VERIFYING OF VIRTUAL AND REAL HYDRODYNAMIC MODELS BY FLOW VISUALIZATION METHOD IN LOW LEVEL BATH

Markéta PETŘÍKOVÁ [1], Václav DVOŘÁK [1], Miroslav VEREŠ [2]

[1] Mechanical Engineering Faculty, Technical University of Liberec, Studentská 2, Liberec
Czech Republic
[2] Slovak University of Technology Bratislava, Slovakia, miroslav.veres@stuba.sk

ABSTRACT

The contribution deals with qualitative assessment of fluid flow around and between machine parts which permits the determination of their proper shapes. For these purposes the thread probe method and methods of imposing the dye or dust particles were used. Today these tasks are usually solved using virtual models (DMU) in the environment of specialized FEM software products. It appears, however, that this does not always produce correct results and therefore it is appropriate and necessary to verify the reliability of virtual models. Experimentation using real parts is expensive, so the authors devoted attention to the fluid flow visualization in a low-level hydrodynamic tank.

*Keywords***:** *fluid flow, low-level hydrodynamic tank.*

INTRODUCTION

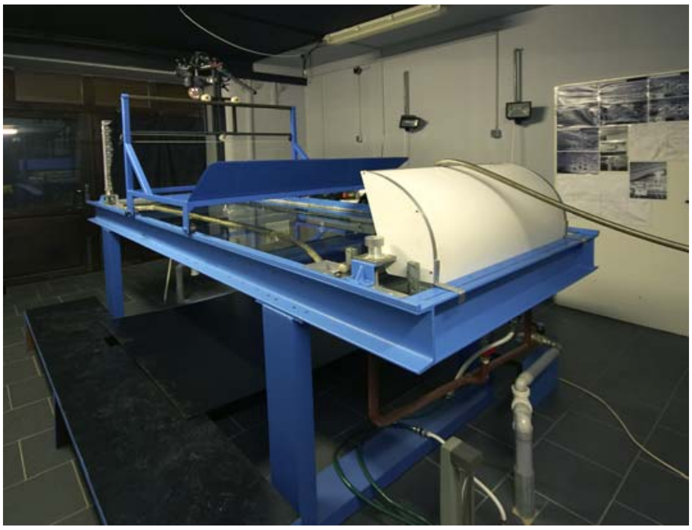

Fig. 1 Low-level hydrodynamic tank.

The low-level hydrodynamic tank (Fig.1) is an experimental device, which is used for the visualization of fluid flow. The results obtained by the combination of real measurement on simplified models, and numerical simulation on the digital mock-up models are still used in the design and modification of existing mechanisms or their parts. This paper is focused on the experimental investigation of fluid flow and describes individual steps in the measurement of particular examples, and also on the possibilities of verifying the accuracy of both models – the virtual model used for computer analysis and the simplified one used for visualization of fluid flow in the low-level hydrodynamic tank. The fluid flow can be visualized by two methods - in the first one, the surface of the profile is modified. In the second method the dye or visualization particles, the properties of which differ from the liquid properties, are injected into the liquid. Also the changes in the optical properties of the liquid can be observed. The surface of model can be

modified chemically, physically and mechanically.
When the liquid is modified by injecting the visualization particles, the particles can create (or not)

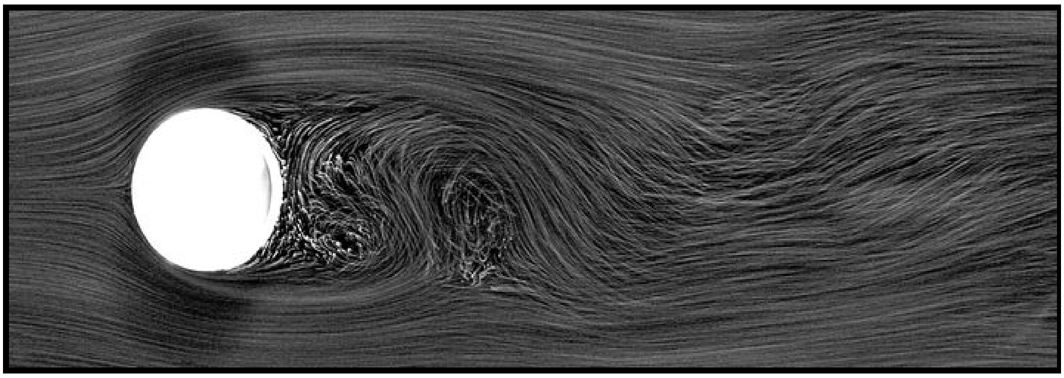

Fig.3 Visualization of flow around the cylinder using dust particles method, sprayed on the surface level.

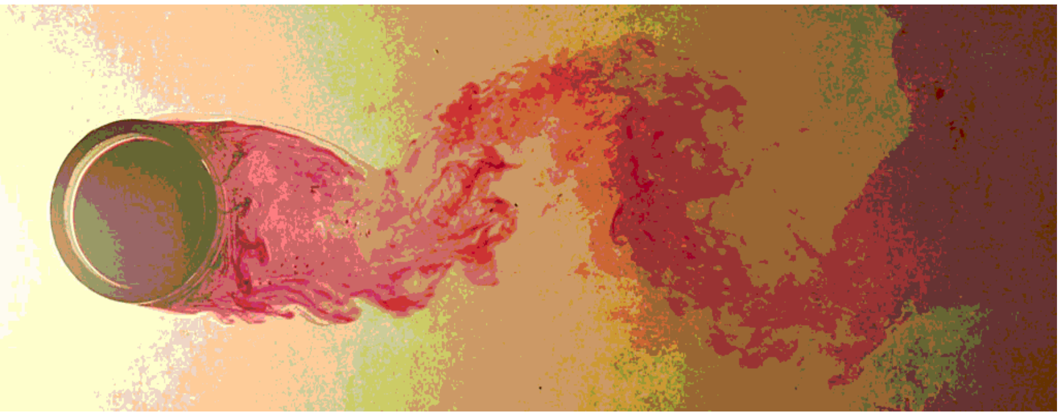

Fig.4 Visualization of fluid flow around the cylinder using the method of dyes introduced into the flowing liquid volume.

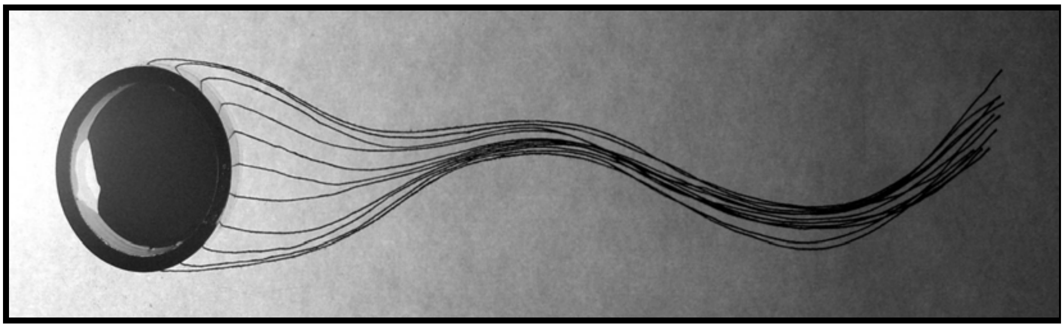

Fig.5 Visualization of fluid flow around the cylinder by the thread probes method.

filaments or continual areas. Both of the modifications can be used in visualization of liquids and gasses. In the contrast to the previous cases, the observation of changes in the optical properties of liquids is not convenient for the hydrodynamic bath.

For our defined purposes, the thread probe method and the method of dust particles were used. When preparing the experiment in a hydrodynamic bath it is necessary to apply the theory of similarity between the real object and its model.

The visualizations performed in the hydrodynamic bath are recorded by a camera. The flow figures are recorded on the model and then evaluated and transferred to the real piece based on the hydrodynamic analogy. The base of the analogy is the geometric similarity between the model and the real piece and the equality of the minimum number of criteria parameters. The Reynolds and Mach numbers are the most important in the modelling of real fluids. The values of these parameters on the model (index M) have to be equal to those on the real part (index D) ($\mathrm{Re}_M = \mathrm{Re}_D, M_M = M_D$). Having equalized the parameters one can conclude that the influence of the compressibility is unimportant for the low velocity flow, and does not have to be taken into account in this case. On the contrary the conservation of Mach numbers between the model and real piece is necessary for high velocity flow. The way to reach the equality $M_M = M_D$ is based on the problem dealt with here, with the exception in the case where the liquid velocities on the model and on the real item are the same. When the velocity on the model is low, a liquid has to be used which has a small sound velocity. The velocity on the model depends only on the ratio between the dimensions ($w_M = w_D \cdot \frac{d_D}{d_M}$), when identical liquids are used. The reduction ratio is selected according to the capablities of the experimental device. Also the possible increase in the Mach number M_M has to be taken into account. When the equality $\mathrm{Re}_M = \mathrm{Re}_D$ requires the increase in Re_M, the kinematic viscosity of the liquid on the model have to be increased.

VISUALIZATION OF BEHAVIOR OF WORKING LIQUID IN THE CYLINDER SPACE DURING THE FILLING AND EMPTYING

The experiment was performed by the method in which the water was dyed with a solution of Saturn black A 1341, at a concentration of 5 gm per litre of water in the container. The aluminium powder ALPU was dispersed with an airbrush on the free surface with an average particle diameter of 35 micrometers. Regarding the aluminium powder properties, it was necessary to create dispersion. The aluminium powder was dispersed in water (0,48 g per litre of water in a dispersion container) with tenzid UFAROL NA30, at a concentration of 1ml per litre of water in the dispersion container. The values of concentration in the particular ingredients were set based on knowledge from previous experiments carried out.

The model, which consists of static and dynamic parts, was made from plexiglass and fixed on the glass with flexible cement. The level of the free surface of the dyed water was set using the stoppers at a value of 10 mm. For this kind of experiment it was necessary to obtain a large static field of liquid. The stoppers ware set up to an identical level in order to utilize the complete surface of the liquid. The moving parts of the model were manipulated by hand according to the given time limits.

The recorded figures were evaluated and the selected figures below show the experiment process. In figures 6 to 17 figures from the measurement are plotted, where the recording was performed with an exposure time of 1s and a shutter aperture setting of 3,6. The time delay between the frames was extended up to 8s.

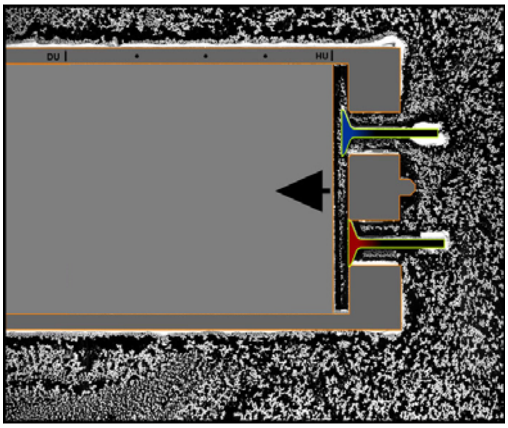

Fig. 6 Intake initiation – upper valve is open, piston is in upper dead position.

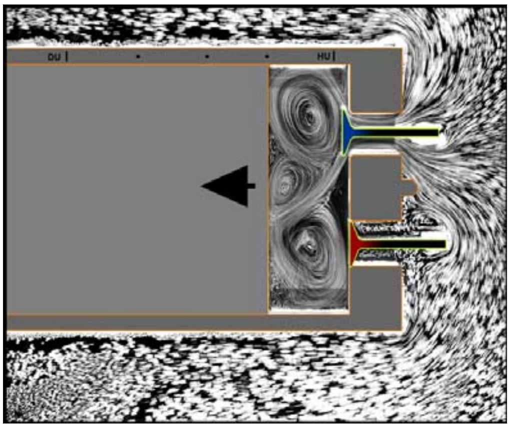

Fig. 7 Intake – first consecutive phase.

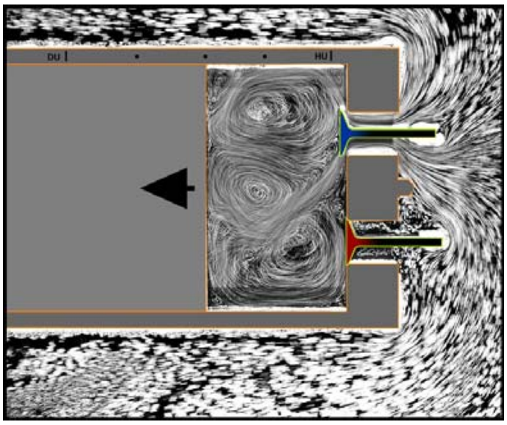

Fig. 8 Intake – second consecutive phase.

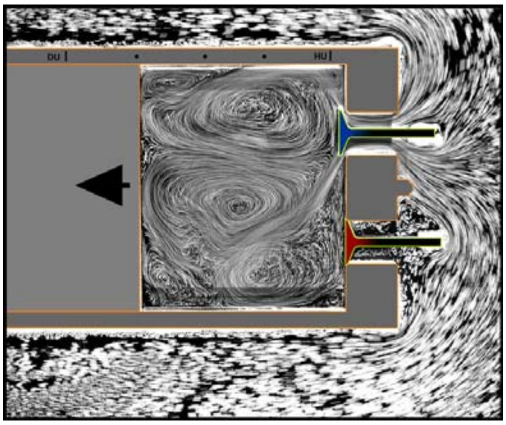

Fig. 9 Intake – third consecutive phase.

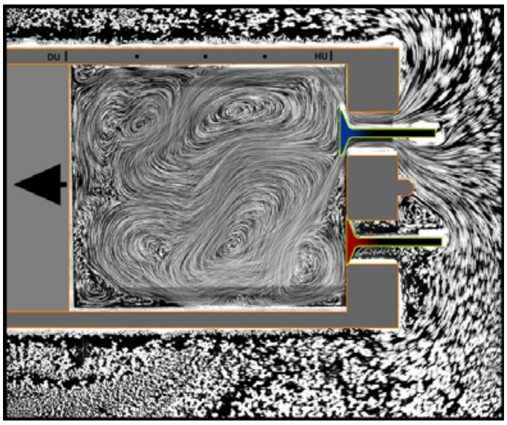

Fig. 10 Intake–maximum size of the space, piston in inner dead centre.

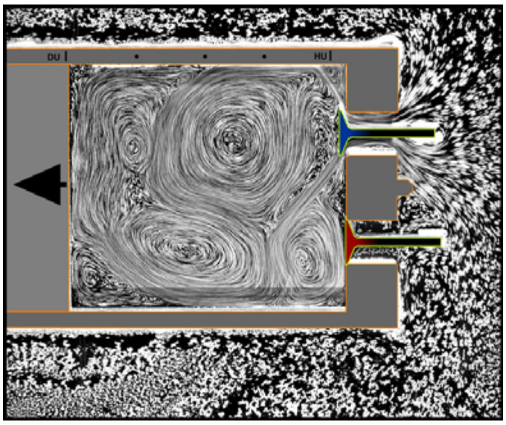

Fig. 11 Instant when the working fluid takes effect.

VISUALIZATION OF OIL FLOW BETWEEN MATING NONINVOLUTE TEETH PROFILES

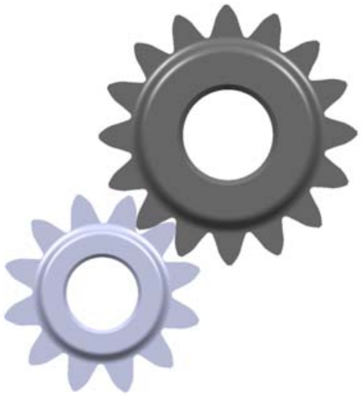

Fig.12 Noninvolute toothed wheels in gearing.

Theoretically, the issue of oil lubrication of mating toothed gears is a very complicated process. This problem is relatively well managed for involute gearing, although in this case, sometimes there are difficulties in achieving the required quality of lubrication. A much more difficult task is to reflect the requirement for quality lubrication for noninvolute profiles where this requirement may act as an optimization parameter for defining the correct mating teeth profiles. In essence, there is no need to quantitatively assess the quality of lubrication, but just qualitatively. This can be achieved on a virtual model, or by observing the flow of oil between the teeth of a simplified model of real gears, provided that it envisages the creation of a hydrodynamic lubrication layer (although in fact such lubrication free teeth are shown in the picture). Fig.13 and Fig.14 show the results of both procedures. It is obvious that the results are different. As experimentally observed, the flow in the bath with low level visibility thread probes corresponds to the nature of the oil film in real transfers (change of flow direction in the pitch point),and the results of computer analysis of this match.

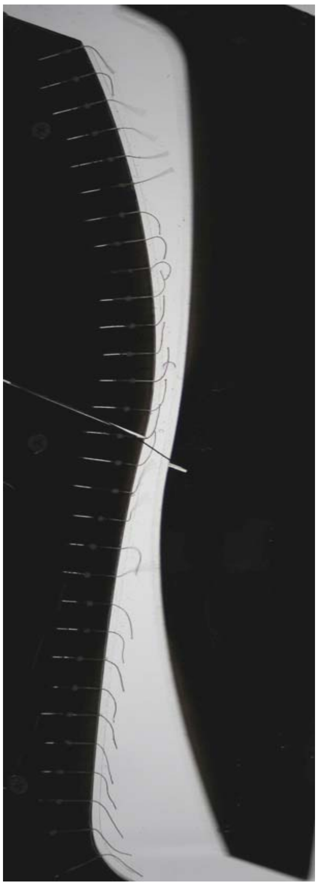

Fig.13 Oil flow between model of noninvolute teeth profiles recorded in low level tank.

CONCLUSION

The experiment of filling and emptying the cylinder during the piston movement between the upper and lower dead points was repeated 12 times for the time limits 5s and 8s. The figures were exposed when the flow passed a defined position at a given time. Having reached the lower dead position, it was necessary to wait until the visualization particles were not in motion. This time was in the range 150 – 160s. A more accurate value was not possible as the observation of the experiment with the naked eye allows only an estimation. The particles of aluminium experienced movement, which was undetectable with the naked eye. This movement was detectable only in the photos. From the figures obtained, the state of the working fluid was influenced by the momentum of liquid outside the piston surroundings, which was connected to the outside space by the open valve. The comparison of corresponding piston positions and corresponding events (filling and expression) was ensured by the figure similarity. The abbreviations were registered at the lower dead point. For the slower piston movement, i.e. for a greater time limit between the particular positions, it took a shorter time to bring the liquid to the rest than

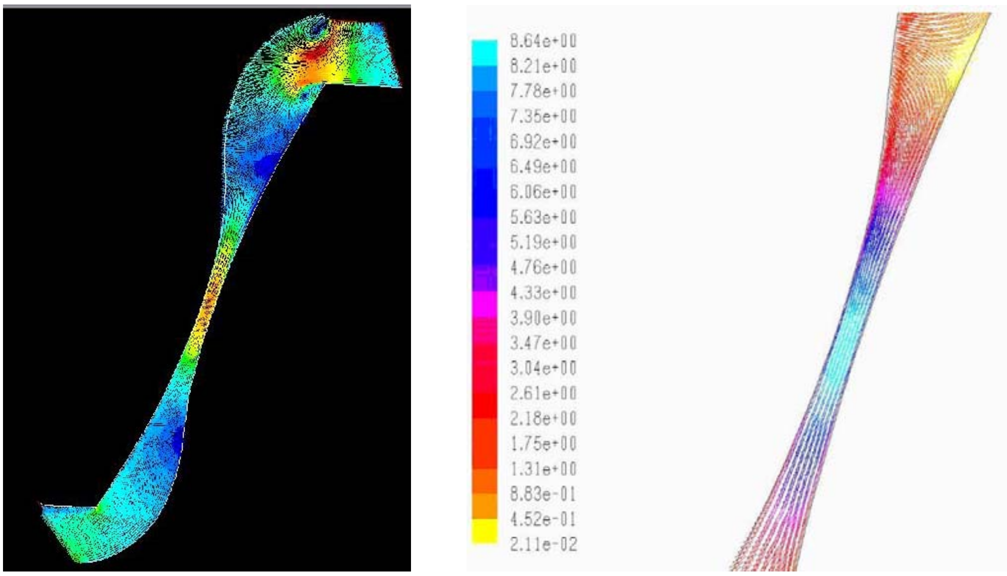

Fig.14 Oil flow between noninvolute teeth profiles (on right is plotted detail near the pitch point) generated in FLUENT software environmen.

by the faster liquid to the rest than by the faster movement. The obtained results, however, fully correspond to the ratio of filling, respectively discharging a real cylinder. Similarly, correct results were achieved in the experiment with the flow of lubricating oil of two mating gears. On the other hand, the results from the analysis of the virtual model were not correct. This shows that the usage of low-level tank is a very efficient and reliable way of verifying the reliability of virtual models, as well as of simplified real models. Visualization can provide quick qualitative assessment of the model and the quantitative evaluation of flow can then be used for similarly defined virtual models.

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