Structural Integrity Evaluation for Overhead Crane of a Research Reactor

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1. Introduction

The purpose of this document is to confirm the structural integrity of overhead crane through the numerical simulation. The analysis results of overhead crane are evaluated with design limits of the KEPIC MCN Codes and Standards. The main function of overhead crane is to handle the fuel assembly, reactor components, and utilization facilities in the research reactor. The overhead crane as a double girder type crane system is classified into safety class NNS (Non-nuclear Safety) and seismic category II [1].

2. Design

2.1 Structure

The overhead crane consists of double girder mounted on a saddle that travels on rails at the floor and hoist assembly. The crane travels along the rails to transport the fuel assembly, irradiated object, and reactor components in the pools by using tools. Hoists are installed at the center position of the double girder. The hoist is suspended from the monorail by means of a motor driven trolley that runs along the monorail. Movements of hoist and trolley are controlled by using the control pendant switch. All controls are on the pendant station. The controls provide a means for moving the girder, the trolley, and the hoists. The traveling speed of the crane has several steps. The speed of the hoist and the trolley has several steps in both horizontal and vertical directions.

3. Structural Integrity Evaluation

3.1 Analysis

To evaluate the structural integrity of the overhead crane, the response spectrum analysis has been performed under the seismic load of SSE(Safe Shutdown Earthquake) by using ANSYS software. The elements used in the analysis model are shell, beam, and mass 21 element. The main member of crane, trolley/rail, and wire rope of hoist are modeled as the shell 181, beam 188, and combine14 elements, respectively. Lifting object is modeled using mass21 element. The total number of elements is 22,827 and the total number of nodes is 22,707. Boundary conditions at four wheel assemblies of the overhead crane are reasonably defined in terms of KEPIC MCN [2] and ASME NOG-1 [3].

The crane is designed to withstand the seismic load after SSE event. The structural integrity of the crane is evaluated in accordance with KEPIC MCN [2]. Computer code used for this analysis is ANSYS version 18.0. Dead load and seismic load are considered in load condition and the lifting load is applied using the added mass in the analysis.

The seismic response analysis uses response spectrum method which is widely employed in the seismic design of structures as it reduces the computation time in comparison to other methods. It is performed with each directional floor response spectrum. The number of modes considered in mode combination is 30ea. The mass participation factors are 95.1% (vertical), 98.7% (traveling direction), and 88.7% (traversing direction), respectively. Fig. 1 shows the finite element model of overhead crane. The square root of the sum of the squares (SRSS) method is used to combine the total response in each direction [4].

Table I. Boundary condition at four wheel assemblies of overhead crane

Position	Translational motion		
	Traversing	Traveling	Vertical
A	Fixed	Fixed	Fixed
B	Fixed	Free	Fixed
C	Free	Fixed	Fixed
D	Free	Free	Fixed

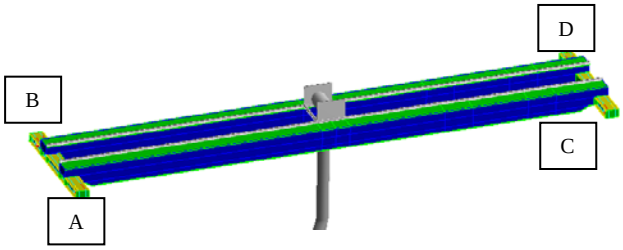


Fig. 1. Finite element model for overhead crane

3.2 Evaluation

In order to investigate the dynamic characteristics of the overhead crane, modal analyses of the developed finite element models are performed. The typical measure of the dynamic characteristics, natural frequencies and mode shapes, are obtained by ANSYS program. Fig. 2 shows mode shapes in the structural models of the crane. Table I represents the first to fourth natural frequencies. The bending mode is happened to the first frequency. The lifting load including the vertical impact load is 3,500kgf and applied loads in the transverse and longitudinal

horizontal direction are 6867N and 3433.5N. The material property of SS400(Equivalent to SA36) with minimum yield strength 245 MPa is applied in the analysis. The operation and extreme environmental loading combination is considered in accordance with the KEPIC MCN [2,3]. When the operation and extreme loading combination are applied, the maximum membrane stress intensities of crane is about 34 MPa and 147 MPa, respectively. All the response spectrum results according to load combinations are tabulated in Table II and Table III. The character C, Q, and E represent the mid-span, 1/4 span, and end. The character H and L mean the high and low position applied credible critical load on hook.

The maximum axial and shear stresses of the crane occur on the connection part between girder and saddle. The figure 3 shows the detailed configuration of These analysis results show that maximum stresses under extreme load condition are within maximum allowable stresses given in the KEPIC MCN [2, 3].

Table I. Natural frequencies of overhead crane

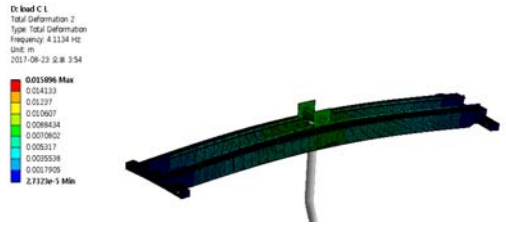
1st frequency	4.11 Hz
2nd frequency	10.44 Hz
3rd frequency	11.95 Hz
4th frequency	12.47 Hz

Table II. Response spectrum analysis results of crane according to operation load combination

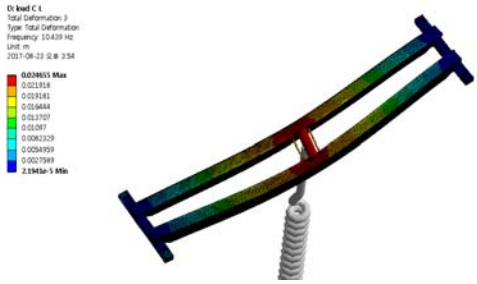
Load Condition	C H	C L	Q H	Q L	E H	E L	Allowable Stress [MPa]
Axial	21	21	21	21	27	27	122.5
Compressive	34	34	34	34	30	30	120
Shear	26	25	22	22	19	19	98
Lateral Disp.(e^{-3})	1	1	1	1	0	0	24
Vertical Disp.(e^{-3})	10	10	8	8	4	4	12

Table III. Response spectrum analysis results of crane according to extreme environmental load combination

Load Condition	C H	C L	Q H	Q L	E H	E L	Allowable Stress [MPa]
Axial	144	145	147	147	147	141	220.5
Compressive	144	145	147	147	147	141	220.5
Shear	89	89	84	84	78	75	122.5
Lateral Disp.(e^{-3})	11	11	10	10	8	8	80
Vertical Disp.(e^{-3})	22	21	19	17	16	12	48



(a) 1st mode shape



(b) 2nd mode shape

Fig. 2. Mode shapes of overhead crane

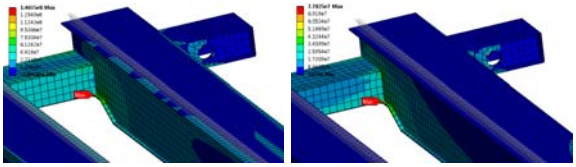


Fig. 3. Maximum axial and shear stresses of crane under extreme environmental load

4. Summary

The structural integrity evaluation for the crane is performed by using response spectrum analysis. The analysis results show that the maximum stresses of the crane under the seismic loads is within the KEPIC Code limits [2, 3]. Thus, the validity of the present design of the overhead crane has been demonstrated.

Acknowledgements

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