New Materials in Flameproof Apparatus

Use of porous materials for safe avoidance of flame transmission

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Figure 1: Pressure vessel for testing electrical equipment with type of protection Flameproof enclosure "d"

Type of protectionFlameproof enclosure "d" is frequently used for safe avoidance of effective ignition sources in explosive atmospheres owing to its degrees of freedom for the electrical characteristics. New types of materials and design methods have been developed to dispel the problem of "flame transmission" of an internal explosion for designers of corresponding apparatus.

Electrical equipment and protective systems for use in hazardous areas must be designed explosion protected in accordance with Directive 94/9/EC. Due to the requirements of explosion protection, they shall not become a source of ignition either in normal operation or in the event of a fault. Various types of protection have arisen during the course of technical development and these types of protection are defined in harmonised European Standards. In the case of some of the types of protection, i.e. encapsulation "m", powder filling "q", pressurized apparatus "p" and oil immersion "o", contact between the components of an electrical device which could cause a possible source of ignition and the explosive atmosphere is prevented by suitable design measures. In types of protection Increased safety "e" and Intrinsic safety "i", effective ignition sources are avoided on a general basis by special measures and requirements.

By contrast, in case of type of protection Flameproof enclosure "d", ignition of an explosion inside the equipment is possible and permitted, but the pressure resistance must guarantee that the enclosure is not destroyed. In addition, there must be no propagation of the explosion to the surrounding atmosphere, so-called flame transmission, owing to design-related openings in the enclosure. Due to this second requirement, this type of protection is listed as Flameproof enclosure by the International Electrotechnical Commission (IEC).

The product range of flameproof apparatus extends from small gas sensors with a few cubic centimetres internal volume to rotating electrical machines with an output of several hundred kW. Normally, this equipment for use in Zone 1 is developed as equipment of Category 2G so that type tests by a notified body are prescribed as mandatory in order to ensure conformity with Directive 94/9/EC.

The requirements applicable to the design and the required tests in accordance with type of protection Flameproof enclosure "d" are defined in Standard EN 50018. Admittedly, conformity with the Standard is no longer absolutely necessary since compliance with the essential healthy and safety requirements of Directive 94/9/EC may also be represented in another way. However, deviations from the aforesaid series of Standards must be clearly indicated in the EC Type Examination Certification. The explosion tests defined in EN 50018 are used to determine the reference pressure and the non- transmission of an internal ignition. Type tests and routine tests to ensure that all devices of a series are designed flameproof are defined in accordance with the reference pressure, i.e. the maximum verified pressure to be determined in defined explosion tests.

Admittedly, problems occasionally occur in practical testing when ensuring explosion pressure resistance but, in general, this requirement is reliably ensured by manufacturers, even if this is done by designing oversized wall thicknesses. However, the requirement of non- flame transmission design is a far more difficult task to master. The causes of this are presented in detail below.

Flame transmission of internal ignition

The test of electrical equipment for flame transmission is conducted in an explosion pressure resistant vessel (Figure 1). An explosive atmosphere is created in such a tank inside and outside the apparatus. After ignition of the gas mixture inside the enclosure, a test is conducted in order to establish whether the explosion can be propagated to the outside through joints necessary owing to the design. This explosion propagation is based both on the interaction of chemical reactions and turbulent flow and on the interaction of reactive flow with the joint walls.

In order to cope with the complex problem, EN 50018 defines three different ignition locations inside the enclosure. Consequently, there may be a wide variety of conditions, when the explosion enters a joint. The equipment under test must always safely avoid flame transmission.

The physical and chemical processes occurring during flame transmission are investigated in Working Group 3.41 "Flameproof Enclosure" of the German Federal Institut Physikalisch Technische Bundesanstalt (PTB) using modern experimental and numeric methods. Figure 2 shows a typical ignition of the outside atmosphere by emerging hot exhaust gas. Simultaneous application of the Schlieren technique and planar laser-induced fluorescence of OH radicals in Figure 2 clearly shows that the ignition occurs at the head of the merging hot general diffusion and that then the combustion reaction progresses into the cold hydrogen/air mixture.

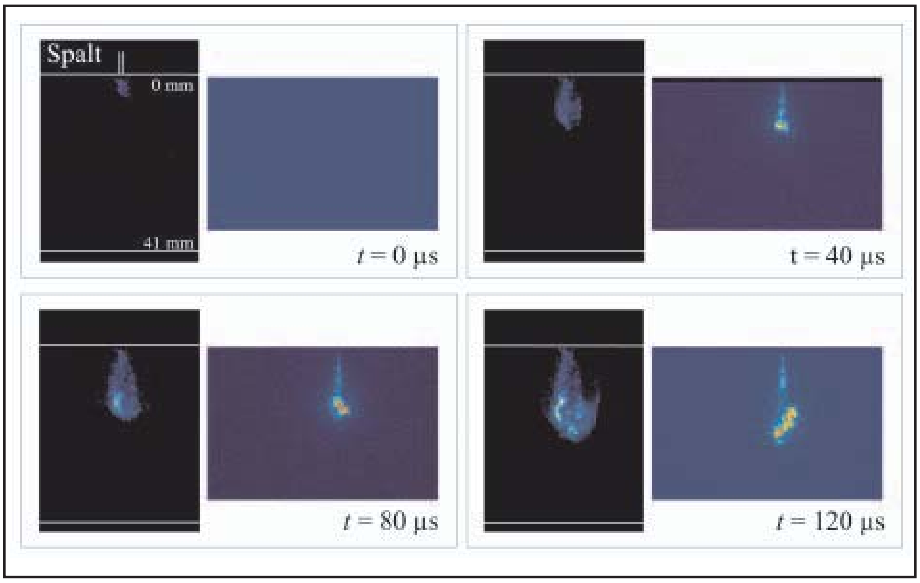

Figure 2: Ignition of a hydrogen/air mixture after hot exhaust gas is ejected from the joint-simultaneous visualisation of gas jet (left) and chemical reactions (right)

Numeric simulation of the ignition process occurring by the PTB has indicated that the ignition is dependent on the mixture composition of the emerging exhaust gas on the one hand. On the other hand, the temperature of the gas jet is of crucial importance owing to the exponential temperature dependence of the chemical reactions. These fundamental investigations make a contribution to our understanding of the precise interrelationships of explosion propagation through narrow gaps of joint. Such findings are incorporated directly in investigations into avoidance of flame transmission on commercially available electrical apparatus.

Avoidance of transmission

The protection principle of type of protection Flameproof enclosure "d" is based on containment of explosions. Appropriate dimension of a joint is intended to safely prevent the explosion being propagated through such a joint into the surrounding explosive atmospheres. In the case of rotating electrical machines for instance, the joints for shaft glands are generally designed as cylindrical joints.

EN 50018 does, admittedly, define minimum requirements in respect of the relevant joint dimensions,but testing practice indicates that these dimensions are frequently insufficient. Unlike the situation relating to the question of "pressure resistance", the designer is unable to eliminate this problem right from the very start by using joints which are of any width and of any small gap. Regardless of the requirements applicable to production, which then become more stringent, clear power losses would have to be accepted on rotating electrical machines. In accordance with EN 50018, labyrinth joints are also permitted, but these are complex to produce. However, they do allow the designer greater degrees of freedom, since it is only necessary to ensure that the joint walls do not come into contact.

German patent DE 198 26 911 describes various other methods for routing hot, reactive gas mixtures through narrow joints, each of them intended to safely avoid flame transmission. On the basis of this, an attempt was launched in the year 2001 to investigate these methods for flameproof apparatus within the framework of a research project, sponsored by the Federation of Industrial Research Facilities (Arbeitsgemeinschaft industrieller Forschungseinrichtungen, AiF) in cooperation with the KEK GmbH company, by Working Group 3.41 of the PTB.

One particularly promising aspect in this →

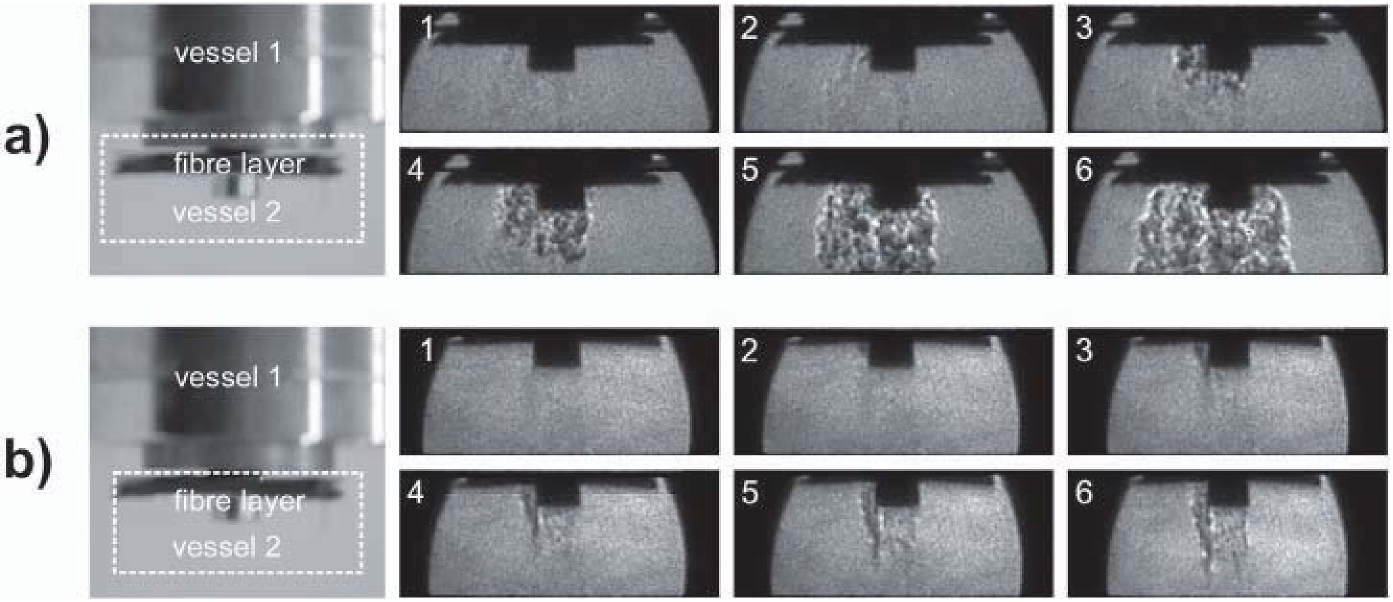

Figure 3: Comparision of the influence of two different fabric layers on hot reactive flow. Series a) shows flame transmisstion. In experiment b), flame transmission is prevented by adequate cooling. The time interval between the two photographs is Δt = 80 µs, the image size corresponds to 25 mm x 60 mm and it is shown in the figure at the left.

respect is directly influencing the hot flow by porous materials in the flow path. Figure 3 shows the differing effect of two different material packings. The explosion was admitted into vessel 1 in each case. Directly at the exit point of a joint with a gap of 520 µm, hot exhaust gas flows into vessel 2 in which there is a cold fresh gas mixture of 28 % hydrogen in air. Whilst ignition of the external atmosphere is observable in Figure 3a, Figure 3b shows only ejection of hot gas with a slightly modified packing. An ignition is safely avoided.

Investigation of various materials in respect of their effectiveness and corrosion resistance to outflowing hot gas under test conditions approximating those in practice was one task of the research project. New types of high-temperature-resistant fibre structures in particular proved to be ideal for this application. The starting materials for manufacturing these fibres may be high temperature-resistant steels and Ni3Al alloys. Fibres made of the Ni3Al alloy with a 13-%-by-weight share of aluminium feature a very good oxidation resistance even at high temperatures owing to a thin aluminium oxide layer on the metal surface. Such materials unite high porosities up to 95 % at a very good reproducibility with adequate stability and dimensional stability under all conditions investigated. The manufacturing process involves sintering the melt-extracted fibres under pressure. Pore sizes in the range of 10 to 250 µm are possible depending on the required porosity and the selected fibre diameter.

Use of new types of materials

Directly influencing a hot reactive flow, as shown in Figure 3, is easily possible on model enclosures. By contrast, it is a far more complex task to use this technique in commercially available flameproof enclosures. Consequently, the above research project developed prototypes for safe avoidance of flame transmission specifically for joints for shaft glands of rotating electrical machines. These prototypes essentially consist of a suitable fixture for the porous materials to be used and must comply with two conditions: the function of the apparatus must always be reliably ensured and, at the same time, flame transmission must be safely avoided.

The explosion tests required for this were conducted in explosion pressure resistant test vessels in accordance with the tests specified in EN 50018. Video recordings of the tests, as can be seen in Figure 4, allowed appropriate modification in order to improve the results if flame transmission occurred. The research project concluded with development of a prototype. The subject of investigations still underway is the market launch of the methods established for avoidance of flame transmission of internal ignition. Versions for equipment of moderate to large size are presented below.

Figure 4: Flame transmission of internal ignition at a shaft gland joint

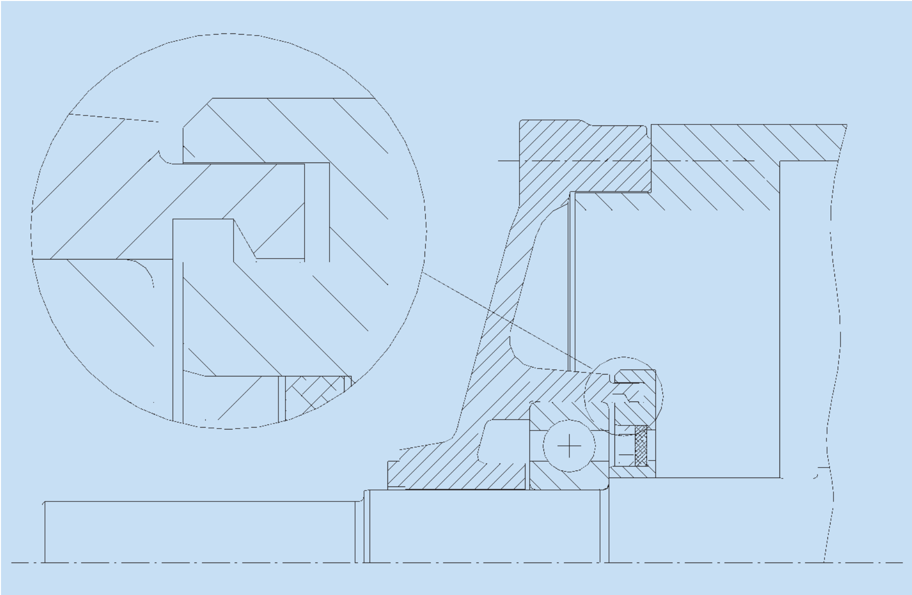

Figure 5: Use of a fixture for porous structures on rotating electrical machines of moderate size

Apparatus of moderate size

Figure 5 shows the basic structure for use of porous structures in flameproof apparatus. On this type of solution, a cylindrical joint between shaft and end shield and a cage with a porous structure are used for safe avoidance of flame transmission. EN 50018 is complied with by designing the cylindrical joint in compliance with the Standard. However, for Group IIC, for instance, it suffices to provide a joint with a width of 25 mm and a gap of 250 µm. The fixture with the porous material with a depth of only 16 mm is located in front of the ball bearing inside the enclosure on the shaft. There is a labyrinth joint with a non-critical gap of ≥ 500 µm between the fixture and the end shield. Defining the corresponding porosity is intended to ensure that the hot reactive flow is largely routed through the element used and is cooled adequately at this point.

The advantage of safe and easy design must be weighed up against the additional costs of the elements to be used. However, it will be endeavoured to achieve low unit costs, if enough units are to be produced, so that overall, there will be a very good price-performance. Moreover, higher shaft deflections are permitted on the version presented above by comparison with conventional designs owing to the short joint width, which is the same as saying that higher transverse forces are permitted.

Apparatus of large size

Rotating electrical machines of large size are frequently manufactured only in small quantities as special machines. The problem of "flame transmission of internal ignition" in this field of application may lead to overall costs, which were not estimated right from the very start or to a not inconsiderable deadline risk.

In this field of application as well, use of porous materials should simplify the design of flameproof enclosures. Figure 6 shows the prototype of a corresponding solution type for the shaft joint of the machine. This consists of a rotating element and a stationary element, which both contain porous structures for safe avoidance of flame transmission. The joint between these elements is designed as a labyrinth joint so that this application also complies with EN 50018. The additional cost of such a prototype is

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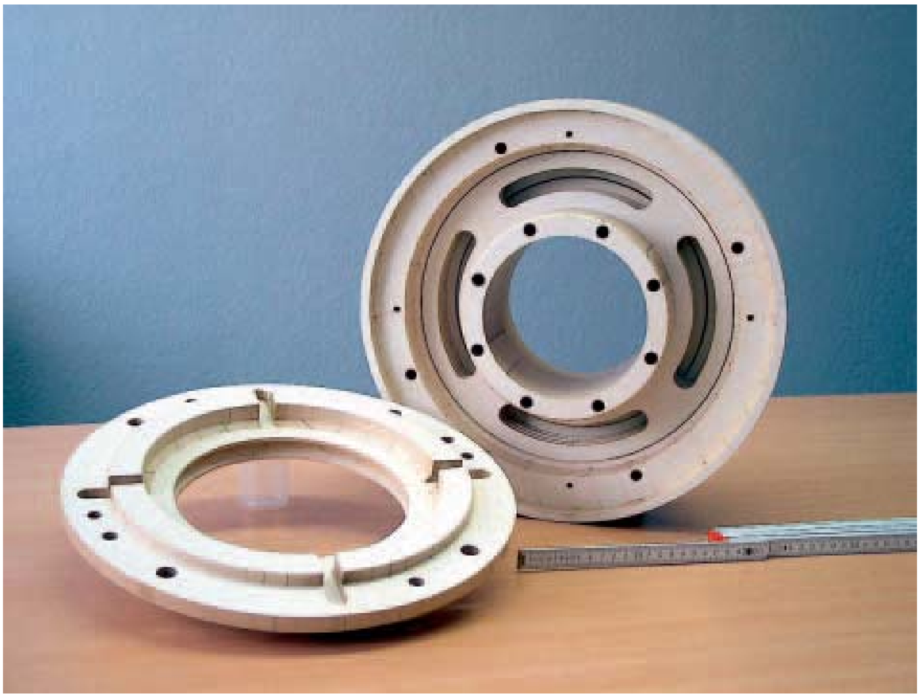

Figure 6: Prototype of a fixture for porous structures for avoidance of flame transmission on rotating electrical machines of large size

far outweighed by the few requirements applicable to the design and testing for flame transmission so that, here as well, there will be a good price-performance ratio.

Summary and outlook

A research project of Technical Laboratory 3.5 "Flameproof Enclosure" of the PTB was able to verify that flame transmission could be safely avoided by the use of new types of materials. Work is currently underway on implementing the research results for use in commercially available flameproof apparatus. The aim is to achieve a simplified design of the equipment whilst complying with EN 50018.

The broad range of appropriate electrical equipment suitable for this is of special interest. This range of equipment extends from the small gas sensor to the large rotating electrical machine. In order to better utilise the interaction of the hot reactive flow with the porous fibre structures under various boundary conditions owing to the various housing sizes, it is intended to investigate this question in detail in conjunction with the Fraunhofer Production Technology and Applied Material Research Institute.

The findings in relation to the need for new types of design catalogues specifically for equipment with type of protection Flameproof enclosure "d", obtained within the framework of the project presented, are to be investigated in cooperation with the Department of Mechanical Engineering of Magdeburg University and R. STAHL Schaltgeräte GmbH on flameproof empty enclosures. The aim is to develop suitable design aids to simplify design of corresponding empty enclosures for this application as well.

Literature

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