SYSTEM FOR TESTING RESISTANCE FOR STATIC EXPOSURE TO DUST

System testowy do badania odporności na statyczne oddziaływanie pyłów

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Abstract: The article presents the method and a prototype system to verify the degree of protection against dust penetration developed in accordance with the PN-EN-60529:2003 standard requirements. The solution in question enables the performance of normative tests with reference to the degrees of protection provided by enclosures (IP code) as well as extended tests concerning the evaluation of operational reliability of devices exposed to dust. The authors present the test method, the architecture of the developed system, and the prototype verification tests.

Keywords: Dustiness, IP code, protection against dustiness, dust-tightness, verification test

Streszczenie: W artykule przedstawiono metodę i prototypowy system badania odporności na statyczne oddziaływanie pyłów, opracowany na podstawie wymagań normy PN-EN 60529:2003. Przedstawione rozwiązanie umożliwia realizację badań normatywnych w odniesieniu do stopnia ochrony IP zapewnianych przez obudowy, a także w zakresie rozszerzonym do oceny niezawodności działania urządzenia poddanego oddziaływaniu pyłu. Zaprezentowano opis metody, strukturę opracowanego systemu i badania weryfikacyjne prototypu.

Słowa kluczowe: zapylenie, kod IP, ochrona przed zapyleniem, pyłoszczelność, badania testowe

Introduction

The Łukasiewicz Research Network – Institute for Sustainable Technologies is the third biggest research network in Europe. It delivers attractive, comprehensive and competitive technological solutions, also those tailored to the needs of and requested by companies as part of the “challenge us” campaign – a company’s request is analysed by a group of 4,500 scientists within no more than 15 business days and an effective solution that is ready to implement is proposed. In doing so, Łukasiewicz Network, at no extra cost to be incurred by a company, engages recognised and highly-qualified researchers and unique scientific equipment, which enables the network to meet companies’ needs and expectations. A business owner may choose to contact the network via an on-line form available on https://lukasiewicz.gov.pl/en/for-business/, or visit one of its affiliated institutes or branches in more than 50 locations across Poland, and they may be sure that they will always be provided with the same high-quality product or service, no matter which entity they contact. Łukasiewicz’s Network scientific potential is concentrated in the following research areas: Health, Smart Mobility, Digital Transformation, and Sustainable Economy and Energy. The innovative system to monitor the safety of operation of technical devices working in a dust-filled environment, developed at the Łukasiewicz Research Network – Institute for Sustainable Technologies and described in this article, is an example of a solution proposed in response to a “challenge us” request made in the Health and Energy areas.

The device enclosure provides the user with protection against access to live or moving mechanical parts of the device, the contact with which may be hazardous in different operating conditions [2, 12]. The enclosure also constitutes basic protection against external influences or conditions, such as dustiness, electromagnetic radiation, moisture, water, etc. Such influences or conditions may increase the risk of electrocution, explosion, deterioration of operating parameters or a device failure. Particularly stringent requirements as regards dust tightness apply to armament systems [6, 7], fire protection systems [10, 9], aviation systems [8], and mining systems [1].

Tests to verify dust tightness of device enclosures are carried out in order to define the degree of protection against dust penetration or to evaluate the operational reliability of a device exposed to dust (e.g. transported or operated in a dust-filled environment).

One of the methods to define the degree of protection provided by enclosures is discussed in the PN-EN 60529:2003 standard [5]. The identification code contains the IP code and two characteristic numerals and two additional letters (non-obligatory) that define additional requirements or provide additional information about the enclosure. First characteristic numerals (0–6) refer to the following two acceptance conditions:

- the degrees of protection against access to hazardous parts by preventing or limiting the ingress of a part of the human body or an object held by a person; and
- the degrees of protection against the penetration of solid foreign objects (including dust). As regards special manufacturing, additional requirements defined in separate standards apply [4].

Method description

The method for testing the degree of protection against dust penetration provided by a device enclosure is defined and regulated by normative requirements (Fig. 1). Tests need to be carried out with the use of an advance test device composed of pneumatic, mechanical, measuring, and control systems.

Following the general guidelines laid down in applicable normative documents, the authors designed the required functionality of the test system including:

- enclosure, casing and sealing tests to ensure failure-free operation of mechanical and electric devices exposed to dust;
- electric enclosure dust tightness tests – determination of the degree of protection against dust penetration (IP code);
- operational reliability tests carried out on firearms exposed to dust;
- packaging, casing and personal protection equipment dust tightness tests; and
- automotive industry component dust tightness tests.

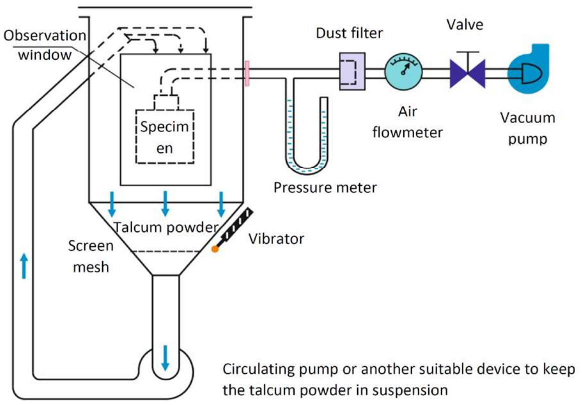


Fig.1. Structural diagram of the test system in accordance with the PN-EN 60529:2003 standard

The specimen is placed in a tight dust chamber with an observation window. The test consists in exposing the specimen to dust suspended in the air blown onto the enclosure. The amount of the dust to be used is 2 kg per cubic metre of the test chamber volume. The circulating air passes through a square-meshed sieve with the nominal wire diameter of 50 µm and the nominal width of the gap between wires of 75 µm. To avoid dust deposition on chamber components, vibrators are placed in key areas (diagonal wall, sieve enclosure). Where tests are carried out on enclosures inside of which, in the normal working cycle, the air pressure is below that of the surrounding atmospheric pressure, a vacuum pump is used to extract the air from the enclosure at a predefined extraction rate and pressure.

In accordance with the adopted functionality, the authors defined detailed technical parameters, both general (Table 1) and with reference to structural materials ensuring failure-free operation.

Table. 1. Basic technical parameters of the test system

Parameter	Value
Test area dimensions	1000 x 1000 x 1000 mm
Velocity of dust-filled air movement	<1 m/s
Dust type	talcum powder
Dust granularity	<75 µm
Partial vacuum	<2 kPa
Extraction rate	<60 enclosure volume per hour

Structural model

The construction of test devices that enable the simulation of conditions in which objects are exposed to dust causes a lot of problems that mainly concern the proper dosage of dust and the control over the amount of the agent used [3]. Given the scope of the recreated parameters, test devices are modular in structure, which enables flexible adaptation of their operating properties by means of an exchange of individual modules or their structural modification.

The test device described in this article is composed of the following functional modules:

- the process chamber;
- the air circulation system;
- the dust dosage system;
- the enclosure; and
- the control system.

In the process chamber, the specimen is exposed to dust in controlled dustiness, temperature and humidity conditions. The air circulation system ensures proper air circulation inside the dust chamber and even distribution of dust. The dust dosage system helps to keep the dust dry and to maintain it in suspension. At the same time, the measuring system controls the amount of dust in the tank and enables the use of a feedback loop. The device has a frame onto which individual modules and enclosure elements preventing dust outflow to the external atmosphere are mounted.

3D model

At the concept stage, the authors defined user software and hardware requirements and on that basis developed in the CAD environment the structural geometric 3D model enabling computer visualisation and simulation. The 3D model has a modular structure complying with the specification of the structural model.

The 1 m^3 process chamber was designed as a thin-walled sheet metal structure and it was equipped with a steel grating on which the specimen is placed (Fig. 2). In the chamber walls, process connections and LED illuminators are mounted.

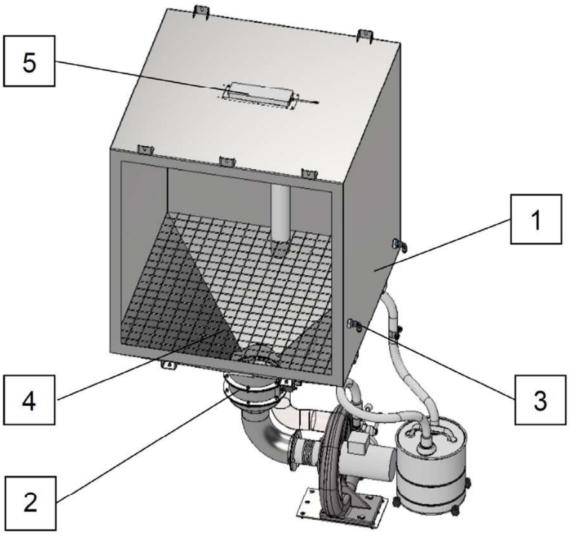


Fig. 2. Process chamber 3D model: 1 – casing; 2 – hopper; 3 – connections; 4 – grating; 5 – illuminator

The hopper connects the chamber with the air circulation system (Fig. 3) composed of the process and dust extraction circuits (Fig. 4). The process circuit is made of modules connected in series that include: filtration, blower with connections, stream separating valves, and dust ducts. The dust extraction circuit is intended to extract the used (polluted) dust and it is composed of the dust separator and flexible cords. To switch from one circuit to another, the separating valves need to be turned manually. The dust is transported using a side channel blower, the speed of which is controlled with an inverter.

The dust (talcum powder) with defined granularity is placed in the dose tank (Fig. 4). The 3 dm^3 tank with supports at the bottom is placed on three weight sensors that enable dust use monitoring. To eliminate clumping, four foil heaters and a vibrator are used – the first heat the dust and reduce humidity, while the latter keeps the dust in suspension and prevents its deposition.

Dust is supplied through an ejector. As regards the weighing system, the operations of equalisation, calibration, taring and reading conversion into dust mass were applied. After the tank is filled with dust, the weighing system needs to be tared to establish how much talcum powder or other agent has been placed in the tank. The ejector cyclically doses the required dust mass. The user enters the dosing and interval times in seconds – the process lasts until the specified mass is obtained.

All modules were mounted onto a frame made of aluminium profiles. For ergonomic reasons, the dust chamber was mounted on a level enabling its manual operation. Below the chamber, the dust dosage and air circulation modules were fixed (Fig. 5).

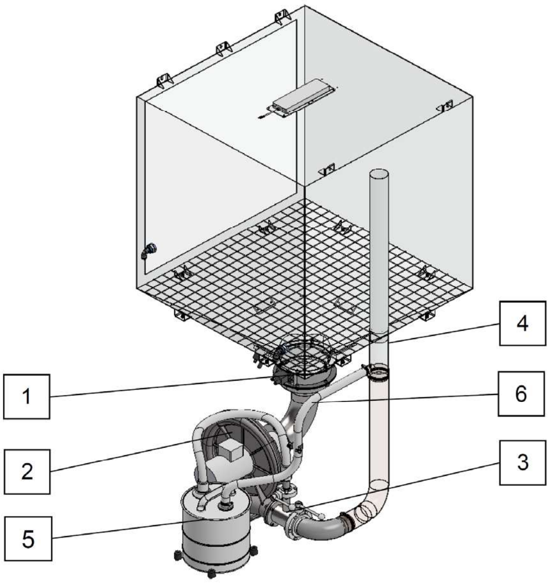


Fig. 3. 3D model of the air circulation system: 1 – filter; 2 – blower with connections; 3 – valves; 4 – dust duct; 5 – dust separator; 6 – flexible cords

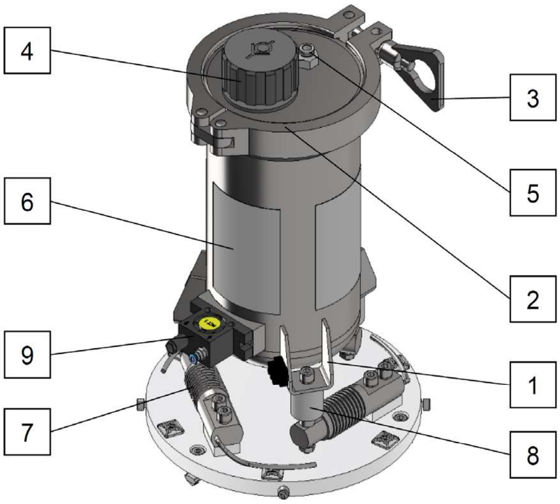


Fig. 4. 3D model of the dust dosing module (view without casing): 1 – tank; 2 – cover; 3 – clasp; 4 – breather valve; 5 – suction connection; 6 – heater; 7 – weighing sensor; 8 – vibration isolator; 9 – vibrator

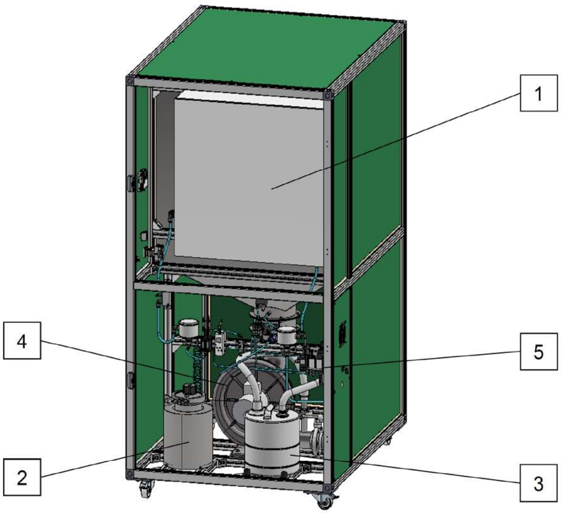


Fig. 5. 3D model of the dust chamber: 1 – control panel cabinet; 2 – dust dosage module; 3 – separator; 4 – blower; 5 – control element

Measuring and control system

Based on the adopted structure, the authors developed the algorithmic model of the control system, taking into consideration information processing circuits as well as the hardware and software layers. The measuring and control elements were selected in accordance with the 24VDC standard for binary signals, the 4-20mA/0-10V standard for analogue signals and Modbus RTU communication protocol. The HG2G touch user interface communicates with PLC resources via Ethernet. The PLC, HMI, and the external computer are connected to a switch.

In the measuring and control system the IT system was divided into software modules for analogue blocks, alarms, and modules controlling individual functional modules of the chamber.

The software is of hybrid nature and combines several programming paradigms. The PLC and HMI software resources enable so-called systematic programming. The HMI software has the characteristics of so-called object-oriented programming. Additionally, in the user interface, the authors used scripts to facilitate the preparation and use of the PLC recording resources. A modular, asynchronous architecture of the chamber software in the PLC was assumed. Flags (so-called relays type M) activate and synchronise the individual modules in line with the idea of distributed software.

Prototype verification

The prototype dust chamber was built based on the adopted assumptions and the developed model. The prototype was equipped with a complete set of instrumentation to verify the correct operation of the individual units (Fig. 6).

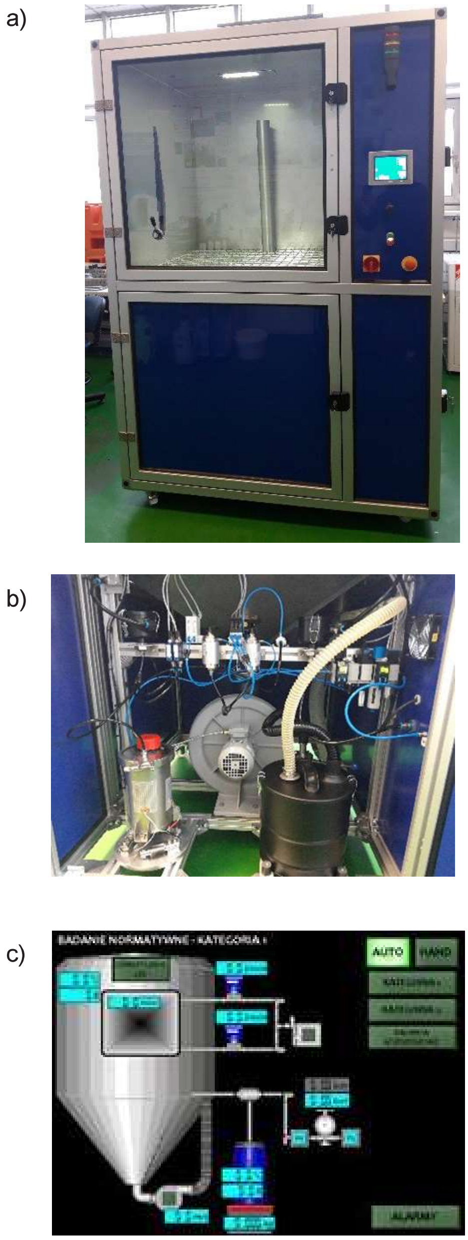
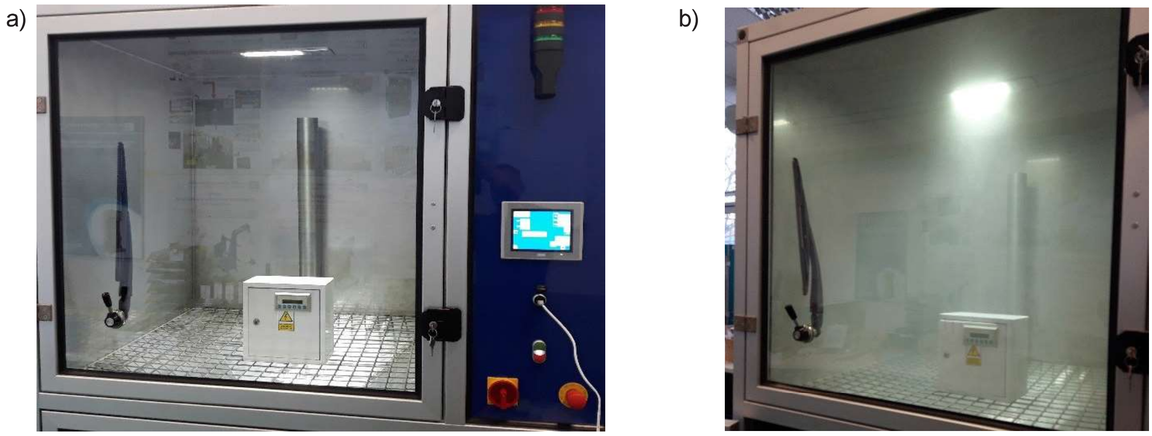


Fig. 6. Chamber prototype: a) front view; b) air circulation system dust dosage system; c) control panel

The verification and validation tests were carried out in the actual operational environment [13]. During the tests trial technological processes were performed. The test results enabled the authors to evaluate the technical solutions used and to verify all technical documentation drafted.

From the verification it followed that the dust dosage process was not effective enough, which was mainly caused by the inappropriate length of the ejector's suction and delivery hose. This led to a significant drop in partial vacuum, as a result of which the suction force was too weak to extract the dust from the tank. Moreover, the insufficient effectiveness of the dust dosage process was also caused by the inadequate performance of



the breather valve located in the chamber's casing. As a result of the ejector's operation, relative pressure was created, which prevented dust ejection on the discharge side.

Prototype verification tests ended with a trial dust tightness test carried out on the complete enclosure with control systems (Fig. 7).

The prototype allowed the authors to carry out the planned tests in keeping with normative requirements. The enclosure proved tight and no dust was found inside it.

Conclusions

Test system to verify the degree of protection against dust penetration enables enclosure dust tightness tests to be carried out in accordance with normative requirements. The developed hardware and software architecture also allows tests to be carried out under expanded conditions defined individually to imitate the actual operational environment. Talcum powder or another agent (e.g. sand or ash) with granularity enabling the discharge fluidization and dust cloud creation can be used as dust.

As a result of the prototype verification the authors were able to identify structural issues and implement relevant corrective actions. From the enclosure tests it followed that the system is suitable for the determination of the degree of protection against dust penetration.

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