Stand tests of an innovative mixing drum with a capacity of 12 m³

Badania stanowiskowe innowacyjnego bębna mieszalnika o pojemności 12 m³

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Design and material assumptions were developed for a specialized test stand in terms of the implementation of the destructive testing process of the mixer drum of a 12 m³ hydraulic concrete mixer truck – individual elements of the mixing and unloading spiral and shell segments. A complex research process was carried out, the results of which were subjected to elaboration and analysis in order to determine the degree of wear of the sheet metal used for the construction of the mixer made of selected steel grades. In the research process, a representative aggregate was used, which imitated the properties of concrete mass transported in real (operational) conditions.
KEYWORDS: stand research, mixer drum, hydraulic concrete mixer truck.

Opracowano założenia konstrukcyjno-materiałowe dla specjalistycznego stanowiska badawczego z myślą o realizacji badań niszczących bębna mieszalnika hydraulicznej betonomieszarki samochodowej o pojemności 12 m³ – elementów spirali mieszająco-rozładowującej i segmentów płaszcza. Przeprowadzono złożony proces badawczy, którego wyniki poddano opracowaniu i analizie w kierunku wyznaczenia stopnia zużycia zastosowanej do budowy mieszalnika blachy z wybranych gatunków stali. W procesie badawczym wykorzystano reprezentatywne kruszywo, które właściwościami imitowało masę betonową transportowaną w warunkach rzeczywistych – eksploatacyjnych.
SŁOWA KLUCZOWE: badania stanowiskowe, bęben mieszalnika, hydrauliczna betonomieszarka samochodowa

Introduction

The publication is the result of a complex process of research included in the project entitled "Research and development work for the design and manufacture of an innovative mixer drum with a capacity of 12 m³", co-financed by the European Union from the European Regional Development Fund. A complex process of destructive testing of the drum of the mixer of a hydraulic truck concrete mixer with a capacity of 12 m³ was carried out using a specialized test stand of the author's design. The stand was developed in the direction of determining the key operating parameters in the specified test resourse. Significant is the application in the research process of a dedicated aggregate, which by its action imitates the concrete mass with the highest degree of abrasion of the surface of the elements of the drum shell and the mixing and unloading spiral. Thus, the test results provide a measurable indicator of the level of wear of the sheet metal used in the manufacture of the drum under operating conditions.

Specialized test stand

A dedicated specialized test stand was developed to provide a comprehensive process for analyzing the key operating parameters of a 12 m³ mixer drum [1,4–6]. A simplified schematic of the stand is shown in Fig. 1.

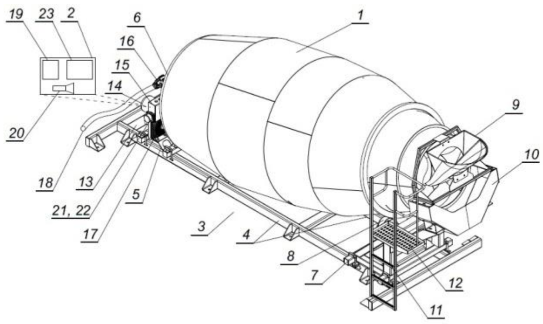

Fig. 1. Simplified diagram of a specialized test stand: *1* – mixer drum, *2* – control system, *3* – frame, *4* – frame arms, *5* – front bracket, *6* – planetary gear, *7* – rear bracket, *8* – rollers, *9* – hopper, *10* – chute, *11* – ladder, *12* – platform, *13* – drive system, *14* – electric motor, *15* – hydraulic pump, *16* – hydraulic motor, *17* – oil cooler, *18* – high-pressure hoses, *19* – inverter, *20* – vision system, *21*, *22* – temperature and oil pressure sensors, *23* – dynamic balancing system

The analysis of the state of the issue confirmed that the state of the art known test stands and test systems for concrete mixer drums of truck mixers lack solutions that make it easy and simple to carry out operational and performance tests on the drums of a mixer with an operating volume of 12 m³. In addition, no solutions have been found that feature the mapping of the actual operating parameters of the drums and

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comprehensively collect data on the operating parameters of the drums, such as deflection arrow, vibration, temperature and oil pressure in the hydraulic system of the device.

The author's test stand for the concrete mixer drum of a truck mixer, containing a control system, is characterized by the fact that it is equipped with a frame consisting of at least two arms with a total load capacity of at least 8 t, a front bracket constituting the first point of support of the mixer drum, with a planetary gearbox mounted in the front bracket, a rear bracket constituting the second point of support of the mixer drum, containing support rollers, hopper and chute, as well as a ladder with a platform connected to the rear bracket, whereby the stand has a hydraulic drive system for the mixer drum seated at the front bracket, containing an electric motor driving a variable displacement hydraulic pump supplying the hydraulic motor, an oil cooler with thermostat, a set of high-pressure hoses and a hydraulic drive system that is controlled by a control system, and the hydraulic motor is connected to a planetary gearbox, with the front bracket and the rear bracket mounted on the frame in a sliding manner. The hydraulic pump has a maximum oil flow of no more than 89 cm^3/rev, and the hydraulic motor has a maximum oil flow of no more than 90 cm^3/rev. Other advantages are obtained with a control system equipped with an inverter to control the speed of the electric motor. In addition, the control system is equipped with a vision system to measure the deflection arrow of the mixer drum. The hydraulic drive system is provided with a dedicated oil temperature sensor and an oil pressure sensor.

The control system provides the function of a dynamic balancing system. In addition, the control system provides adjustment of the drum speed up to 20 rpm and changes the direction of drum rotation – mixing and unloading. The planetary gearbox has a minimum torque of at least 70 kNm. The support rollers have adjustable spacing on the rear bracket.

The test stand of the author's design allows for easy implementation of technical tests, performance and operation tests, and development work on new types of drums of concrete mixer trucks. Thanks to its technical features, it is dedicated to testing drums with a working volume of 12 m^3.

Thanks to the application of a ladder with an operating platform, connected to the rear support, it is possible to safely view the destructive medium inside the drum of the mixer during testing – dedicated to the research process of aggregate. Thanks to the placement of the hopper and chute on the rear support, it is possible to easily fill the drum under test with the specified type of reference material, while there is no loss of excess material that stops at the chute. Thanks to the control system, in particular, equipped with an inverter and the drive system controlled by it, it is possible to smoothly regulate the rotation of the mixer drum and control the rotation of the drum allowing operational tests in a wide range of parameters.

By using a dedicated vision system, it is possible to measure the deflection arrow of the mixer drum and thus control its static and fatigue strength. By equipping the drive system with an oil temperature sensor and an oil pressure sensor, it is possible to comprehensively and efficiently control the parameters of the working oil, allowing a more thorough examination of the condition of the hydraulic system of the mixer drum.

The specialized test stand is shown in Figs. 2–4.

Fig. 2. Test stand – test object – 12 m^3 mixer

Fig. 3. Test stand – management center

Fig. 4. Test stand – main control cabinet

Material

Material analysis, including a review of sheets available on the market, which can be used in the production of an innovative mixer drum with a capacity of 12 m³, resulted in the selection of steel grades with increased strength parameters, including above all abrasion resistance [2, 3, 7]. Out of the eight analyzed species, five available species were selected for the production of prototype research copies of the mixer drum. Selected species – their basic parameters are presented in the table below.

TABLE. List of materials selected for the research process – catalog data

No.	Designation	Hardness [HB]	Yield strength R_E [MPa]	Ultimate strength R_M [MPa]
1	HARDOX450	425÷475	1200	1400
2	S 355MC	220*	355	490÷630
3	S 420MC	150÷190	420	480÷620
4	TBL	230	430	680
5	S690QL	230÷280	690	770÷940

* In a softened state.

Test stand

Based on the specialized test stand for the mixer drums of a 12 m³ hydraulic concrete mixer truck, characterized above, a complex test process of prototype drums was carried out at a resourse of 500 hours. One of the main parameters measured during the tests was the wall thickness of the mixing and discharging spiral segments and the thickness of the mixer shell. Measurements of the thickness of the spiral and drum shell were carried out at 12 points, three for each segment of the mixer.

Fig. 5 shows the averaged results of shell thickness measurements for 3 measurement points in the cylindrical part of the mixer. Measurements were made every 50 working hours. In order to compare the results, the shell thickness is shown on a percentage scale. This is due to the slight differences in the thickness of the sheets measured before the tests began.

It can be noted that the most resistant materials to abrasion were S690QL and HARDOX 450. After 500 hours of operation, the mixer shell wear for these materials did not exceed 4%.

As part of this work, the results of measurements are presented only for the cylindrical part of the mixer. Analyzing the remaining segments of the mixer, analogous conclusions can be drawn.

As part of the research, the thickness of the walls of the mixing and unloading spiral segments was also measured. Fig. 6 shows the averaged measurement results for the spiral in the cylindrical part of the mixer in relation to its initial thickness.

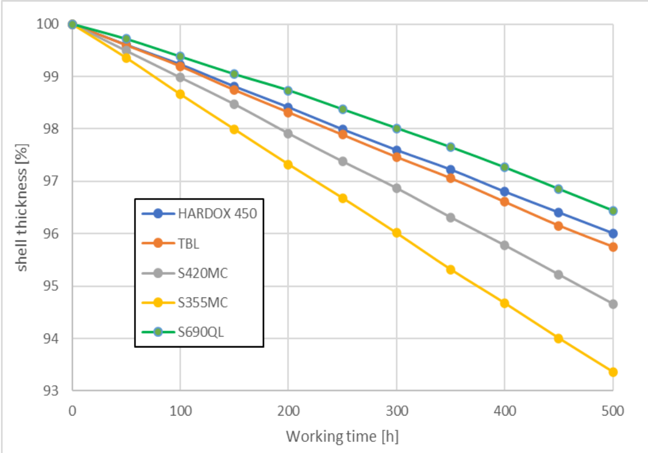

Fig. 5. Graph of changes in the wall thickness of the mixer shell for the tested materials depending on the length of operation

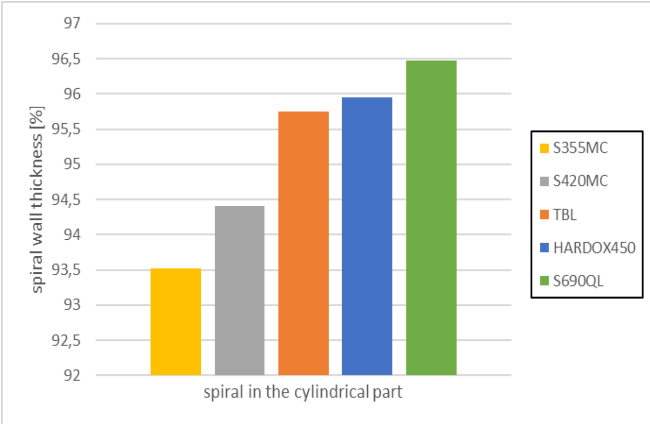

Fig. 6. Diagram of the change in wall thickness of the segments of the mixing-discharge spiral in the cylindrical part

The results of the spiral thickness measurements are similar to those of the drum shell. Based on this, it can be concluded that the elements of the shell as well as the spiral are being wiped out at a similar rate.

Conclusion

Bench tests of the prototype drums of the mixer of a 12 m³ hydraulic truck concrete mixer, using a specialized stand of the author's design, made it possible to precisely assess individual operating parameters, including, first of all, the abrasion resistance of selected grades of structural materials – sheets used in the production process of the shell and the mixing and discharging spiral.

Based on the analysis of the determined test results, it was concluded that the best materials having the highest abrasion resistance are the prototypes of the mixer made of S690QL and HARDOX450 grade sheets. Alternatively, the prototype mixer made of TBL sheet, the test results of which are slightly different from the HARDOX 450 grade.

In addition, it should be mentioned that an extremely important factor directly affecting the choice of material is the economic factor – each production process should be preceded by a thorough economic analysis.

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REFERENCES

[1] Bernaczek J., Fudali P., Kalandyk A., Koperski M., Nagnajewicz M. "Structural and material analysis of an innovative mixer drum with a capacity of 12 m³ [Analiza konstrukcyjno-materiałowa innowacyjnego bębna mieszalnika o pojemności 12 m³]". *Mechanik*. 96, 5–6 (2023): 56–60, doi:10.17814/mechanik.2023.5-6.12.
[2] Blicharski M. „*Inżynieria materiałowa stali*". Warszawa: Wydawnictwo Naukowe PWN (2019).
[3] Bogucki W., Żyburtowicz M. „*Tablice do projektowania konstrukcji metalowych*". Warszawa: Arkady (2006).
[4] Dietrich M. „*Podstawy konstrukcji maszyn. T. 2*". Warszawa: Wydawnictwo Naukowe PWN (2019).
[5] Dziurski A., Mazanek E., Kania L. „*Przykłady obliczeń z podstaw konstrukcji maszyn. T. 1: Połączenia, sprężyny, zawory, wały maszynowe*". Warszawa: WNT (2015).
[6] Feld M. „*Podstawy projektowania procesów technologicznych typowych części maszyn*". Warszawa: Wydawnictwo Naukowe PWN (2018).
[7] Skrzypek S.J., Przybyłowicz K. „*Inżynieria metali i technologie materiałowe*". Warszawa: Wydawnictwo Naukowe PWN (2019).