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FINITE ELEMENT APPROACH TO STRESS ANALYSIS FOR ELEVATOR CAR SLING

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ABSTRACT
The aim of this study is to focus on the elevator car sling structure which is used to carry car death load and the weights of passengers. It consists of the crosshead, vertical uprights, bottom channel, and car platform. For a safety operation, elevators must be designed that their members can withstand the loads and the moments imposed on them under whole operational conditions. In this study stresses and displacements occurred on the car sling members have been investigated by both analytical and finite element methods. In order to compare the stress results from the analysis, an illustrative example of elevator car sling is given.
Keywords: elevator car sling, finite element method, stress analysis

1. INTRODUCTION
Elevator is a mechatronic system used to move passengers and goods safely, swift and comfortable in high-rise buildings. Elevator is also essentially a platform that is pushed up by a mechanical means and consists of a car mounted on a platform within an enclosed space called a hoistway. It is extremely hard to predict location of passengers entered to the car as well as their distributions in normal running condition. Loads imposed on car sling members are more complex than other elevator equipments since there are various type of loads going into the car. In this case, certain assumptions as regard location and type of loads must have been devised. Car sling calculation includes the most important knowledge about safety of loads and/or passengers whom in the car and which increases lifetime of car. Car sling and guiding members must be designed withstand to which loads and moments exposed under whole running conditions. In this study, car sling structure with bolted joints to be analysed is discretized to the its members and analytical solutions considering two type of approach in compliance with EN 81-1 and static stress analysis are performed utilizing ANSYS.

Janovsky has discussed the calculation methods of stress in individual parts of car frame and welded slings in [1,2]. The work done by Solmazoğlu and Akışın is about comparison between a conventional calculation on a freight elevator and one made on the basis of the single-side operation of a safety gear. They have considered that two NPU-200 beam supporting beam profiles and two lateral beam profiles, with the above sections [3]. Authors, in recent studies [4,5] have proposed a frame-shaped steel construction for stress analysis and performed stress and displacement calculations with considering load distribution on the car platform. In this study stresses and displacements occurred on the car sling members have been investigated by both analytical and finite element methods. In order to compare the stress results from the analysis, an illustrative example of elevator car sling is given.

2. ANALYTICAL APPROACHES TO THE CAR SLING SYSTEM
Two approaches may be used for calculating the stresses and displacements of car sling structure. The first method used for analytical calculations consist of simplified method considering the safety

calculations of elevator systems and calculations. Those are accurate and detailed more than simplified method, and involve inner moments occured at the corners of sling. In the second approach, loads on the platform regard uniformly distributed on the bottom channel and since sling is symmetric and installing of loads as a symmetric to the vertical axes of sling, inner moments occurred on the overhead beam corners are same values M_1, in the same way inner moments occurred on the bottom beam corners are same values M_2 as shown in Figure 1. In elevator installation, car dimensions have been occured according to number of passengers. These specified dimensions have been used for modelling process. In this study, 5 passenger car design as an illustrated example is considered for stress and displacement analysis.

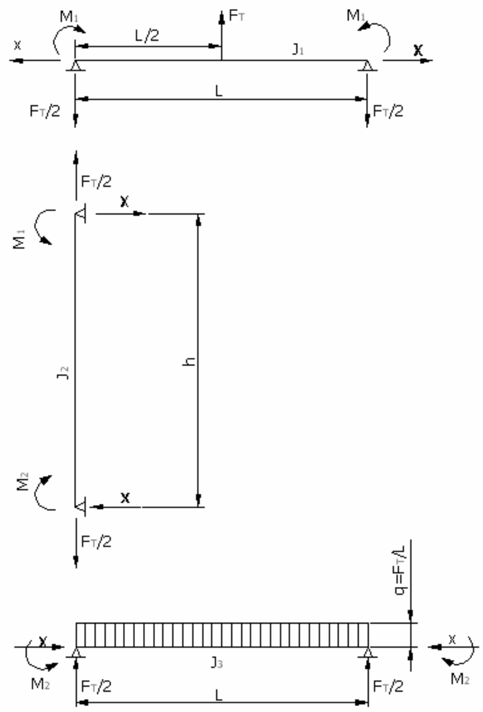


Figure 1. Force and moment distribution on car sling members

3. MODELING OF ELEVATOR CAR SLING

In the field of engineering design, solving many complex problems is usually tedious and impossible to find exact solutions. Therefore, numerical methods such as finite element method can be used rather than analytical methods. Finite element approach is used to model the structure as an assembly of elements or components with various forms of connection between them. Thus, a continuous system such as a solid or plate is modeled as a discrete system with a finite number of elements interconnected at finite number of nodes. The approximate solution is formulated over each element matrix and thereafter assembled to obtain the stiffness matrices, and displacement and force vectors of the entire domain. The elements of different type and shape with complex loads and boundary conditions can be used simultaneously. By means of a variation principle, a set of equations is obtained for each element to be assembled to represent the equilibrium or compatibility of the entire body [6-8]. The critical parts of a car sling are the crosshead, uprights and the bottom channel are depicted in Figure 2.

The crosshead beam is the upper member of the car sling and aligned with the stiles. Crosshead beam must be parallel to the safety plank for no distortion. The crosshead is a pair of structural members, generally channel-shaped. In this study, elevator ropes suspension has been performed by means of hitch plate. The vertical uprights are the vertical structural members at the side of the car. Stiles are U-shaped and L-shaped steel profiles. The safety plank is the structural member which is leveled sideways and front to back Safety plank supports the car platform, on which passengers and/or loads rest during the travel.

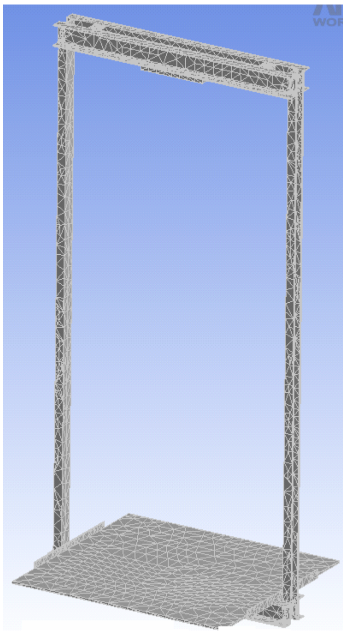
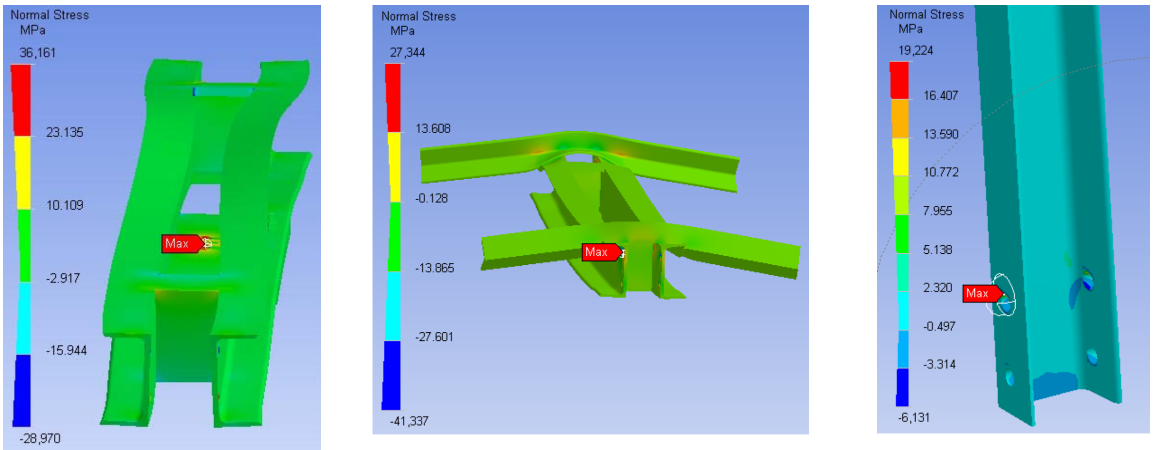


Figure 2. Isometric view of the car sling model

4. NUMERICAL EXAMPLE

An elevator car sling is designed for 5 passengers with 400 kg capacity (F_y) and 525 kg car weight (F_k). Car sling model has been formed by bolt connection as shown Figure 2. All holes of bolts that are found end of the beams have been fixed as boundary conditions and having taken into consideration loads (F_y + F_k) equally imposed on holes of hitch plate of crosshead beams. Car weight equally imposed on car floor connection brace surfaces contacted by car as uniformly distributed load and consideration load with weight of ropes equally imposed in holes of bolt connections. In this study, SOLID187 finite element with 10-nodes, each of 10 nodes of this element has three translational degree of freedom in the nodal x, y, z directions has been used. Structural steel (Young's Modulus (E) is $2.1\text{x}10^5$ N/mm^2 and Poisson Ratio (ν) is 0.3) has been selected as a beam material [9].

Results from finite element analysis have been depicted separately for each independent beams of car sling. The stress contours occurred on crosshead is depicted in Figure 3a, bottom beam is depicted in Figure 3b, vertical beam is depicted in Figure 3c, respectively.



(a) crosshead beam *(b) bottom beam* *(c) vertical uprights*

Figure 3. Stress analysis of car sling members

The stress and deflection values occured on crosshead beam and safety plank and the stress values occured on vertical uprights have been given in Table 1.

Table 1. Analytical and FEA results.

Analysis method		Crosshead Beam		Bottom Beam		Vertical Upright	
		Max. Stress (MPa)	Max. Disp. (mm)	Max. Stress (MPa)	Max. Disp. (mm)	Max. Stress (MPa)	Max. Disp. (mm)
Anaytical Solutions	First approach	34.52	0.414	13.34	0.179	14.03	--
	Second approach	32.02	0.37	16.4	0.243	9.82	--
FEA Solution		36.161	0.238	27.334	0.0755	19.224	--

Finite element analysis have been executed for under certain loading and boundary conditions for each car sling members. Table 1 shows that stress value determined by second analytical approach decrease according to the first anaytical approach on crosshead since inner moments which are at the corner side of the beam curtail maximum moment. In addition stress values determined by second analytical approach increase according to the first analytical approach on bottom beam since considering load equally distributed on bottom beam rather than single load. Instead of these certain loading conditions, for finite element analysis when we regard more accurate loading condition for bottom beam which car weight equally imposed on car floor connection brace surfaces contacted by car as uniformly distributed load, stress value virtually increased twice times than analytical solutions and stress value determined by second analytical approach decrease according to the first analytical approach on vertical beam. Finite element analysis displacement values decrease for all of car sling members according to analytical solutions.

5. CONCLUSION

The design of a car sling system with for 5 passengers with 400 kg capacity and 525 kg car weight and a case study has been investigated. In this study, the stress and displacement analyses of carframe system have been examined considering as independent simple beams. Stress values obtained on crosshead and vertical beams are adjacent to the FEA solutions but stress on bottom beam increase virtually twice times than analytical solutions since regarding more accurate loading condition. Occurred stress values quite less than allowable stress value (90 MPa) specified in EN81-1. Stress results from finite element method is a highly reliable numerical method when comparing analytical solutions.

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