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ANALYSIS OF A BOOM CONVEYOR

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Abstract: *The aim of this paper is to analyse the reaction forces between the chassis of a boom conveyor and a rail-track. The study includes the determination of the stability of the machine. Increased attention was paid to recommendations for modification of the construction for better stability and wider usage.*

Keywords: Boom conveyor, Chassis, FEM analysis.

1. Introduction

Every machine always has some design problems. A boom conveyor is no different. For example, Velmurugan et al. (2014) described some of them. Without hesitation, it can be said that they covered only a small number of them. This paper focuses on issues with the stability of a conveyor on a rail and recommendations for eliminating these problems.

2. Analysis of the boom conveyor

Finite element method (FEM) analyses of the construction were performed using MSC.Marc software with approximately 778000 elements.

2.1. FEM model

A CAD model of the boom conveyor was prepared from technical documentation and drawings that were provided by the contracting authority. It is necessary to realize that the CAD model is too complicated to be converted to a FE model. Therefore, the FE model was simplified and the computational model only includes parts relevant for the calculation. Fig. 1 shows the final FE model.

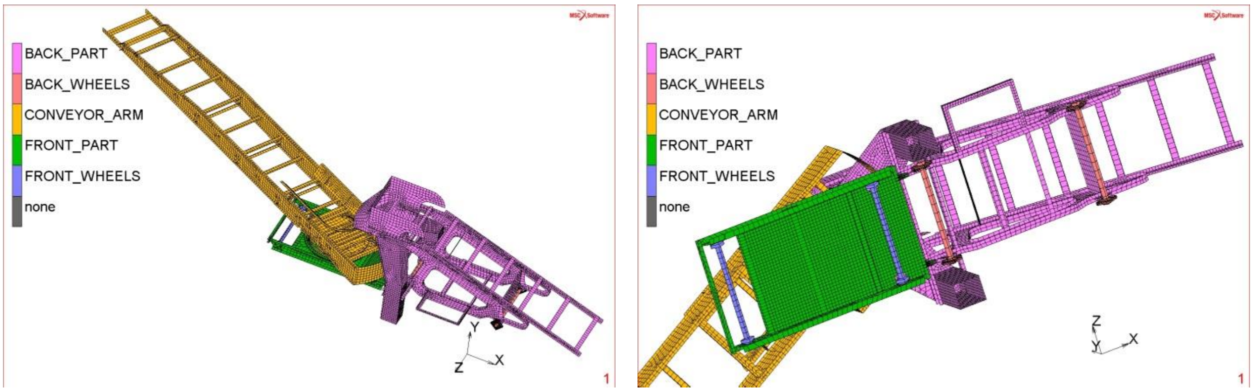

Fig. 1: FE model for numerical calculation.

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The FE model was created by combining structured and unstructured meshes. The main parts of the machine are welded from thick plates or profiles. Therefore, to reduce the computational time, these parts were meshed with bilinear thin-triangular shell elements (tria3 - element 138) and bilinear thin-shell elements (quad4 - element 139), with global displacements and rotations as degrees of freedom. Rotational parts (wheel axles, wheels) were meshed with three-dimensional, arbitrarily distorted bricks (hex8 - element 7). This classification of the element types is shown in Fig. 2.

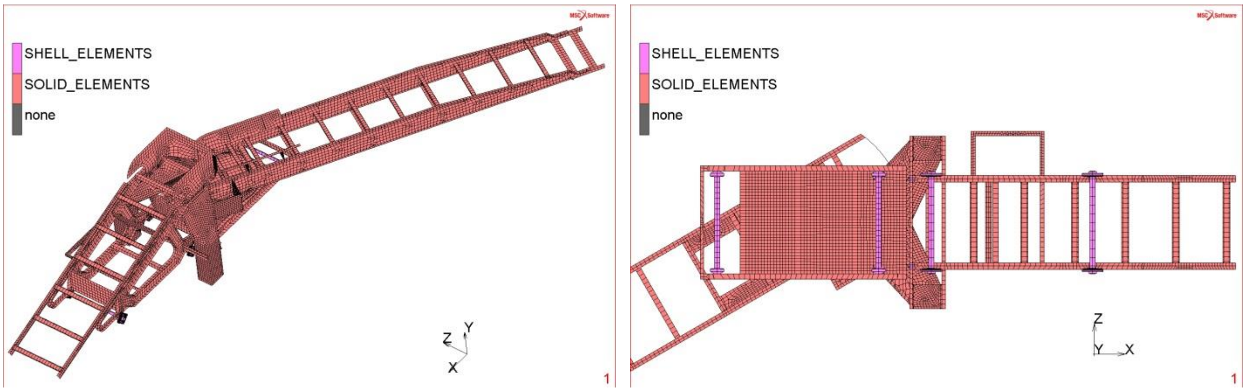

Fig. 2: Classification of the element types.

The individual parts were interconnected by aligning appropriately selected nodes for all parts except the arm of the conveyor. A rigid link (type 80) was applied between the front part and the arm (the stiffest part of the machine), that allows tilting according to the deformation of the frame (see Fig. 3).

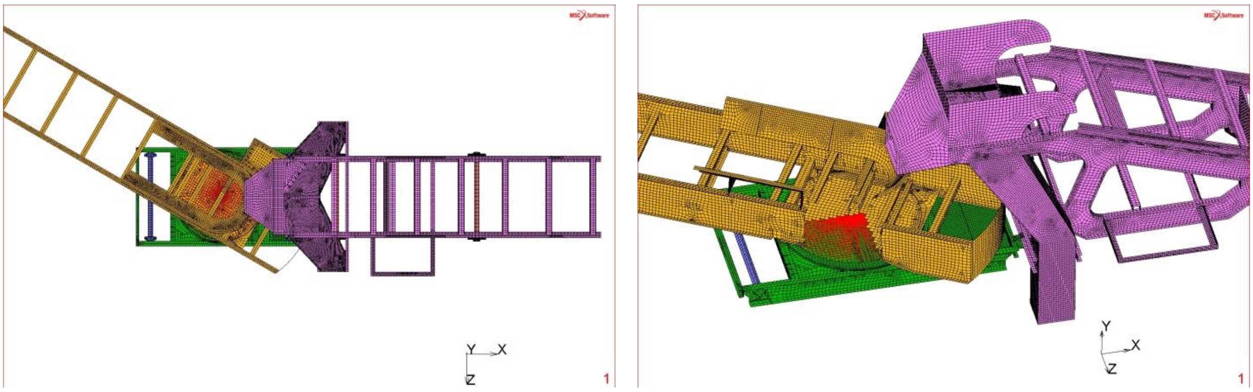

Fig. 3: Interconnection of parts.

2.2. Boundary condition

Fig. 4 (left) shows the approximate weight distribution of the main components of the machine which was replaced by specifying the appropriate boundary conditions applied to the computational model. Fig. 4 (right) shows the boundary conditions (FIX_XYZ; FIX_Y) for the chassis and also the labelling of the wheels which are referred to in Tab. 1.

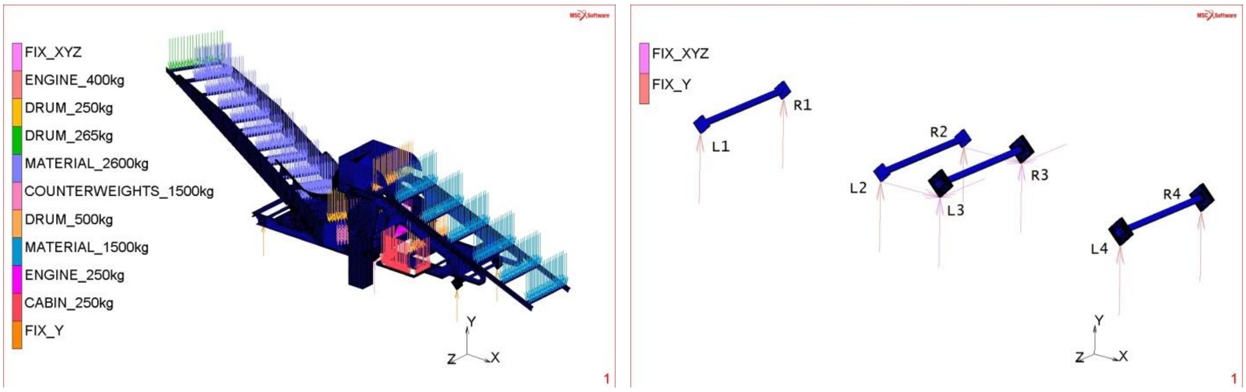

Fig. 4: Boundary condition: all (left), axles (right).

Boundary conditions FIX_XYZ and FIX_Y were modified during the calculation. If the results of the calculation showed a negative reaction force at one of the wheels (when the wheel moved away from the rail), the boundary condition FIX for the Y-axis was disabled and the task was solved again. This procedure was repeated until all of the reaction forces acquired positive values.

3. Results

Since the computational model and loads are almost symmetrical, the task was solved only for tilting of the arm to the left side. The initial angle was 0 degrees and the increment for the other variants was 5(10) degrees. The reaction forces are shown in Tab. 1. Loss of contact between the wheel and the rail is marked by the symbol "-". Figs. 5 – 7 show the displacement in the Y-axis and Fig. 8 shows the values of the equivalent static stress.

Tab. 1: Reaction forces for the wheels.

	REACTION FORCES [kN]										
WHEEL	*60 °*	*50 °*	*40 °*	*35 °*	*30 °*	*25 °*	*20 °*	*15 °*	*10 °*	*5 °*	*0 °*
L1	*69.4*	*79.4*	*80.6*	*82.1*	*78.9*	*75.2*	*71.0*	*66.4*	*61.3*	*55.6*	*48.5*
L2	*70.2*	*52.5*	*38.0*	*27.0*	*21.8*	*16.8*	*11.9*	*7.3*	*3.0*	*-*	*-*
L3	*-*	*8.4*	*15.2*	*16.1*	*17.2*	*18.2*	*19.3*	*20.3*	*21.4*	*21.6*	*20.0*
L4	*31.3*	*21.1*	*15.3*	*16.8*	*16.7*	*16.6*	*16.5*	*16.4*	*16.3*	*16.2*	*16.4*
R1	*-*	*-*	*7.3*	*10.2*	*16.5*	*22.9*	*29.5*	*36.0*	*42.6*	*49.3*	*56.4*
R2	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*	*-*
R3	*-*	*-*	*-*	*6.3*	*7.5*	*9.0*	*10.7*	*12.6*	*14.6*	*16.6*	*18.3*
R4	*2.7*	*12.1*	*17.4*	*15.2*	*15.1*	*14.9*	*14.8*	*14.6*	*14.4*	*14.2*	*14.1*

3.1. Displacement

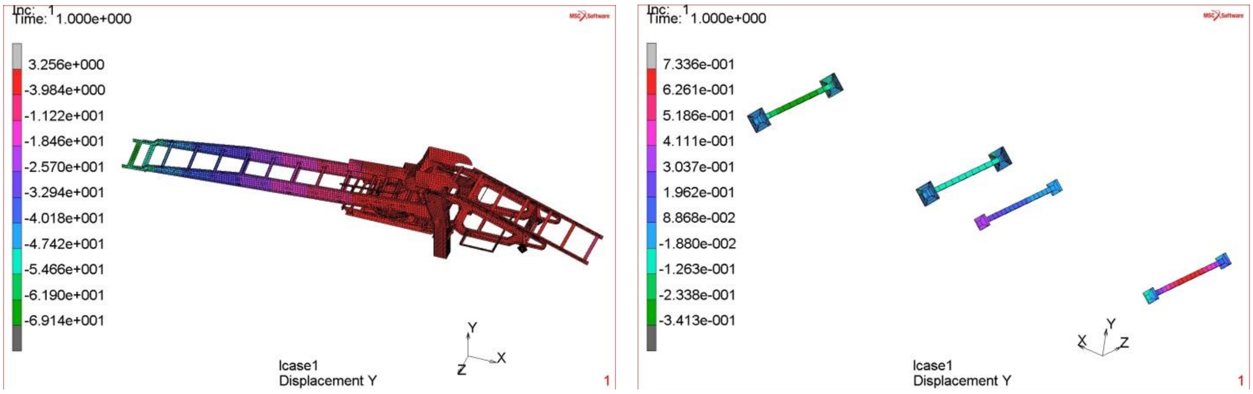

Fig. 5: Displacement [mm] of the frame for 5 °: whole construction (left) and wheels (right).

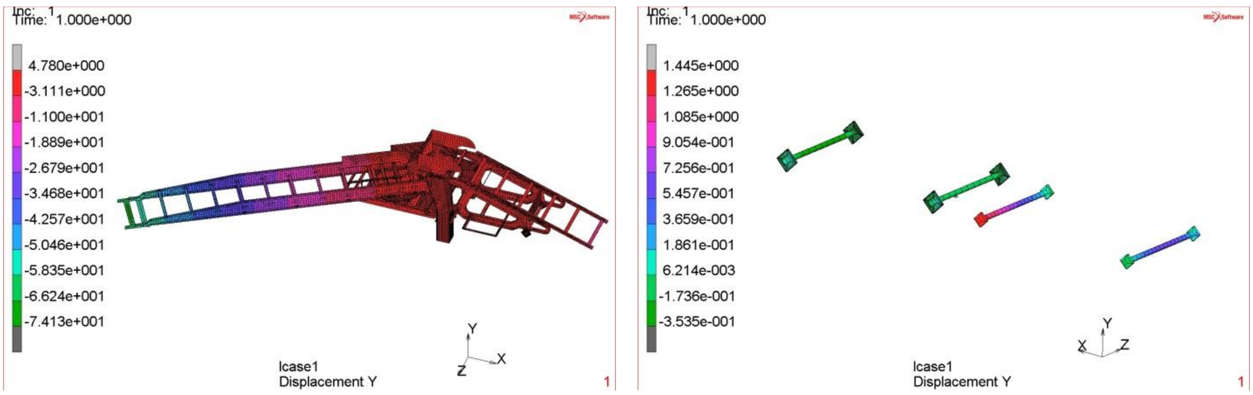

Fig. 6: Displacement [mm] of the frame for 30 °: whole construction (left) and wheels (right).

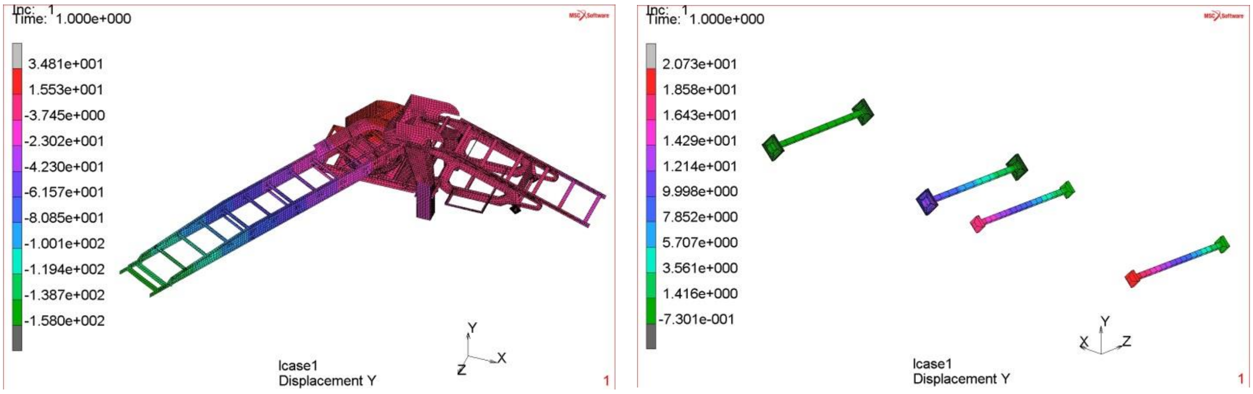

Fig. 7: Displacement [mm] of the frame for 60 °: whole construction (left) and wheels (right).

3.2. Equivalent von Mises Stress results

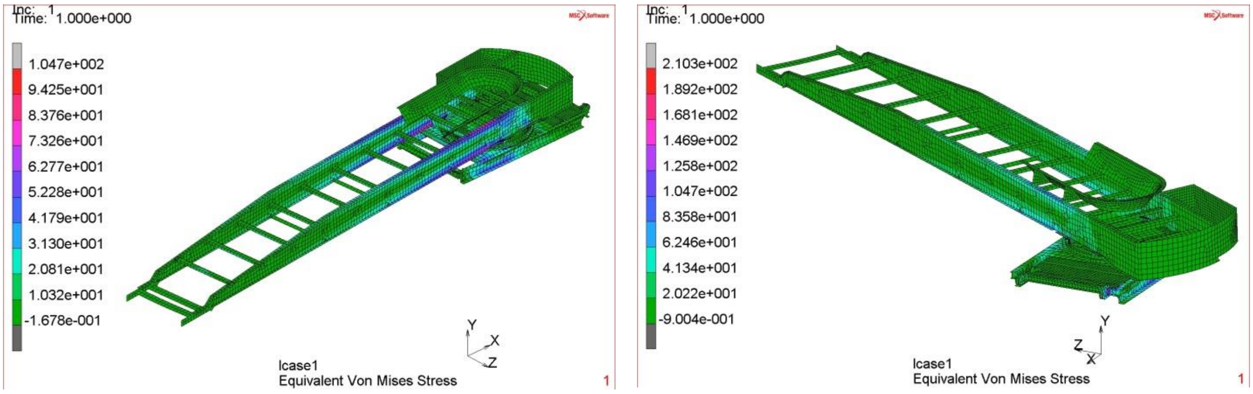

Fig. 8: Equivalent von Mises stress [MPa]: 5 ° (left) 60 ° (right).

3.3. Evaluation of results

With the arm at 0 ° and 5 ° the rear axle of the front part of the machine is significantly lightened and wheels L2 and R2 are not in contact with the rail. By increasing the angle of rotation of the arm between 5 ° to 35 ° (resp. -5 ° to -35 °) the machine is stabilized and the reaction is not only between wheel R2 (resp. L2). A further increase of the angle leads to enlargement of the gap between the other wheels and the rail, and operation begins to be dangerous. The machine is unstable and flips after exceeding 60 ° rotation of the arm.

Conclusion

The results indicate that the machine (for the existing design) is safely operable only for relatively small angles of rotation of the arm (about 30 °). Therefore, the machine cannot be used to its full potential. This problem could be solved by, for example, changing the design of the arm, because from the perspective of stiffness and stress the construction is significantly oversized, see Fig. 5 – 8. It is clear that displacement of the arm in the Y axis is heavily influenced by tilting the front part of the vehicle. The aim should be to move the centre of gravity closer to the axis of rotation of the arm, perhaps by placing more counterweights on the frame.

Acknowledgement

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References

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