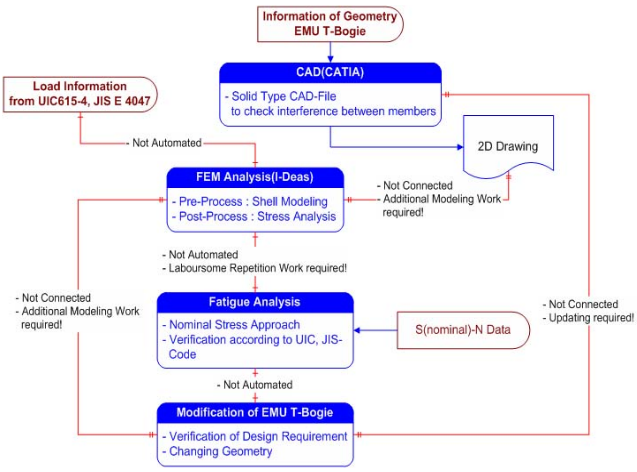

Fig.2. Conventional manual process for fatigue durability analysis.

2 Architecture of overall system

The architecture of the overall system for the automation and parametric study for the fatigue durability analysis is shown in Fig.3. A multi-agent based engineering framework manages the overall process and integrates sub tasks for fatigue durability analysis. It also uses distributed resources dynamically. This framework is based on the JADE (Java Agent DEvelopment) platform to satisfy the standard specification of the FIPA (Foundation for Intelligent Physical Agent) and composed as follows: the Interface Agent and the Monitoring Agent to generate data for displaying of Applet/JSP pages; the Job Management Agent and the Engineering Server Agent to manage engineering jobs; the Problem Solving Agents to manage an engineering task. XML based Problem Solving Wrappers are developed to use several kinds of traditional engineering programs without extra modifications of input files. Web pages based on Applet/JSP for user interfaces, Servlet controllers to manage HTTP requests and responses are also realized. The system requirement is listed in Table 1.

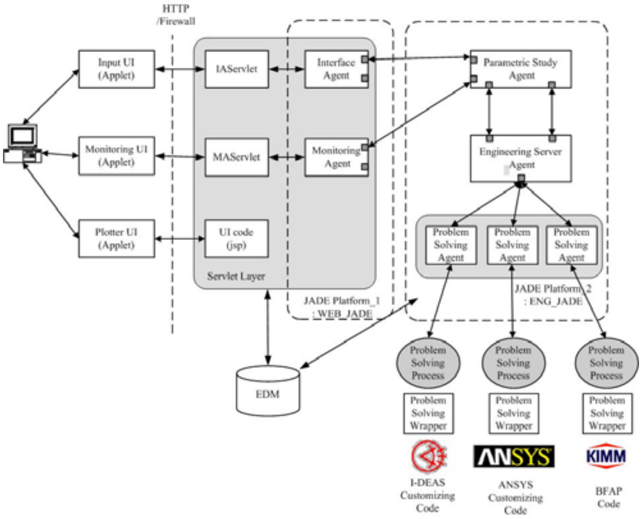

Fig.3. Architecture of overall system.

Table 1. System requirement.

Operating system	Windows 2000/XP, Linux 9.0
Development language	JDK 1.4.2
Agent middleware	JADE 3.3
Web server	Apache 2.0
JSP/Servlet engine	Tomcat 5.0
DBMS	MySQL 4.0
CAD & Pre-processor	I-DEAS 9.0
Stress analysis	ANSYS 9.0
Fatigue analysis	BFAP 1.0

3 Detailed implementation

3.1 Web based data management and user interface

Whole engineering data are managed through the EDM (Engineering Data Management) as three entities; i.e. project, job, and task. Table 2 explains entities in detail.

With the log-in system, a user can see project and job lists and Applet/JSP based web pages to input design parameters as shown in Fig.4. The distance between two transom support brackets, the weight of passengers, the weight of empty vehicle, and the weight of bogie frame, the number of bogie frame installed per a car body, and elastic constants of primary suspension are selected as design parameters.

Table 2. Entities for data management.

Project	The classification of two projects depends on what kind of stress is considered as representative stress to assess the cumulative fatigue damage. BogieNominal: Nominal stress. BogieHotSpot: Hot-spot stress.
Job	The job is an entity executed with specified design parameters corresponding to each project and has its own unique serial number to be managed. Example) JOB_20051111175155.
Task	The task is a sub process to execute a job. The BogieNominal and the BogieHotSpot are composed of four tasks and five tasks, respectively. BogieNominal: NominalIDEAS → NominalANSYS → NominalPost → NominalBFAP. BogieHotSpot: HotSpotIDEAS → HotSpotANSYS → HotSpotPost → HotSpotSLSFitting → HotSpotBFAP.

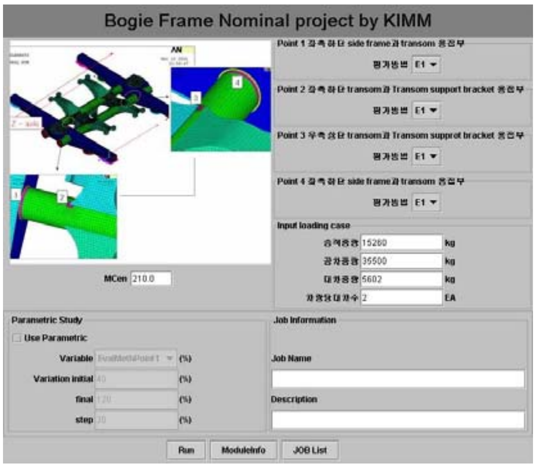

Fig.4. Web page to input design parameters.

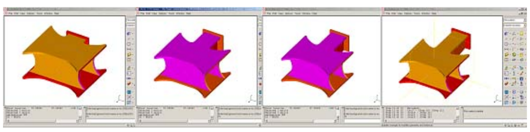

Fig.5. Change of geometry due to the location of transom support bracket.

3.2 Process of BogieNominal project

This project consists of four tasks, i.e. NominalIDEAS, NominalANSYS, NominalPost, and NominalBFAP as explained in Table 2.

3.2.1 NominalIDEAS task

In the NominalIDEAS task, the macro program of I-DEAS is used to change the location and geometrical shape of transom support bracket, to designate positions for imposing loading and boundary conditions parametrically, and to make finite element models for ANSYS automatically. The change of geometry due to the location of transom support brackets and the automatic process by the macro program are shown in Fig.5 and 6, respectively. Anchor nodes are imposed to control the position of resulting nodes and to get stress values at specified locations. The four positions, i.e. the left bottom of welded zone between side frame and transom (position 1), the left bottom of welded zone between transom and transom support bracket (position 2), the right top of welded zone between transom and transom support bracket (position 3), and the right top of welded zone between side frame and transom (position 4) are selected to evaluate each cumulative fatigue damage as shown in Fig.7.

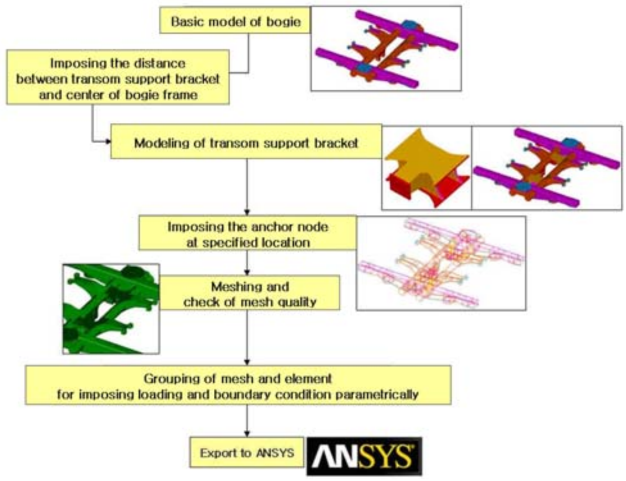

Fig.6. Automated process by the macro-program of I-DEAS.

3.2.2 NominalANSYS task

In the NominalANSYS task, the APDL (ANSYS Parametric Design Language) is used to add springs and rigid body beams to the finite element model made in NominalIDEAS. Additionally, it performs the grouping of nodes and elements for the automatic generation of finite element models; defines material properties and thickness of shell elements; performs 36 cases of static stress analysis in accordance with the UIC Code 615-4 [2]; and extracts values of maximum and minimum principal stresses and corresponding directional cosines from output files automatically. Two input files based on the APDL (input.txt, modeling.txt) are used to automate the overall process as shown in Fig.8. Load components consist of two vertical loads (Fy1, Fy2) on secondary suspensions, two lateral loads (Fz1, Fz2) on the transom support bracket, and twist loads (Ty) on the axles diagonally as shown in Fig.9.

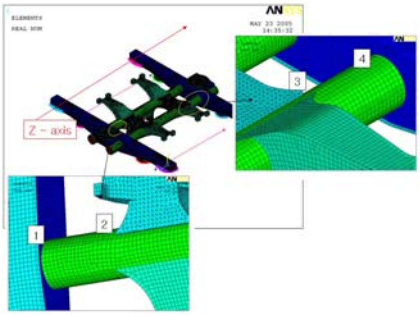

Fig.7. Positions to evaluate cumulative fatigue damages.

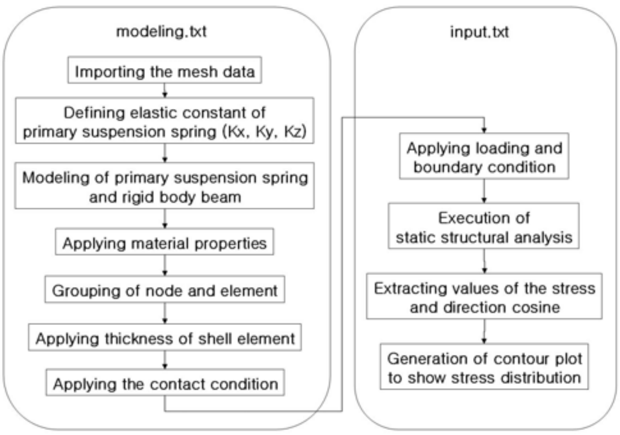

Fig.8. Automated process by the APDL with two input files.

3.2.3 NominalPost task

The NominalPost task converts extracted values, such as maximum and minimum principal stresses and corresponding directional cosines, into specified input data for the NominalBFAP task.

3.2.4 NominalBFAP task

In the NominalBFAP task, the BFAP is executed to estimate the cumulative fatigue damage at four positions using stress amplitude and life curves based on the concept of BS7608 [6].

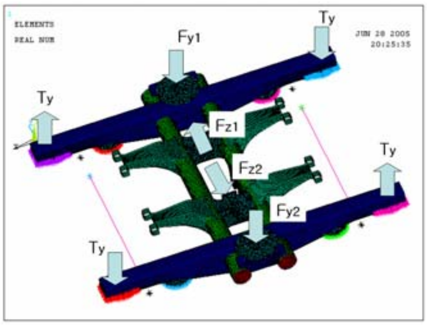

Fig.9. Load components.

3.3 Process of BogieHotSpot project

This project consists of five tasks; i.e. HotSpotIDEAS, HotSpotANSYS, HotSpotPost, HotSpotSLSFitting, and HotSpotBFAP as explained in Table 2. Among them, descriptions about the HotSpotANSYS, HotSpotPost, and HotSpotBFAP task will be omitted due to the similarity to those of the BogieNominal project.

3.3.1 HotSpotIDEAS task

The overall process and positions, where stresses and the cumulative fatigue damage are evaluated, are similar to those of NominalIDEAS task. Only the different meshing technique [7] is applied, in which hot-spot stress can be calculated taking into account of element thickness; relative position of nodes; and stress in perpendicular direction (z direction) to the welded bead, instead of the principal direction.

3.3.2 HotSpotSLSFitting task

The HotSpotSLSFitting task calculates the hot-spot stress by the two point's linear extrapolation after performing the least square fitting for stresses at anchor nodes as shown in Fig.10.

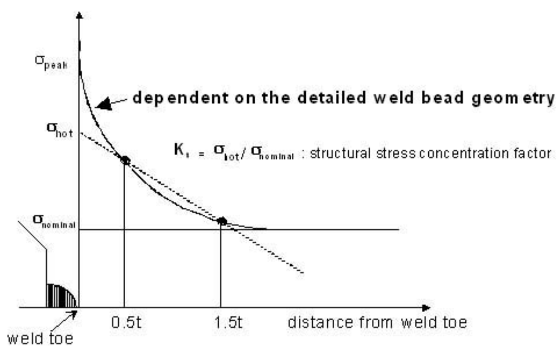

Fig.10. Two point's linear extrapolation to calculate the hot-spot stress.

3.4 Web based process monitoring and post processing

Users can see how many jobs or tasks are finished and whether any problem occurs or not during the process via the web page as shown in Fig.11. Different colors of icon imply that the state of tasks, i.e. finished, on-going, and not-started. With the completion of each job or task, users can review results through the web page. Pop-up pages are provided for detailed values of design parameters and contour plots showing the stress distribution as shown in Fig.12 and 13.

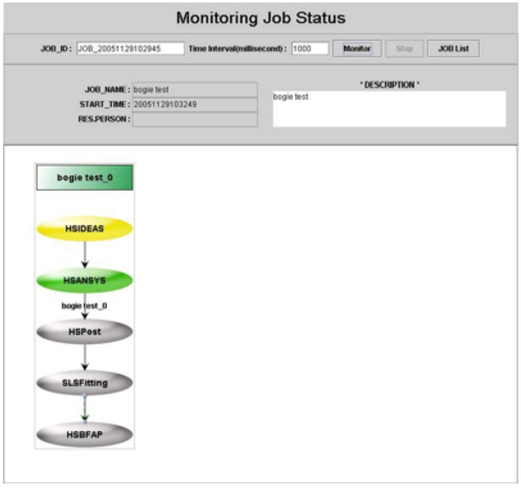

Fig.11. Process monitoring.

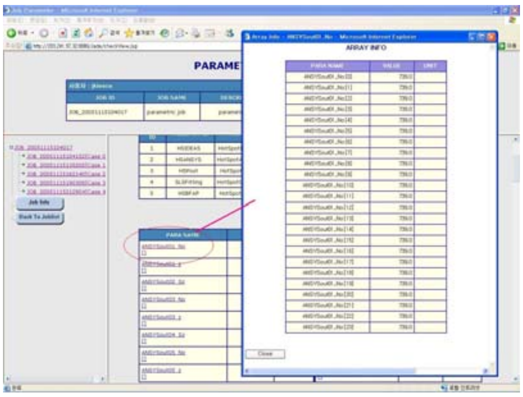

Fig.12. Pop-up page showing values of job parameters.

web page as shown in Fig.14, which shows the cumulative fatigue damage at position 1~4 as a function of the distance between two transom support brackets, the MCen. Damage values at position 1, 2, and 4 are below 0.02, suggesting a very low fatigue failure probability. On the other hand, the damage value at position 3 is much higher 0.28~0.47 and 0.13~0.30 in the case of the BogieNominal and BogieHotSpot project, respectively. With increasing the MCen, the damage value increases slightly and then decreases significantly after holding with constant value. As two transom support brackets approach each side frame of bogie, resistance to the twist behavior of bogie frame may be increased.

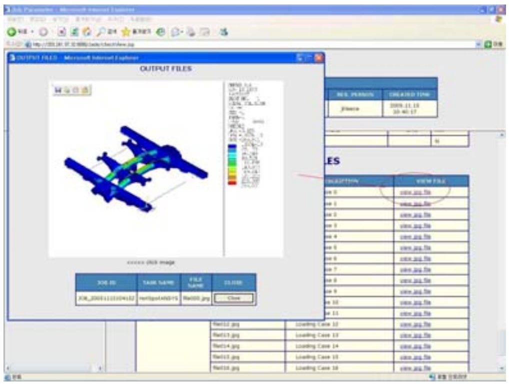

Fig.13. Pop-up page for contour plot showing the stress distribution.

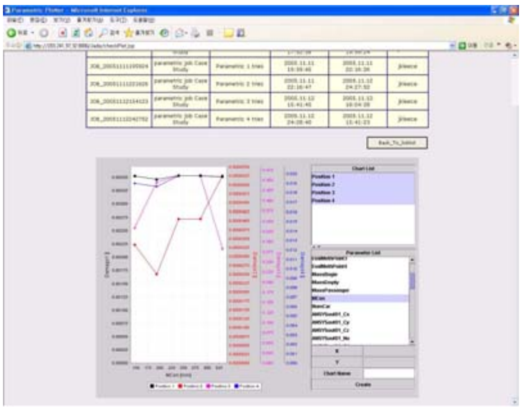

Fig.14. Graphical results of parametric study.

4 Results of fatigue durability analysis for welded bogie frame

The issue of the parametric study is to evaluate quantitatively the influence on the cumulative fatigue damage at the four positions due to changes of location and geometrical shape of the transom support bracket. Results of this study are presented graphically in the

5 Conclusion

The web based automation of fatigue durability analysis for welded bogie frame of railway vehicles is realized with several kinds of system integration techniques. Sub tasks for the fatigue durability analysis such as the parametric geometry modeling, the automatic generation of finite element models, the

static stress analysis, and the fatigue durability analysis is automated with the macro program of I-DEAS, the APDL of ANSYS, and the BFAP. The multi-agent based framework is used to manage the overall process. Developed automation techniques show the significant decrease in man-hours in order to achieve the fatigue durability analysis. Compared with a conventional manual process of fatigue durability analysis, this brought a time reduction about up to 80%.
Currently, we are trying to develop the more decentralized engineering framework which has intelligent capabilities such as a dynamic distributed resource allocation, load-balance, fault tolerance, and conflict resolution and to apply it to the optimal design considering mutually interactive physical phenomena in the future.

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