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TESTING OF DILATATIONS BY COLD WATER TEST OF STEEL AND COMPOSITE SELF–CONTAINED BREATHING APPARATUS (SCBA) BOTTLES

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Abstract: Bottles of breathing apparatus can be filled with a compressor and directly connected to "air banks". During the filling of the bottles of breathing apparatus with high–pressure compressors, or with the help of "air banks", there is an increase in pressure in time and the amount of compressed medical air in the bottle. The consequence is an increase in tension in the bottle material, which is in direct connection with the specified parameters. The intensity of the stress and the influence of the increase in pressure over time on the stresses of steel and composite cylinders are also identified using strain gauges. With tensometric measuring tapes, dilatation measurements were performed on a steel and composite bottle/cylinder of breathing apparatus (SCBA – self–contained breathing apparatus) with a cold–water test. They are used to measure local deformations on real structures. The aim of the research is to define the gradient of bottle filling speed, which ensures safety, and reliability of this procedure and which is influenced by parameters such as: bottle material, bottle correctness, correct airflow valve, temperature rise, minimum bottle filling time, etc.
Keywords: breathing apparatus, expansion joints, stresses, strain gauges, cold water test

1. INTRODUCTION

In exploitation, container under pressure, from the aspect of safety, represent specific energy equipment. They can be stable and mobile. Stable pressure containers are containers under the pressure of liquid, compressed and pressurized liquefied gases, air or overheated liquids that do not change the place from charging to discharge. The design, use and production of this type of pressure containers is regulated by the Regulations on technical normatives for stable pressure containers.

Pressure containers can be found in all branches of industry, have a certain accumulated energy, which is presented to the parameters of the energy medium that they are fulfilled. In the event of a failure on a pressure container or explosion, there are destructive effects, damage to the facility and installations, with the occurrence of risks to the lives and health of people that are in the immediate vicinity. If the medium contained in the pressure container is in the category of hazardous substances, then the environmental risk is much higher.

According to SRPS (Serbian standard) M.E2.150, pressure containers are divided according to: volume, wall thickness, pressure, temperature, accumulated energy (pV), the aggregate state of the working substance, the physical and chemical state of the working substance, the material from which they were made, technology of fabrication and merging, purpose, shape and construction.

The SRPS M.E2.151 standard determines the classes of the containers under pressure based on risks to people, environment and material assets. A higher class corresponds to a lower risk of critical failure, or a higher likelihood of reliable functioning. Critical fracture is considered a failure when a friction of one part is pressed (mantle, bottom, pipe or connection) or the release of screws to close the main parts of the container, resulting in the sudden release of a larger amount of working material from the container", [1].

2. MEASURING EQUIPMENT

Quantum X data acquisition system

During the experimental test of dilatations on the bottles of breathing apparatus, a device for signal conversion and data acquisition from the manufacturer Hottinger Baldwin Messtechnik (HBM), Quantum MX440A was used, (Figure 1).

The device is characterized by: high–resolution measurement acquisition (24 bit), adjustable sampling rate (up to 192 kHz), low–pass signal filters to eliminate high frequency signals (i.e. interference of the base signal or noise signal that occurs as a regular occurrence during high frequency measurements), automatic identification sensor and channel configuration, operation in a wide ambient temperature range (from –20°C to +65°C), reliable measurement results and high test quality. [2]

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Figure 1. Device Quantum MX440A.

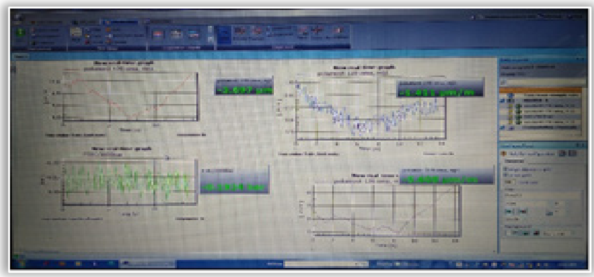

Figure 2. Catman Easy software interface for acquisition and analysis

Adjustment of filter parameters according to the nature of the basic signal and noise content is achieved with the help of Catman Easy software (Figure 2), as well as synchronous recording of data from the sensor in real time. Communication between the acquisition and the encoders is via a standard connection, and between the acquisition and the PC is via an Ethernet connection.

Measuring tapes

Measuring tapes (Figure 3) have been in use for more than 60 years, and the technology of their production and application is constantly being improved. The use of HBM measuring tapes for experimental analysis with two measuring fibers for a biaxial tension state of known direction, resistance of 120 Ω represents safety and reliability in use. They are used to measure local deformations on real structures or models.

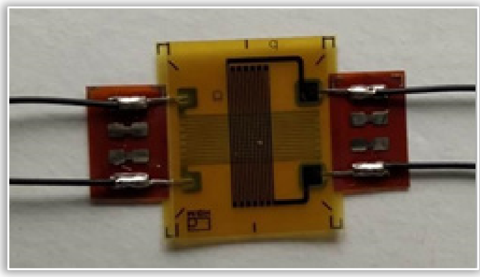

Figure 3. Double measuring tape XYxx

Since these measurements are of a local character, their disadvantage is that deformations are obtained only at one measuring point. Also, when using measuring tapes, problems can occur which are reflected in the impossibility of gluing them on the measuring surface, which results in the impossibility of obtaining the maximum values of deformations, [3].

Pressure sensor and transmitter HBM 1–P3IC / 3000 bar

The pressure sensor and transmitter (Figure 4), manufactured by HBM, is used to measure pressure in many industries. The monolithic steel housing and robust design offer reliability in use and exceptional load resistance, even in very poor environments, are corrosion resistant and have IP67 protection. Their reliability has been proven at vibration shock pressure or oscillating pressure. In combination with HBM measuring tapes, they give reliable results in extremely dynamic applications with a large number of load cycles, [4]. A special adapter was made for the purposes of this experimental research.

Figure 4. HBM 1–P3IC / 3000 bar pressure sensor and transmitter with adapter.

Hydraulic manual test pump high pressure CCP 700–H

Hydraulic manual test pump or pressure generator (Figure 5), used for testing or calibration of mecha–nical or electronic instruments through comparative measurements. These tests can be performed in a laboratory, workshop or on site. Taking into account the compactness and dimensions of the pump, it is possible to easily create a pressure of up to 700 bar. Hydraulic fluids that can be used in the pump are: mineral oils and pure water (with or without calcium carbonate), [5].

Figure 5. Hydraulic manual high pressure test pump CPP 700–H

3. TESTING OF SCBA APPARATUS BOTTLES OF WATER UNDER PRESSURE

The experimental part of this research was performed at the Department of Environmental Engineering, Faculty of Mechanical Engineering, University of Banja Luka (water under pressure).

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Immediately before performing the experimental part, the necessary preparations were made (table 1): weighing of filled pressure vessels (steel and semi–composite bottles) of SCBA devices, which were used during this experiment, measuring the noise level on valves when discharging CMA, then weighing after draining the CMA and unscrewing the valve (at the connection to the bottle connection). The bottles were cleaned of impurities, and in the places where the measuring tapes were placed, a layer of protective paint was carefully removed to the material from which they were made – steel or composite material (Figure 6, 7 and 8).

Table 1. Technical data for steel and composite bottles (measured values).

Manufacturer, bottle type, serial number, year of manufacture	Internal number of bottles	P (bar)	Mass of filled pressure bottle (factory weight) (kg)	Weight of empty bottle with valve (kg)	Mass of empty bottle without valve (and without rubber linings) (kg)	Noise level when discharging KMV (dB)
MSA, Luxfer, semicomposite, FCVK 07860, 12/2018	67	290	6,4 (3,9)	4,5	4,0	–
Interspiro, SCI, semicomposite, 8538, 07/2009*	XX	285	7,3 (4,9)	5,5	4,7 (4,3)*	93
MSA, Luxfer, steel, 185038, 04/2006	4	160	9,7 (8,37)	8,7	8,3	–

* Measuring tapes are not glued to the Interspiro composite bottle, they have rubber linings in the upper and lower part to protect against mechanical damage, which was removed during weighing.

Figure 6. Hydraulic manual high–pressure test pump CPP 700–H.

Immediately before gluing the measuring tapes, with the degreaser that came with the two–component glue, the places where the measuring tapes were glued were cleaned, and the two components of the glue were mixed, so that the measuring tapes were glued to the previously determined and measured places. After that, they were soldered (Figure 7 and 8) and resistance was checked, as well as the numbering of measuring tapes on both bottles at the positions (measuring point 1 – bottom of the bottle, measuring point 2 – middle of the bottle and measuring point 3 – top of the bottle).

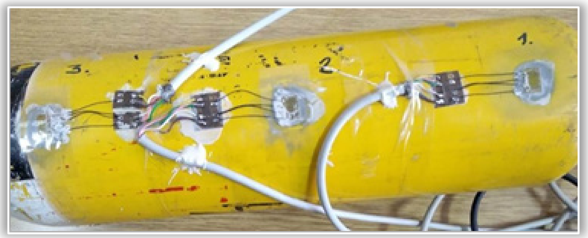

Figure 7. Steel bottle with glued measuring tapes.

Figure 8. Composite bottle with glued manual.

The equipment for experimental analysis (Figure 9) consists of: measuring tapes XY31–6 / 120, pressure transmitter and transmitter HBM 1–P3IC / 3000 bar, hydraulic manual high pressure pump CPP 700–H with pressure relief valve and PCs (laptops).

Since the tests were performed at high pressures, massive steel plates were installed next to the hydraulic manual high–pressure pump and the valves of the steel or semi–composite cylinder for safety reasons.

Depending on the volume of the bottle tested by the water under pressure sample, the test fluid was poured, water (in a steel bottle – 6 *l*, and in a composite bottle – 6.8 *l*), temperature 20 ° C, and then the installation was vented.

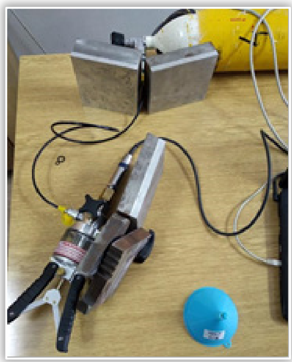

Figure 9. Steel bottle with glued measuring tapes

Experimental tests on both types of SCBA bottles were performed for the case of internal pressure loading, manually, and processed and recorded with Catman Easy software. During the experimental test, the cylinders were tested for longitudinal, tangential and resulting deformations at pressures of: 100, 250 and 300 bar. After the examination of each type of bottle, the processing of the recorded results was started.

4. RESULTS & DISCUSSION

Analyzing results of deformations (diagrams 1 to 6) on steel and composite cylinders for pressures of 200 and 300 bar, it can be concluded that they grow linearly.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Results of experimental research test with a water under pressure for a steel bottle

The highest values of deformations during the experimental tests of longitudinal deformations on the steel bottle (diagram 1) were read at measuring point 1 (MP 1 – the lower part of the bottle), while the deformations at measuring point 3 (MP 3 – the upper part of the bottle) have higher values than the deformations at measuring point 2 (MP 2 – in the middle of the bottle).

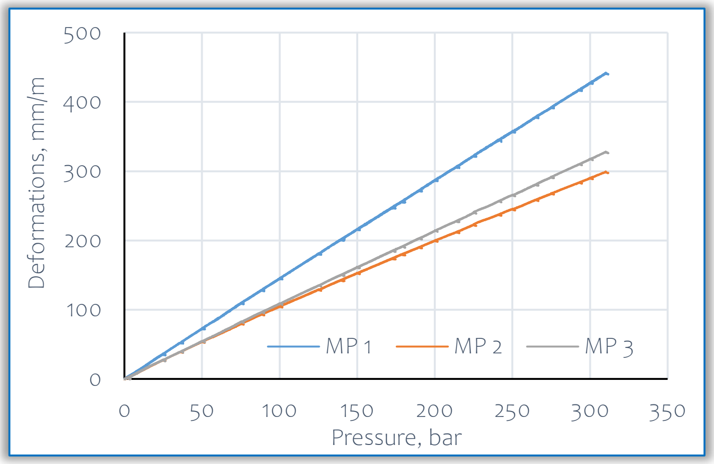

Diagram 1. Steel bottle-longitudinal deformations, 300 bar.

- MP 1 - measuring point 1 (lower cylindrical part of the bottle),
- MP 2 - measuring point 2 (cylindrical part in the middle of the bottle),
- MP 3 - measuring point 3 (upper cylindrical part of the bottle).

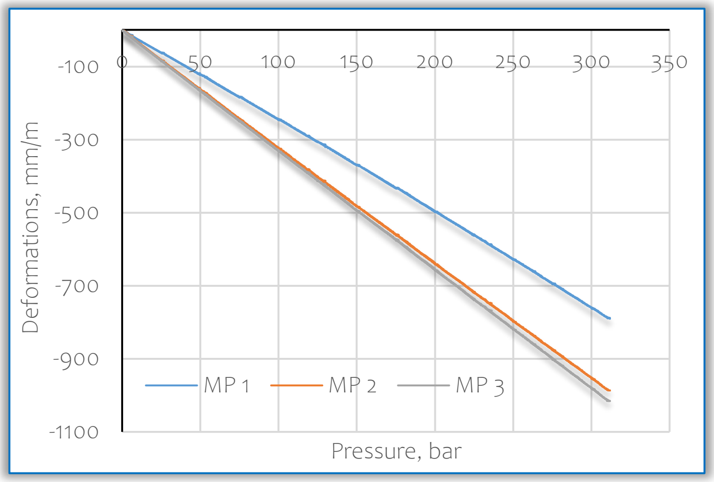

Diagram 2. Steel bottle–tangential deformations, 300 bar.

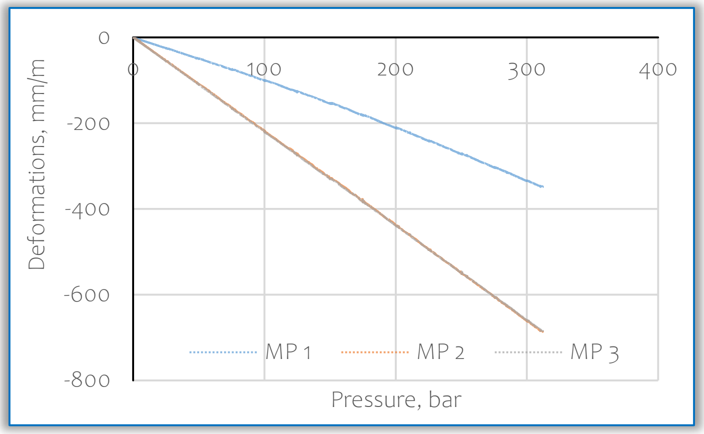

Diagram 3. Steel bottle–resulting deformations, 300 bar.

When detection of tangential deformations on the steel bottle (diagram 2), the highest deformation values were read at measuring point 3 (MP 3 – upper part of the bottle), then at measuring point 2 (MP 2 – in the middle of the bottle), while the deformations at the measuring point place 1 (MM 1 – lower part of the

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

bottle) significantly less compared to the deformations at the previous two measuring places. Deformations values at all three measuring points have a negative sign.
Analysing the results of the resulting deformations on the steel bottle (diagram 3), the highest deformation values are observed at the measuring points (MP 3 – upper part of the bottle) and (MP 2 – in the middle of the bottle), while the deformation values at (MP 1 – lower part of the bottle) significantly smaller compared to the deformations at the previous two measurement locations. Deformations values at all three measurement locations have a negative sign.

Results of experimental water under pressure research for composite bottle

The highest values of deformation during the detection of longitudinal deformations on the composite bottle (diagram 4) were read at measuring point 3 (MP 3 – the upper part of the bottle), while the deformations at measuring point 2 (MP 2 – in the middle of the bottle) have higher values than the deformation at the measuring point place 1 (MP 1 – lower part of the bottle). Oscillations of intensity (MP 2) are also noticeable.

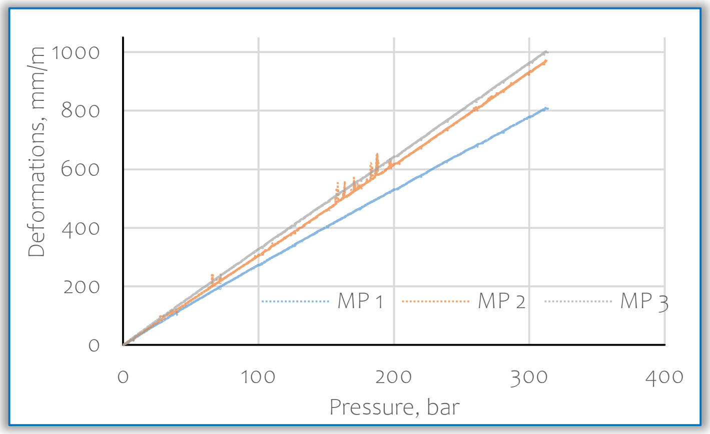

Diagram 4. Composite bottle–longitudinal deformations, 300 bar.

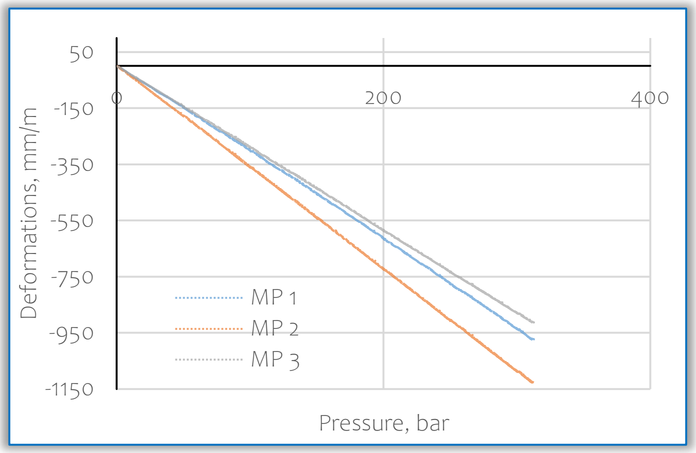

Diagram 5. Composite bottle–tangential deformations, 300 bar.

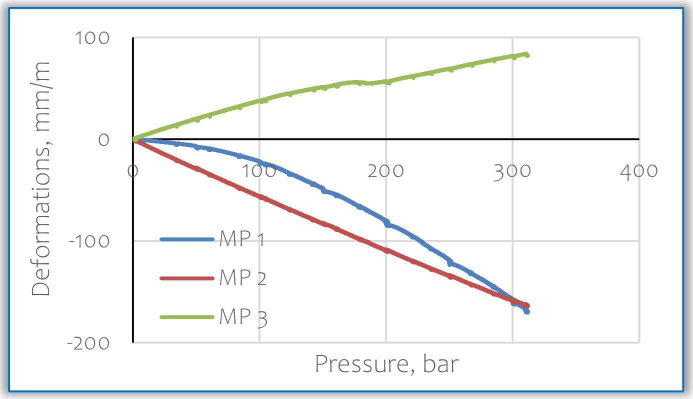

Diagram 6. Composite bottle–resulting deformations, 300 bar.

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During the detection of tangential deformations on the semi–composite bottle (diagram 5), the highest deformation values were read at measuring point 2 (MP 2 – in the middle of the bottle), then at measuring point 1 (MP 1 – lower part of the bottle) while the deformations at the measuring point 3 (MP 3 – the upper part of the bottle) slightly less compared to the deformations at the previous two measuring points. The strain values at all three–measurement locations have a negative sign.

Analysing the results of the resulting deformations (diagram 6), the highest deformation values can be observed at the measuring points (MP 2 – in the middle of the bottle) and (MP 1 – the lower part of the bottle) and they are negative, while the deformations at (MP 3 – the upper part of the bottle) positive and slightly less compared to the deformations at the previous two measurement sites.

5. CONCLUSIONS

The experimental analysis was conducted in order to define the parameters that significantly affect the safety of users in accident situations, but also to arrive at significant parameters that affect the increase of user safety, especially when choosing equipment.

Based on previous research, it can be concluded that a very small number of authors focused on the protection of respiratory organs, face and eyes, i.e. the field of breathing apparatus, which confirms the lack of appropriate databases and knowledge bases that could be used in real conditions, but also in current and further research.

Risk assessment determines the degree of probability for determining factors that may endanger the safety of users, but also defining preventive measures in solving problems that are likely to lead to accidents and assess the possibility of their occurrence.

When it comes to technical systems like this, hazard identification is done at the design stage, which further enables the safe operation of the installation and components with high reliability during use.

All deformations during testing of both types of bottles (steel and composite) are in the area of elasticity.

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ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN–L 1584 – 2665