# Analysis of the control and measurement system in terms of its application in concrete mixer trucks

## Analiza układu kontrolno-pomiarowego w aspekcie jego zastosowania w betonomieszarkach samochodowych

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**The article presents the results of research work in the form of the implementation of the control and measurement system of a 9 m³ truck concrete mixer. The necessity of recording key operating parameters during its operation, the measurement components used, as well as their adaptation to an existing truck concrete mixer, are discussed.**
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**KEYWORDS: hydraulic truck concrete mixer, control and measurement system**

**W artykule przedstawiono wyniki prac badawczych w postaci implementacji układu kontrolno-pomiarowego betonomieszarki samochodowej o pojemności 9 m³. Omówiono konieczność rejestracji kluczowych parametrów eksploatacyjnych podczas jej pracy, wykorzystane komponenty pomiarowe, jak również przedstawiono ich adaptację do istniejącej betonomieszarki samochodowej.**
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**SŁOWA KLUCZOWE: hydrauliczna betonomieszarka samochodowa, system kontrolno-pomiarowy**

## Introduction

The fourth industrial revolution, referred to as Industry 4.0, is based on the fact that computerized production systems are additionally equipped with network connections, i.e. information and communication technologies are used. This makes it possible to communicate with other objects and provide information about the devices themselves [1, 2, 5]. The interconnection of all systems leads to the creation of smart factories or plants in which production systems, components and people communicate via a network. Some enterprises are actively implementing smart manufacturing standards, combining manufacturing and operations with smart digital technology, machine learning, and big data to create a more holistic and more connected ecosystem for companies that focus on manufacturing and supply chain management.

Many of these innovations are still in their infancy, but this is the direction of their further development. The changes also affect the construction and machinery industries, including the concrete mixer industry. This article presents the results of work aimed at improving the existing concrete mixer solutions, with particular emphasis on control and measurement systems.

## Load weight measurement

One of the problems when operating a concrete mixer truck is exceeding the permitted weight of the vehicle. Road regulations specify the maximum weight of a vehicle that can travel on public roads. Limiting the number of trips entails saving time and fuel consumption. As a result, the maximum amount of concrete mix is often carried, just to avoid exceeding the permissible total weight of the vehicle. The mass of the concrete mixture is not precisely determined in the concrete mixing plant, as it is determined based on volume. Measuring the mass would make it possible to know the parameter in question for a given loading of concrete mass, as well as enable control of the elementary operational cycle. Additionally, during the operation of the concrete mixer, due to insufficient cleaning, dried concrete deposits appear on the inner surface of the mixer shell and the mixing and unloading spiral, the weight of which may amount to several dozen kilograms after each transport cycle. Precise mass control allows for simultaneous control of cleanliness and whether there are any remains of concrete mass in the

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mixer drum. Another advantage is the ability to control the degree of emptying of the mixer drum, i.e. you can estimate the time remaining until the unloading process is completed.

The above factors make determining the mass of the mixer during the operational cycle – before loading, during transport and after unloading the concrete mass – important information for the operator. During loading and on the route between the concrete batching plant and the place of delivery of the load, controlling the weight by using an on-road scale is very difficult or often even impossible. As part of the research, attempts were made to design, manufacture and test devices aimed at determining the current loading weight.

One of the approaches to the problem was using a set of strain gauges, with which a dedicated specialized stand was equipped for the complex procedure of testing the performance of the author's construction of a custom-built concrete mixer with a capacity of 9 $m^3$. The purpose of the station was to test the operation of the mixer structure for various road conditions, simulating them by tilting and inclining. Therefore, the strain gauges were placed in the four corners of the structure. The signals were collected by the transducer, displayed in real-time and archived. Software developed for these needs was responsible for the presentation of the results. An example program window is shown in fig. 1.

In the case of strain gauges, which measure the deformation of the element on which they have been glued, it has become necessary to calibrate them. The calibration was carried out on a horizontally arranged structure. It consisted of gradually filling the drum of the mixer with working material of a precisely defined mass. The dependence of the strain gauge readings on the currently loaded batch weight is the key information for determining the current loading weight.

Due to tough operating conditions, a strain gauge sensor was used which, according to specifications, can be used for outdoor applications (IP67), demonstrating shock and vibration resistance. The sensor is equipped with a temperature-compensated Wheatstone bridge sensor. A digitally programmable amplifier allows factory settings to meet the requirements of a specific application. The sensor can be used for static and dynamic measurements. The sensors are positioned on a front and rear bracket, as shown in fig. 2.

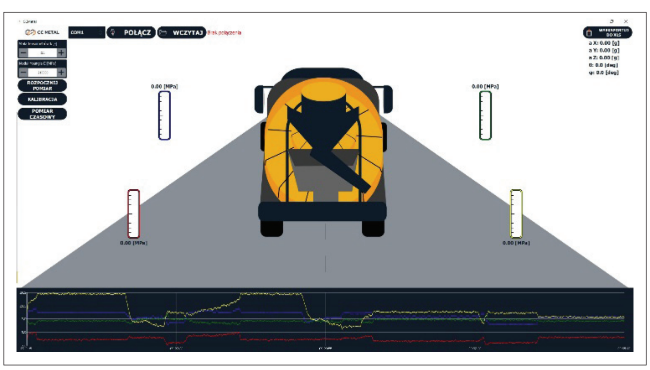

Fig. 1. View of the application for reading strain gauge and determining the loading weight

Fig. 2. Construction with a mass sensor

## Measurement of mixer drum revolutions

Another important parameter determining the proper operation of a concrete mixer is the rotational speed of the mixer drum. Concrete mixtures, particularly specialized ones, require appropriate conditions during transport, which result mainly from the specific values of drum rotation speeds. As part of the research, a sensor was used, placed on the roller body, which measures the rolling speed of the roller ring (fig. 3).

Therefore, controlling the recommended rotational speeds of the mixer drum is crucial from the point of view of operating a road concrete mixer.

## Operator's panel

The measured parameters, mentioned in earlier chapters, are important for the concrete mixer operator during his work – the complex operating cycle of the vehicle. Therefore, it was ensured that they were available in the cab of the vehicle (fig. 4). A module was developed that takes signals from the sensors and clearly displays them (presents current data readings) [3, 6]. It is powered by an automobile auxiliary power outlet and has been equipped with a 15,000 mAh battery to enable operation during power disconnection. The innovative control and measurement system is equipped with a display that shows the tested parameters.

Fig. 3. Mixer drum rotational speed sensor

Fig. 4. Operator panel located in the vehicle cab

In addition to weight and speed, the concrete mixer operator is informed of the vehicle's current speed, its orientation – tilt and roll – and current battery status. The built-in GPS sensor measures speed, while the AHRS system is responsible for orientation.

A safe operating range can be imposed on each of the measured parameters, beyond which an alert is displayed on the screen as a safeguard against, for example, oversized tilt that could result in a rollover.

All the above-mentioned functionalities, relevant from the operator's point of view, were presented on the panel's screen [7, 9]. However, the work carried out as part of the project ran further, and therefore the panel was equipped with a GSM module, which sent data to the server.

## Network service

All data received from the operator's panel have been stored on the server. The supervisor can view the current operating parameters of the concrete mixer, as well as filter the data by date and time. The review of this data is done via a web page, an example window of which is shown in fig. 5.

The current position of the concrete mixer, its route, alerts, current speed of movement, vibration levels, values of loading weight, speed of the mixer drum, roll and tilt can be viewed in real-time, or it is possible to view these parameters in a selected time range. This creates the possibility of comprehensive and precise control of the full operational process of the vehicle

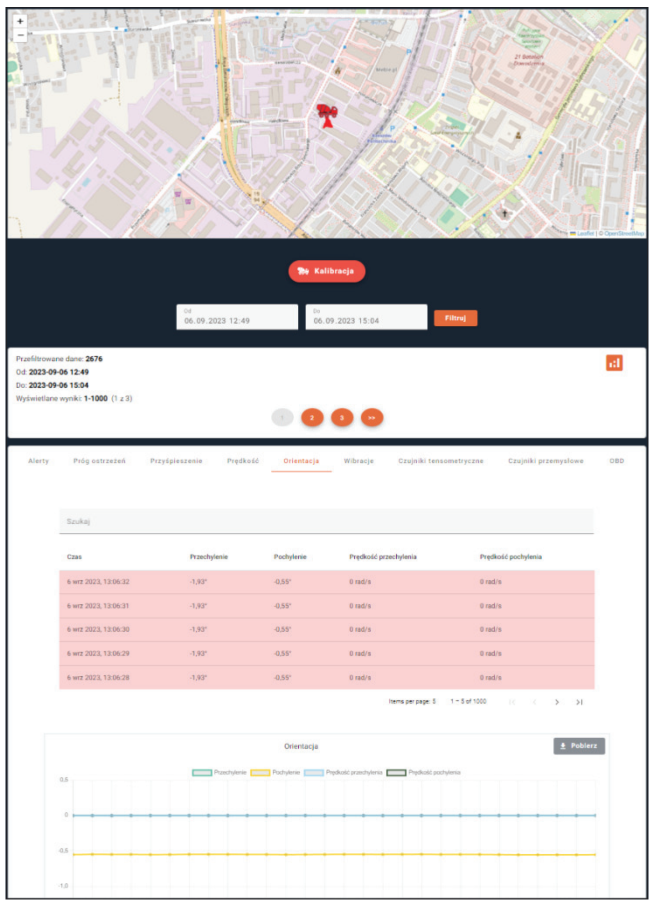


Fig. 5. Website that manages the display of measurement data from the operator panel

– a hydraulic concrete mixer truck, i.e. the process of delivering the concrete mass to the customer, as well as searching for the causes appearing in irregularities or, as a consequence, the failure of the mixer.

## Summary and conclusions

Industry 4.0 enables business owners to better control and understand every aspect of their business and allows them to leverage instant data to increase productivity, streamline processes and drive an entity's growth against competitors. Within the scope of the article, the work presented to implement a control and measurement system for a truck-mounted concrete mixer is a step forward towards solutions that fit into the Industry 4.0 strategy. The completed research process resulted in the integration of all components into a working monitoring system. Further work will include, in particular, the extension of the system's functionality to include tools for real-time management of the vehicle fleet, optimizing travel routes, loading order, minimizing queues, saving time and fuel.


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REFERENCES


[1] Ajovalasit A. "The measurement of large strains using electrical resistance strain gages". *Exp Tech.* 36 (2012): 77–82, https://doi.org/10.1111/j.1747-1567.2011.00761.x.

[2] Bolton W. "Instrumentation System Elements". "*Instrumentation and Control Systems*". 3rd ed. Elsevier Ltd. (2021), https://doi.org/10.1016/B978-0-12-823471-6.00002-2.

[3] Broel-Plater B. „*Układy wykorzystujące sterowniki PLC. Projektowanie algorytmów sterowania*". Legionowo: Wydawnictwo BTC (2019).

[4] Gilchrist A. "*Industry 4.0: The Industrial Internet of Things*". APress (2016), https://doi.org/10.1007/978-1-4842-2047-4

[5] Hena D.A., Akhmad J., Kurriawan B.P., Endarko Endarko, Melania S.M. „Strain Gauge Sensor of Mass Measurement Using a Brass Cantilever". *Jurnal Neutrino Jurnal Fisika dan Aplikasinya*. 9(2):52 (2017), https://doi.org/10.18860/neu.v9i2.4138.

[6] Kasprzyk J. „Programowanie sterowników przemysłowych". Warszawa: Wydawnictwo Naukowe PWN (2018).

[7] Kisielnicki J., Pańkowska M., Sroka H. „*Zintegrowane systemy informatyczne*". Warszawa: Wydawnictwo Naukowe PWN (2014).

[8] Schwab K. „*Czwarta rewolucja przemysłowa*". Warszawa: Studio Emka (2016).

v[9] Szelerski M. „*Automatyka przemysłowa w praktyce. Projektowanie, modernizacja i naprawa*". Krosno: Wydawnictwo Kabe (2016).

[10] Ustundag A., Cevikcan E. "*Industry 4.0: Managing The Digital Transformation*". Springer International Publishing AG (2017): https://doi.org/10.1007/978-3-319-57870-5. ■