UCRL-JC-130322
PREPRINT

Three-Dimensional Simulation of Rotary Latch Assembly in Seismic Response and Interactions

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This paper was prepared for and presented at the
1998 ASME/JSME Joint Pressure Vessels and Piping Conference
San Diego, California
July 26-30, 1998

March 2, 1998

Lawrence Livermore National Laboratory

THREE – DIMENSIONAL SIMULATION OF ROTARY LATCH ASSEMBLY IN SEISMIC RESPONSE AND INTERACTIONS

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ABSTRACT

The finite element method has been used to investigate the stress field in mechanical suspension systems. The critical seismic loads are depended on three-dimensional dynamic response of vacuum vessels and interactions of the equipment supporting structures to the vacuum vessels and supporting system. In this study of the optics assembly equipment (15 to 27 Hz), it was shown that the pressure vessel systems which supports the optics assembly systems (6.5 to 13 Hz) have significant influence in the seismic response of the rotary latch assembly. A potentially critical failure location is identified. An axisymmetrical elastic analysis predicts stress at the inner radius of the lower housing can be reduced by 60% with simple design modification. Use of three-dimensional dynamic model and static model to evaluate the combined complex stress permits prediction of the rotary latch assembly operating life and seismic safety.

Introduction

With the advancement of science and technology, there is an increasing need to design scientific equipment as integrated part of the pressure vessel. Safety design of the pressure vessels can not be separated with the safety design of the integrated equipment under seismic event. Early development of three-dimensional finite element model to study dynamic coupling effects on the Fast Flux Test Facility for the breeder reactor equipment, piping systems and buildings shown experimental and finite element analysis results in good agreement (Leung,1975). Similar results were reported in the finite element approaches in structural design of the particle accelerator equipment to survive earthquake, Lorenz force, and to predict dynamic motion in submicron level (Leung, 1993).

The rotary latch assembly (RLA) is a critical structural component in the operation of the National Ignition Facility (NIF) that has a mission to unleash the power of the heavens to make earth a better place (Pena, 1998). The design specification of the RLA is to survive earthquake and to transport hundred of equipment called the line replacement unit, LRU, in a continuously dynamic environment under automatic processing.

The basic procedures of seismic analysis on equipment are well known but little help is available in developing an integrated model to predicte the loading distributions and their interactions. The purpose of this paper is to describe modeling of a three-dimensional dynamic model of the RLA and to determine the seismic loading distribution and use it to evaluate the structural reliability of the RLA. With the seismic loading distribution obtained from 3-D modeling, the stress field on the RLA can be predicted on a three-dimensional static model including areas of discontinuity such as fillet radius and gapping interfaces.

Load distribution Analysis

Four RLAs are mounted on the top of a space frame called canister. The canister, with a height of 140 inches and 70 x 48 inches on the base, is designed to transport the LRU with the RLA for coupling and decoupling the LRU in various locations the automatic processing operation. The integrated structural system including the LRU, RLA the canister and the supporting system is modeled for three dimensional finite element analysis. Figure 1 shows the rotary latch assembly (unit in mm). Figure 2 shows the structural system used in the integrated finite element model for seismic loading distribution analysis of the RLA. The supporting system includes the transport special filter structure at the bottom, pressure vessel at the middle, the canister on top left. The top-loading canister system with the LRU coupled by the rotary latch assemblies (RLA) in the lowest position is shown on top-right on Figure 2.

Loading distribution on rotary latch assembly is calculated on the integrated finite element model of the canister as shown in Figure 3. Response spectrum analysis are performed with the finite element code ANSYS (ANSYS 5 3 1997) The integrated model considers significant mass in the dynamic motion that related to the seismic excitation. Local motions of secondary structural members have insignificant contribution to seismic response loading are ignored with modeling technique in locating dynamic degree of freedom or selecting shear panel type element. Structural elements with effective stiffness in dynamic motion such as the diagonal field beam approximation are used for large thin wall panel

Shear panel compressive capacity is approximately represented in the linear dynamic model with simplifying assumptions (Kuhn 1956). Joint stiffness of mounting and connecting pins in the model have significant contribution in the analytical result of the loading distribution in term of vibration frequencies and dynamic response Experimental data (Alley & Leadbetter 1963) may be used for the dynamic modeling. The joint stiffness are incorporated in the present integrated model as part of the elastic system for loading response evaluation Uncertainties exist concerning the loading distribution analysis including tolerances of holes and gapping between all contacting parts. Experimental factors (Peery 1950) are used to account for such effects on the of response loading in the present design analysis. Fig 4 shows the simulated dynamic model of the pressure vessel and supporting system. Fig. 5 shows the canister model with four rotary latch assemblies that couple the LRU. Response accelerations results by SSRS method, regulatory guide 1.92 (NRC 1974), a combination of modes and spatial components in seismic response analysis, is applied for the calculating the modal sum in each direction and applied to loading distribution analysis. Fig 6 shows the integrated dynamic model used for response spectrum analysis loading distribution.

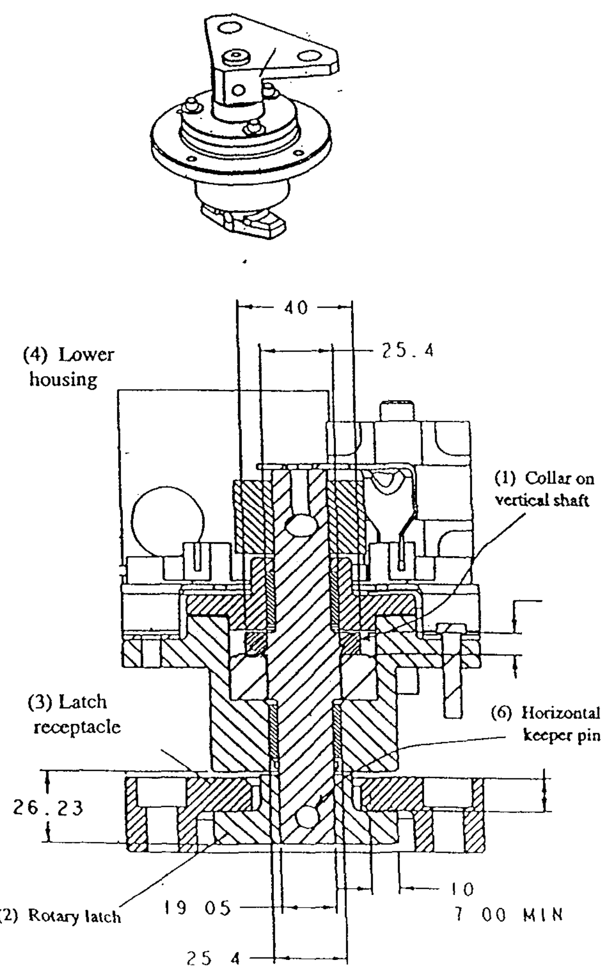

Fig.1 Rotary latch assembly by National Ignition Facility

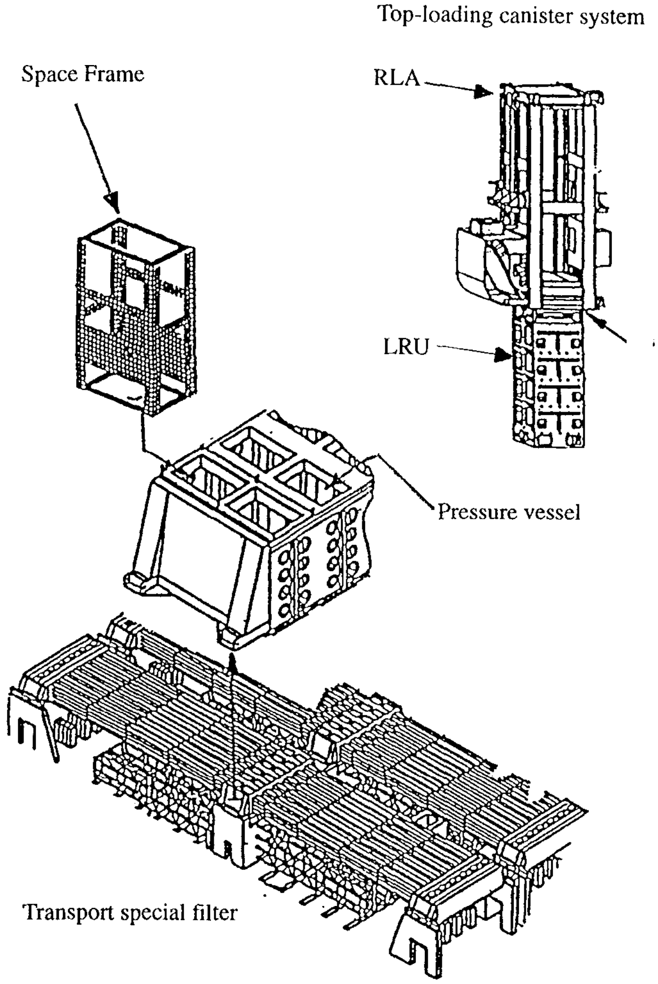

Fig. 2 Structural systems used in the integrated model

Stress Analysis

The RLA is designed as an automatic coupling device in the automatic control system. Loads for each RLA are calculated for both seismic and operating conditions. The RLA stress from operation is specified with a factor of safety of 3 0 to account for service life and dynamic load conditions. Seismic stress is designed with a factor of safety of 1 0 static yield strength for the short term loading with the dynamic yields strength as the additional safety factor. The RLA design are optimized to satisfy requirements for factor of safety Materials of components included stainless steel and aluminum are evaluated by the state of triaxial stress. Stress analysis is performed on the following component with finite element analysis including the collar-shaft, rotary latch, latch receptacle and the lower housing as shown in Fig 1

Table 1 lists the calculated results and factor of safety for the von-Mises stresses against the static elastic yield strength under seismic and operational loading conditions.

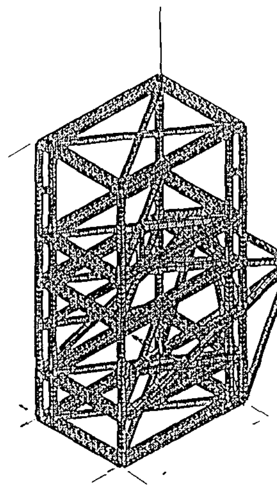

Fig. 3 LRU equipment model

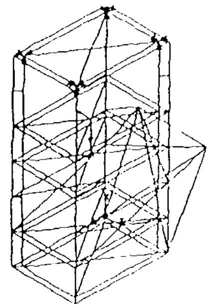

Fig. 5 Model with RLA

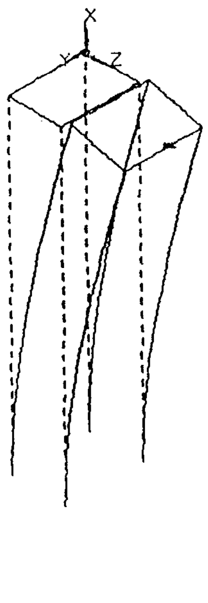

Fig. 4 Pressure vessel and supports model

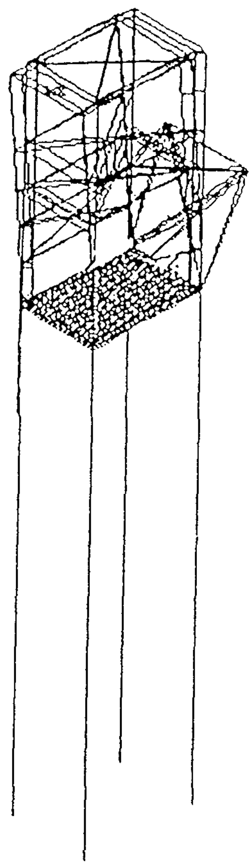

Fig 6 Integrated model

The stainless steel collar-shaft is subjected only to axial load The horizontal loads are resisted by the lower portion of the shaft in contacting with the lower housing An axisymmetrical model with 9444 elements is sufficient for detail stress evaluation of the collar-shaft loaded with symmetric axial load with 5224 lbs Finite element model with boundary condition are shown in Fig 7 Von Mises seismic stress contours with maximum peak is 23 ksi (Indicated by ***) at the intersection of shaft to collar as shown in Fig 8

The rotary latch is subjected to axial load and retained by a horizontal keeper pin Area along the pin is modeled as vertical reaction boundary One quarter of the latch with boundary plane in both x-z and y-z as shown in Fig 9 is used to simulate the three-dimensional stress field Critical stresses are found at the top of the cylindrical section. The 3-D simulation requires 16,608 solid tetrahedral element (10 nodes per element) to simulate the seismic stress Von Mises seismic stress contours with maximum peak is 72 ksi as indicated by *** at both top and bottom area as indicated in Fig 10

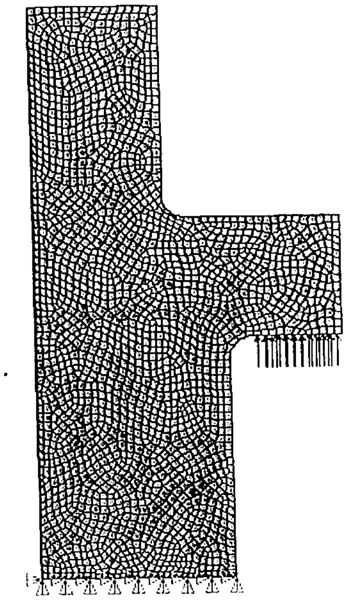

Fig. 7 Collar-shaft boundary condition

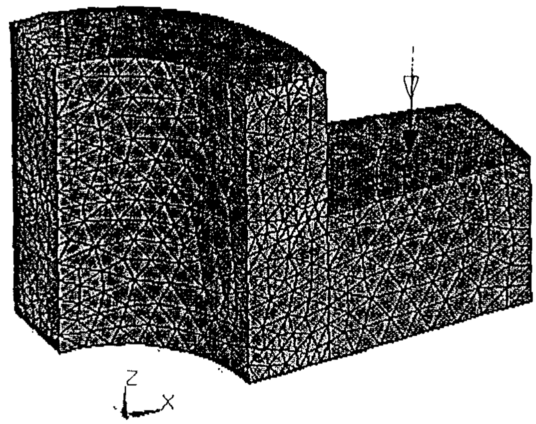

Fig. 9 One quarter model of rotary latch

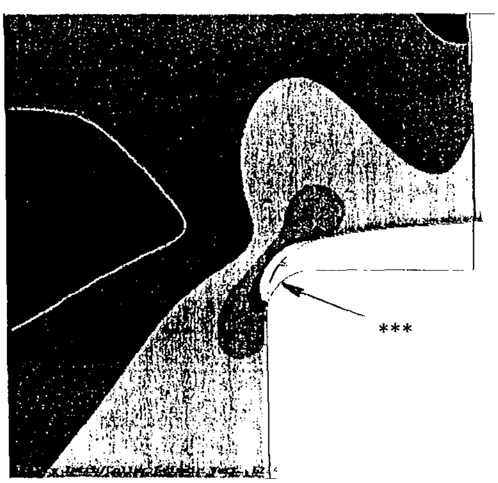

Fig 8 Collar-shaft von Mises stress contours

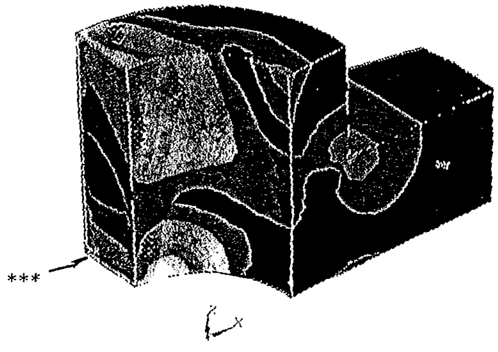

Fig 10 Rotary latch von Mises stress contours

Three-dimensional analyses on a one quarter model of the latch receptacle were performed The rectangle opening of the receptacle is designed for engagement with the latches in 90 degree rotation for locking and unlocking Uniform contact pressure from the latch is used because angular flexibility in a suspension system on top of the receptacle has been designed to eliminate rocking motion There are 18007 solid (ten nodes) tetrahedral elements used in the finite element model as shown in Fig. 11 Mesh generations are developed with 4 volumes, 31 areas, 65 lines and 65 keypoints Results of stress analysis is shown in Fig 12 Von Mises seismic stress contours with maximum peak is 20 ksi as indicated by ***

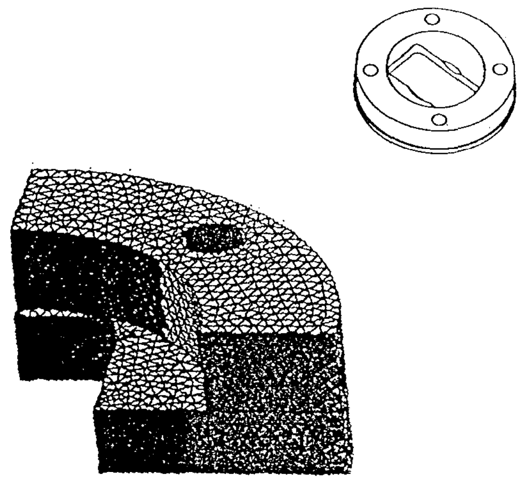

Fig 11 FEA quarter model of rotary latch

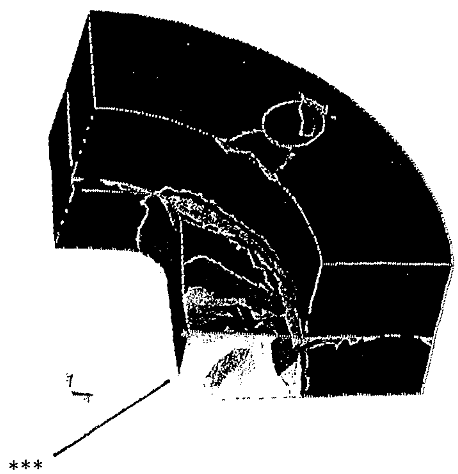

Fig. 12. Latch receptacle von Mises stress contours

Three-dimensional analyses on a full model of the lower housing were performed. The housing is designed to transfer not only the vertical load from the collar, but also transfer horizontal load from the lower shaft Loading applied to the housing is shown in Fig. 13 There are 37957 solid tetrahedral element (10 nodes per element) used in the model Mesh generations are developed with a single volume (revolution) and area, 65 lines and 65 keypoints Results of stress analysis is shown in Fig 14 Von Mises seismic stress contours with maximum peak stress is 12 8 ksi as indicated by ***

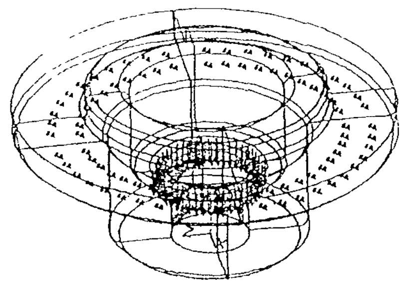

Fig 13 FEA model of lower housing

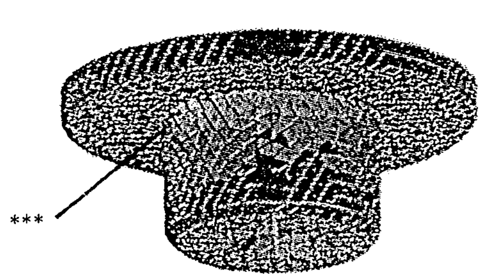

Fig. 14. Lower housing von Mises stress contours

Table 1 Calculated Stress results and Factor of safety for RLA

	Component Name	Stresss by Seismic Loads	Material & Allowable Yield Strength	Safety Factor	Remarks
1	Collar on Shaft (14 mm version)	23 Ksi	416 CRES 40 Ksi	1.7	Axisymmetrical model, vertical loading only Modified by increase thickness
2	Collar on Shaft (8 mm version)	40 Ksi	416 CRES 40 Ksi	1.0	Axisymmetrical model, vertical loading only. Existing design
3	Latch	72	17-4PH, Cond. H1025. 145 Ksi	2.0	3-D with Quater Model. Vert./ Side Loads. Upgradeto high strenghth material.
4	Receptacle	22.8 Ksi	Nitronic 60 56 Ksi	2.45	3-D with Quater Model. Vert./ Side Loads. Acceptable
5	Lower Housing	12.85 Ksi	Aluminum 6061-T6. 35 Ksi	2.7	Full Model. Vert. & Side Load. Fillet radius to be increase to 0.063 in (min)
	Component Name	Stresss by Operating Loads	Material & Allowable Yield Strength	Safety factor	Remarks
1	Collar on Shaft (14 mm version)	11.5	416 CRES 40 Ksi	3.4	Satisfy for SF = 3.0
2	Collar on Shaft (8 mm version)	20	416 CRES 40 Ksi	2.0	Not satisfy for SF =3.0
3	Latch	36	17-4PH, Cond. H1025. 145 Ksi	4.0	Satisfy for SF = 3.0
4	Receptacle	11.8	Nitronic 60 56 Ksi	4.7	Satisfy for SF = 3.0
5	Lower Housing	6.4	Aluminum 6061-T6. 35 Ksi	5.4	Satisfy for SF = 3.0

Conclusions

(1) Seismic loading analysis on an integrated finite element model, including the laser transport special filter structural system, pressure vessel, the canister space frame and the line replacement unit equipment, has been developed to examine the seismic stresses in the rotary latch assembly (RLA). Mechanical designs of the RLA are modified by using material with adequate strength and changing dimensions and curvature at the discontinuity areas to reduce stress in meeting the specified factor of safety requirement.

(2) Three-dimensional finite element dynamic analysis is employed to determine the seismic loads and their distribution in the RLA with considerations of site-specific seismic excitation, supporting system dynamic amplification and mode shape and frequencies of the structural systems. Detailed three-dimensional static finite element model and analysis are used to determine the combined stress in the component to improve structural reliability with considerations on the interaction between the latch, collar, housing and latch receptacle with the application of gapping and fitting factors, and discontinuity at fillet area and maximum distortion theory of failure concept.

(3) With a increasing speed on desktop computer and the high speed mesh generator of the finite element code, three-dimensional simulations, modeling and analysis as shown in this paper, offer cost effective way in determining the seismic and operating loads in complex scientific equipment and system for long term operation and seismic safety.

Acknowledgments

The author wishes to thank D. Tiszauer, S. Lu and A. Rowe for their support and recommendation in the present study. The author also wishes to thanks E. Grase, P. Hurst and S. Yakuma of the NIF Operations Group for their encouragement in publishing this paper.

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This work was performed under the auspices of the U.S. DOE by LLNL under contract No. W-7405-Eng-48.

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