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Do We Still Need an Experiment at All?

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Motto: G. Irvin (1926) "Let us first ask the experiment."
R. van Geen (1971) "Finite Element Method is the death of experiment."

Introduction

This contribution is carrying similar title as former published two ones [1,2] , as until today there is some discussion about relationship of numerical simulation a experiment during structure construction,. What is better and what is more trustworthy. Looking at motto we see that any of the separate application cannot fulfill recent requirements for high quality, warranted life time and lower mass of structures together with economic approach (short term of design).

Having very powerful method and tool for determining stress and deformation state as well as kinematic value in the form of simulation method (FEM) is, we are able to determine stress and strain state in the examined component of structure, with no respect to its shape and loading by simulation approach based on schematization. But every schematization, joint with modeling of geometry and embedment, material qualities and character of loading contribute to less or more latent variation from reality and due it brings danger of divergent results [3,5].

Only experiment can approve reliability of the schematization. In some cases, such as residual stresses determination [4], stress state identification cannot dispense without experiment. Thus the experiment becomes controlling procedure of manufacture process and this role becomes more significant than for analysis [5].

Application of traditional methods using contact approach, as for example strain gages, are renewed by acoustic, optical interferential and thermometric methods (acoustic emission, X-radiography, shearography, electronic speckle pattern interferometry), utilizing changes of outer surface quality the of the examined component [6]. New composite materials and bonded joints, which are more and more used in structure, are monitored by Fibers Brag Grating sensor integrating in the adhesive and giving signal about stiffness relating acceptability of the examined part loading.

Broad spectrum of experimental method and instrumentation prove that experiment often is sometimes an end in itself. The reason of experiment disappears under heap of numbers and diagrams. People moving round experiment have to have basic knowledge about the examined problem what require previous analysis of the examined problem, planning and careful preparing of the experiment itself. Processed data give the clear reply. For it is necessary to comply with the following tasks.

Primary Tasks of Experimental Mechanics

Relating problems with mechanics of rigid and deformable bodies and media include basic tasks:

a) Specifying data for calculating and numerical modelling.

One of principal keystones for dimensions determining and assessing of structure is knowledge of its operating conditions, particularly values and time course loadings acting on it. Experimental structure investigation enables to cover broad spectrum of frequencies, time and operating conditions, even the costs for such complex experiment may not be cheap, but it is necessary to count with possible application of the results in the future and it is worth.

Another non-substitutable role of experiment is determining of material data. Special branch is shock dynamics, which cannot give any result without material data received by material tests under shock loadings, what is possible to realize only by controlled experiment.

It is necessary to mention that many valuable experiences from the past were forgotten due to reorganization of our research institutes, often joint with archives liquidating. And thus procedure of receiving experience or data costs time ("training" of service crews) and finances, given for now solved physical problem.

Close contacts between numerical calculation and experiment exists during the whole time of design and solving the technical part of the problem [3], sometimes during production and even in operation. Non-omitting role of experiment is proved.

b) Verification of results given by numerical solution.

Structure quality proves fully operation, but it is necessary to eliminate possible errors and imperfections during design and production of the he structure before its full operation either as it is meant operation of unique structure or before starting mass or large scale production. The experiment has to cover verification of stress state in concentrators, reliability and life time under projected spectrum of structure loading and kinematic quality as frequency response.

c) Monitoring and diagnostics.

In any challenging or important structures as in nuclear plants, requirements for complex experimental research are not only during putting into operation, but during the hole life. It covers not only stress state analysis, but is a part of complex control system ensuring safe operation of structural parts or sometimes of the whole plants.

d) Obtain of new piece of knowledge.

All methods of experimental mechanics are mighty means for recognition of operating processes, to obtain knowledge and discovering new relations and natural laws, what can be applied during design of future structures and plants.

Practical Experiences

The collaboration between modeling and experiment during solving a complicated problem of the whip of a real pipe line structure (Fig. 1) at the postulated failure [7] will be demonstrated. To avoid the abnormal swing pipe limiters of the shape "U" were designed [8].

For above mentioned elasto-plastic material behaviour it was taken the material model by Johnson-Cooke [10] taking in account the loading velocity. Tensile tests were carried out for two materials (Czech steels ČSN 11 523 and ČSN 12 060) under 13 levels of loading piston rod velocity in the range 0.3 to 800 mm/s. Stress, resp. deformation values were determined from the data of the loading force, resp. displacements data gained by optical instrumentation ARAMIS HS [11]. This procedure gave us load characteristics, from which constants of Johnson-Cook relations, used in numerical simulation, were received. It is possible to note that material characteristics at higher loading velocities do not change excessively (material CSN 11 523, Fig. 2).

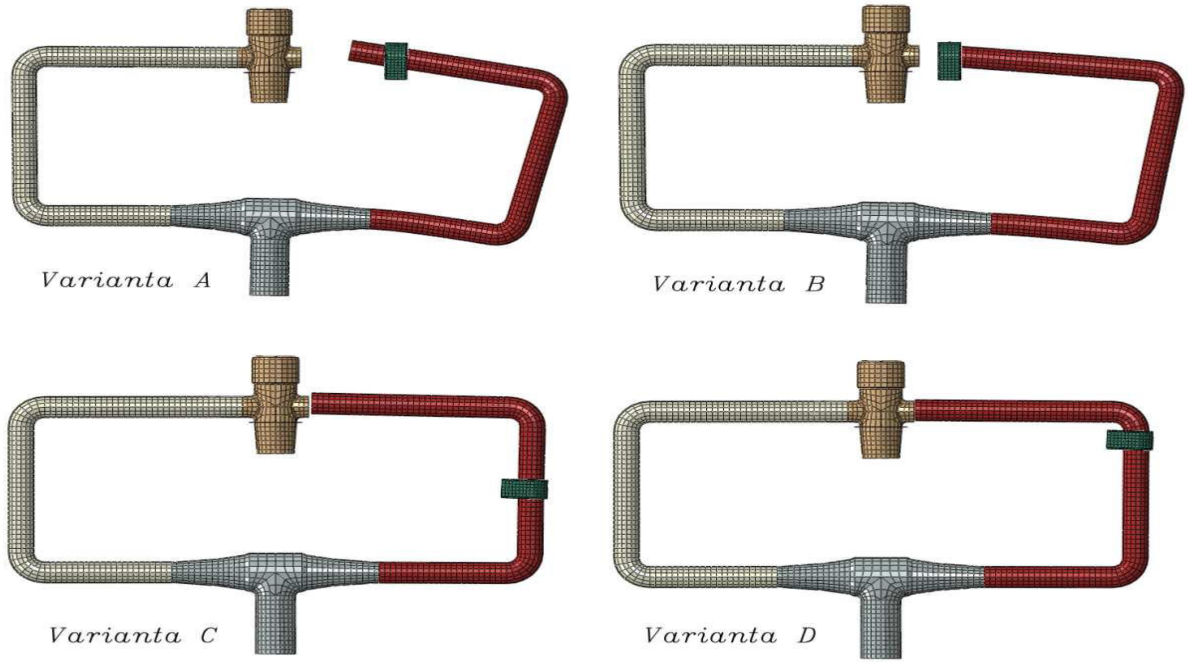

Fig. 1.

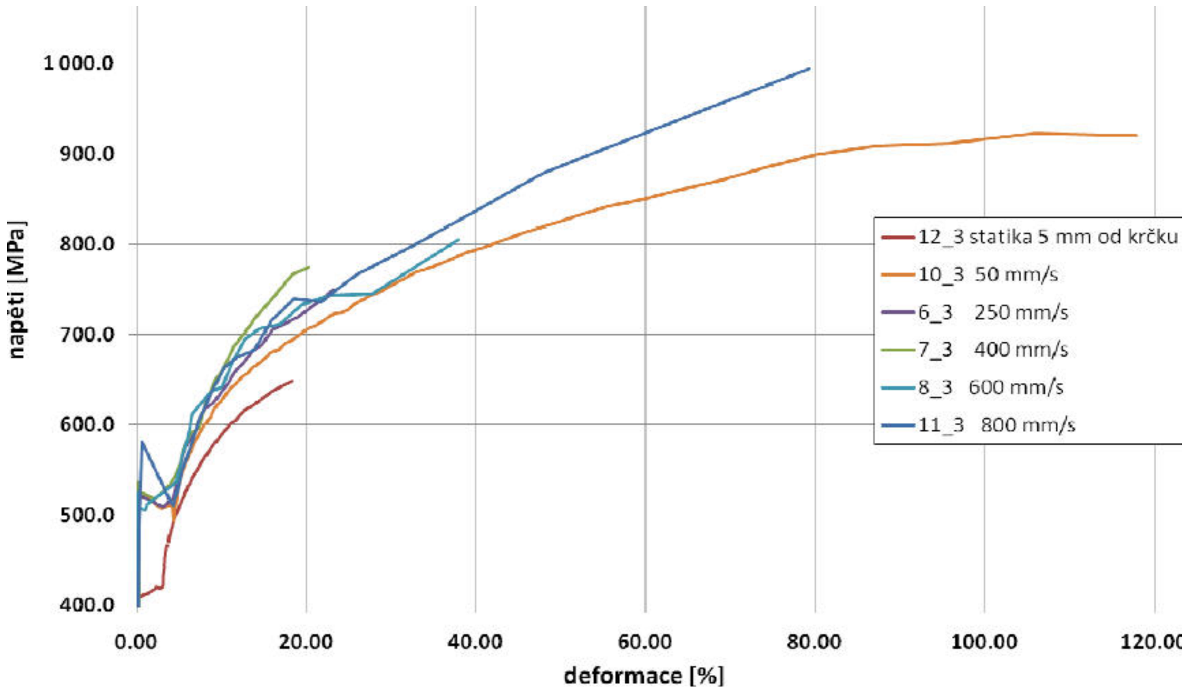

Fig. 2.

The legitimacy of the use of the whip limiter is documented in Fig. 3, where is the time course of acceleration of the reference point of the broken section. Internal damping material has been neglected.

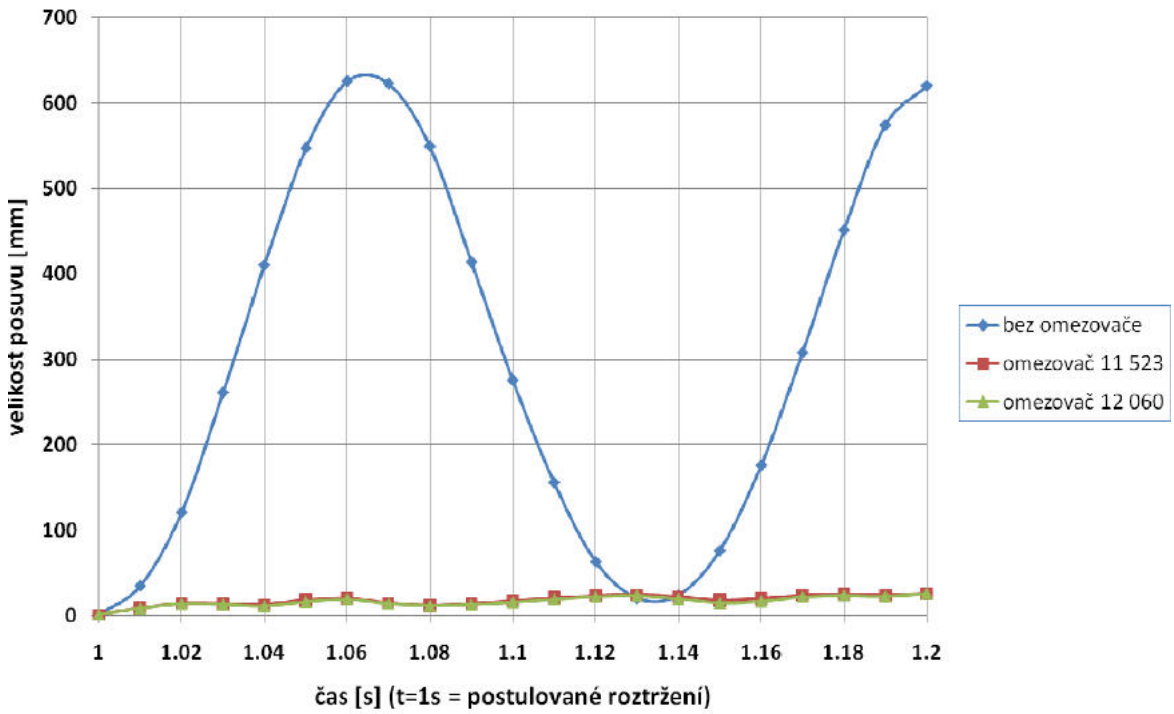

Fig. 3.

Conclusion

Results of numerical analysis proved that the postulated failure of the mentioned pipe structure without a whip limiter should bring further failure in the lower bend of the loop. Any of the four variants brings lower acceleration of the reference point of the free pipe end in the cross-section of the postulated failure and the best position of whip limiter is given by case D.

There is no doubt about rightfulness and serviceability of both during their collaboration – experiment and numerical simulation for solution of the challenging task.

Closing motto: N. Wiener (1948) "Simulation is one variety of experiment" in Cybernetics.

References

[1] S. Holý, An Invisible Danger of Schematization and Its Deleting by Means of Experiment, in: Proceedings of the 4th Bilateral German-Czech Symposium Experimental Mechanics Methods in Nondestructive Testing of Structures and Elements, Bergische Universität Wuppertal, Wuppertal, 1993, pp.1-2.

[2] S. Holý, Is an Experiment in Solid Mechanics still in Fashion?, in: Proceedings of the 5th Bilateral Czech/German Symposium Experimental Methods of Mechanics and Their Development in accordance with Numerical Modeling, ITAM and IT CzAS, Liblice, 1995.

[3] H.A. Mang, A plea for cooperation of experimental and analytical research in the field of solid mechanics, in: Proceedings of the 6th Danubia-Adria Symposium on Experimental Methods in Solid Mechanics, Seefeld, 2000.

[4] O. Šedivý, C. Krempasky, S. Holý, Residual stress measurement by electronic speckle pattern interferometry, in: Proceedings of the 5th Australasian Congress on Applied Mechanics ACAM 2007, Engineers Australia, Brisbane, 2007, pp. 342-347.

[5] S. Holý, Monitoring and Control of Technology and Service Safety by Means of Experimental Mechanics, in: Abstracts of GAMM Jahrestagung 1996, Charles University in Prague, Prague, 1996.

[6] M. Vlk, M. Hrabovský, S. Holý, Experimental mechanics in solids – today and future, in: L. Houfek, P. Hlavoň, P. Krejčí (Eds.), Proceedings of the National Conference with International Participation Engineering Mechanics 2002, Brno University of Technology, Svratka, 2002, CD-ROM.

[7] J. Anděl et al., Elastoplastic response of the pipeline TX 60 Z01 to failure in the room A 820, Research report, DITI 300/249NRI, NRI Řež, Řež, 2005. (in Czech)

[8] Holý, Z. Hrubý, J. Blažek, L. Pečínka, Experimental Evaluation of Material Para-meters for High-rate Phenomena Simulations with Respects to Johnson-Cook Plasticity, in: Proceedings of the 28th Danubia – Adria – Symposium on Advances in Experimental Methods, Siófok, 2011, pp. 251-252.

[9] J.L. Chaboche, On some modifications of kinematic hardening to improve the description of ratchetting effects, International Journal of Plasticity 7 (1991) 661-678.

[10] G.R. Johnson, W.H. Cook, Fracture Characteristics of Three Metals Subjected to Various Strains, Strain rates, Temperatures and Pressures, Engineering Fracture Mechanics 21 (1985) 31-48.

[11] D. Novotný, M. Kadlec, Loading test Nr. P-PK-0012/10, CTU in Prague, Prague, 2010. (in Czech)