The Time Saving Structural Analysis of the Elevator Platform

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Keywords: Elevator, FEM, Concerned Stress

ABSTRACT. *In machinery industry, FEM is used as a basic tool to analyze and design a structure. However, running FEM solver for the structure which has only varying load conditions every time is time and resource consuming job. We suggest a method to use once analyzed structure to apply it to other load conditions. Analytical results can be obtained for the structure with different load conditions by using previously solved results.*

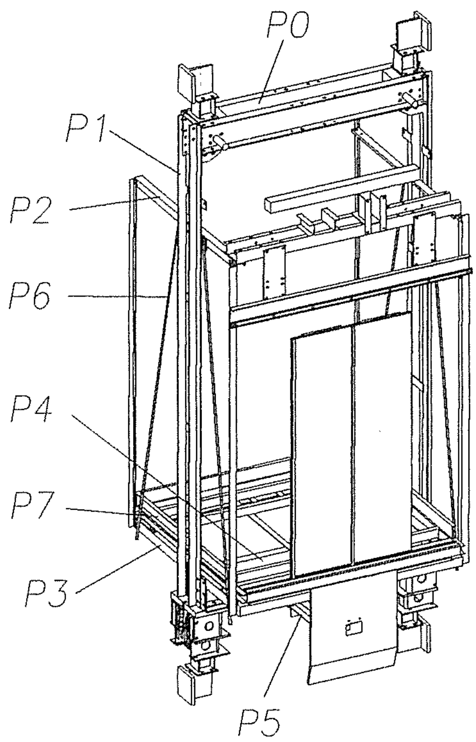
1. INTRODUCTION

Although the advance of computer technology & FEM packages is impressive, running FEM is still time consuming job especially for the engineers whose task is directly connected to the design-modification for customers. And even for the research engineers, running FEM whenever they change the magnitudes of the applied forces to check how system responds to this modification is exhausting. So we devised a matrix(**Hcs**) which maps the load variation to the stresses(we call it concerned stress (CS)) we are interested in. By this, we can check the results from the load variation quickly with just simple arithmetic operations.

2. SYSTEM DESCRIPTION AND MODEL

2.1 3D Model and FEM Model

The 3D Model and the FEM Model of the elevator structure described in this paper are presented in Fig. 1 and Fig. 2 each.



P_0 : crosshead, P_1 : sling, P_2 : fitting plate, P_3 : frame, P_4 : base, P_5 : fitting beam, P_6 : tie rod, P_7 : kick plate

Fig. 1 3D model of elevator

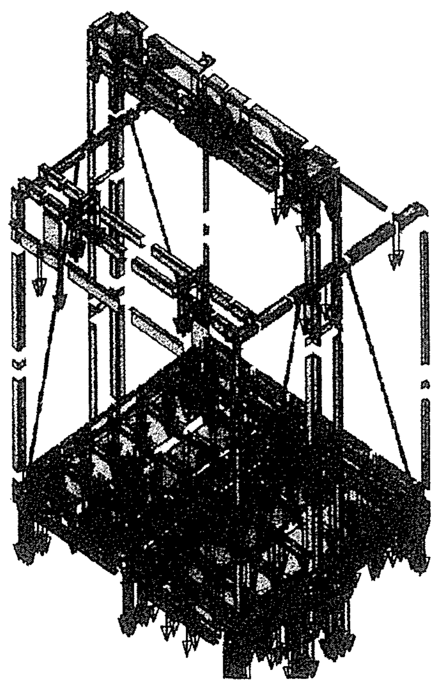


Fig. 2 FEM model of elevator

2.2 Experimental Work

Fig.3 shows the one of the experimental setups to measure strains at crosshead. As illustrated in Fig. 4, the comparison of the stress measured by strain gauge & the stress predicted by FEM at various locations shows qualitative and quantative match (the difference between the two stress values in any point is about 20%). By this experiment, the FEM modeling is verified. Further remarks are on the basis of this FEM model.

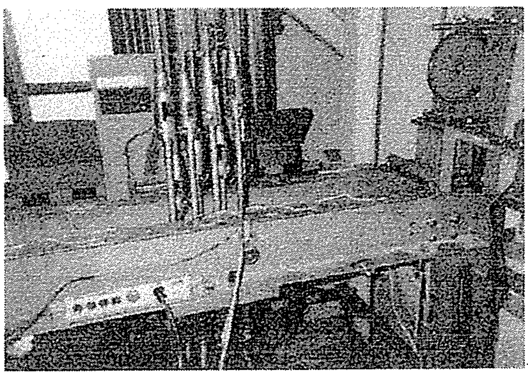


Fig. 3 Strain gauges attached to crosshead

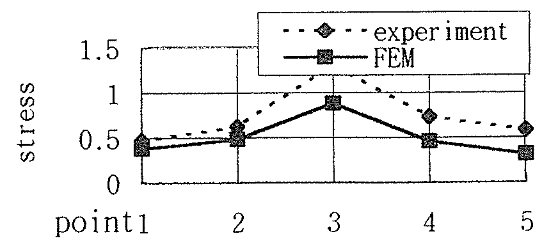


Fig. 4 Stresses of crosshead

3. CONCERNED STRESS FOR UNIT LOAD SET

3.1 Unit Load Set

As shown in Fig.2, the loads applied to the elevator structure are depicted as arrows. UL(Unit Load Set) is defined as the set which is composed of the elevator body force and 8 loads distinguished above whose magnitudes are all 1 ton.

3.2 Concerned Stress Set

CS(Concerned Stress Set) is defined as the set of stresses which is important in the view of the structural strength and should be checked whenever the loads are changed in the real situation.

CS specified for this paper is followed;

$$CS = [\, Cs_0 \;\; Cs_1 \;\; Cs_2 \;\; Cs_3 \;\; Cs_4 \;\; Cs_5 \;\; Cs_6 \;\; Cs_7 \,]^t \qquad \textbf{(3.2.1)}$$

(Cs_0 : σ_X at crosshead, Cs_1 : σ_Z at sling, Cs_2 : τ_{xy} at fitting plate, Cs_3 : σ_X at frame, Cs_4 : σ_X at base, Cs_5 : σ_Z at fitting beam, Cs_6 : σ_X at tie rod, Cs_7 : σ_X at kick plate)

3.3 Hcs for the Unit Load Set

UL(Unit Load Set)   Hcs(System Characteristics of the Concerned Stress for the Unit Load Set)

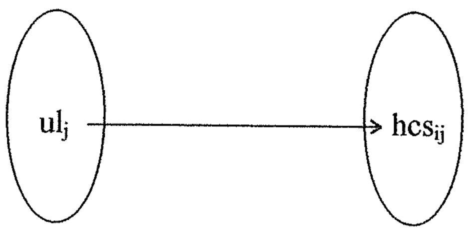


Fig. 5 **Hcs** for the unit load set

Hcs_{ij} is defined as the Cs_i which is the result from running the FEM solver by applying only ul_j as the load condition as depicted in Fig. 5. Let's explain it for crosshead. At crosshead, σ_X of the interesting point is followed. σ_X is 0.304kgf/mm^2 which is the result of FEM when ul_0 is used as the only one applied force. At the same way, σ_X is 1.640kgf/mm^2 for ul_1, -2.858 kgf/mm^2 for ul_2, -1.268kgf/mm^2 for ul_3, 2.338kgf/mm^2 for ul_4, 0.962kgf/mm^2 for ul_5, -1.990kgf/mm^2 for ul_6, -1.111kgf/mm^2 for ul_7, 0.495kgf/mm^2 for ul_8.

In vector form,

$$\mathbf{hcs}_0 = [\ \ldots hcs_{0j} \ \ldots\ ] \qquad (j = 0, \ldots, 8) \qquad (3.3.1)$$
$$= [\ 0.304 \quad 1.640 \quad \ldots \quad -1.111 \quad 0.495\ ]$$

Applying this procedure step by step to sling, fitting plate, frame, base, fitting beam, tie rod, kick plate, we get hcs_{ij} as the followings.

$$\begin{aligned}
\mathbf{hcs}_1 &= [\ 0.260 \quad 0.646 \quad \ldots \quad -0.053 \quad 0.295\ ] \\
\mathbf{hcs}_2 &= [\ -0.088 \quad -0.150 \quad \ldots \quad -0.208 \quad -0.005\ ] \\
\mathbf{hcs}_3 &= [\ 0.118 \quad -0.065 \quad \ldots \quad -0.520 \quad -0.430\ ] \\
\mathbf{hcs}_4 &= [\ -0.128 \quad 0.005 \quad \ldots \quad 2.644 \quad -0.081\ ] \\
\mathbf{hcs}_5 &= [\ -0.128 \quad 0.013 \quad \ldots \quad -2.274 \quad 0.006\ ] \\
\mathbf{hcs}_6 &= [\ 0.260 \quad 1.119 \quad \ldots \quad -0.236 \quad 0.036\ ] \\
\mathbf{hcs}_7 &= [\ -0.249 \quad -1.799 \quad \ldots \quad 0.000 \quad 0.000\ ]
\end{aligned} \qquad (3.3.2)$$

In matrix form,

$$\mathbf{Hcs} = \begin{bmatrix} \mathbf{hcs}_0 \\ \vdots \\ \vdots \\ \mathbf{hcs}_7 \end{bmatrix} \qquad (3.3.3)$$

3.4 The Concerned Stress for the Actual Load Set By Using the Hcs

The actual load set is defined as the loads actually applied to the elevator structure in the real situation. Then, the concerned stress can be obtained for the actual load condition without rerunning the whole FEM solver by using the **Hcs** formulated in Eq. 3.3.3 as the followings.

$$\underset{(m\times 1)}{\mathbf{CS}} = \underset{(m\times n)(n\times 1)}{\mathbf{Hcs} \circ \mathbf{AL}}, \quad m=8, \ n=9 \qquad (3.4.1)$$

4. CONCERNED STRESS FOR STANDARD LOAD SET

4.1 Standard Load Set

Standard load set is the load set which is applied to the same location where the unit load set is applied,but the magnitude of each element needs not to be 1 ton. The magnitudes of the standard loads are set during the development process of a specific elevator model.

4.2 Hcs′ for the Standard Load Set

SL(Standard Load Set) **Hcs′**(System Characteristics of the Concerned Stress for the Standard Load)

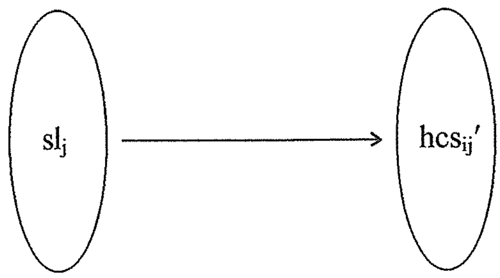


Fig. 6 **Hcs′** for the standard load set

Hcs_{ij}' is defined as the Cs_i which is the result from running the FEM solver by applying only sl_j as the load condition. However, we can easily formulate **Hcs′** by using **Hcs**(Eq. 3.3.4) without running FEM solver as the followings.

$$hcs_{ij}' = hcs_{ij} \cdot sl_j \qquad \textbf{(4.2.1)}$$

$$\mathbf{Hcs'} = \begin{bmatrix} hcs_{ij}' \end{bmatrix} \quad \begin{pmatrix} i = 0, \ldots, 7 \\ j = 0, \ldots, 8 \end{pmatrix} \qquad \textbf{(4.2.2)}$$

4.3 The Concerned Stress for the Actual Load Set By Using the Hcs′

We introduce vector **DLR**(Dimensionless Load Ratio) followed as below.

$$dlr_j = al_j / sl_j \qquad \textbf{(4.3.1)}$$

$$\mathbf{DLR} = \begin{bmatrix} dlr_j \end{bmatrix} \quad (j = 0, \ldots, 8) \qquad \textbf{(4.3.2)}$$

The concerned stress for the actual load set can be easily calculated without rerunning the whole FEM solver by using the **Hcs′**(Eq. 4.2.2) and **DLR**(Eq. 4.3.2) as follows

$$\underset{(m\times 1)}{\mathbf{CS}} = \underset{(m\times n)}{\mathbf{Hcs'}} \circ \underset{(n\times 1)}{\mathbf{DLR}} \quad , \; m=8 \; , n=9 \qquad \textbf{(4.3.3)}$$

4.4 Concerned Stress Attribution Factor(CSAF) and Concerned Stress Variation Factor(CSVF)

During design process, the standard load set is determined with consideration about several design parameters. However, it is not expected that customers want the standard model or the standard configuration to be installed in their buildings. So it is necessary for design department to figure out the stress variations occurred between the standard model & the model incorporating the customer's needs. Following two factors are useful for this need.

$$csaf_{ij} = hcs_{ij}' \,/\, Cs_i(SL) \tag{4.4.1}$$

$$\mathbf{CSAF} = \begin{bmatrix} csaf_{ij} \end{bmatrix} \quad \begin{pmatrix} i = 0, \ldots, 7 \\ j = 0, \ldots, 8 \end{pmatrix} \tag{4.4.2}$$

$$\begin{aligned} csvf_{ij} &= hcs_{ij}' \cdot (dlr_i - 1) \,/\, Cs_i(SL) \\ &= csaf_{ij} \cdot (dlr_i - 1) \end{aligned} \tag{4.4.3}$$

$$\mathbf{CSVF} = \begin{bmatrix} csvf_{ij} \end{bmatrix} \quad \begin{pmatrix} i = 0, \ldots, 7 \\ j = 0, \ldots, 8 \end{pmatrix} \tag{4.4.4}$$

By **CSAF**, an engineer in the design department can see how much portion each sl_j contributes to Cs_i and the order of the magnitude of **CSAF** elements can be a guidance for him to figure out the relationship between Cs_i and sl_j. On the other hand, **CSVF** implies how much CS is affected by the difference between actual load sets and standard load sets indicated by DLR.

5. CONCLUSION

This paper formulates **Hcs'** to obtain the stress which is important in the view of the structural strength for the varying actual load condition without running a FEM solver. In next stage, the concept described in this paper would be expanded to incorporate the geometrical dimension variation of the elevator.

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BIOGRAPHY

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