COMPUTING OF THE CHASSIS FRAME DISPLACEMENTS CONDUCTED ON CARGO VEHICLES

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UDC: 629.11.011.11:539.3:004.42CATIA

1. INTRODUCTION

Supporting constructions of cargo vehicles are made mostly of standard profiles, which means that the geometric characteristics and characteristics of materials are known. Such structures are often upgraded, and in this way cargo vehicles are obtained for different purposes. Performance of the final vehicle depends on the shape and the weight of the upgraded structure..

Ignorance of the change of displacements and chassis frame's stresses after the chassis has been upgraded – raises the question: whether the upgrading activities have caused the frame overloading or, on the other hand, the frame is unnecessarily over-dimensioned and overweight. The over-dimensioned and robust construction has resulted in a smaller payload. Considering the aspect of the chassis frame strength, we are coming to a conclusion that there are some vehicles that are not adequately used from the point of view of capacity, but, on the other hand, there are some vehicles with a risky loading regime. By means of a detailed analysis of the displacements, a clear picture of the frame's elastic deflection is obtained, which is also very important because of the motion of the elastic suspension system.

In practice, engineers are facing the problem of a stress analysis of an upgraded chassis that occurs due to the connection of some special structure with the chassis and the process of burdening it with maximum loading. The problem still exists after the chassis was redesigned.

In order to perform a linear analysis of the chassis frame of cargo vehicles, the CATIA software package was used.

2. CANTILEVER DISPLACEMENTS COMPUTING BY USING THE FINITE ELEMENT METHOD

In order to conduct numerical calculations by means of the finite element method the CATIA software was used, which integrates all aspects of the product development process. It includes the simultaneous usage of data and geometrical information; ranging from a product concept to a definition of the production process itself.

The finite element analysis in the CATIA software package is made for small displacements, and that refers to the linear analysis, applied to the isotropic material. In order to perform an analysis, it is necessary to predefine the CAD model. For a model defined in this way, the finite elements mesh has to be generated in the same manner as the set of boundary conditions and loads.

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After the finite elements mesh with flat quadrial elements is generated and boundary conditions are specified, a static calculation was performed, i.e. the linear analysis, which is necessary for the quick control of displacements, without any type of nonlinearity.

A simple cantilever model is shown in Figure 1. This is a square section thin–walled beam, 30x30x? (mm). The finite elements mesh is generated by the quadrangular linear thin shell element. The length of the cantilever is 1500 mm. The cantilever is loaded with the concentrated force F, acting in the middle of it.

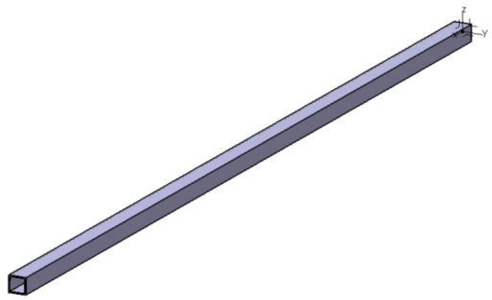

Figure 1: *The model of a simple, clamped cantilever*

The displacements' field is shown in Figure 2.

Figure 2: *Displacements obtained by using CATIA*

The same results obtained in the corresponding nodes with the AL–SHELL software are shown in Table 1.

Table 1

Distance from the Support (mm)	Displacement (mm)	Distance from the support (mm)	Displacement (mm)	Distance from the support (mm)	Displacement (mm)
10	-0.2	260	-5.4	510	-10.1
20	-0.3	270	-5.6	520	-10.2
30	-0.5	280	-5.8	530	-10.3

Distance from the support (mm)	Displacement (mm)	Distance from the support (mm)	Displacement (mm)	Distance from the support (mm)	Displacement (mm)
40	-0.7	290	-6.0	540	-10.5
50	-0.9	300	-6.3	550	-10.6
60	-1.1	310	-6.5	560	-10.7
70	-1.3	320	-6.7	570	-10.8
80	-1.5	330	-6.9	580	-10.9
90	-1.7	340	-7.1	590	-11.0
100	-1.9	350	-7.3	600	-11.1
110	-2.1	360	-7.5	610	-11.2
120	-2.3	370	-7.7	620	-11.3
130	-2.5	380	-7.9	630	-11.3
140	-2.7	390	-8.1	640	-11.4
150	-3.0	400	-8.3	650	-11.5
160	-3.2	410	-8.5	660	-11.5
170	-3.4	420	-8.6	670	-11.6
180	-3.6	430	-8.8	680	-11.6
190	-3.8	440	-9.0	690	-11.7
200	-4.1	450	-9.2	700	-11.7
210	-4.3	460	-9.3	710	-11.7
220	-4.5	470	-9.5	720	-11.8
230	-4.7	480	-9.6	730	-11.8
240	-5.0	490	-9.8	740	-11.8
250	**-5.2**	**500**	**-9.9**	**750**	**-11.8**

3. EXPERIMENTAL DETERMINATION OF DISPLACEMENTS

Experimental examinations are conducted in the Laboratory for Static and Dynamic examinations in the Institute of Automobiles – the „Zastava vozila“ Group. A block diagram is given in Figure 3, whereas the measuring equipment is shown in Figure 4.

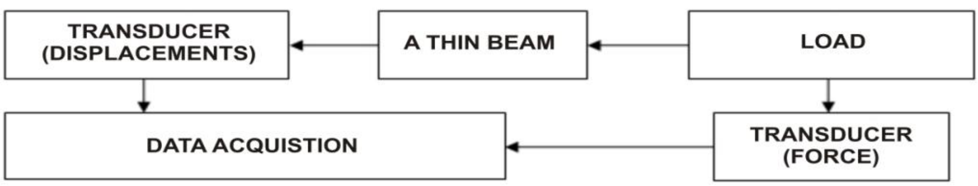

Figure 3: *Measurement equipment – a block diagram*

Figure 4: *Measurement equipment*

The force is measured by means of the U2A load sensor, Figure 6. The basic characteristics of this sensor are:

- It is made of corrosion–proof materials ,
- it is intended to measure the extension loads
- measuring range : 0÷500(kg) ,
- sensitivity: 2 (mV/V),
- hysteresis error: <±0.15 (%),
- input resistance: 340÷450 (Ω),
- output resistance: 356±0.2 (Ω),
- nominal incentive voltage range: 0.5÷12 (V),
- nominal temperature range: -10 ÷ +40 (°C).

The measuring principle of the U2A force sensors is shown in Figure 5.

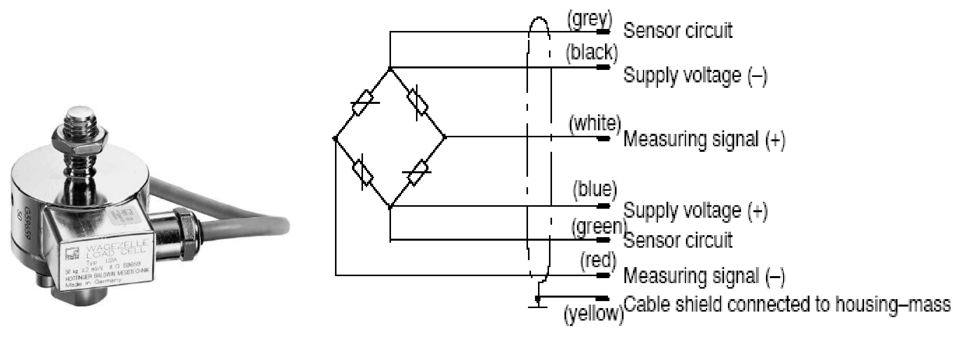

Figure 5: *The U2A force sensor and its measuring principle*

Displacements of a cantilever are measured by the WA motion sensors, Figure 6. The characteristics of these sensors are:

- corrosion resistance,
- shock resistance,
- vibration resistance,
- compact design,
- nominal movement:
  - WA20-sensor: 0 ÷ 20 (mm)
  - WA50-sensor: 0 ÷ 50 (mm)
- nominal sensitivity: 80 (mV / V)
- linear deviation: ≤ ± 0.2 ≤ ± 0.1,
- nominal temperature range: -20 ÷ +80 (° C)
- input-resistance: 350 ± 10% (Ω),
- output resistance: 680 ± 10% (Ω),
- nominal excitation voltage: 2.5 (V).

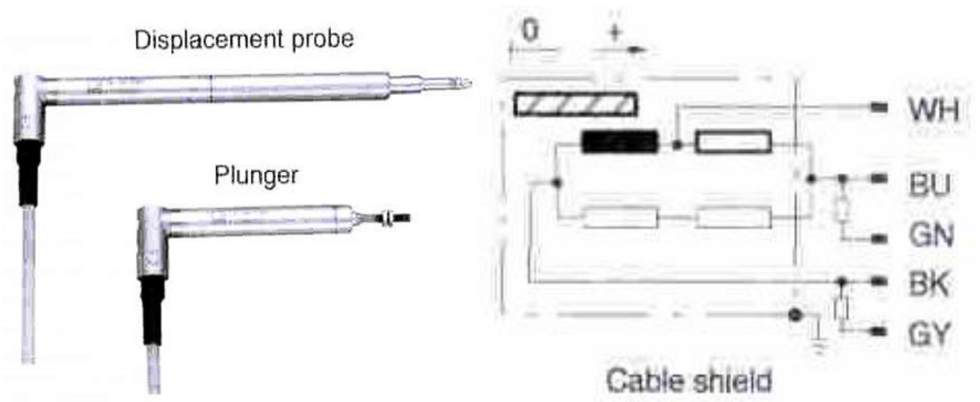

Figure 6: *The WA Motion sensors and their measuring principles*

where :

WH (white) – a measuring signal,
BU (blue) – incentive tension,
GN (green) – a sensor of the electric circuit,
RD (red) – a measuring signal,
BK (black) – incentive tension,
GY (gray) – a sensor of the electric circuit.

The measurement of a cantilever's deflection was conducted at the three measuring nodal points that are set within 250, 500 and 750 mm from the left cantilever's support, as it is shown in Figure 7.

The WA20 sensor was set at the first measuring nodal point NP1, Figure 8, whereas the WA50 sensor was set at the measuring nodal points NP2 and NP3.

Figure 7: *The measuring nodal points*

A schematic view of the measuring nodal points is shown in Figure 8.

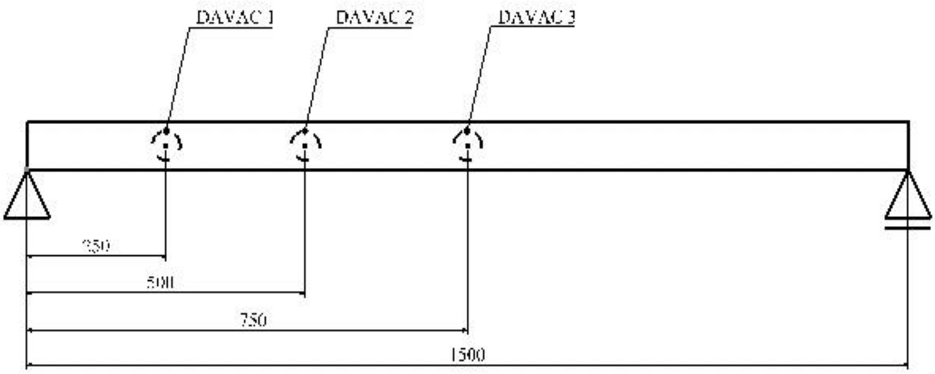

Figure 8: *A schematic view of the measuring spots*

An electronic recording of the results' measurement was made by means of the Spider 8 device, with the following characteristics:

- high testing speed,
- PC is not required as the mediation device,
- excitation voltage: 2.5 (V)
- carrier frequency: 4800 (Hz)
- resistance: 110 ÷ 1100 (Ω),
- voltage-measuring range: ± 10 (V)
- measuring range of frequencies: 0.1, 1, 10; 100; 1000 (kHz).

The CATMAN 2.1 software was used for the data acquisition.

Figure 9: *The spider 8 and data acquisition device*

A simulation of the cantilever loading was carried out by means of a manual lift-jack. By turning the handles of the lift-jack, the cantilever is gradually loaded untill the maximum force of 100.17 (kg) is achieved, i.e. 983 (N), and then a gradual unloading of the cantilever was done, Figure 10.

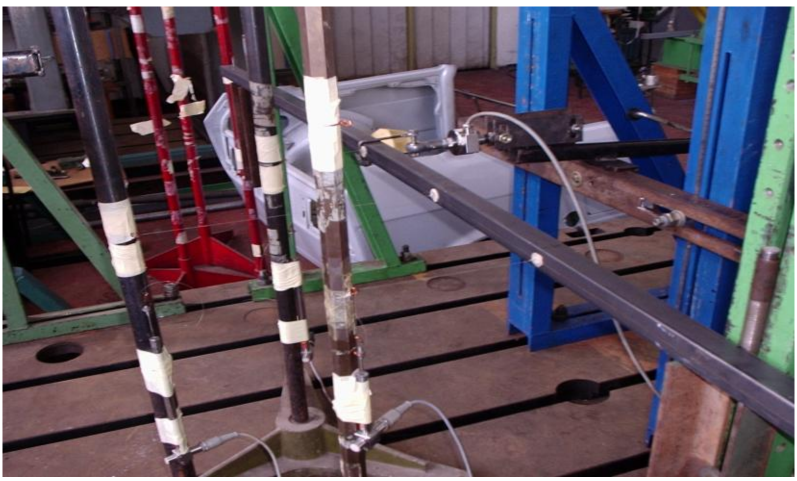

Figure 10: *A position of the maximum loaded cantilever*

Time dependence of the force is shown in Figure 11.

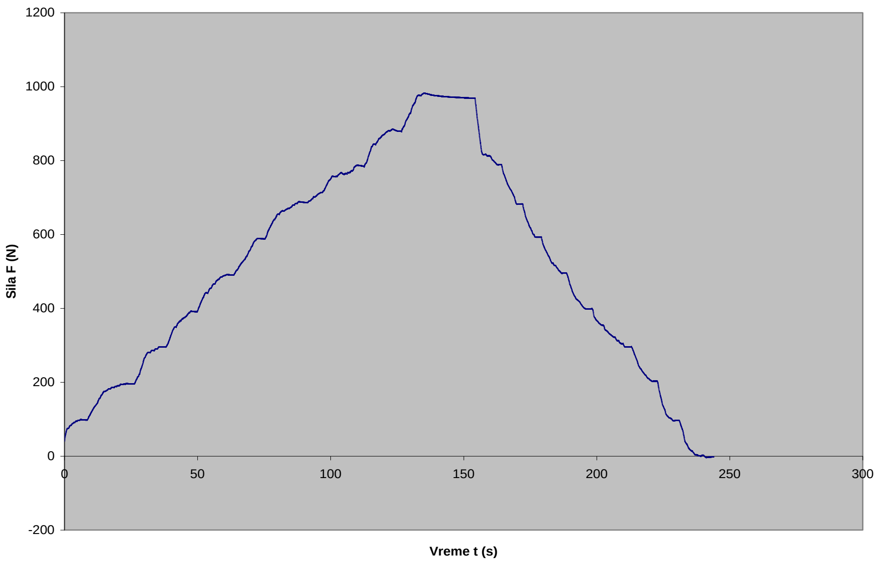

Figure 11: *Time dependence of the force*

Thus, hysteresis curves were obtained, as it is shown in Figure 12.

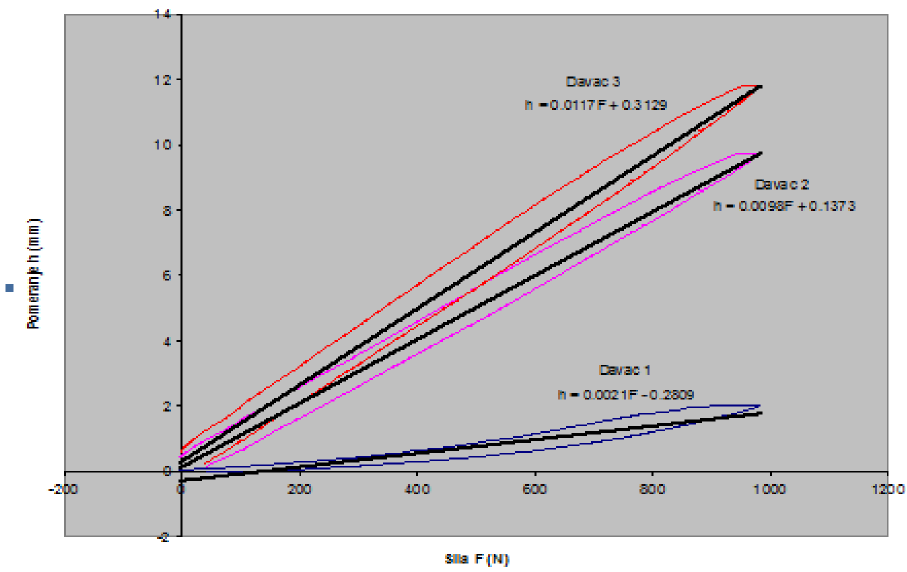

Figure 12: *Hysteresis curves*

On the basis of these curve lines, the following values can be determined: h_1=1.8 (mm); h_2=9.8 (mm); h_3=11.8 (mm).

In order to evaluate the accuracy of the obtained results, the following relative error equation (ε), expressed in percentage, was used:

$$\varepsilon = \frac{(N-n)\cdot 100}{n} \ (\%)$$

where: N- is an exact value and n- is an approximate value.

On the basis of the obtained theoretical, numerical and experimental results, the following statements can be concluded:

- at the measurement place 1, there is a considerable deviation of the numerical values of a displacement, especially when compared to the experimental values,
- at the measurement place 2, there is a considerable coincidence with those values, with a difference of only 1%,
- at the measurement place 3, the computed value is identical to the experimental one.

4. COMPUTING OF THE CHASSIS FRAME OF THE NEW TURBO RIVAL 49.10 VEHICLE

In the following section of this paper the results of a static calculation of the chassis frame, applied to cargo vehicles, will be presented.

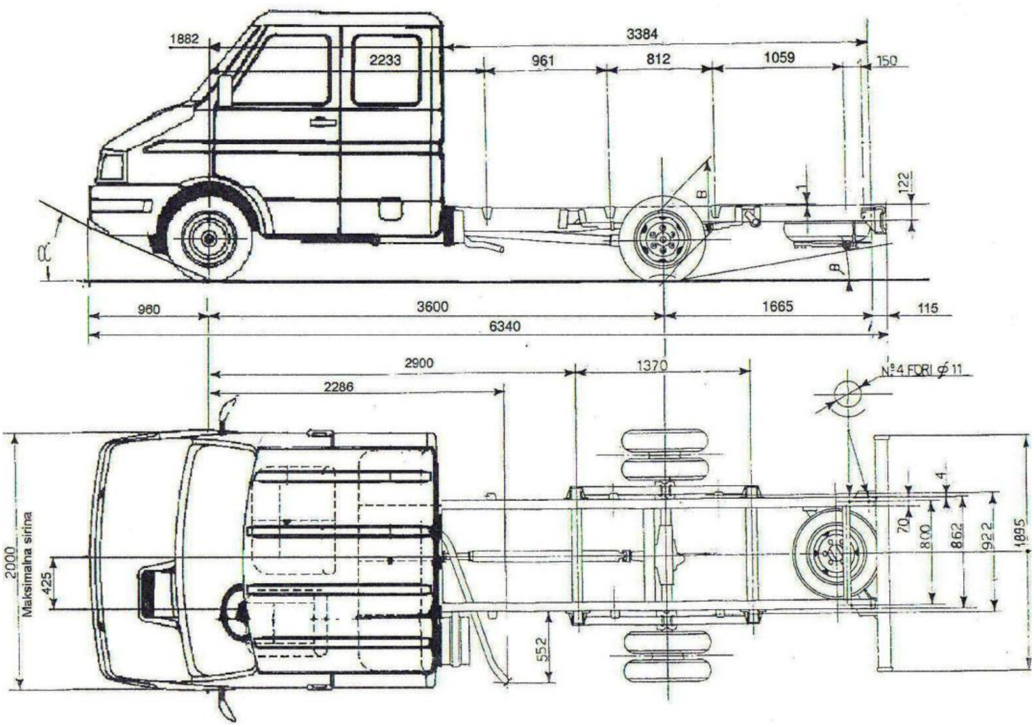

Figure 13: *The New Turbo Rival 49.10*

The chassis frame of the vehicle is shown in Figures 13 and 14, [12].

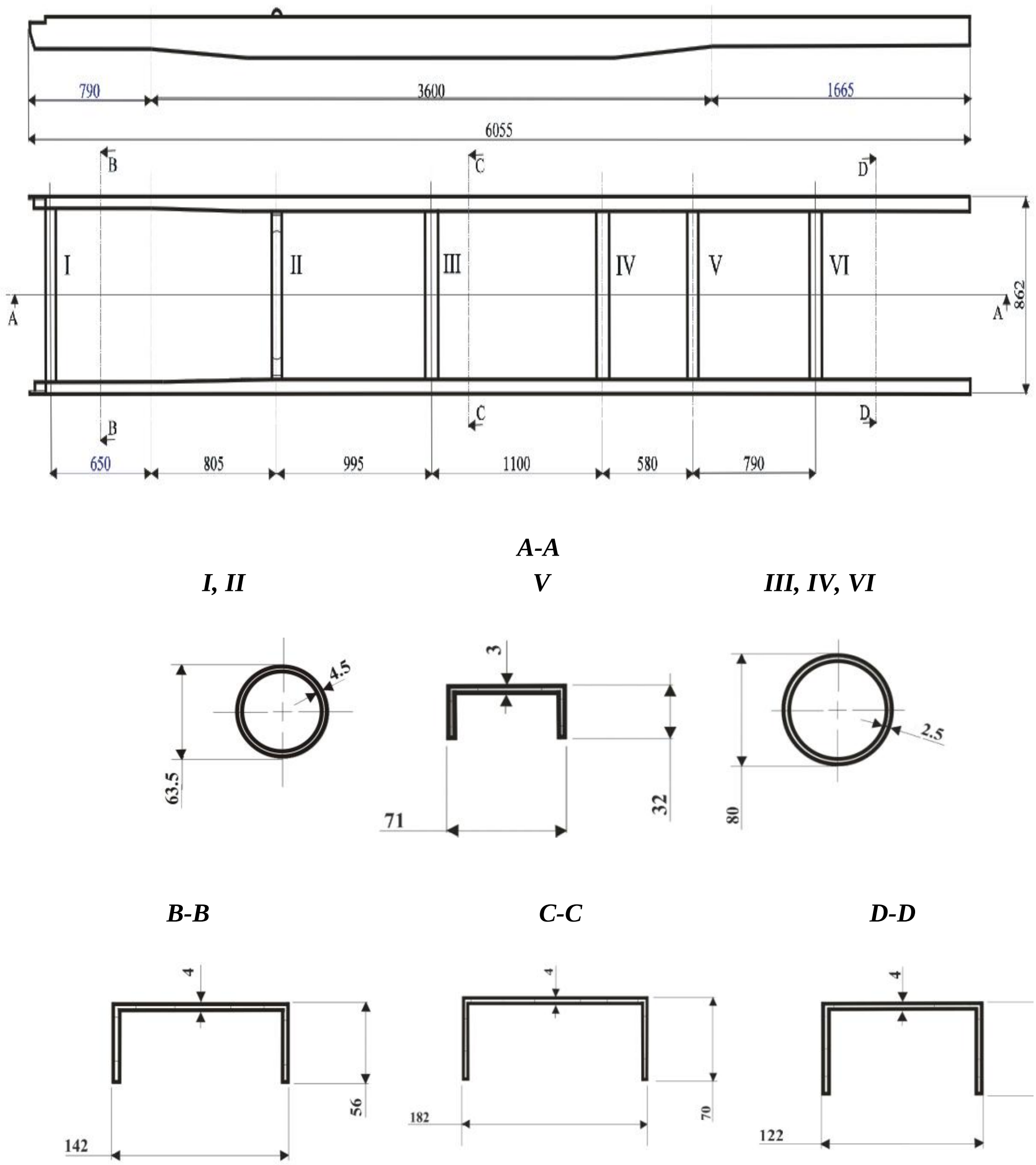

Figure 14: *The chassis frame of the New Turbo Rival 49.10 vehicle*

Vehicle's characteristics relevant for the calculation are:

- Vehicle's weight: 5000 (kg);
- Load capacity: 3000 (kg);
- Wheelbase: 3600 (mm);

The supporting structure of the vehicle is modeled by means of the linear quadrangular shells.

Frame brackets are placed in the connection spots of the chassis and elastic suspension system. The forces that represent the external load of the chassis frame, and the vehicle's carrying capacity are placed in the connection spots on the frame itself (these forces are marked in yellow – Figure 15). The intensity of each of these forces is 4900 (N). The forces are also taken into account, the ones that react on the front side of the vehicle, (the engine, transmission, cabin, etc..), acting in the connection spots between the cabin and the frame (these forces are marked in red in Figure 15). The intensity of each of these forces is 1545 (N).

It is assumed that between the longitudinal and transversal bracket there is a clamped connection which corresponds to the real situation in practice. The results that represent the frame's displacements are shown in Figure 15, and it is obvious that the maximum ones are registered in the rear area of the chassis frame, with the value of 94.4mm.

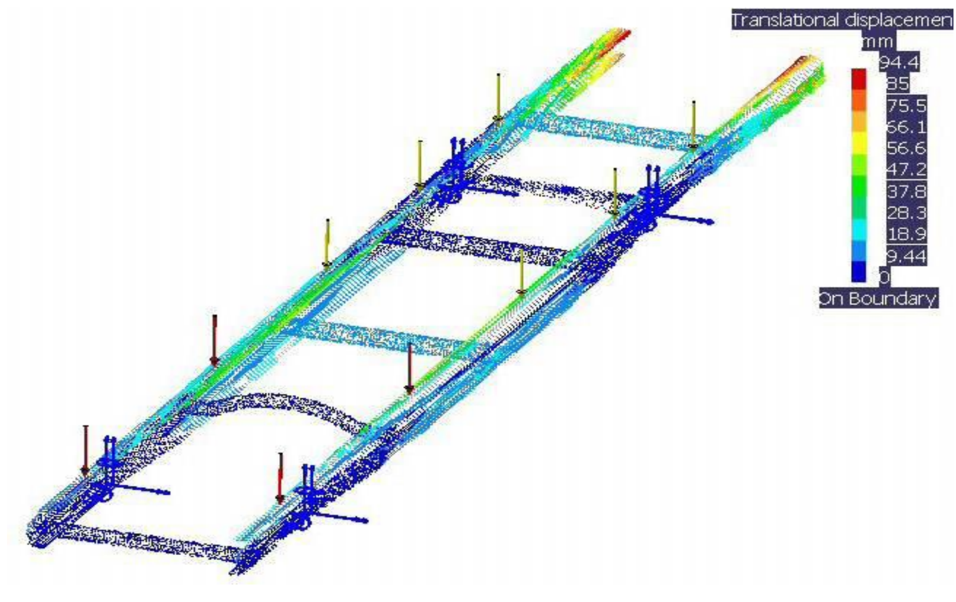

Figure 15: *The longitudinal bracket deflection of the frame*

The initial and deformed configurations of the frame are shown in Figure 15. The computing was performed with a very precise discretization in the CATIA software package.

The computing was performed by using the AL–SHELL program package, which was conducted within the references [1] and [2], containing the computing only, without the graphical output.

The measurement of displacements is possible in the Laboratory of the Faculty of Mechanical Engineering.

5. CONCLUSIONS

The problem of overloaded cargo vehicles reflects directly on the load of roads, vehicles performances, load of the chassis frame and a vehicle's stability. What is discussed in this work is the aspect of frame's stiffness, i.e. the field of displacements in the relation of the static load capacity, which refers to the optimization of supporting structures of cargo vehicles.

What was made by means of the cantilever case, is a comparison of the results obtained by 1) the analytical calculations, a deflection based on the engineering theory 2) the computing by means of the finite element method and 3) the experimental measuring of a deflection. The results which are obtained by the CATIA software packages, the AL–SHELL domestic research-development software and the experimental results – are in accordance. Which method will be applied, depends on the possibility occuring at the moment.

ACKNOWLEDGMENTS

Special thanks to the colleagues from the „Zastava vozila" Group for their technical assistance and performed experiments.

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