THE UNSTEADY VORTICAL STRUCTURE IN A JET IMPINGING INTO A TROUGH CAVITY

Martin, Knob/ Václav, Uruba
Institute of Thermomechanics, Czech Academy of Sciences, v.v.i., Prague

In a blind, retcangular, trough- like cavity subject to a jet impingement, the jet-switching phenomenon has been known for decades. This is caused by the double-Coanda effect: at the very beginning, as the jet starts to blow the fluid into the cavity, the fluid is bent towards one of the sidewalls due to the Coanda effect. Then the jet is divided into two different wall jet- like streams, one of which flows straight to the cavity opening ("upwards"), the other flows "downwards" along the sidewall toward the cavity bottom wall. As the second wall jet reaches the bottom wall, it turns in the right angle along it and continues toward the opposite sidewall, along which it turns again and flows "upwards", i.e. towards the cavity opening. However, at this moment it starts to interact with the jet, placed on the top of the cavity. Since both the free jet and the wall jet entrain their surrounding fluid, in the region between them, a region of low pressure is created, which then causes the jet to swing to the other side. After the jet is swung, the process is repeated in the same manner on and on.

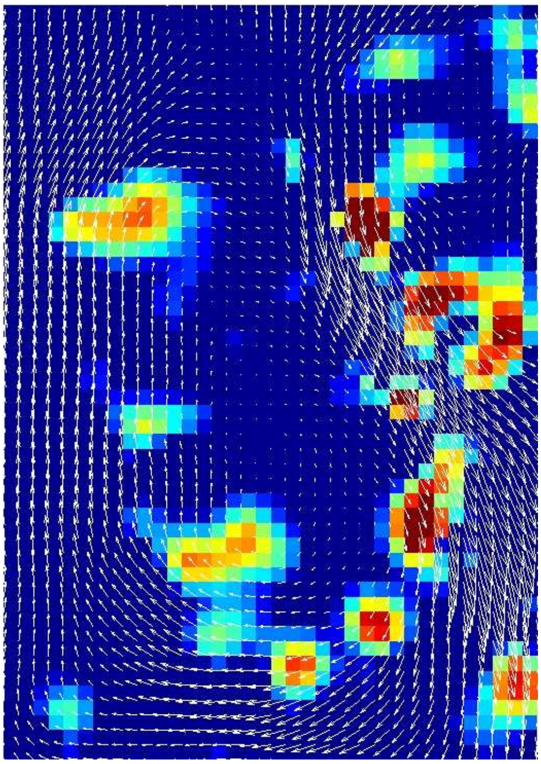

Fig. 1: The instantaneous flowfield with visualized vortical structure; the Kelvin-Helmholtz instability is clearly visible

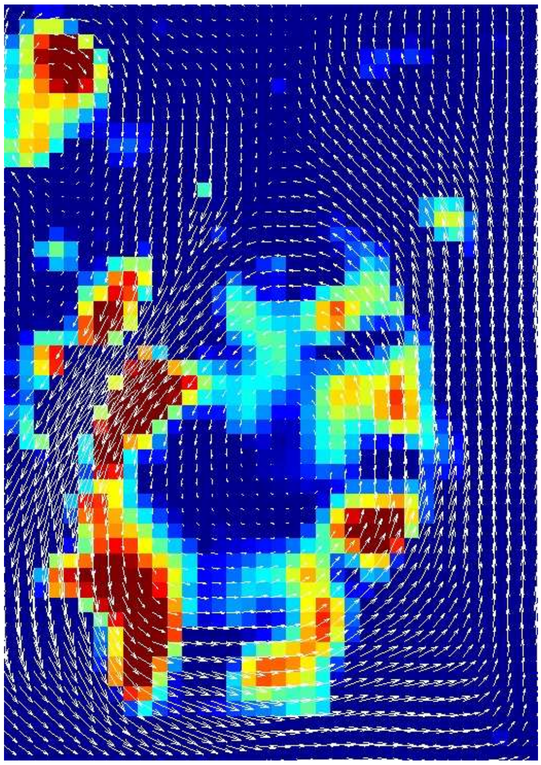

Fig. 2: The instantaneous flowfield with visualized vortical structure; the vortex loop just formed

In the reported research, the TR PIV system was used for the investigation of the vortical structure, visualized using the Δ- criterion. On the results obtained, several phenomena are observed. First, on the edges of the jet, the Kelvin- Helmholtz instability forms “large” vortices, which are further entrained by the fluid and grow in size (see Fig. *1*). Second, after the impingement on one of the cavity walls, the flow together with the vortices is bent in the direction towards the cavity opening. At the moment, the vortices start to interact with the just- formed vortices on the edge of the impinging jet- following the basic rules of vortex dynamics, the pathlines are changed, and the vortices are bent back into the cavity, forming a kind of closed vortex loop (see Fig. *2*). During this process, the fluid between the impinging jet and the quasi- wall- jet is entrained and, therefore, the low- pressure area is created and the jet is swung.

As may be understandable from the text and pictures above, the vortex paths are of high interest. These, however, can be observed only manually- although the authors have their own method to do that. This procedure is based on the secondary application of the PIV algorithm on the succesive images of the instantaneous vortical structures, and thereby evulating the vortices displacements; the following steps are straightforward. It should be mentioned here, that the above mentioned procedure requires at least five times faster PIV system than that available at the institute and, consequently, is not applied here.

From the mainly visual analysis of the given set of successive vortical structures, it can be said, that the vortices, formed by the Kelvin- Helmoholtz instability, can be divided into three different groups. In the first group, the vortices, which are formed by the K-H instability and, after the impingement onto the appropriate sidewall, turimmediately leave the cavity. In the second group, the vortices, which are entrained deep into the cavity, can be found. These vortices leave the cavity, following the cavity bottom wall and one of the sidewalls. The third group contains vortices, which, similarly to the second group, are entrained deep into the cavity, however, they turn back as a result of the vortex- vortex intaraction and thereby form the vortex loop.

References:

[1] Knob, M., Uruba, V.: A Brief Survey of Vortex Identification Methods with Application to 2D PIV data, Symposium on Anemometry, 2007

[2] Knob, Martin - Antoš, Pavel - Adamec, J.: Experimental and Numerical Investigation of Unsteady Behaviour of a Jet Impinging into a Trough- like Cavity. Experimental Fluid Mechanics 2006, Liberec 2006

[3] Knob, M. - Šafařík, P. - Adamec, J.: The Unsteady Behavior of a Plane Jet Impinging into a Through Cavity, Topical Problems of Fluid Mechanics 2007

Acknowledgement

The authors gratefully acknowledge financial support of the Grand Agency of the Academy of Sciences of the Czech Republic by the research project No. IAA2076403 and Grand Agency of the Czech Republic No. 101/05/0675.