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Testing leaktightness of welded joints using a bubble test with a vacuum cap

Abstract: Testing of leaktightness of welded joints with the use of bubble test with vacuum cup and the principles of such a testing by means of the UKS device have been characterized. It has been presented also the UKS device design and the requirements concerning such an inspection. The UKS device satisfies the requirements specified in the PN – EN 1779 and PN – EN 1593 standards.

Keywords: inspection, UKS device, leaktightness of welded joints, bubble test

Introduction

The leaktightness of welded joints poses a technical challenge addressed by many testing methods and techniques, the purpose is to detect material discontinuity through a tested object, also referred to as leaktightness. A method characterised by more advantages than others, particularly in relation to welded joints, is a bubble test with a vacuum cap. In the list of methods and techniques employed for testing leaktightness provided in standard PN – EN 1779, a bubble test with a vacuum cap belongs to a group of methods using pressure changes. This testing technique, designated with the symbol of C.3., is characterised by a minimum leak detectable in industrial conditions having the value of 10^{-3} Pa · m³/s.

In order to facilitate the implementation of this method for testing welded structures in welding practice it was necessary to develop guidelines for its application [1], based on valid regulations, as well as to design and build a device, for which the general and detailed conditions of testing the leaktightness of welded joints have been established [2, 3, 4].

The article describes the principles which govern testing the leaktightness of welded joints by means of a bubble test with a vacuum cap using a UKS device.

Testing characteristics

Testing leaktightness by means of a bubble test with a vacuum cap consists in using the phenomenon of gas penetration from a centre characterised by a higher pressure to a one in which a pressure is lower when there is a connection between these centres.

Testing welded joints takes place in the atmospheric air at a negative pressure created in a chamber placed on a section under examination (Fig.1).

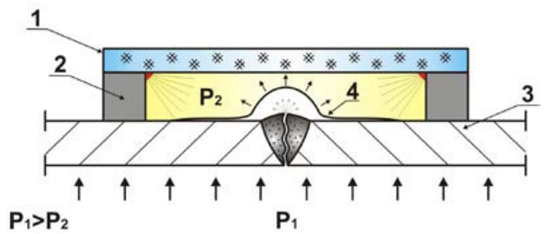

Fig.1. Principle of testing the leaktightness of welded joints by means of a bubble test with a vacuum cap: 1 – transparent observation plate, 2 – sealing ring, 3 – welded joint with a leak, 4 – bubble.

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Leaks in a joint constitute connections between centres of various pressures. In a joint covered with a foam-producing solution (liquid detector) air enters the chamber from the atmosphere through leaks due to a pressure difference. As a result, a bubble enabling the detection and location of a leak is formed.

The described method of testing leaktightness can be used in relation to such products as non-pressure tanks for gases and liquids, silos, tankers on independent chassis, non-pressure pipelines and systems, container bottoms, covers, parts of various types of jackets, segment knees, containers, flat objects of ships, etc. The methods are not used for testing the leaktightness of pressure equipment. A bubble method with vacuum cap does not replace a pressure leaktightness test or a structural strength test.

Advantages and disadvantages of bubble test

The advantages and disadvantages of leaktightness tests of welded joints by means of a bubble test with a vacuum cap are listed in Table 1 [1].

As can be seen in Table 1, a bubble test with a vacuum cap can be an alternative to leaktightness tests with such methods as compressed air, chalk and kerosene, penetrant or gaseous ammonia and phenolphthalein.

UKS device for testing leaktightness of welded joints

A device for testing the leaktightness (UKS) of welded joints using a bubble test with a vacuum cap, designed and built at Instytut Spawalnictwa, is presented in Figure 2.

A device consists of two basic components, i.e.: a vacuum cap (exchangeable vacuum chambers) and a suction pump. The vacuum chamber limits the space in which a negative working pressure is generated. The chamber consists of a transparent observation plate and a seal (usually a rubber or plastic one). The transparent plate enables the observation of a joint section during testing. The seal, tightly adhering

Table 1. Advantages and disadvantages of bubble test with vacuum cap in comparison with other leaktightness testing methods.

comparative criteria	**leaktightness testing method**						
	bubble test with vacuum cap	with compressed air			With chalk and kerosene	with penetrant	with ammonia and phenolphthalein
		by blowing	by immersion in water	with soap solution			
Method sensitivity	-	lower	lower		lower	lower	higher
Access to joint	from one side	from both sides	from one side (necessity of manoeuvring with the structure)	from one side	from both sides	from both sides	from one side
Type of test rig	portable	stationary	stationary	stationary	-	-	portable
Testing rate	approximately 30 m/h (chamber 1 m in length)	lower	lower	lower	lower	lower	lower
Additional requirements	necessity of possessing a chamber adjusted to a joint shape	compressed air system or compressor	compressed air system or compressor	compressed air system or compressor	-	-	gas supply system

to the base, isolates a chamber volume from the environment. The observation plate of each chamber has been provided with a connector to a flexible duct and a vent valve. The suction pump generates a required negative pressure in the chamber by pumping air out of the chamber through the flexible duct connecting the connector with the pump. The valve enables the aeration of the chamber after a test as well as the adjustment of a pressure in the chamber by appropriate setting with adjustment knobs. In order to provide appropriate observation conditions of bubbles, the chambers have been equipped with diode lighting of adjustable intensity. Such a solution enables testing to be carried out in any operator's work environment lighting conditions. The current version of the device features oblong chambers of three testing lengths (92 cm, 75 cm and 50 cm) and a round chamber with an internal diameter of 21 cm. The chambers weigh approximately 12 kg, 10 kg, 7 kg and 3 kg respectively.

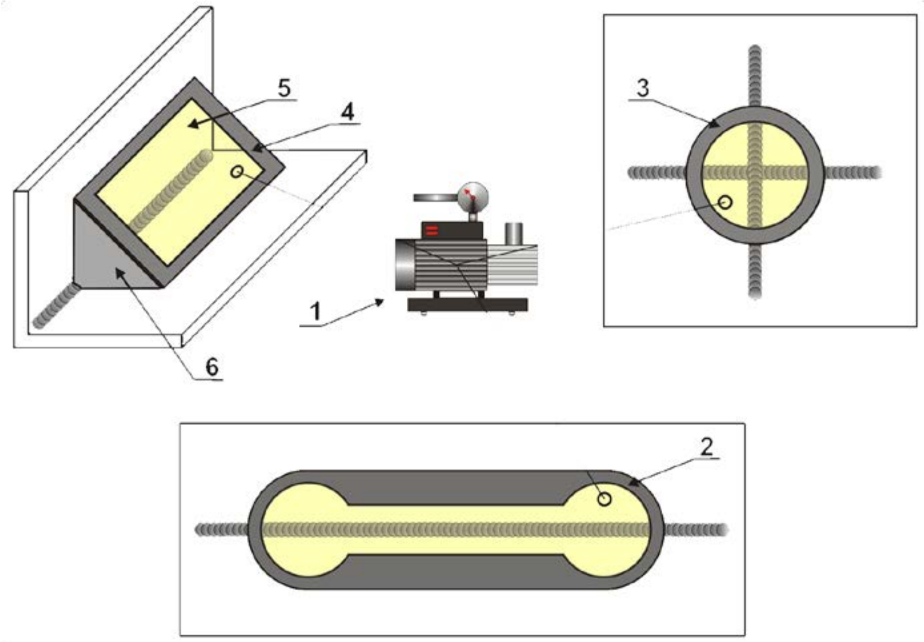

Fig. 2. Device for testing the leaktightness of welded joints using a bubble test with a vacuum cap: schematic diagram: 1 – suction pump, 2 – oblong chamber, 3 – round chamber, 4 – angular chamber, 5 – observation plate, 6 – seal.

The oblong chambers are intended for testing flat butt joints. In turn, the round chamber is used for testing butt cruciform joints and joints on curved surfaces (e.g. spherical ones) (Fig.3).

Testing flat joints with the round chamber is also possible, yet a testable section is only 21 cm in length. As can be seen the round chamber is characterised by a significant versatility. However, during testing flat joints the oblong chambers are characterised by a considerably greater efficiency. Both the oblong and the round chamber enable testing the leaktightness of fillet welds in overlap joints, where the thickness of the base metal of an overlap should not exceed 20–12 mm.

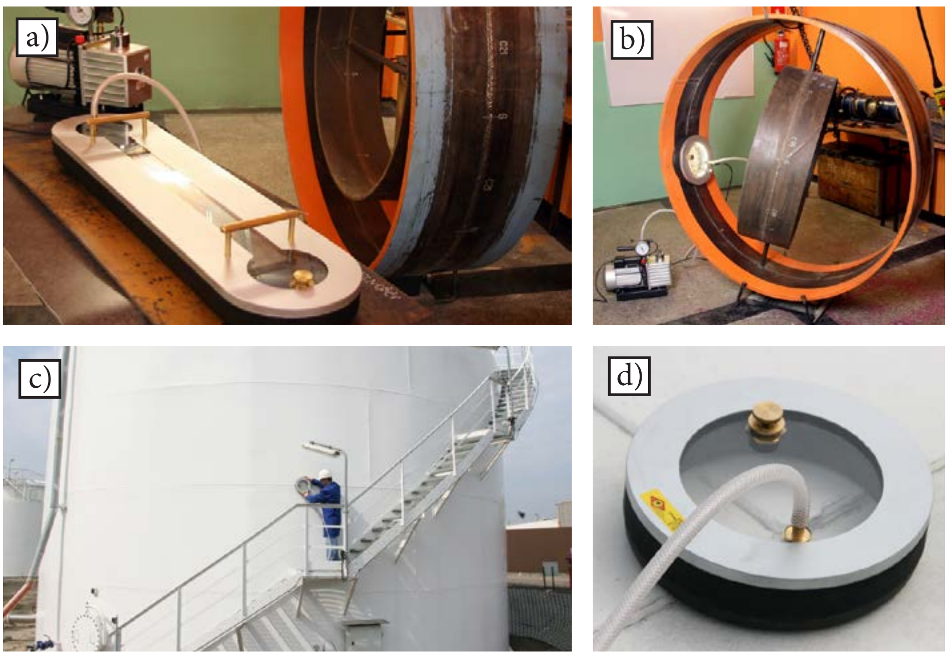

Fig.3. Testing the leaktightness of welded joints using: a) oblong chamber, b) round chamber, c) container for liquid fuels, d) cruciform joint.

General requirements for leaktightness test

Personnel qualifications

Testing the leaktightness of welded joints using a bubble test with a vacuum cap should be carried out by personnel having sufficient knowledge and skills. For this reason it is recommended that personnel should be certified in accordance with the requirements of standard PN – EN ISO 9712 or an equivalent. Testing the leaktightness of welded joints can be also conducted by uncertified personnel, yet they should have undergone training in the testing method and the operation of the testing device confirmed with an appropriate certificate.

Indicator

It is recommended that in a bubble test with a vacuum cap, the air or an inert gas (e.g. nitrogen) should be used as the indicator (detector) of leaks. However, in the latter case one should take into account an operator's safety factors related to the possibility of oxygen deficit in the atmosphere surrounding a test rig.

Surface temperature

The temperature of a surface to be tested for its leaktightness should be between +10°C and +50°C. Temperatures lower than recommended are also acceptable on condition that they are not lower than +5°C due to the possibility of steam condensation on surfaces to be tested and in leaks to be detected. Such a situation may prevent the formation of a bubble demonstrating the existence of a leak. In order to maintain a temperature within the range specified above it is allowed to locally heat or cool an area under investigation.

If observing surface temperature restrictions is technically or economically problematic, other temperature values, specified in a related instruction (procedure) as appropriate, can also be used.

Requirements for welded joints

The height of the reinforcement and the roots of butt welds in joints tested for leaktightness using a bubble tests with a vacuum cup should be in conformity with use-related standards and gently pass to the base metal (welded). The face of fillet welds should be flat or slightly concave and also gently pass to the base metal. No special requirements have been established in relation to plug welds. Gentle passing of welds to the base metal facilitates the adhesion of the seal of the vacuum cap to a joint and prolong the life of the former.

A weld to be tested for leaktightness and at least 40 mm wide zones adjacent to the weld (on both sides) should be thoroughly cleaned. All slag, rust, paint, lubricants, scale and weld deposit spatters must be removed.

Note: impurities left on the surface of joints may screen forming bubbles or cause false indications.

Detecting liquids

Leaktightness tests by means of a bubble test with a vacuum cap should involve surface-active liquids (foam-producing solutions). Such leak-detecting liquids should be non-volatile, i.e. they should not dry up at the testing temperature. They should also be viscous and not foam at a generated negative pressure. Commercially available liquids not intended for leaktightness tests should not be used, unless their usability has been previously demonstrated (e.g. by a type test or through a comparison with the properties of an approved liquid). In the case of detected gas leaks bubbles should maintain their shape during the duration of a test. While testing vertical surfaces the viscosity of a detecting liquid can be enhanced, if need be, by using approved methods. A detecting liquid should demonstrate the conformity with the structural materials of objects (products) tested.

A contaminated detecting liquid or a liquid undergoing spontaneous foaming during testing may cause false indications and for this reason the use of such liquids should be forbidden.

Testing conditions and procedure

The conditions for the leaktightness tests of welded joints using a UKS device have been specified for a foam-producing solution composed of water, soap and glycerine in the following proportion: water – 1 litre, toilet soap 0.50 g, glycerine – 5 g. The testing conditions are the applied difference of pressures and the time at which it is maintained, the temperature of the detecting liquid (foam-producing solution) as well as the intensity of lighting of the surface being tested.

- Difference between the atmospheric air pressure and the pressure of the air in the vacuum chamber (negative pressure value) cannot be lower than 50 kPa.
- Pressure difference maintenance time should be at least 30 seconds.
- Temperature of a detecting liquid should be not lower than +20°c.
- Intensity of lighting of a welded joint surface being tested should be at least 500 lx.

A surface-active detecting liquid should be applied on the surface of a welded joint with a soft brush, by spraying or using other methods. A leaktightness test of a joint with a UKS device consists in placing a vacuum chamber (vacuum cap) on a section tested, pressing the cap against the surface, pumping the air out and observing whether bubbles are formed (Fig.4).

The formation of bubbles indicates discontinuities through a joint, which also implies the presence of leaks. Afterwards, the chamber is aerated and placed on another section of a joint and the actions described above are repeated.

The formation of bubbles is observed with the naked eye from approximately 10 cm (near point) to a maximum of 60 cm (measured in relation to a surface being measured) and at an angle between 300 and 900. In order to improve the angle of view it is allowed to use auxiliary measures such as mirrors, magnifying glasses, telescopes, endoscopes, grain flow patterns or other appropriate devices. It is recommended that the resolution of such devices should be at least equivalent to the resolution obtained during testing with a naked eye.

If necessary, the results of leaktightness tests of welded joints using a bubble test with a vacuum cup should be presented in a test report. A report should contain at least the identifier of an object and the joint being tested, the type of detecting liquid used, the difference of pressures (negative pressure) applied, the time for which the difference of pressures was maintained, the temperature of the detecting liquid, the temperature of the surface examined, the intensity of the lighting of the surface examined, the description of the manner of designating places containing leaks (test results), the operator's name and surname, the date of the test and the operator's certificate.

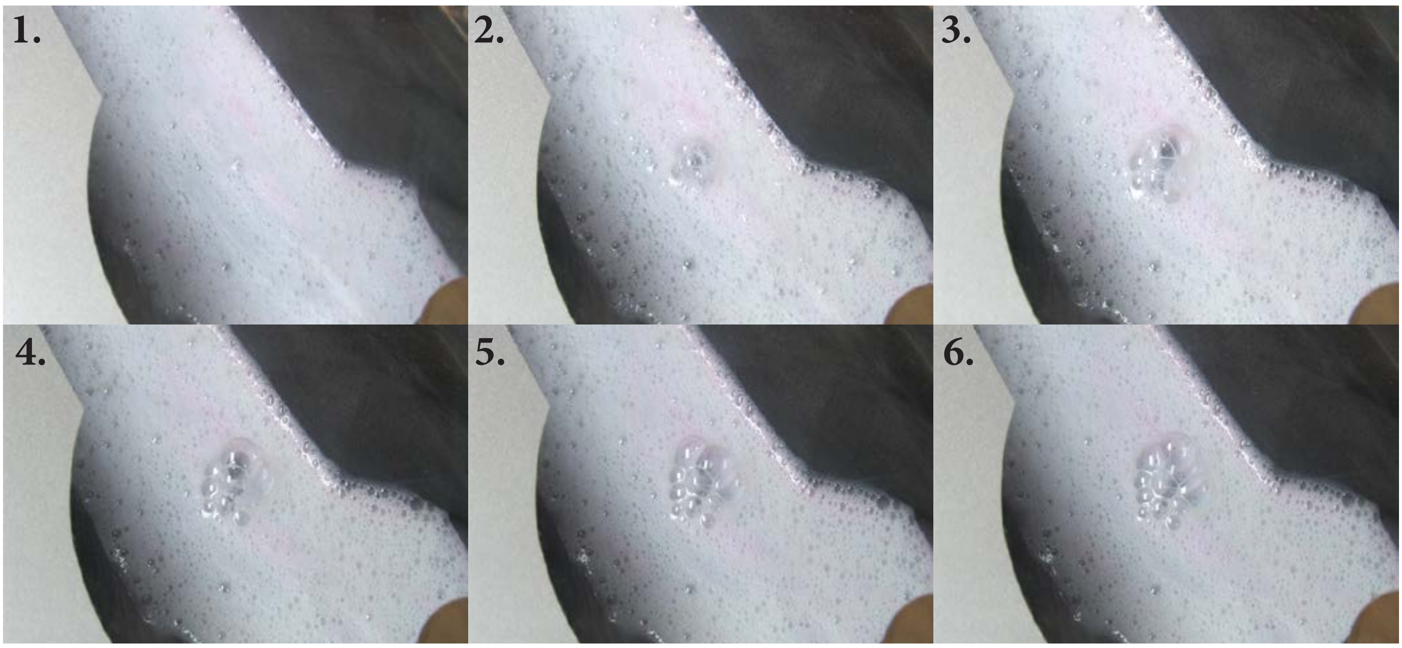

Fig.4. Bubbles indicating the presence of leaks on the surface of a welded joint. Sequence frequency: 6 seconds.

Summary

The development and building of a UKS device partly filled the gap in monitoring the leaktightness of welded joints using a bubble test with a vacuum cap. It has enabled a wider use of a bubble test in industrial practice, particularly in relation to products, whose basic operation approval condition is the leaktightness of welded joints. The device is characterised by the simplicity of structural solutions used and the fulfilment of the requirements referred to in standards PN – EN 1779 AND PN – EN 1593. An unquestionable advantage of the device is its easy operation and the environmental friendliness of testing substances.

The design of the UKS device has been recognised by the Polish Patent Office. In decision no. DT/WP.20509/6/EDO of 12.03.2013 Instytut Spawalnictwa in Gliwice was granted **an industrial design right** entitled “Device for monitoring the leaktightness of welded joints using a bubble test with a vacuum chamber”.

The UKS device underwent an assessment at an invention fair held in Paris this year as well as at Poznań International Fair held in June this year. As a result, in both cases the device was distinguished with gold medals and related diplomas (Fig.5 and 6).

The UKS device has proved a commercial success finding applications in everyday industrial practice. It should be mentioned that the device is continuously modernised. It is expected that the nearest future will see the extension of the product range with new solutions and applications of vacuum chambers.

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Fig.5. Medal and a related diploma obtained at an invention fair in Paris

Fig.6. Medal and a related diploma obtained at Poznań International Fair

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Reference standards:

– PN – EN 1330 – 8 "Non-destructive testing – Terminology – Terms used in leak tightness testing".
– PN – EN 1593 "Non-destructive testing – Leak testing – Bubble emission techniques".
– PN – EN 1779 "Non-destructive testing – Leak testing – Criteria for method and technique selection".
– PN – EN ISO 9712 "Non-destructive testing– Qualification and certification of NDT personnel".