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Experimental stand for internal pressure testing of pipes

MINESCU MIHAIL[*], DINITA ALIN, RAMADAN IBAHIM NAIM, ZISOPOL DRAGOȘ GABRIEL

Petroleum – Gas University of Ploiesti, Blvd. Bucuresti, no. 39, Ploiesti, Romania

Abstract*:* The experimental programs carried out on the stands for the research of mechanical stress behaviour typically target the following objectives: to determine the behaviour of the pipes at internal pressure and / or other mechanical stresses (which may secondary occur as accidental loads during exploitation), to establish the processes and factors of in-service degradation and to determine the load carrying capacity of pipes and other components of pipelines systems with defects of different types and configurations. For this paper an experimental stand was designed and developed for the purpose of determining the behaviour of the pipes with different types of imperfections / defects. The experimental results were verified and validated using the finite element method.

Keywords*:* pipe defects; experimental stand; internal pressure test; finite element method.

1. Introduction

The experimental programs carried out on the stands for the research of mechanical stress behavior typically target the following objectives: To determine the behavior of the pipes at internal pressure (the main mechanical stress that occurs in service for the composing elements of the pipeline system) and / or other mechanical stresses (bending, compression, torsion, shear, which may secondary occur as accidental loads during exploitation of pipelines); To establish the processes and factors of in-service degradation of pipelines systems and defect formation on its components (pipes, elbows, curves, tees, reinforcements, welded joints, etc.); To establish the load carrying capacity of pipes and other components of pipelines systems with defects of different types and configurations types and configurations (lack of material, local indentations, cracks, etc.) and to define criteria for assessing defects severity.

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[*] Correspondence address: mminescu@upg-ploiesti.ro

2. Bibliographical study of experimental stands

In the research conducted in the field of mechanical stress behavior of tubing and pipeline sections experimental tests are made on different types of experimental stands, some of which were projected by the authors of this article.

The experimental stand shown in Fig. 1, is used in order to study the behavior of pipes at internal pressure. Items tested on the stands (tubes, pipeline sections) may be free from defects or may have machined defects of different configurations and sizes; the stands can also be used for the experimental research of the quality of repairs made by various technological processes, if these repair procedures are applied on the samples containing machined defects which are then subjected to internal pressure test on the stand.

The experimental programs made on the stand were mainly oriented towards the comparative determination of the tensile strength of both the pipes without defects and on pipes with lack of material type defects (with different configurations and dimensions, made by mechanical machining).

Another experimental program carried out on this stand was aimed towards comparing the internal pressure behavior of tubes and pipe sections with different types of superficial defects (located on the base material of the pipes or in the circular welded area of the tubular sections), with the behavior at the same mechanical stress of pipes or tubular sections with defects repaired by various technological processes: by applying a welded sleeve, by applying a filled coat of epoxy resin, by applying a composite material wrap (clock spring type) or by welding procedures. The tubular elements after the internal pressure test are shown in Fig. 2.

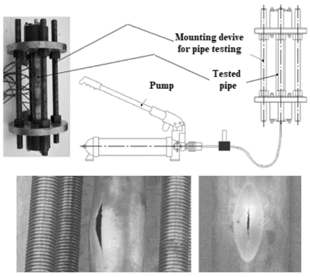

Fig. 1. Experimental stand for internal pressure testing of tubing and pipe sections. [2,4]

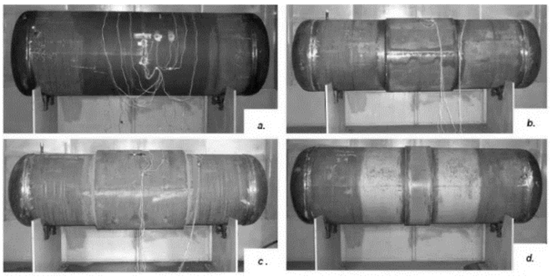

Fig. 2. Piping test pieces prepared for internal pressure testing [3] a. pipe sample with an external surface defect; b. pipe sample with external local surface defect repaired; c. Pipe sample with external local surface defect repaired by application of a coating filled with epoxy resin; d. Pipe sample with local surface defect repaired.

Pressure tests of tubes or pipe sections with defects repaired by various procedures can also be carried out on site using specialized equipment for pipeline pressure tests. A first example of this type is the pressure test of pipe sections recovered from disused pipelines (the pipes were manufactured in 1960) with repairs being made on the local lack of material type defects by applying welding patches (circular or rectangular) or type B sleeves, as can be seen in Fig. 3.

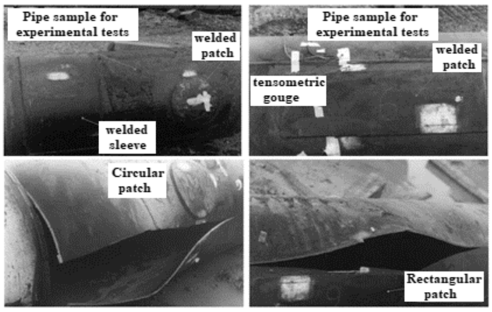

Fig. 3. Pipe sample repaired by the application of Type B sleeve and patches subjected to internal pressure test until burst [2,5]

Another experimental program has been achieved using full-scale pipe specimen taken from natural gas transmission pipelines, on the occasion of performing corrective maintenance works, as is shown in Fig. 4. The authors have initially designed a stand for the determination of the bursting pressure of the volumetric surface deformation pipes presented in Fig. 5.

The problems related to the imposed seals and the materials necessary for the experimental stand led to a redesign for the simplification of the sealing mode, designed an experimental stand for determining the bursting pressure of copper pipes showing different surface volumetric defects. By using the principles of similarity, the results obtained on the copper pipe can be transferred to the steel pipes, thus reducing the costs incurred by the construction and operation of such stands.

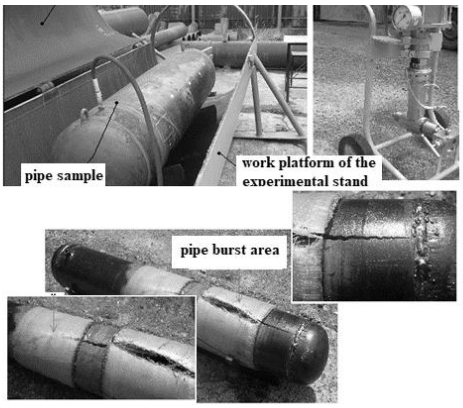

Fig. 4. The design scheme and main components of the stand used for internal pressure testing. of pipes with local surface defects [1]

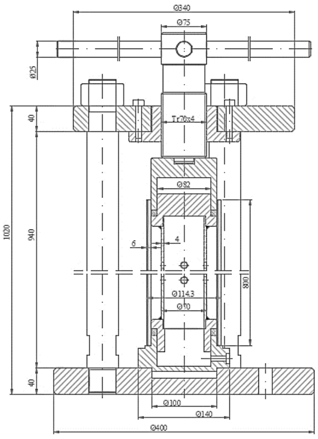

Fig. 5. Experimental stand initially designed to determine the bursting pressure of pipes.

The complexity of the stand shown in Fig. 5 is very high due to the large number of components, so it has been decided to optimize the bench for determining the bursting pressure by reducing the number of components, thereby also reducing the cost.

3. Designing an experimental stand for testing internal pressure of pipes

The experimental stand was designed to determine the bursting pressure of pipes with defects, using CAD design software as it is shown in Fig. 6. For the optimization of the stand, both the size reduction of the sealing elements and lowering the related costs of the stand were taken into account. Fig. 6 shows the cost-optimized stand and the number of components.

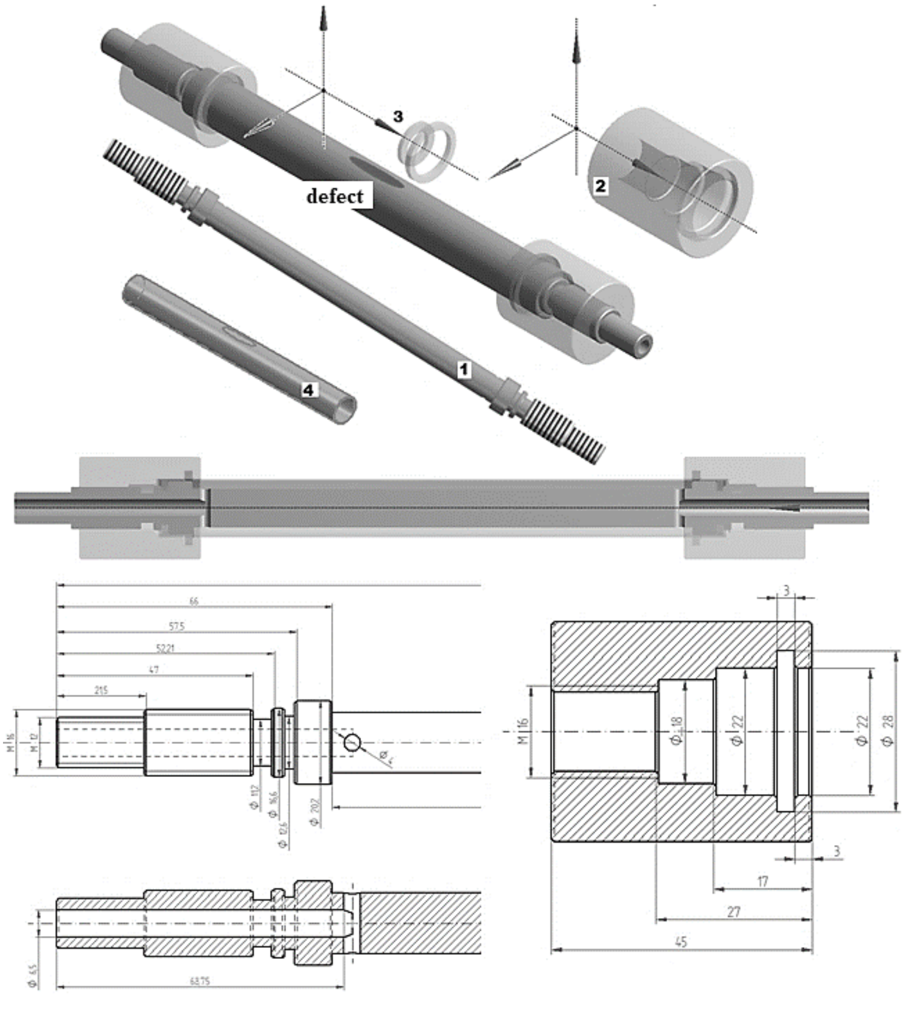

Fig. 6. Stand optimized in terms of number of components and sealing system:
1. Central axis of pressure distribution; 2. Threaded bush. 4. Rubber seal; 4. Copper pipe

The experimental stand made after the design process is shown in the Fig. 7. The C45 steel used in the production of rolled products (round steel) was chosen for central axis of pressure distribution and for the threaded bush.

Fig. 7. Experimental stand used to determine the bursting pressure for Copper pipes with volumetric surface defect.

The Copper pipe used in the experimental tests had the external diameter D_e = 22 mm and the wall thickness t = 0.8 mm and the length of l = 210 mm. The main geometrical characteristics of the defects to be considered in subsequent analyses and tests are shown in Fig. 8.

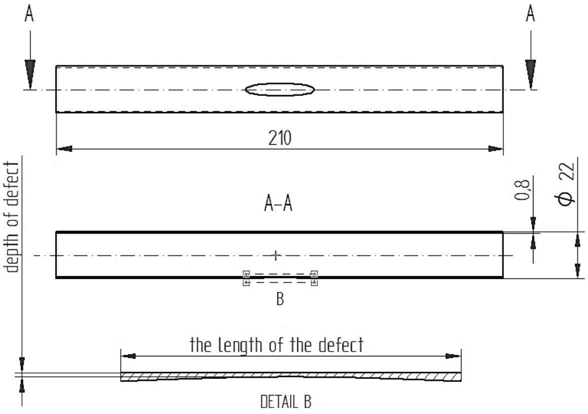

Fig. 8. Geometrical characterization of the pipe sample subject to experimental analysis.

The design of the experimental stand took into account the following aspects [2]:

- the pipe samples to be tested on the stand must be of sufficient length, so that the stress-intensifying effects in the passage areas of the end elements do not affect the behavior of the pipe samples studied - it is recommended that the length of the tubing elements being attempted to have the length Lt = min. (6 ... 10)De.
- the pump from the stand shall have the ability to raise the pressure inside the test tubing to the level that makes it possible to burst.
- The stand shall be located in a protected enclosure corresponding to the high pressure tests.

- The stand may be equipped with appropriate recording equipment for the test results to be carried out: manometers, displacement transducers, computerized acquisition of results, camera, etc.

4. Burst pressure determination for the copper pipe using the finite element method

Copper ($R_{p0.2}$ = 205 N/mm^2) was used for pipe and C45 grade steel for the stand. The mechanical characteristics for Copper and C45 were entered in the "Engineering Data" and the resulting 3D model and meshing are shown in Fig. 9 [6,7].

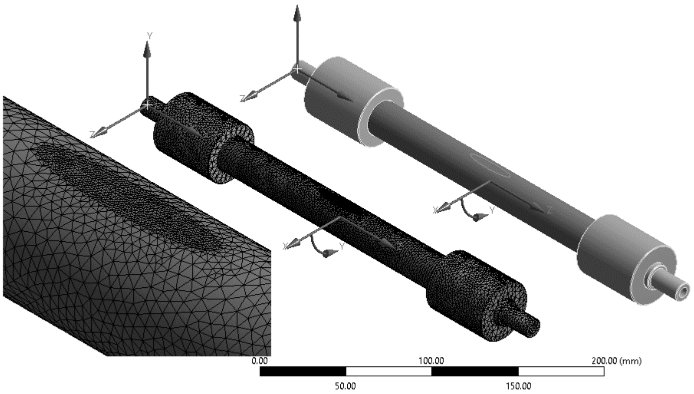

Fig. 9. Geometrical modeling and meshing of the experimental stand (AnsysWorkbench).

Finite element analysis of the designed stand (see Table 1 and Fig. 10) was conducted in order to determine both the burst pressure (6 analyzed cases) as well as the pump capacity needed for the stand.

Table 1. Detailing the scenarios taken into account in burst pressure determination

	D_e	***s***	***Depth of defect [mm]***	***The length of the defect [mm]***	**$R_{p0.2}$ [N/mm^2]**	***bar***	***σ N/mm^2***
1	22	0.8	0.4	16	205	20	$110<R_{p0.2}$
2	22	0.8	0.4	16	205	40	$220>R_{p0.2}$
3	22	0.8	0.4	16	205	60	$330>R_{p0.2}$
4	22	0.8	0.6	20	205	20	$238>R_{p0.2}$
5	22	0.8	0.6	20	205	30	$356>R_{p0.2}$
6	22	0.8	0.6	20	205	40	$475>R_{p0.2}$

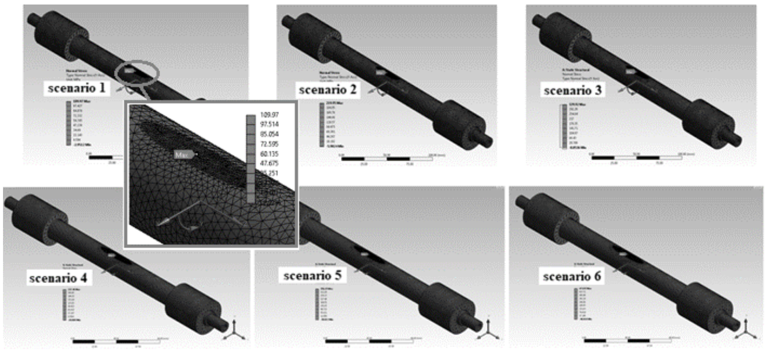

Fig. 10. Finite element analysis for the 6 cases studied, according to Table 1.

Industrial equipment under applied loads develops in its body stresses that must be below the yield strength limit of the material they are made of. Since the material of the pipe undergoing the burst pressure test is Copper, the finite element analysis performed has highlighted the fact that, for the designed stand, a pump capable of providing a minimum pressure of 60 *bar* is required, taken into account the scenarios taken in consideration.

5. Experimental determination of burst pressure for pipes with the defects

In order to determine the bursting pressure [7] of a pipe with local loss (corrosion) type defects, a pump is required to ensure that the maximum load bearing capacity of the pipe is reached. This problem has been solved by finite element analysis, resulting a pump with a minimum capacity of 60 bar. The schematic diagram of the stand and its composing elements (pump, test system + defective pipe, pressure gauge, control valves) are shown in Fig. 11. Subsequently, a 500 bar pump was used in order to determine the burst pressure and several tests were performed at different pressures like 10 bar, 20 bar, 40 bar, 80 bar, 200 bar. Experimental tests were performed using 5 samples, as can be seen in Fig. 12, with the features shown in Table 2.

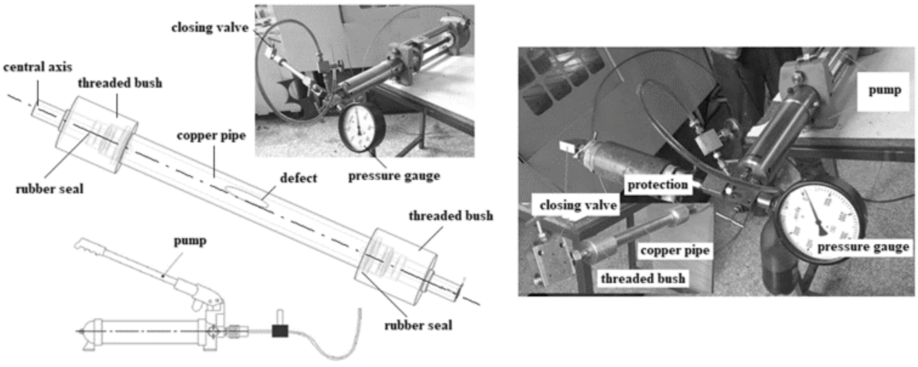

Fig. 11. Assembling the components of the experimental stand.

Table 2. Burst pressure values

	D$_e$	***s***	***Depth of defect [mm]***	***The length of the defect [mm]***	***bar***
1	22	0.8	0.6	20	11
2	22	0.8	0.4	20	18
3	22	0.8	0.3	20	39
4	22	0.8	0.1	20	82
5	22	0.8	no defect		205

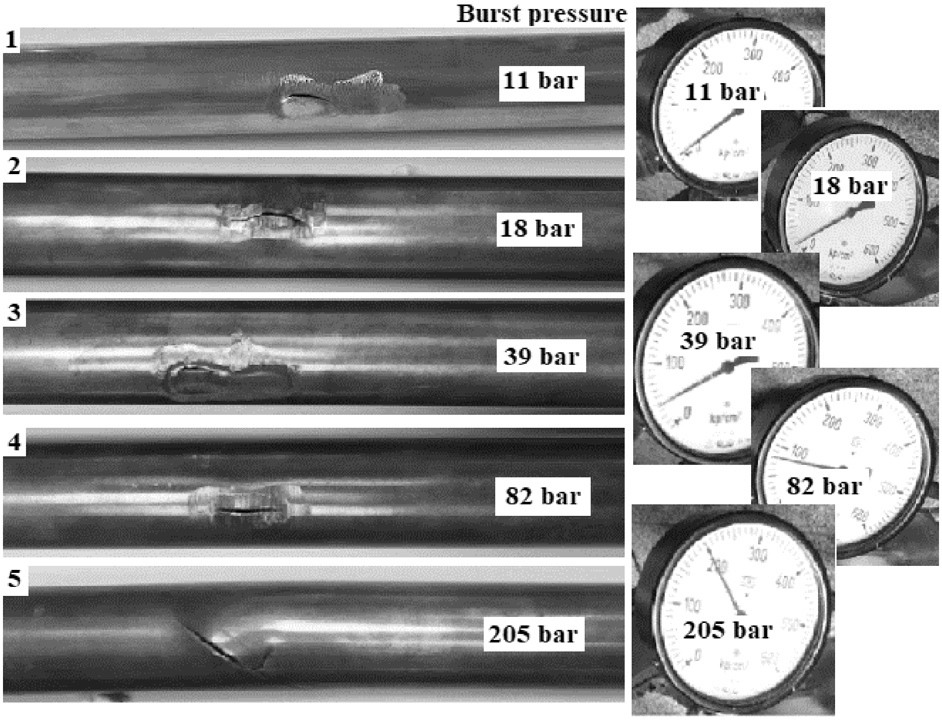

Fig. 12. The Copper pipe samples after the burst pressure tests.

The burst pressure obtained is influenced mainly by the depth of the defect, the longitudinal and circumferential length of the defect having a less contribution to the pressure value. The results of experimental tests performed on the design stand (the values of burst pressure) can be extrapolated from Copper pipes to steel pipes using the principles of similitude.

6. Conclusions

Experimental stands for conducting pipeline behavior research are governed by different assumptions and prerequisites imposed by operating conditions and must meet certain requirements related to the internal pressure behavior, the behavior of welded pipe joints, the bearing capacity of the pipes in the presence of different defects, various ways of repairing pipes with different defects.

Experimental methods of studying the effects of pipeline repairs on residual bearing capacity and their remaining life play an important role, the results obtained by such methods having a high level of confidence and being particularly useful for the accumulation of experience and the establishment of practical criteria for selecting repair procedures. Also, the experimental study of the effects of the various categories of defects on the bearing capacity of the pipe piping allows for the definition of effective practical criteria for assessing the technical condition of the pipelines and for taking decisions on the operating regime pipelines with defects.

The main objectives of the Finite Element Method - MEF verification were to analyse the bearing capacity (burst pressure) for the copper pipeline with volumetric surface defect. Verification can be done experimentally, on natural scale piping elements or on models, or by numerical simulation, applying, for example, the MEF. Numerical simulation using MEF is the recommended method for performing verification, as it provides for quick results, allows analysis of as many variations and technological solutions as possible, and does not inadmissible increase design costs. The experimental results obtained in the presented study were confirmed by finite element analysis. Burst pressures determined for cases broken down by different characteristic dimensions of the defect applied to the pipe sample can be used to further assess the carrying capacity of these pipes.

References

[1] Zecheru Gh, Yukhymets P., Draghici Gh., Dumitrescu A., *Methods for Determining the Remaining Strength Factor of Pipelines with Volumetric Surface Defects*, Rev. Chim. (Bucharest), **66**, 2015, p. 710-717.

[2] Zecheru Gh., Draghici Gh. e.a., Contract research no. 13, *Studies and researches on the development of technologies for repairing the defects found on the tubular material of the transport pipes*, Petroleum-Gas University of Ploiesti, 2006.

[3] Zecheru Gh., Draghici Gh. e.a., Contract research no. 37, *Studies for identifying technologies to repair material loss type of defects using fiber glass wraps*, Petroleum-Gas University of Ploiesti, 2007

[4] Baek J., e.a., *Comparative study for various repair methods of in-service pipeline using full scale burst test*, 23rd World Gas Conference, Amsterdam, 2006.

[5] Otegui J.L., *Influence of multiple sleeve repairs on the structural integrity of gas pipelines*, International Journal of Pressure Vessels and Piping, **79**, 2002, p. 759–765.

[6] Dinita A., Lambrescu I., Chebakov M.I., Dumitru G., *Finite Element Stress Analysis of Pipelines with Adaavanced Composite Repair*, 2018. In: Barkanov E., Dumitrescu A., Parinov I. (eds) Non-destructive Testing and Repair of Pipelines, Engineering Materials, Springer, Cham.

[7] Năstăsescu V., Iliescu N., Marzavan S., *Element-Free Galerkin Method and Finite Element Method. Which is better*?, J. Eng. Sci. and Innovation, **5**, 4, 2020, p. 287-296.
[8] Ilca I., Miloştean D., *Improving the manufacturing technology of structural steels*, J. Eng. Sci. and Innovation, **4**, 3, 2019, p. 273-284.
[9] Jinescu V.V., *Fatigue life prediction for simultaneous cyclic loading with blocks of normal stresses and shear stresses,* J. Eng. Sci. and Innovation, **1**, 1, 2016, p. 1-16.
[10] Akram A., Mustaffa Z., Albarody T., *Numerical Simulation and Experimental Test on the Burst Pressure of ASME A106 Steel Pipe*, MATEC Web Conf. Volume 203, 2018, https://doi.org/10.1051/matecconf/201820306002.