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EVALUATION OF THE STATE OF STRESS IN STRUCTURAL COMPONENTS OF A SCREEN SEPARATOR

SUMMARY

This study summarises the results of FEM analysis of the state of stress generated in structural components of a PZ3R screen separator under the typical operating conditions. Simplifications underlying the numerical analysis were verified by measuring the stresses in selected parts of the machine.
Resistance test data indicated the directions for further modifications of structural elements of the screen separator, at the same time confirming the adequacy of these tests and emphasising the importance of the sequence of the applied tests.

Keywords: *metal structures, state of stress, FEM, strain measurements*

OCENA STANU NAPRĘŻENIA W ELEMENTACH KONSTRUKCYJNYCH PRZESIEWACZA

W opracowaniu przedstawiono wyniki analizy numerycznej stanu naprężenia (MES), jaki powstaje w elementach konstrukcyjnych przesiewacza PZ3R w warunkach normalnej eksploatacji.
Uproszczenia, jakie wprowadzono na etapie analizy numerycznej, zweryfikowano wykonując pomiar naprężeń w wytypowanych obszarach konstrukcji.
Wyniki analiz wytrzymałościowych wskazały kierunki możliwych modyfikacji elementów konstrukcyjnych przesiewacza, a ponadto potwierdziły celowość ich przeprowadzenia, ale przy zachowaniu ściśle określonej kolejności.

Słowa kluczowe: *konstrukcje metalowe, stan naprężenia, MES, pomiary tensometryczne*

1. INTRODUCTION

Design of machines and structures is a difficult task, particularly when their dynamic loading is not fully recognised, which precludes the reliable evaluation of the state of stress in their elements at further stages.

It appears that the designer's expertise might still prove insufficient to guarantee that the newly-designed machine should work properly, even though there are existing machines of this class that work properly.

This is the case of the screen separator PZ3R, whose design is based on that of another screen separator PZ, though a few modifications were introduced and some of its components were re-sized. Some elements of the PZ3R screen separator began to break after a relatively short period of service. The authors decided to find the reasons for this state of affairs, basing on the analyses of the state of stress in structural elements of the machine under the typical operating conditions.

A thorough study of the state of stress or strain in the structural elements has been made possible only recently. Major advances in applied mechanics and application of mathematical methods, including the numerical approach, enabled us to determine the behaviour of the structure under the typical loading.

2. TEST OBJECT

The PZ3R screen separator is not a conventional super-resonance machine (Banaszewski 1990). The major diffe-rences between PZ3R and typical PZ screen separators include: the smaller size of the sieve deck, a larger number of decks and nearly parallel arrangement of vibrators with respect to the sieve decks (Fig. 1).

These differences are responsible for the variations of the kinematic characteristics of particular points along the screen separator's length. Vibrations are generated in the form of rectilinear vibration near the machine's COG (centre of gravity) or in shape of inclined flattened ellipses (Wolny *et al.* 2009) in the vicinity of supports.

Three screen separators PZ3R were installed in a mine in Poland for the purpose of first-stage separation of copper ores. When in service, some structural elements began to break, including:

– breaks in the area of the sieve sideboard support (Fig. 2),

– lasting deformation of the support (Fig. 3).

Attempts were made to restore the separator's operational efficiency through strengthening the most vulnerable points, yet the improvements were only temporary.

To solve the problem comprehensively, the strength analysis (numerical analysis) was performed of structural elements of the screen separator and the results were experimentally verified on a real object through stress and strain measurements at the points with the highest stress concentration. The results should indicate the directions for further modernisation of structural elements thus ensuring the full screening efficiency of the system.

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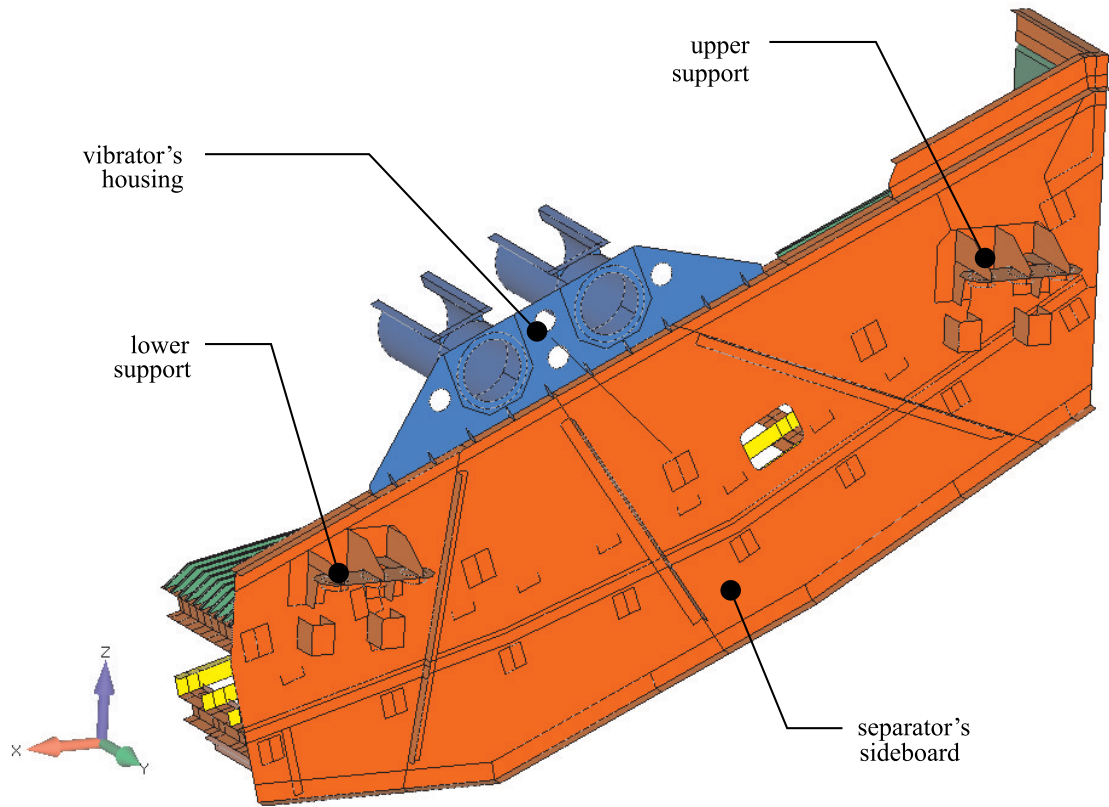
Fig. 1. Longitudinal section of the PZ3R screen separator – a side view

Fig. 2. Fractures in the regions of the sieve sideboard support, damaged HuckBolt bolts

Fig. 3. Lasting deformation of the support

3. STRENGTH ANALYSIS OF THE SCREEN SEPARATOR PZ3R

The strength analysis used the FEM approach. The numerical model was developed basing on the technical specification of the machine (Raszyński and Szczepaniak 2005a, b). The screen separator is modelled with 2D finite elements.

The construction of the screen separator is made of steel sheets and profiles, steel grade St3S (certain elements are made of certified steel grade St3S) whose major parameters are set forth in relevant standards (PN-EN 1993 and PN-88/H-84020):

Young modulus $E = 210$ GPa
Poisson's ratio $\nu = 0,3$
Shear modulus $G = 81$ GPa
Yield strength $R_e = 235$ MPa ($g \leq 16$ mm)
                 $R_e = 225$ MPa ($16 < g \leq 30$ mm)
                 $R_e = 215$ MPa ($30 < g \leq 63$ mm)
                 $R_e = 205$ MPa ($63 < g \leq 100$ mm)
Minimal tensile strength $R_m = 360$ MPa ($3 < g \leq 100$ mm)

The strength analysis was carried out to best demonstrate the effect of each modification on the level of stress in the entire separator's structure, in other words to show its usefulness.

The preliminary strength analysis (Wolny *et al.* 2009) revealed a number of shortcomings in the separator's design, which led to stress concentration.

The revealed zones of stress concentration (Fig. 4) include:

– upper and lower support,
– sieve's sideboard,
– vibrator's housing.

The results of strength analysis led the user to introduce a number of changes in the machine's design. As regard the supports, the modifications include (Fig. 5):

– support's extension shorter by 140 mm,
– modification of ribs reinforcing the sideboard, in the vicinity of supports.

The strength analysis was related to the study of the original construction of the screen separator. The results are shown in Figure 6.

Figures 7 and 8 show the effects of design modification on the state of stress in the machine's elements in relation to that experienced in the original structure (see Fig. 6). Figure 7 shows the state of stress in the construction where the support extension has been shortened by 140 mm and Figure 8 shows the condition after the sideboard has been reinforced by welded C profiles C280.

Table 1 summarises the maximal values of reduced stress for the considered options and the proportional decrease of stress in relation to the maximal stress yielded in the original structure.

In the light of the strength analysis, it may be reasonable to suggest that some elements of the separator, including the supports, should be re-designed
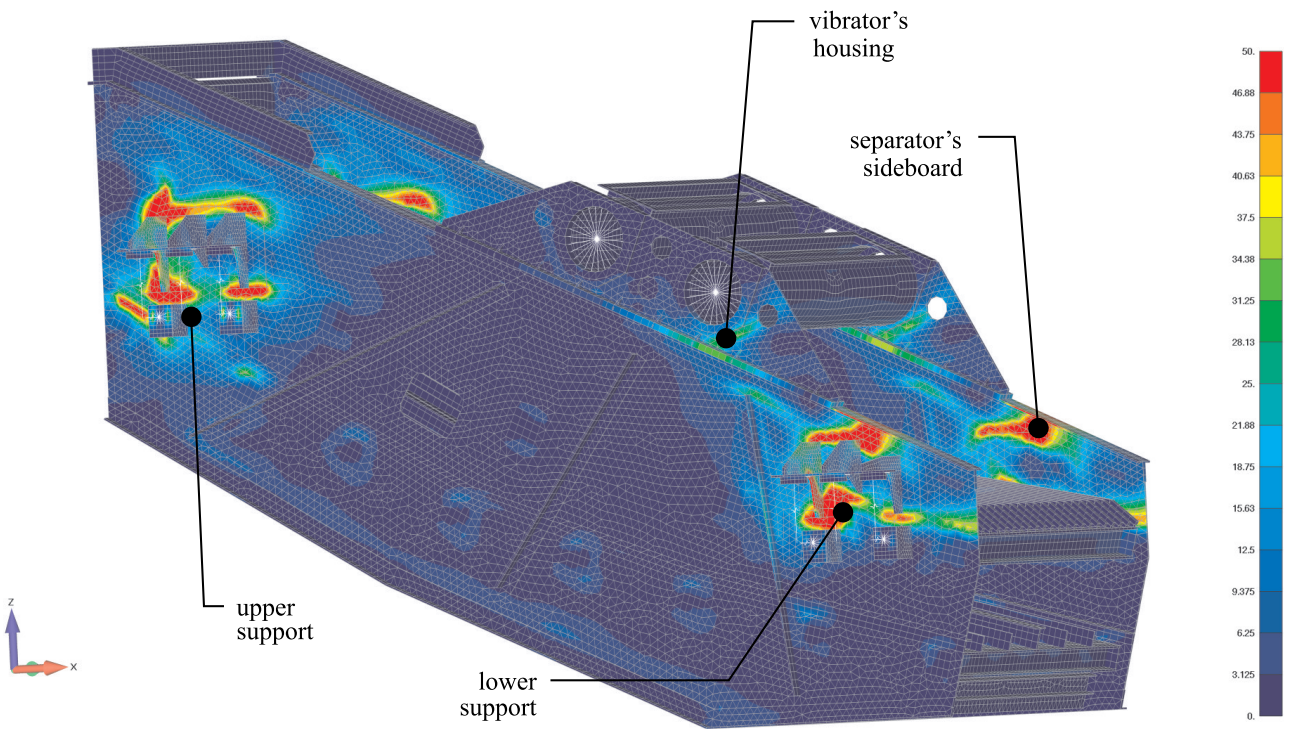
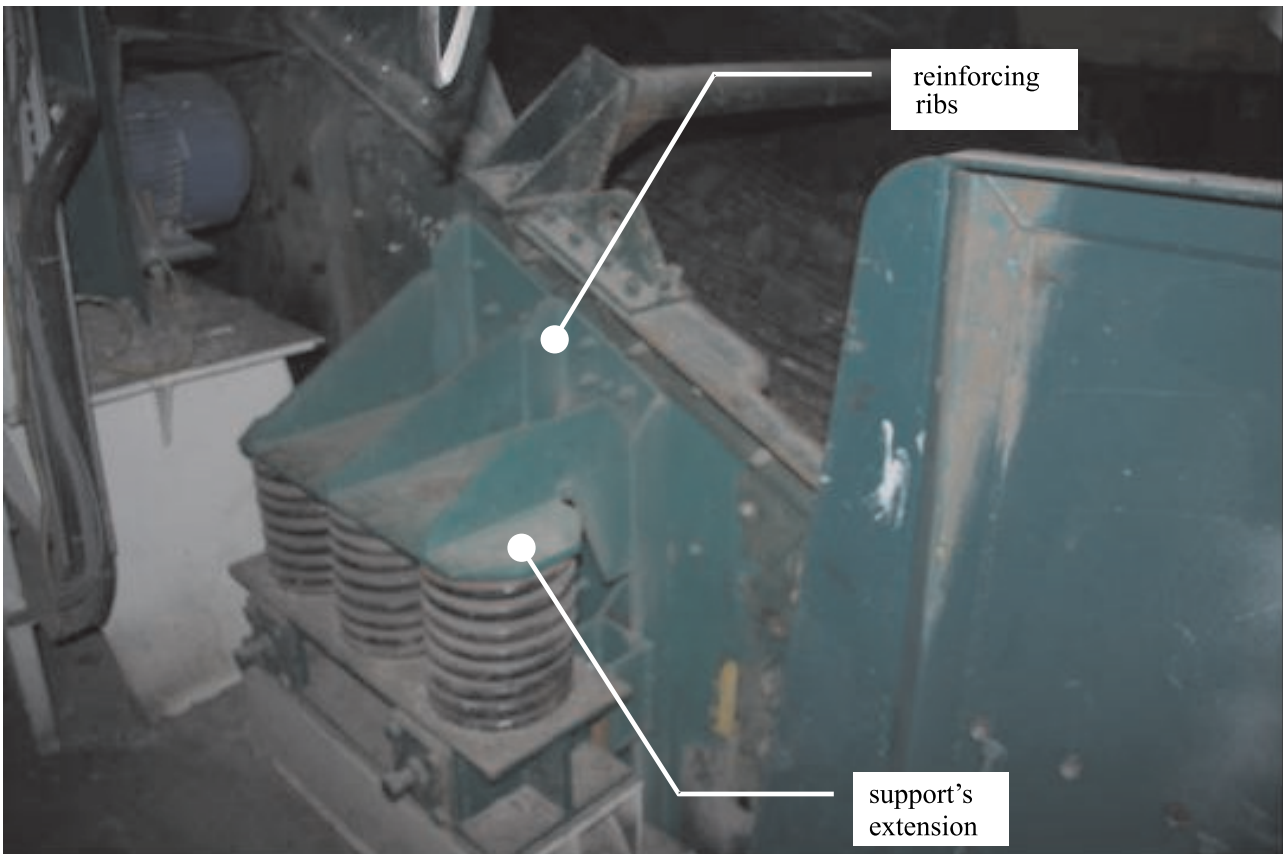**Fig. 4.** Stress concentration zones around the supports, next to the lower shaft and deck beams
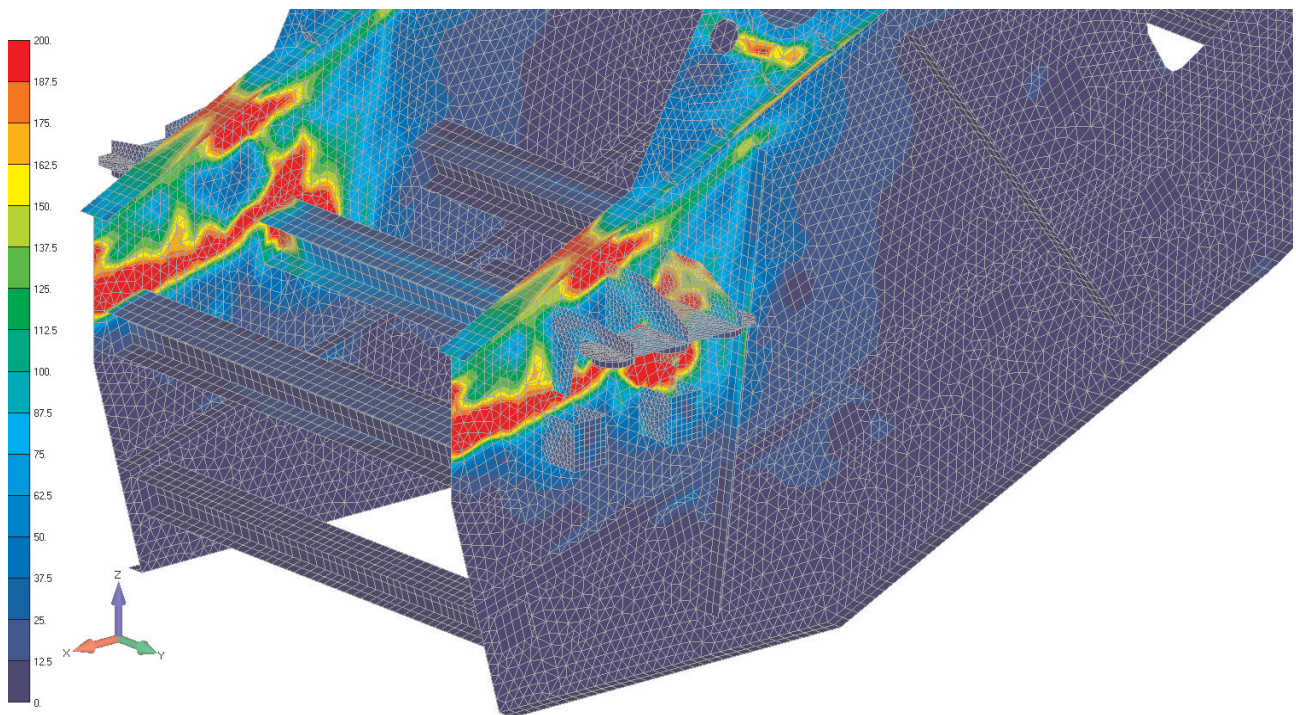

Fig. 5. Modified lower support

Fig. 6. State of stress (contour lines of reduced stress [MPa]) in the original construction of the separator
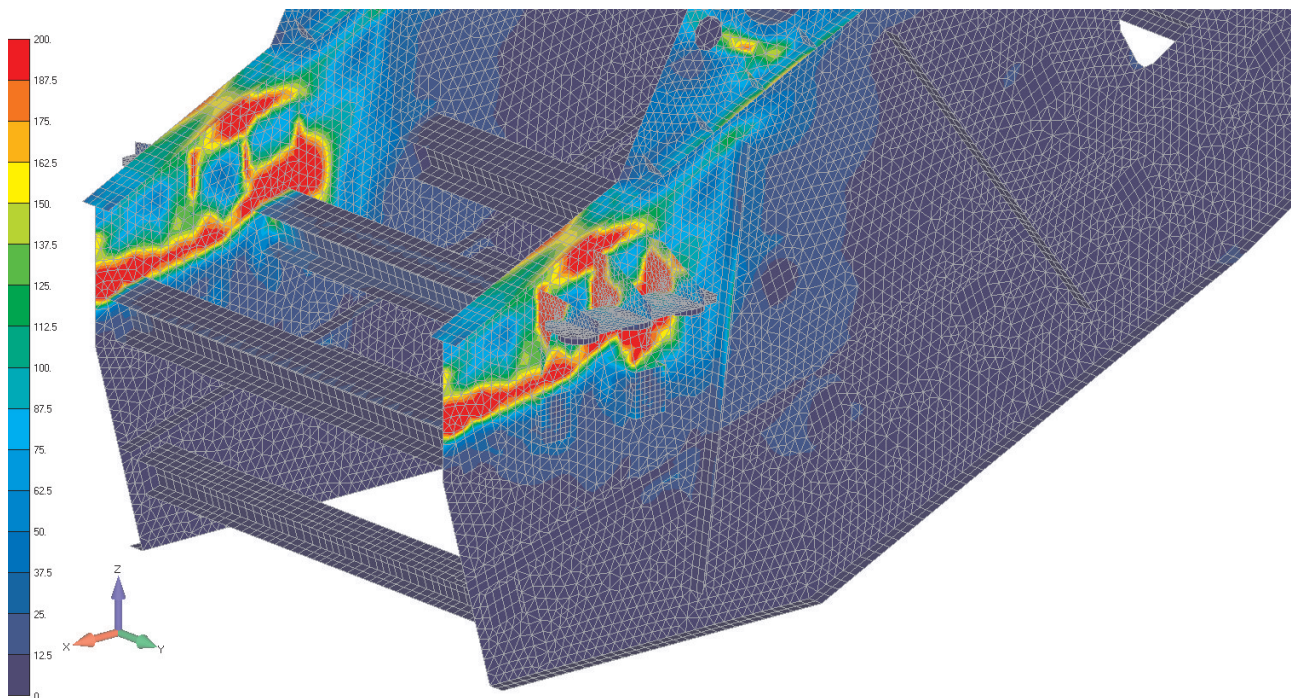

Fig. 7. State of stress (contour lines of reduced stress [MPa]) for construction
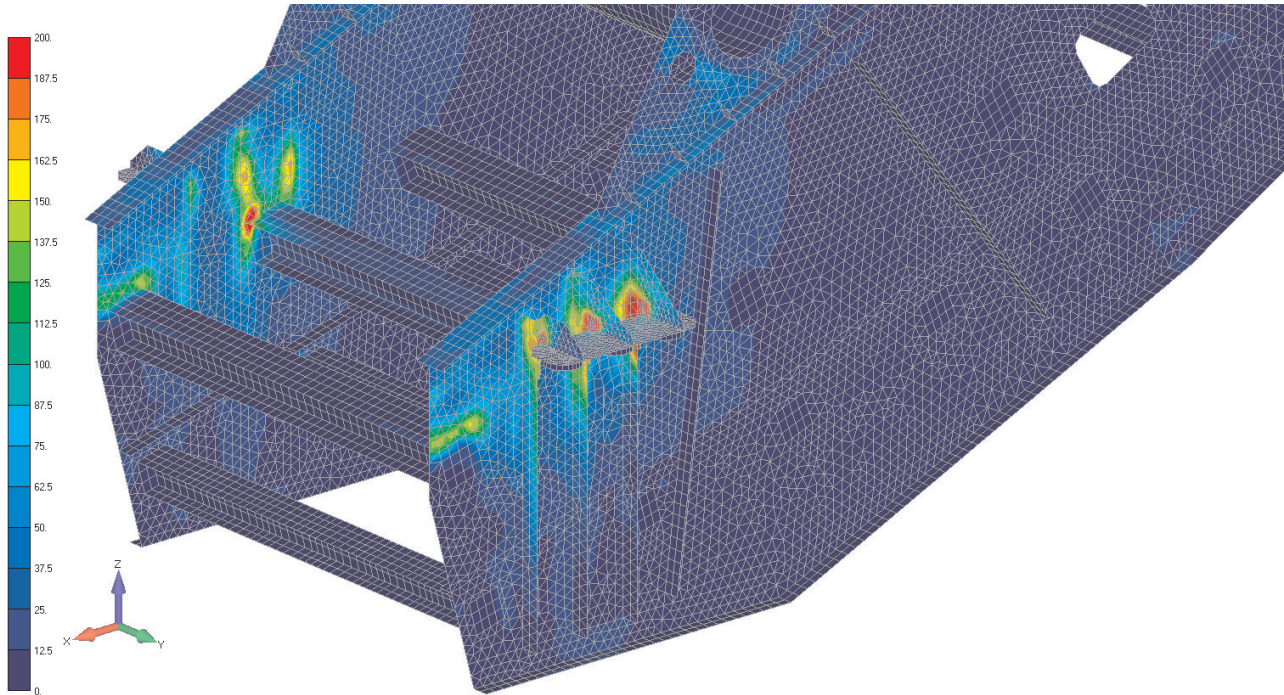with the support's extension shortened by 140 mm

Fig. 8. State of stress (contour lines of reduced stress [MPa]) for construction
with the support's extension shortened by 140 mm and with a reinforced sideboard

Table 1

Maximal values of reduced stress for the considered designs of the screen separator

Body frame	Maximal reduced stress [MPa]	Proportional decrease with respect to the original design [%]
Original design	450	
Support's extension shorter by 140 mm	347	~30
Shorter extension and the sieve sideboard reinforced with C profiles	196	~130

The study of the design option in which the support's extension is shorter by 140 mm indicates that re-designing the support locally is not sufficient to cause a significant decrease of stress generated in the separator's elements (Tab. 1). The solution in which the sieve's sideboards are reinforced with C profiles will lead to a considerable reduction of stress in the investigated areas (Tab. 1).

4. STRAIN MEASUREMENTS IN THE REAL CONSTRUCTION OF THE PZ3R SCREEN SEPARATOR

The results of (numerical) strength analysis were verified by strain (stress) measurements taken on a real objects, at points with the highest stress concentration, identified in the course of numerical analysis.

4.1. Measurement apparatus

Measurements were taken with the bridge system HMB MGCPlus, adapted to handling measurements with the use of resistance and induction sensors. The bridge was connected to a portable computer (or laptop) supported by the professional program "Catman" (HMB), which registered the signals from the sensors. The measuring equipment is shown in Figure 9 (Wolny *et al.* 2009).
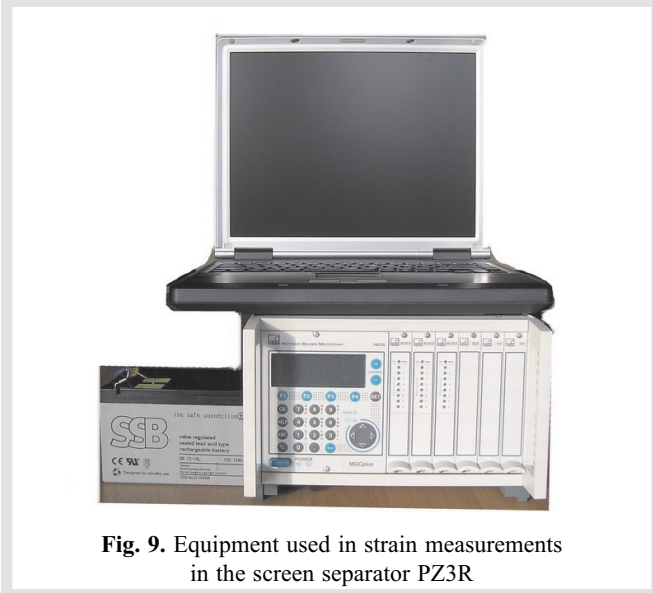

Fig. 9. Equipment used in strain measurements in the screen separator PZ3R

4.2. Location of strain gauges on the screen separator PZ3R

Strain rosettes were located around the attachment point of the lower support, three rosettes on each side of the structure. Delta rosettes 2 and 4 were mounted in the side section of the lower support (Fig. 10). Delta rosettes 1 and 3 were mounted in the bottom part of the lower supports (Fig. 11). In the upper part of lower supports are double-sensor rosettes (5 and 6), shown in Figure 12. Each strain gauge was temperature-compensated.

Applying the formula 1, strains determined experimentally in the directions $0^o/60^o/120^o$ ε_A, ε_B, ε_C yield the principal stresses (Wolny 2007):

$$\sigma_{1,2} = \frac{E}{3(1-\upsilon)}\left(\frac{\varepsilon_A + \varepsilon_B + \varepsilon_C}{3}\right)\pm$$

$$\pm \frac{E}{\sqrt{3}(1+\upsilon)}\sqrt{\frac{(2\varepsilon_A - \varepsilon_B - \varepsilon_C)^2}{3}+(\varepsilon_B + \varepsilon_C)^2} \qquad (1)$$

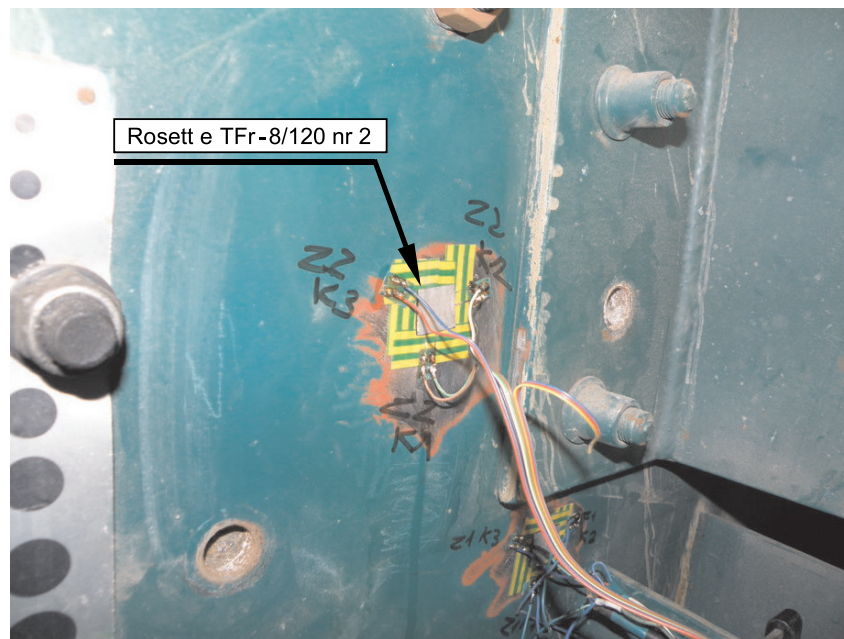where: directions A, B, C are shown in Figure 13.

Fig. 10. Rosette 2 mounted in the side section of the separator's lower support

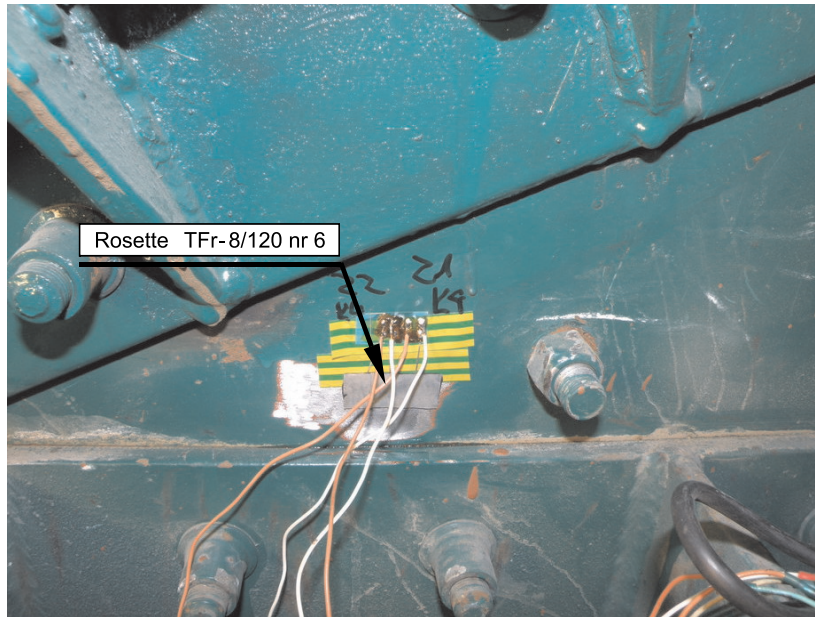**Fig. 11.** Rosette 1 mounted in the bottom part of the separator's lower support

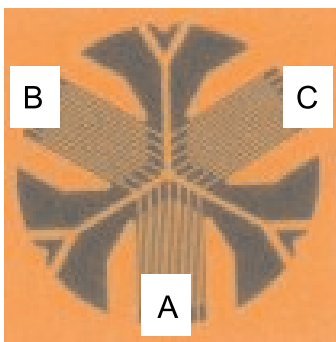**Fig. 12.** Rosette 6 mounted in the upper part of the separator's lower support

Fig. 13. Directions in the formula 1

The experimental procedure involved the strain (stress) measurements at the selected points on the screen separator during various phases of its operation (Wolny *et al.* 2009):

– start-up,
– steady operation,
– braking phase,
– idle run.

Figure 14 shows stress variations in the three phases of the screen separator's operation registered by the rosette 1, fixed in the maximal stress concentration zone identified by the numerical analysis.
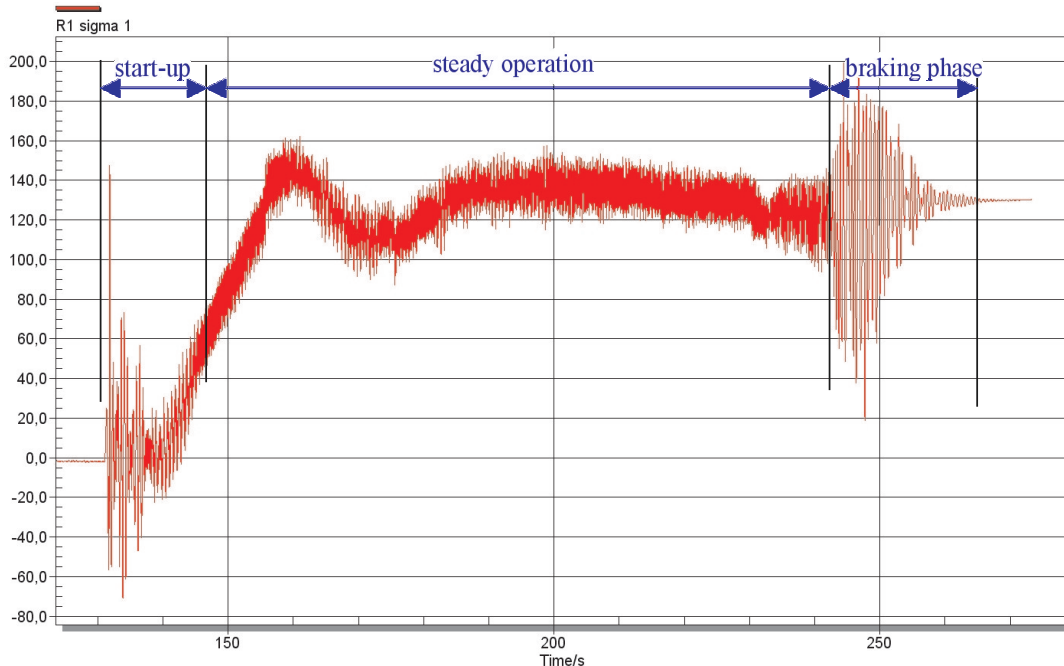

Fig. 14. Stresses σ_1 registered by the rosette 1 throughout the entire duty cycle
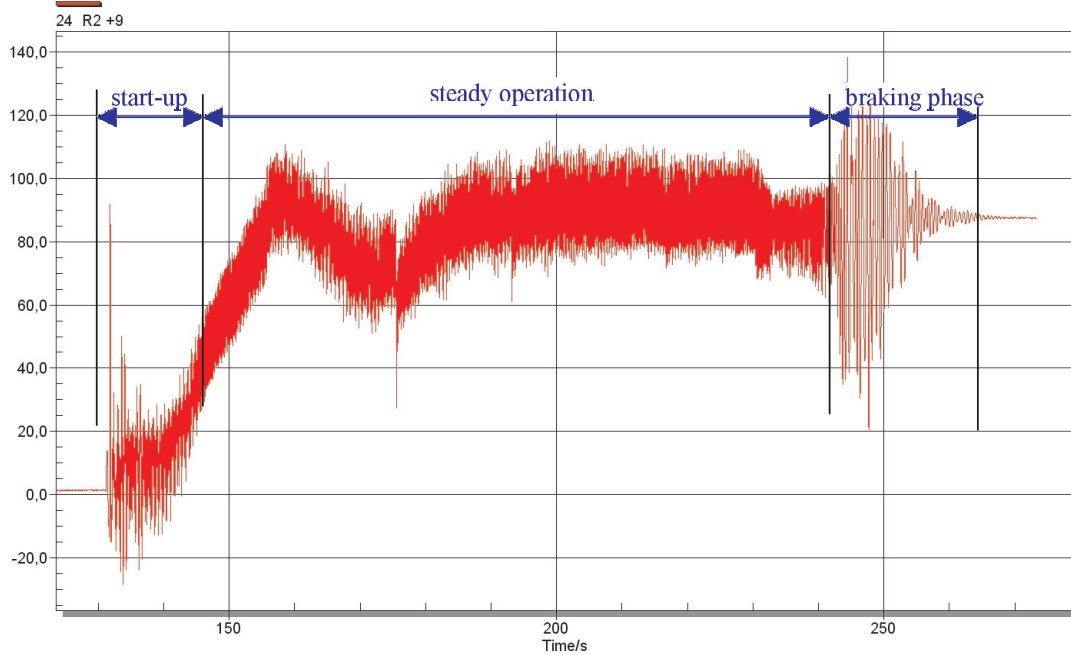
Fig. 15. Stresses σ_1 registered by the rosette 2 throughout the entire duty cycle

The maximal stresses were registered by the strain rosette 1 ($\sigma_{max} \equiv 190$ MPa) during the braking phase (Fig. 14). At the same time, the stress level read off the strain rosette 2 (Fig. 15) was $\sigma_{max} \equiv 125$ MPa. Measurements were taken after the modifications mentioned in section 2 and thus obtained stress levels were only slightly different from those obtained at selected points on the screen separator by the numerical FEM approach.

5. CONCLUSIONS

Strength analyses involving the numerical and experimental procedures revealed that a comprehensive approach is required, including the re-design of critical screener's components. For example, shortening the support's extension is not enough to guarantee such stress decrease as is experienced in the design options where the support's extensions are shortened and sieve's sideboards reinforced.

Strength analysis data confirm the adequacy of modifications of the screen separator's components and the adopted design trends. They showed those modifications were fully justified as long as they were properly correlated.

Besides, they confirmed the possibility of reducing the maximal stresses in structural components of the screen separator through modifications of its structure, bringing them down to the admissible levels enabling its further and safe operation.

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