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Investigations of static and dynamic stresses of flameproof enclosures

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ABSTRACT

Flameproof enclosures house electrical equipment used in hazardous areas. To assess the ability of an enclosure to withstand pressure, a test – which is defined in IEC 60079-1 (2014) for the type of protection *flameproof enclosures* – has to be performed. Based on the maximum pressure measured after igniting explosive gas mixtures inside the enclosure, either a hydrostatic or a dynamic overpressure test has to be performed to verify the mechanical strength of the enclosure. Both tests are considered satisfactory if no permanent deformation or damage invalidating the type of protection can be detected. In this work, these two different test methods are compared and evaluated. The results show that the static and dynamic stress, and thus the two different test methods, cannot be considered equivalent. Especially in case of insufficient damping of the mechanical load, or if this load corresponds to the natural frequency of the enclosure, the dynamic stress is much more critical.

1. Introduction

The type of protection *flameproof enclosures "d"* is generally used for devices where high temperatures or ignitable sparks can occur during operation. The flameproof enclosure is designed to prevent the flame propagation of an inner explosion to avoid the ignition of an external explosive atmosphere. During the type test for the ability of the enclosure to withstand pressure, the internal pressure is recorded as a function of time during several explosion tests using a 5 kHz low-pass filter. The dynamic maximum explosion pressure determined in this way is considered the reference pressure. Depending on the type of testing, and based on this reference pressure, an overpressure test at 1.5 times/4 times (dynamic, static) has to be performed. The static and dynamic overpressure tests are considered equivalent. Both tests are judged to be satisfactory if no permanent deformation or damage invalidating the type of protection can be detected (IEC 60079-1, 2014). In this work dynamic pressure is defined as the value of the smoothed pressure, caused by an explosion of an explosive mixture inside an enclosure, relative to atmospheric pressure. The static pressure is defined as a pressure applied to an enclosure for at least 10 s. Furthermore, dynamic stress is defined as stress as a result of pressure caused by an explosion of an explosive mixture inside an enclosure. Static stress is defined as stress as a result of pressure applied to an enclosure for at least 10 s.

However, the use of the measured value of the maximum explosion pressure as a basis for assessing the mechanical load of the enclosure, or as a basis for an overpressure test, is significant only for a limited number of housing geometries. For example, in complicated flameproof enclosures with divided spaces (e.g. electric motors), brief pressure peaks often occur. This momentary increase in pressure is also called pressure piling and can produce maximum values of up to ten times the actual, longer-acting pressure (Beyling, 1906; Singh, 1994). Studies conducted by Riddlestone (1963) showed that pressure impulses with short rise times can cause stress enhancement in flameproof enclosures. Further investigations by Harcken and Wehinger (1985) on the dynamic stresses of flameproof steel enclosures, established that the natural frequencies of the enclosures are an important value for the analysis of the material stress; these investigations were a source of inspiration for the work presented in this paper.

In this work, the material stress of a model enclosure is investigated for different explosion pressures varying in intensity and frequency. In an extensive series of experiments, the explosion pressure measurement performed with piezoelectric pressure transducers is expanded to include strain gauges to determine the strain of the model enclosure. Furthermore, the strain of the model enclosure caused by static internal pressures of the overpressure test is also considered. The aim is to examine the relationship between the pressure-as-excitation and the material strain of the

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flameproof enclosure as the response. Moreover, the question is investigated of whether possible resonance effects caused by exciting the enclosure's natural frequencies, and thus its associated housing vibrations, can be recorded by observing the explosion pressure. Finally, the results and experience gained with the model enclosure are examined concerning their transferability to practical issues in the field of explosion protection.

2. Experimental set-up

In this work, a model enclosure of two different configurations (configuration 1 and 2) is investigated. All elements of the two configurations consist of cylindrical compartments with an inner diameter of 161.5 mm and a wall thickness of 3.4 mm. The configurations are each sealed airtight by means of a blank flange (flange thickness of 22 mm) at the ends of the compartments. Connections for the supply of the gas-air mixture, as well as the centrally located pressure sensor p_3 for measuring the dynamic explosion pressure, are located on the blank flanges. In addition, a spark plug for igniting the gas-air mixture is installed on one of the blank flanges in each configuration.

Configuration 1 consists of three cylindrical compartments (compartment A, B and C) of different lengths. Compartments A and B are interconnected by an orifice with an aperture of 60 mm. Configuration 1 is shown schematically in Fig. 1.

Configuration 2 consists only of compartment C and is shown schematically in Fig. 2.

For both configurations, an additional pressure sensor p_2 is attached to the casing of compartment C. Additionally, strain gauges are installed on the casing and the end flange of pipe section C to determine the material strain.

In order to compare the investigations of dynamic and static stresses of flameproof enclosures, a measurement system is required that simultaneously records the pressure curves and strain curves, which vary over time. The dynamic pressure is measured by means of piezoelectric pressure transducers. These piezoelectric sensors generate a charge signal proportional to the pressure which is converted by a charge amplifier into an electrical voltage. For the static pressure measurement, a piezoresistive pressure transducer is used whose output signal is also converted by an amplifier into an analyzable voltage signal.

Three different measuring locations M_1 to M_3 are used for strain measurement on compartment C. At each measuring point, Wheatstone measuring bridges are applied that are implemented as temperature-compensated bias bridges (full bridge with two active and two passive strain gauges) for the respective main stress direction. To this end, the strain in tangential direction ε_T (corresponding to $\varepsilon_{tangential}$) and in axial direction ε_A (corresponding to ε_{axial}) has to be measured at different positions (M_1 and M_2) of the

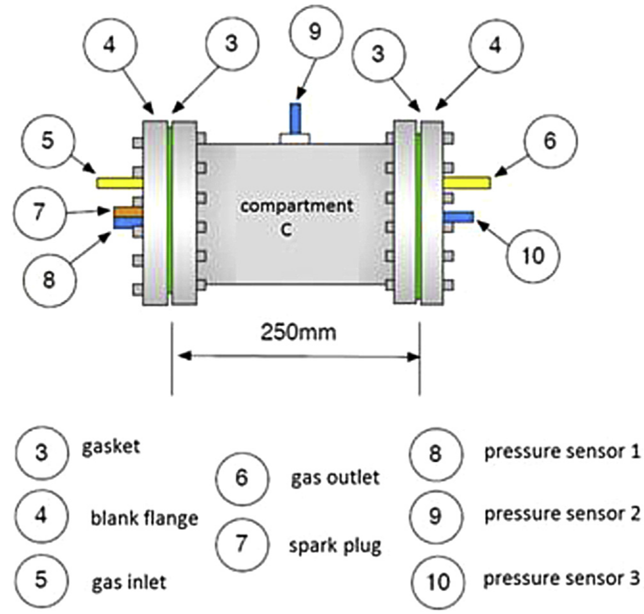

Fig. 2. Diagram of configuration 2 of the model enclosure.

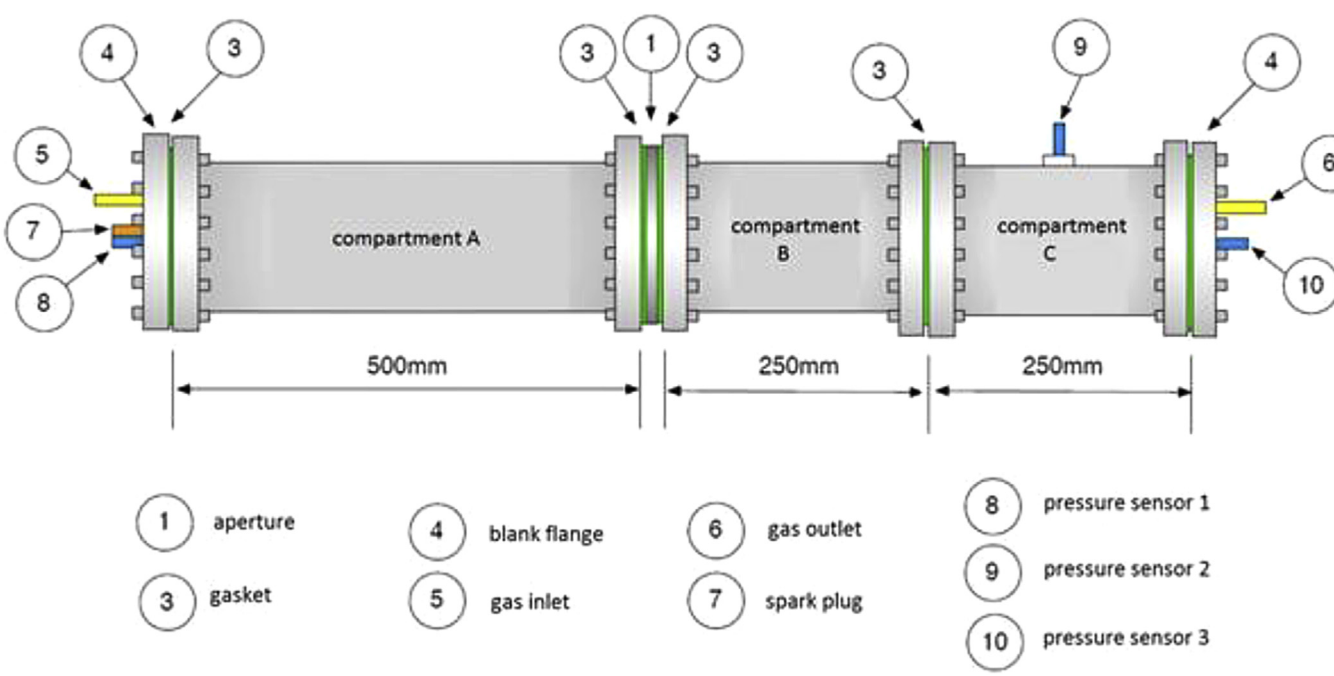

Fig. 1. Diagram of configuration 1 of the model enclosure.