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MACHINE DESIGN

NUMERICAL AND EXPERIMENTAL DIAGNOSTICS OF THE BEHAVIOUR OF THE PALETTE-PACK MACHINE

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Abstract: *The subject of the present investigation is determination of the behaviour for the cement palette-pack mashine in F. C. Beočin. As we wanted to define the reason of the failure of the construction which was in non-stationary impulsive regime of work, it was necessary to analyse the problem using both numerical and experimental approach. The numerical calculation was done using finite element method, specifically program package KOMIPS (T. Maneski). On several places on the construction the gauges were established and appropriate dynamic stresses were measured to verify the numerical results. The failure strength of the material was checked in laboratory on the tensile specimen. A comparative analysis of the obtained results and appropriate calibration was done, and the reason for the failure of the construction was determined. A necessary reconstruction was performed.*

Key words: *stress, deformation, palette-pack, nexus, shakle*

1. INTRODUCTION

Considered machine packs one palette in eight cycles, each with five sacks of 50 kg, so maximal loading of the palette at the end is 2 tons. Packing of the tours is in cross positions. One cycle is consisted of following operations: lifting with rotation of the palette to the position for packing, moving 5 sacks from the transporter to the palette, descending the palette and lifting to the position for removing air from sacks and, at the end, descending the palette for the beginning of the next cycle. The whole palette is packed in minimum 40 seconds, so the period of one cycle is minimum 5 seconds.
Figure 1 presents the construction of the palette-pack machine in F. C. Beočin which consists of the frame, the palette and the drive-unit with nexus.

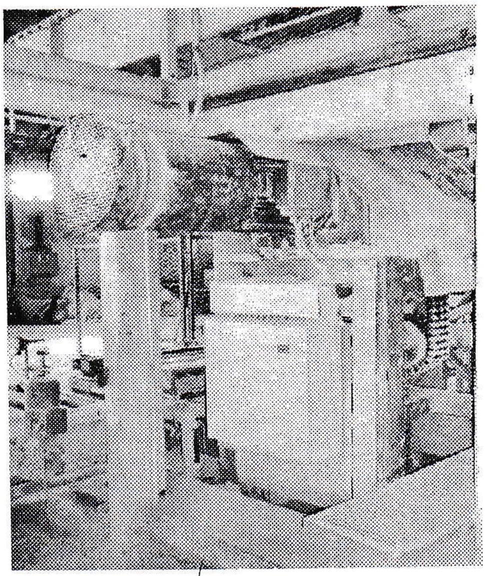


Fig. 1. The construction of the palette-pack machine

The drive-unit consists of electromotor, angular velocity 730 o/min, reductor, catenary and nexus linked to the structure of palette.
During the work, the failure was observed in diagonals of palette, on the frame (Figure 2) and in the nexus which was moving the palette.

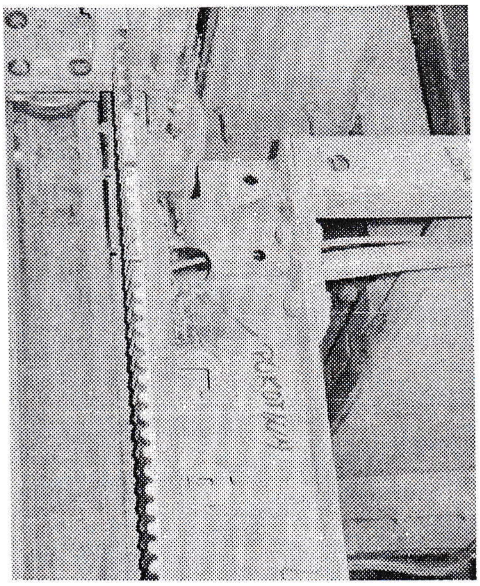


Fig. 2. Failure, crack

In exploitation, on every 30 days of work, the nexus, the palette and the frame had been broken. Because of the non-stationary impulsive way of work, the problem had to be analysed by both numerical and experimental approach to define the base reason for the failure of the construction.

2. FINITE ELEMENT ANALYSIS

Finite element analysis was done by using the program package KOMIPS [1, 2] (T. Maneski). The calculation was derived for all elements that were transferring force: the frame, the palette and the nexus. Appropriate static and dynamic models were formed.

2.1. Frame model in FEM calculation

The drive-unit electromotor is of the cage type. This electromotor type is very unfavourable because it is always working in the regime of short accelerations. As the period of one cycle is only about 5 seconds, the electromotor has never worked in the nominal regime. The electromotor frequency is 12.17 Hz.

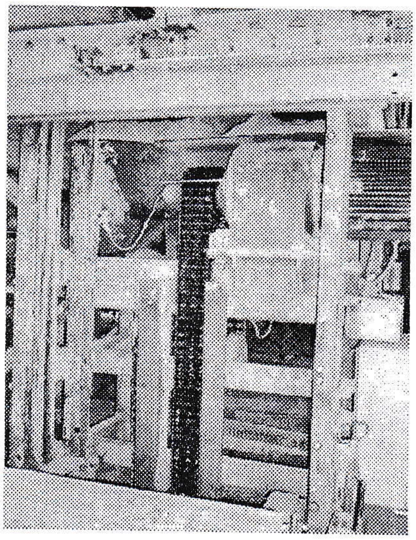
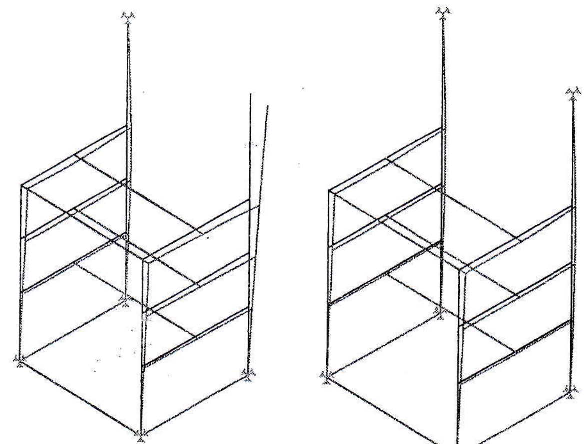


Fig. 3. The construction of the frame

The bearing-frame model was created by using the beam elements. Dynamic behaviour was obtained for two types of supports and appropriate results are presented in Figure 4.



f_{01}=26.7 Hz f_{01}=33.7 Hz

Fig. 4. Dynamic behaviour of the frame

In the first case of boundary conditions primary calculated frequency is f_{01}=26.7 Hz and for the second case primary frequency is f_{01}=33.7 Hz. As the electromotor frequency is 12.17 Hz, behaviour of the frame is satisfied in both cases.

2.2. Palette-pack model in FEM calculation

In this section finite element analysis of the palette that is bearing the cement sacks is presented. The palette is loading incrementally in eight cycles, each with 250 kg weight, so maximum loading is 2 tons. The palette was modelled by using 2D surface and 3D volume finite elements.

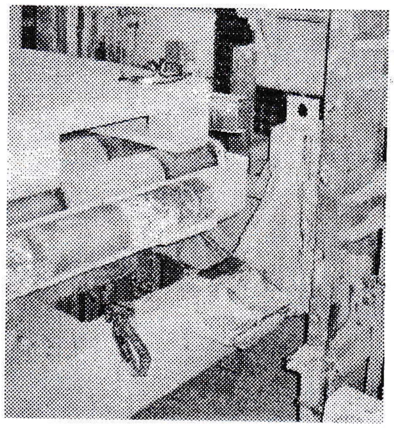


Fig. 5. The construction of the palette

One part of the palette is presented on Figure 5. On Figures 6 and 7 appropriate finite element model is shown in isometric and in two projections.

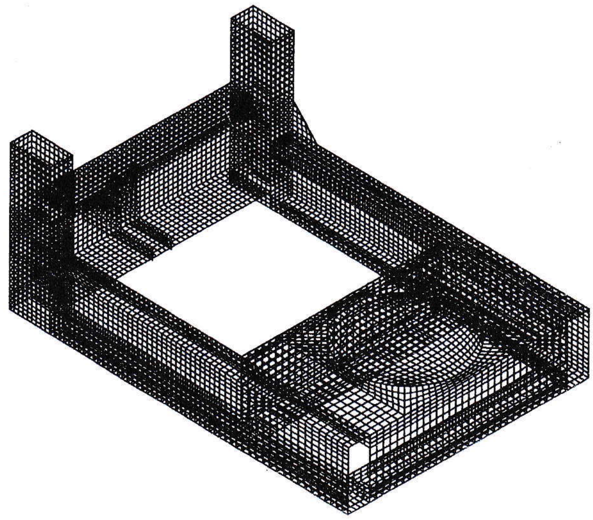


Fig. 6. Model of the palette in isometric

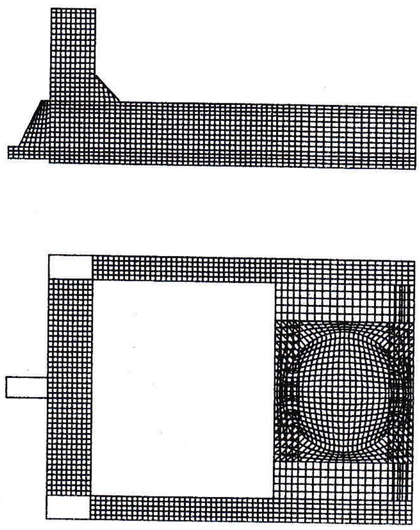


Fig. 7. Two projections of the model

The boundary conditions (supports) and the loading forces are presented in Figure 8. The whole loading of the model is 10 kN or approximately 1 ton.

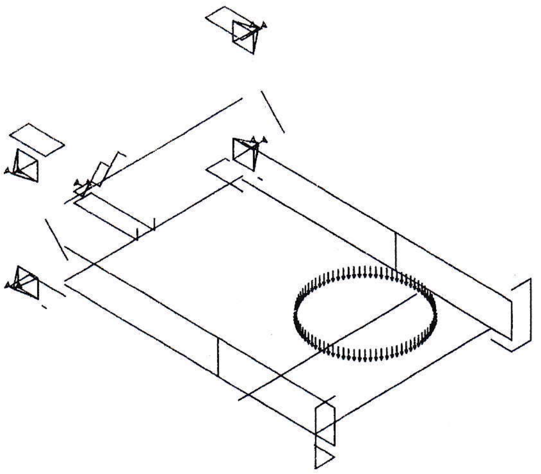


Fig. 8. Loading and supports

The maximum displacement obtained, which is shown on Figure 9, is $f_{max} = 0.45$ mm.

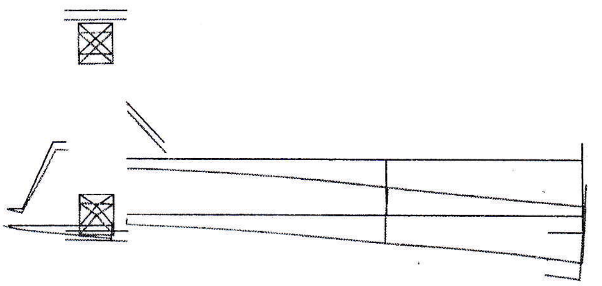


Fig. 9. Deformation of the palette

Figure 10 is presents the palette stress field calculated by FEM for the loading of 10 kN.

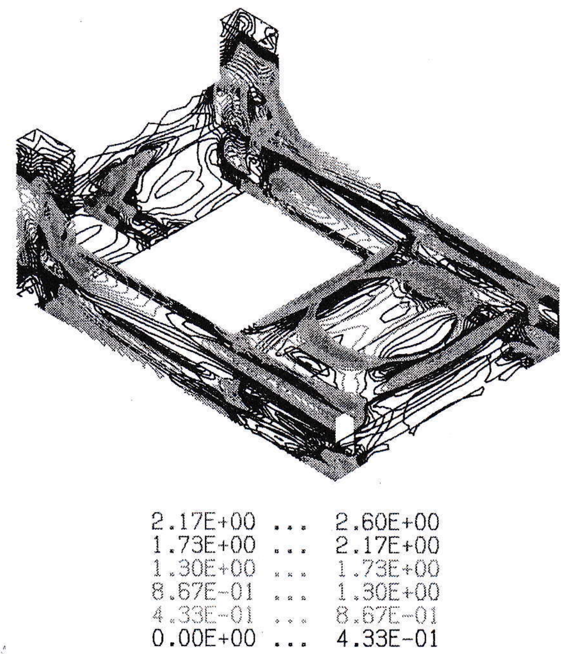


Fig. 10. Stress field in the palette [kN/cm²]

In the same case, the strain gauge was placed on one part of the palette surface. The stress at this location is calculated to be 0.7 kN/cm² for loading of 10 kN. In the case of maximal load of 2 tons of cement, the stress on the strain gauge location would be 1.4 kN/cm². The maximun stress calculated was 26 kN/cm², or in the exploitation 52 kN/cm² in diagonal elements.

2.3. Nexus model in FEM calculation

The nexus finite element calculation was performed in two steps: the static calculation for one shakle of the nexus and the dynamic calculation for the whole nexus. The shakle configuration is presented in Figure 11.

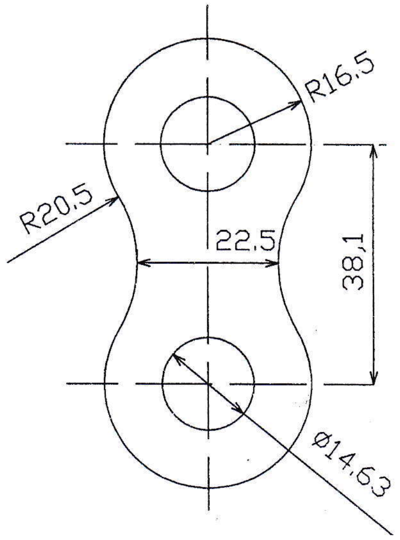
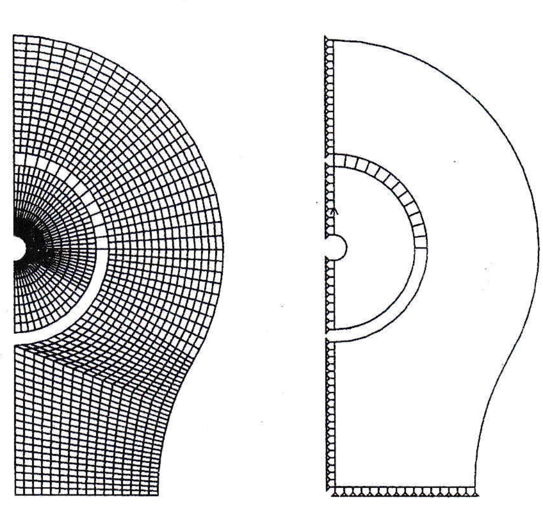


Fig. 11. Configuration of one shakle of the nexus

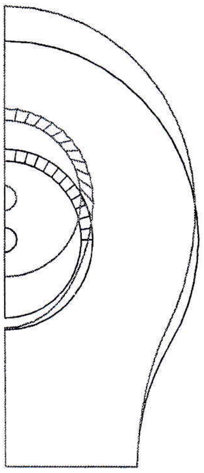
Thickness of the shakle is t=0.4 mm, a cross-section on the neck is A=0.5 cm² and the cross-section around hole A_h=0.36cm².
The static-calculation model for and appropriate boundary conditions for the symmetric case of loading are presented in Figure 12. The model was formed by using the plate elements and the beam elements for the load transfer.



Model *Loading and supports*

Fig. 12. Finite element model of the shakle

The nexus consists of six shakles in each row. As, in the first step of calculation, the nexus transferred the force of 10 kN, one shakle had the force of 0,8333 kN.



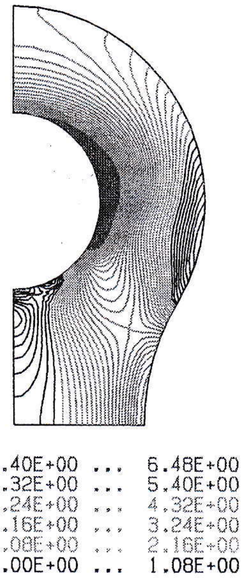
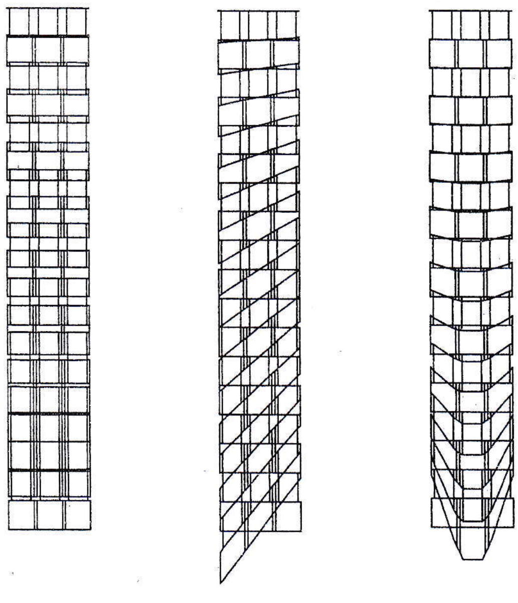


Fig. 13. Deformation *Fig. 14. Stress* [kN/cm^2]

The maximum calculated deformation was $5.5 \cdot 10^{-4}$ cm.
At the same time, on the necks of six shakles the strain gauges were placed in the first and in the last row of the nexus. The calculated stress in the middle element of the neck was 1kN/cm^2 for the whole loading of 10 kN (1 ton).
The appropriate maximum stress in the shakle of 6 kN/cm^2 is located around the hole.
The conclusion from presented calculation is that the maximum stress in the shakle is six times higher then the stress on the place of the strain gauge.
For static loading of 2 tons, the neck stress would be 2 kN/cm^2, and the maximum stress 12 kN/cm^2.
The finite element model for dynamic calculation is presented in Figure 15.



First mode *Second mode* *Third mode*

Fig. 15. First three modes of oscillations

The amplitudes in the first, the second and the third mode of eigen-oscillations of nexus are shown in Figure 15. Appropriate frequencies are presented in Table 1.

Tab. 1. Eigen-frequencies of the nexus

	Angular-frequency [s^{-1}]	Frequency [Hz]	Period [s]
1.	253.28	40.31	.024807
2.	255.40	40.65	.024602
3.	594.13	94.56	.010575

In the second step of dynamic calculation the response of the compulsive force was determined for six shakles in the first row and six shakles in the last row of the nexus. The compulsive force shape was similar to the real stress function determined by the strain gauges placed in the middle of the shakle neck.

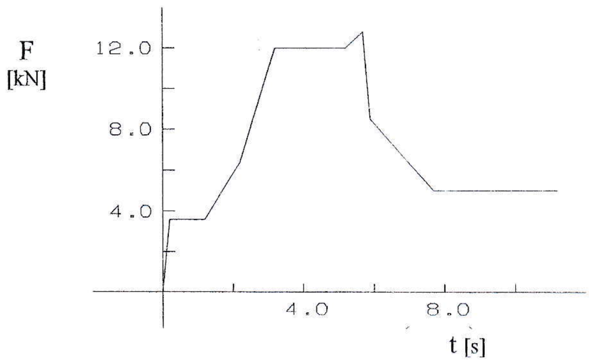


Fig. 16. The function of the compulsive force

The shape of the compulsive force as a function of time is presented in Figure 16.
Appropriate results obtained by using finite element calculation are shown on diagrams from Figures 17 and 18.

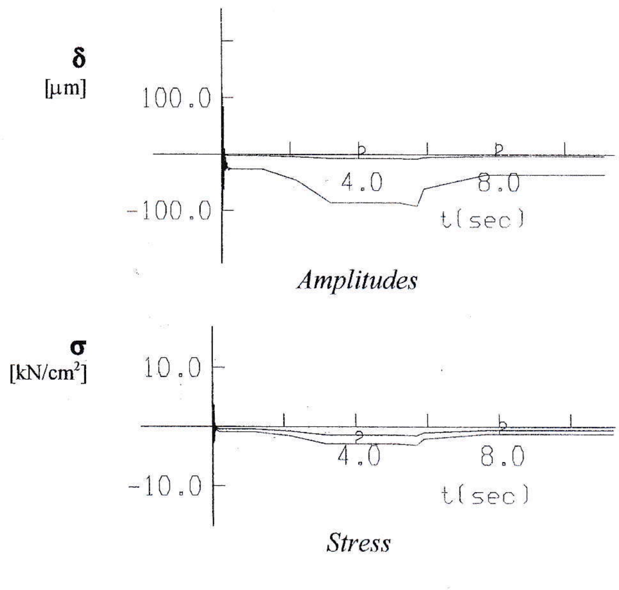


Fig. 17. Response on the left shackle of one row

The smaller stress amplitude curve corresponds to the upper row of shakles and the curve with higher values to the lover row.

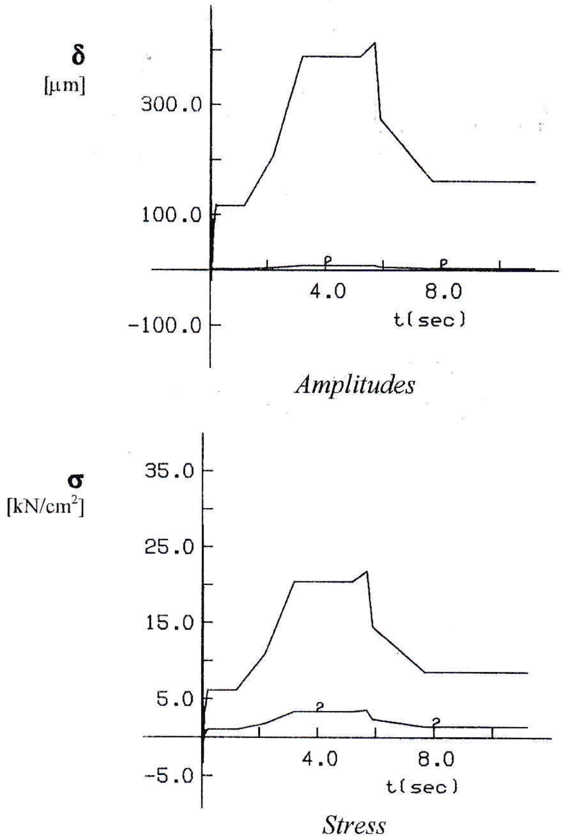


Fig. 18. Response on the right shakle of one row

The influence of the compulsive force is reported for the right shakle of the nexus.
As it is shown in the presented diagrams, the lover row of the shakles is carrying impulsive force.

3. EXPERIMENTAL RESULTS

In the experimental analysis measuring of the dynamic stresses on the constructions of frame and palette, and on the neck of the shakle was done by several strain gauges. Measuring was performed during the work with maximum loading of 2 tones. The positions of three strain gauges are presented in Figure 19.

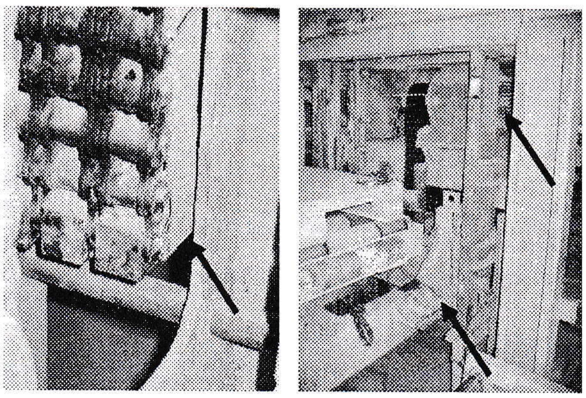


Fig. 19. The positions of the gauges

The obtained results are presented in Figure 20. The line on less values represents the stress on the palette and the other line represents the stress on the neck of the right shakle in lover row.

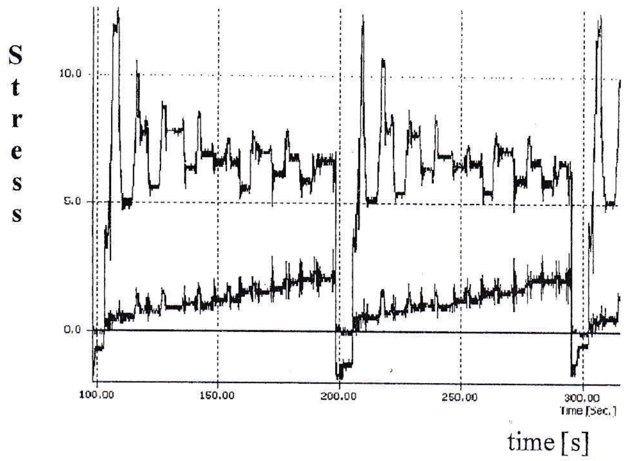


Fig. 20. Dynamic stress on the shakle and the palette [kN/cm^2]

The maximum stress on the palette surface for loading of 2 tones is 1.5 kN/cm^2 as it was calculated by finite elements.
The first impulse of one working-cycle is represented in Figure 21. As we can note, the maximum measured stress in the middle point of the shakle is 15 kN/cm^2.

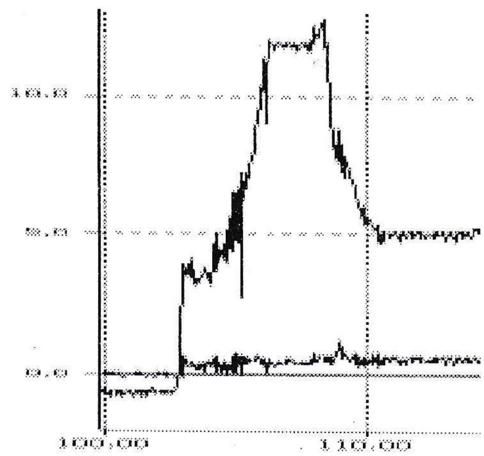


Fig. 21. First impulse of one cycle, stress [kN/cm^2]

As the shakle maximum stress is six times higher then the stress on the neck, the dynamic stress at the beginning of impulse is 90 kN/cm^2.
The failure strength of the shakle material was checked in laboratory.

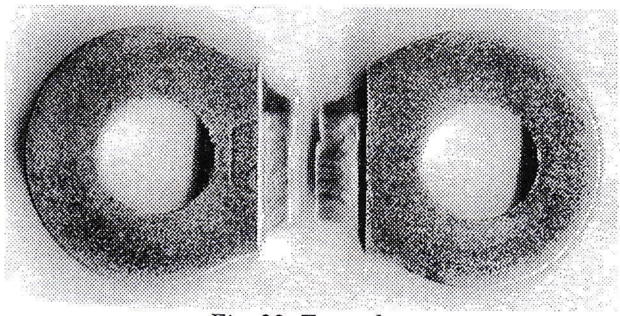


Fig. 22. Test-tube

The test-tube shape is presented in Figure 22. The test tube was subjected to axial loading and obtained result is shown on diagram from Figure 23.
The test tube ruptured at the stress of 100kN/cm^2.

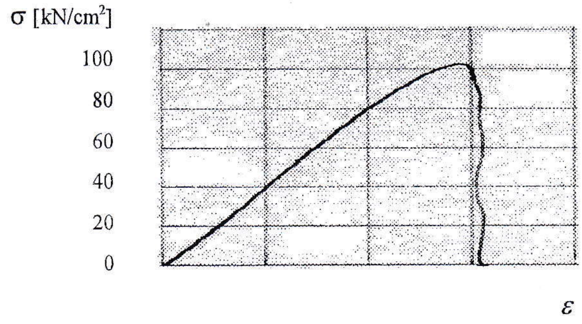


Fig. 23. Experimental curve

4. CONCLUSION

The palette pack machine was working in non-stationary impulsive regime and it had a failure on every 30 days. Analysis of the problem by numerical-experimental way was necessary to define the reason of the failure. The strain gauges were placed on the construction and dynamic stresses were measured. The failure strength of the material was checked in laboratory on test tubes.
The frame numerical model gave that the eigen-frequencies were appreciably higher than the electromotor frequency, so behaviour of the frame was satisfactory.
The experimental results verified the palette numerical model. The maximum stress was in diagonal elements, but it was not the cause of the failure.
The comparison of the numerical and experimental results revealed that the base problem was in the nexus shakles. Appropriate calibration was done and it was determined that the maximum stress in the shakle was six times higher then the measured stress on the neck.

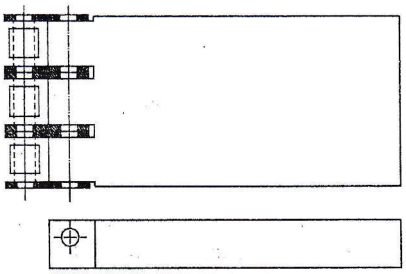


Fig. 24. The nexus before reconstruction

As the dynamic stress on the neck at the beginning of impulse (measured by the strain gauge) was 15 kN/cm^2, the maximum one was 90 kN/cm^2.

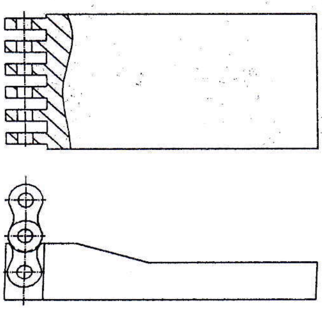


Fig. 25. The nexus after reconstruction

Necessary reconstruction was performed and is presented in Figures 25 and 26. The reconstructed nexus operates successfully (that is without failure) since the last January.

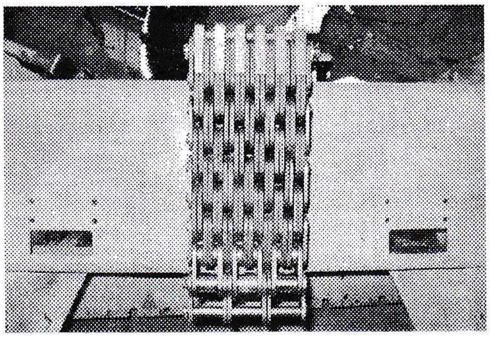


Fig. 26. The nexus after reconstruction

REFERENCES

[1] MANESKI T., *Program package KOMIPS*, Belgrade 1998
[2] MANESKI T., MILOŠEVIĆ MITIĆ V., OSTRIĆ D., "*Postavke čvrstoće konstrukcija*", Monografija, Belgrade 2002
[3] MANESKI T., *Rešeni problemi čvrstoće konstrukcija*, Belgrade 2002
[4] MANESKI T., *Computation Modelling and Calculation of Structures*", Monografija., Belgrade 1997
[5] ANDJELIĆ N., MANESKI T., MILOŠEVIĆ MITIĆ V., *The Influence of the Coupling on the Dynamic Behaviour of Electromotor*, VII MAREN, Bgd. 2006
[6] MILOŠEVIĆ MITIĆ V., ANDJELIĆ N., *Dynamic behaviour of the elements of gear-box*, XVIII Int. Conf. on MHCL, Belgrade 2006
[7] MANESKI T., MILOŠEVIĆ V., IGNJATOVIĆ D., ANDJELIĆ N., *Diagnostic of the Dynamic Behaviour of Drive Unit*; 1st Int. Congress of Serbian Society of Mechanics, Kopaonik 2007, pp 435-440

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