12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26–30 August, 2008

NUMERICAL EVALUATION OF INTEGRITY OF AN OPEN RAILWAY CAR'S COMPLEX STRUCTURE FOR BILLETS TRANSPORTATION

Nedeljko Vukojević, Fuad Hadžikadunić
University of Zenica, Faculty of Mechanical Engineering
Fakultetska 1, Zenica
Bosnia and Herzegovina

ABSTRACT
For an exact industrial needs there is a demand for reconstruction of present railway cars for slag transportation to another kind of application. It is about transportation of 12 (m) long billets, total capacity of 100 (t), from cooling department of electro-steel making plant EAF to store department. An application of this way of transportation results in efficiency of final product's manipulations.
For above mentioned application, a main structure of open railway car is planned to be made of two present wheel support segments, and new - especially designed complex welded structure. Static and dynamic numerical calculations of 3D complex welded lattice structure is made, and results are used for evaluation of structure's mechanical integrity.
Key words: lattice structure, numerical calculation, static and dynamic analysis.

1. INTRODUCTION
An object of interest is a device for transportation problem in specific industrial circumstances. For transportation of 12 (m) long billets with total capacity of 100 (t), from cooling department of electro-steel making plant EAF to store department a railway type of transportation has to be used. An application of this way of transportation results in efficiency of final product's manipulations. For an exact industrial needs there is a demand for reconstruction of present railway cars for slag transportation, Figure 1, to another kind of application. A main structure of open railway car is planned to be made of two present wheel rotary support segments, and new - especially designed complex welded structure, Figure 2. Also, rotary support segments are equipped with automatic clutches and that solution is held for construction of open railway car. A basic complex carrying structure of open railway car is welded lattice solution mostly created of I40, I30 profiles and plate parts. Basic technical datas for complex construction of open railway car are presented in Table 1. An open railway car construction is a four-shaft block-waggon for billet transportation without needs for athmospheric conditions load protection. Cross-linking members for load positioning are beams with 80 x 80 x 2760 (mm) dimensions. This shape of open railway car construction is made under the International European Standards for total load profile, and are created especially for local industrial purpose. After the definition of global and local geometrical characteristics of an open railway car complex construction, some analytical and numerical static-dynamic calculations are made. Also, as a part of an complex project calculation, an analytical calculations of welded essential joints are made but it will not be presented in this paper. As a fact, a short reviewal of numerical static-dynamic calculations will be presented in next chapters of this paper.

Figure 1. Railway car for slag transportation

Figure 2. Railway car for billet transportation

Table 1. Technical datas for construction of open railway car for billets transportation Q = 100 (t)

No.	Technical datas	Waggon
1	Carrying capacity	1000 (kN)
2	Shaft spread	10 140 (mm)
3	Waggon length	12 500 (mm)
4	Automatic clutch's axis spread	13 690 (mm)
5	Carrying area of waggon	35 (m^2)
6	Axle load	26 260 (kg)
7	Clutch type	automatic clutch

In Table 1 global technical datas for open railway car are presented, but more detailed parameters for calculations are presented in next chapter.

2. NUMERICAL MODELLING AND CALCULATIONS OF COMPLEX STRUCTURE

A complex load carrying structure of open railway car is made of welded steel standard profiles and represent a type of static non-determined beam-plate structure loaded with self-weight and continuous loads. It means that a known analitical methods of calculations are not quite sufficient. In that manner, two kinds of software are implemented, but in this paper results of numerical calculations in system "KOMIPS" will be only presented.

Table 2. Characteristics of cross sections for implemented basic profiles

Profile	Cross section, A [mm^2]	Mass over length [kg/m]	Moment of inertia for horiz. axis Ix, [mm^4]	Moment of resistance for horiz. axis Wx, [mm^3]	Moment of resistance for vert. axis Iy, [mm^4]	Moment of resistance for vert. axis Wy, [mm^3]
I40	11800	92,6	$29210 \cdot 10^4$	$1460 \cdot 10^3$	$1160 \cdot 10^4$	$149 \cdot 10^3$
U30	58800	46,2	$8030 \cdot 10^4$	$535 \cdot 10^3$	$495 \cdot 10^4$	$67{,}8 \cdot 10^3$

Table 3. Material characteristics

Sample	Material	Standard	R_{eH} [N/mm^2]	R_m [N/mm^2]	A [%]
Plate	S235JRG2	EN 10025	432-487	555-585	23-25
Profile INP400	S 275JR+AR	EN 10025	333-335	480-482	32-32,2
Profile UNP300	S 275JR+M	EN 10025	315	442	34

In table 2 and 3, characteristics of cross sections for implemented basic profiles and implemented material characteristics are shown. Also, this datas are involved in numerical discretization procedure.

2.1. Static analysis and calculations of complex structure

For evaluationing of detailed stress-strain field state of open railway car platform's complex structure a discretization of structure with 7378 points and 6940 plate type finite elements is made, and adequate boundary conditions are connected to 6 points, [1]. Also, an adequate loads are appointed over total construction, Figure 3.

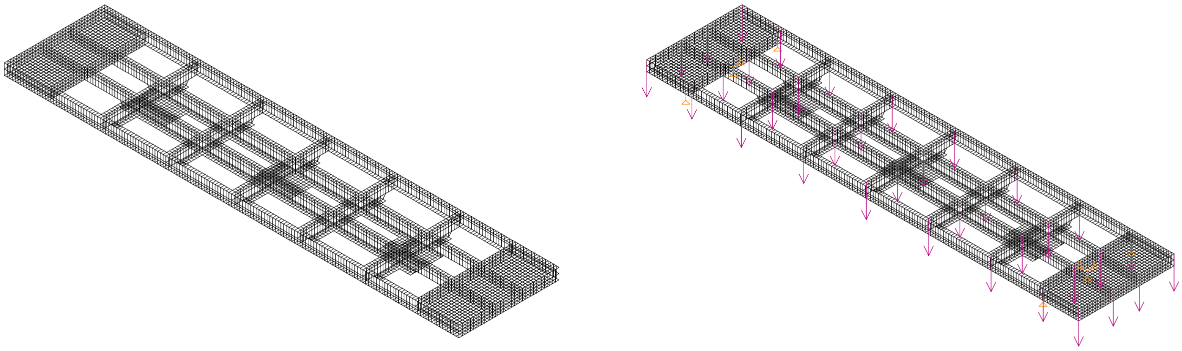

Figure 3. Discretization and boundary conditions of complex structure

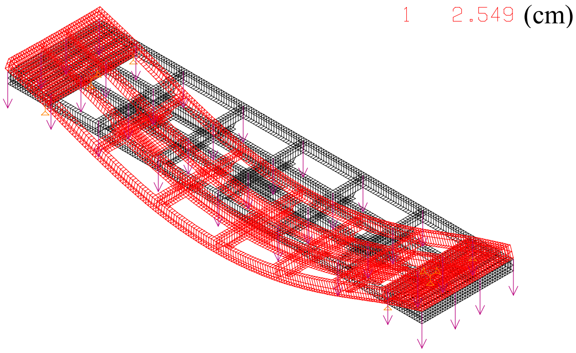

Figure 4. Flection shape of loaded structure

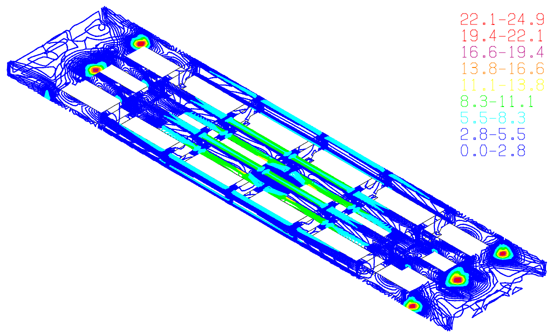

Figure 5. Total equivalent stress state of loaded structure

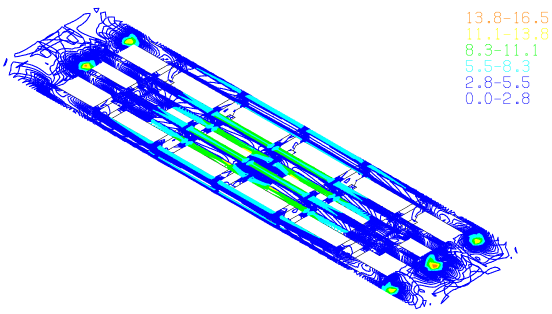

Figure 6. Normal stress field

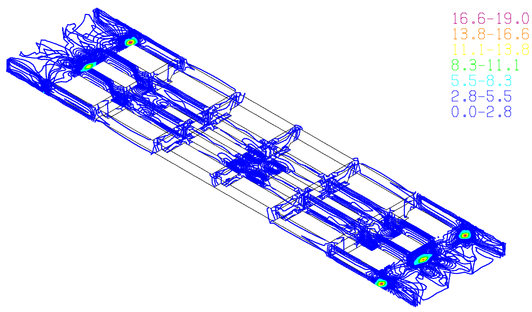

Figure 7. Tangential stress field

Figure 4 shows flection shape of the structure with maximal deformation value of 2,549 (cm) at the middle field. Total equivalent stress state, normal stress state and tangential stress state are shown in Figures 5, 6 and 7, respectively. It can be seen that percentage participation of normal stresses over tangential stresses are good. But, there are places, esspecially around three lower plates, which are very interesting for observation. Stress state shows that two I40 profiles are the most stressed and in the middle zone.

2.2. Dynamic analysis and calculations of complex structure

A discretization of a structure with plate shape finite elements is made for dynamic calculations, [2,3]. Boundary conditions are established according to real state. Natural frequencies characteristics of a structure are obtained for non-loaded and loaded structure. Three modal shapes, only for loaded structure, are presented in this paper, Figures 8, 9, and 10, respectively.

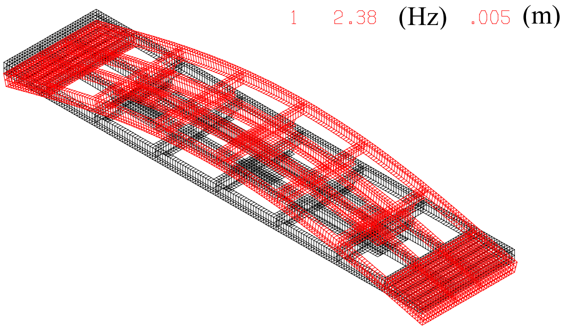

Figure 8. First modal shape

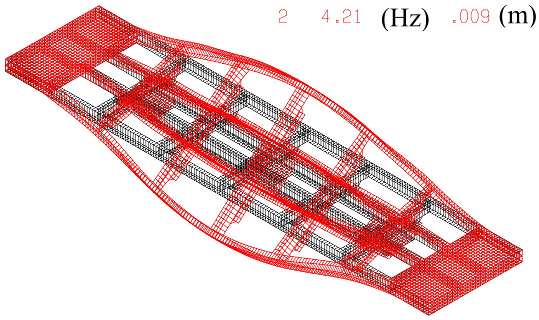

Figure 9. Second modal shape

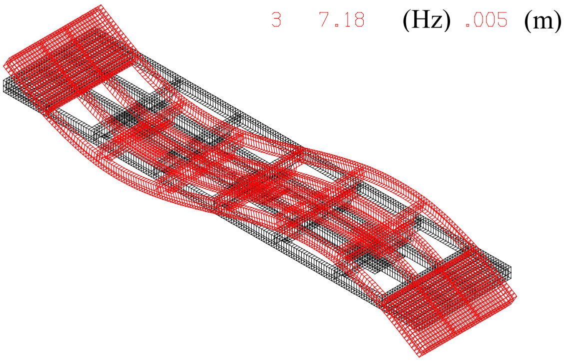

Figure 10. Third (full wave) modal shape

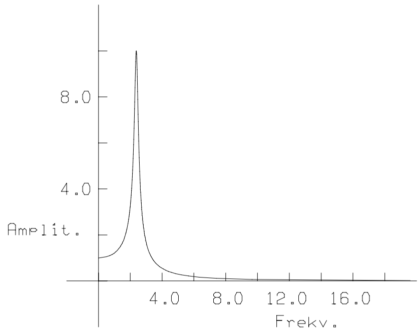

Figure 11. Amplit.-frequ. response characteristic, point 3613, y-direction

Natural frequency characteristics of loaded complex structure are obtained as: f_{01} = 2,38 (Hz), f_{02} = 4,21 (Hz) and f_{03} = 7,18 (Hz). It can be seen that those values are quite small, and has to be appointed in correlation to transportation speed. Also, dynamic behaviour of the system can be presented through diagrams of amp.-freq. response characteristic, Figure11.

3. CONCLUSIONS

Numerical modelling and calculation in static and dynamic of complexe structure is very efficient methodology for evaluation of structure integrity. Static analysis of complex structure of open railway car appointed to correlation to first mode of dynamic natural frequency. Dynamic stability analysis of construction appoints to domain of relatively small speeds of transportation that can be implemented.

4. REFERENCES

[1] Maneski T.: Kompjutersko modeliranje i proračun struktura, Mašinski fakultet, Beograd, 1998.,
[2] Inman J. Daniel: Engineering vibration, Prentice Hall, New Jersey, 2000.,
[3] Ćorić B.: Dinamika konstrukcija, Univerzitet u Beogradu, Beograd, 1998.