Universität Rostock

Traditio et Innovatio

Experimental flow analysis of welded pipe connections

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Introduction

Within the BMBF initiative "Innovative Regional Growth Cores (German: Innovative regionale Wachstumskerne): Centifluidic Technologies", in collaboration with the Dockweiler AG, a process is developed, which enables the welding of the inside of stainless steel tubes with inner diameters < 4 mm without subsequent discoloration.

The chair of fluid technology and microfluidics is involved with the analysis of the flow properties of the welded samples. The influence of the weld shape on the flow profile, the size of the areas which are not captured by the mainstream and the turbulence characteristics are to be investigated using a Micro Stereo PIV (particle image velocimetry) system. In order to be able to carry out such analyses an optical accessibility to the sample is necessary.

Methods

To analyze the flow behaviour, a new method must be created, which ensures both a detailed representation of the weld and also an optical access for the cameras of the PIV system.

In the first step the weld was molded with silicone, so that a core with the geometry of the weld was formed, which could be removed from the welded tube. Next, the core was molded with a transparent silicone in an aluminum profile (Figure 1). For this purpose, the silicone core was clamped between two connectors and then filled with the transparent silicone. The existing bubbles are removed by placing the core in a vacuum. After the drying phase, the core could be removed.

Fig. 1. Impression of a weld

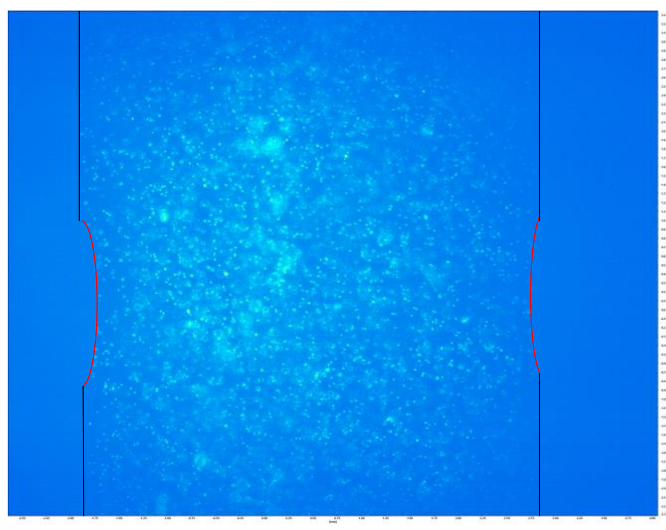

Fig. 2. PIV particles in an aqueous glycerol solution in the region of the weld

In Figure 2 the flow through the molded sample is shown. The weld, which is about 2 mm long, is clearly visible at the edge in the middle region of the flow.

In addition to the mold of a simple welded tube other structures, such as a manifold with different branching angles, can also be produced with the silicone (Figure 3). Due to the high elasticity of the silicone, more complex components can be molded.

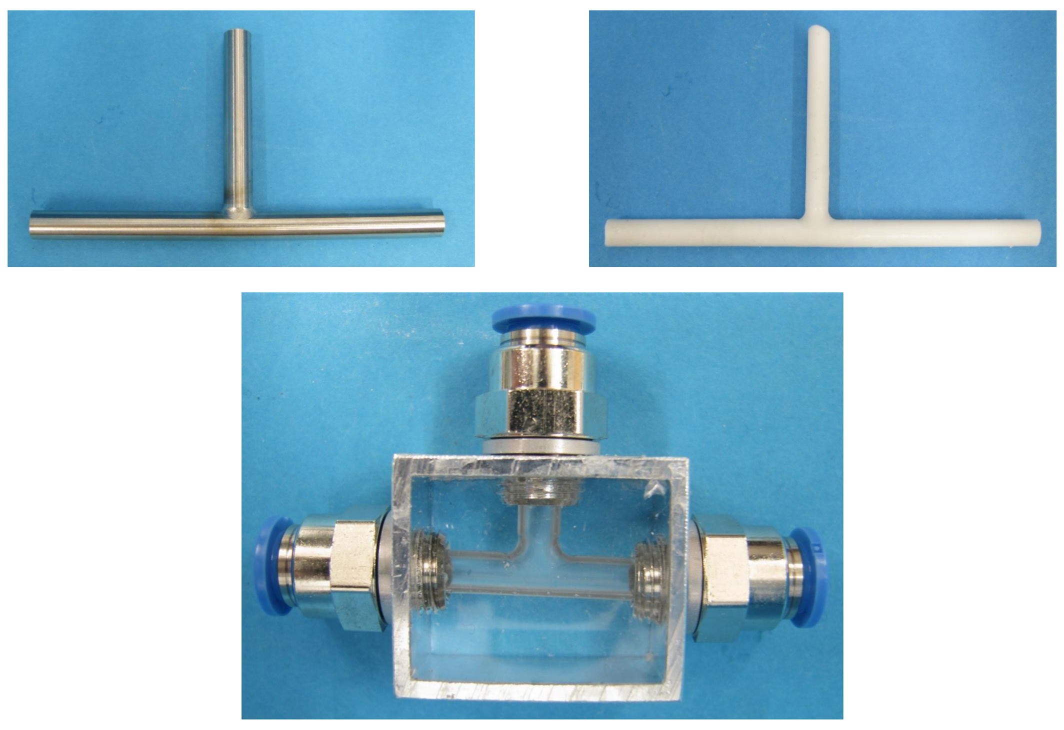

Fig. 3. Silicone impression of a welded manifold with a 90° angle

The velocity field of the flow is determined with a Micro Stereo PIV system. Therefore fluorescent particles, which follow the flow and make it visible for the cameras, are added to a fluid. The particles are illuminated by a laser several times in quick succession and recorded with sCMOS cameras. From the displacement of the particle positions between the two images the velocity vectors are calculated using the cross correlation technique. The used Micro PIV system is shown in Figure 4.

The fluid itself is driven through the sample by means of a pump. In order to avoid errors due to refraction, a fluid with the same refractive index as the used silicone had to be found. An aqueous glycerol solution proved to be effective.

The velocity field of different welds that result from different welding parameters can be compared to optimize the flow. Laminar flow is desired and areas which are not captured by the mainstream are to be reduced or completely avoided.

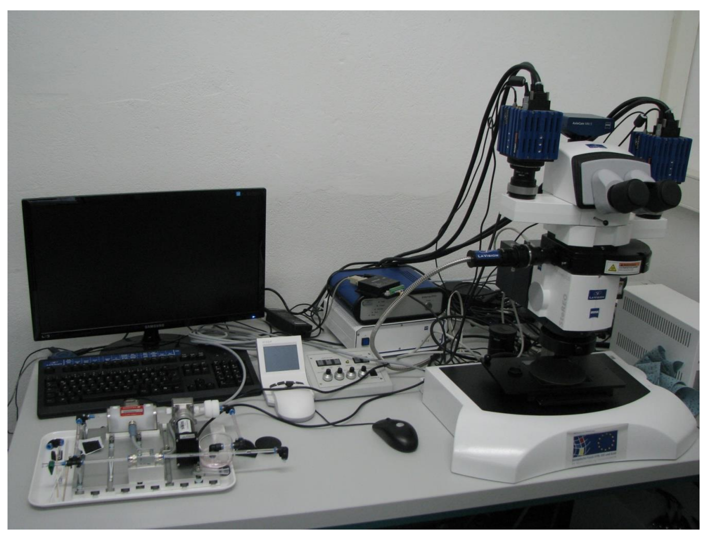

Fig. 4. Micro-stereo-PIV system

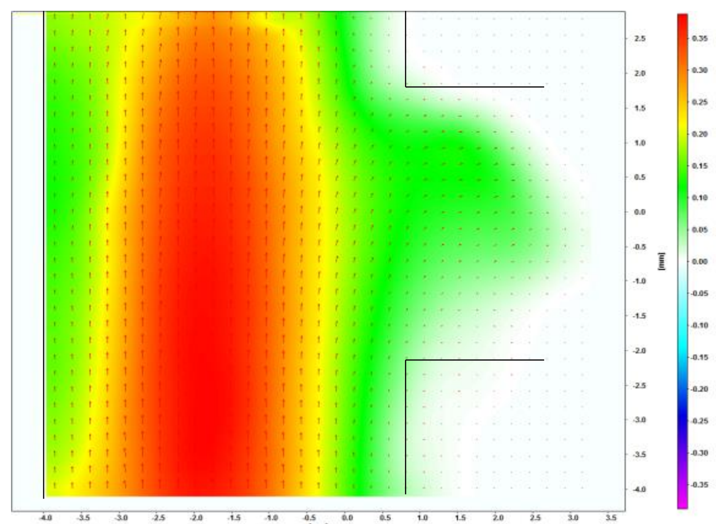

Fig. 5. PIV-velocity field

Results

In Figure 5 the velocity field of a manifold with a 90° branch angle is shown. On the one hand the parabolic flow profile can be represented and thus the influence of the weld quantified. On the other hand, the studies allow for example a comparison of the areas which are not captured by the mainstream of the flow.

The following analysis shows the fluid dynamical advantage of a 60° branch over a 90° branch. The velocity in x-direction (Figure 6, Figure 7) clearly reveals that the 60° branch has fewer areas which are not captured by the mainstream. The influence of the weld is barely recognizable and negligibly small. Also, in the experimental flow analysis of the simple welding, only a small increase of the flow velocity in the region of the weld was recorded.

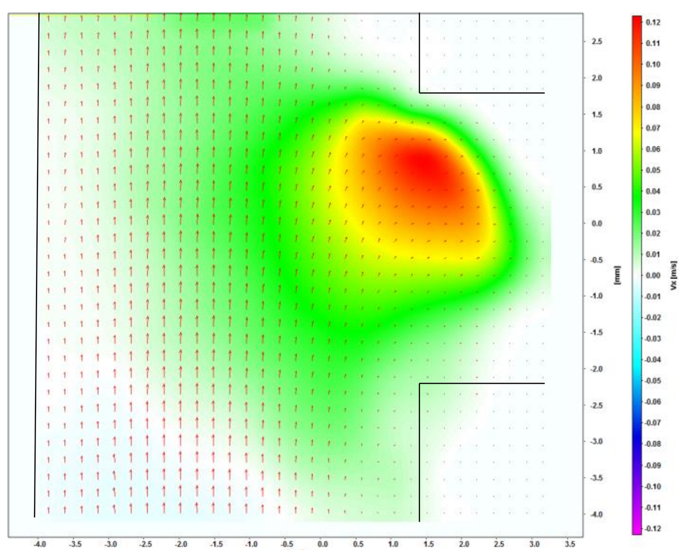

Fig. 6. Velocity field of a 90° branch in the x-direction

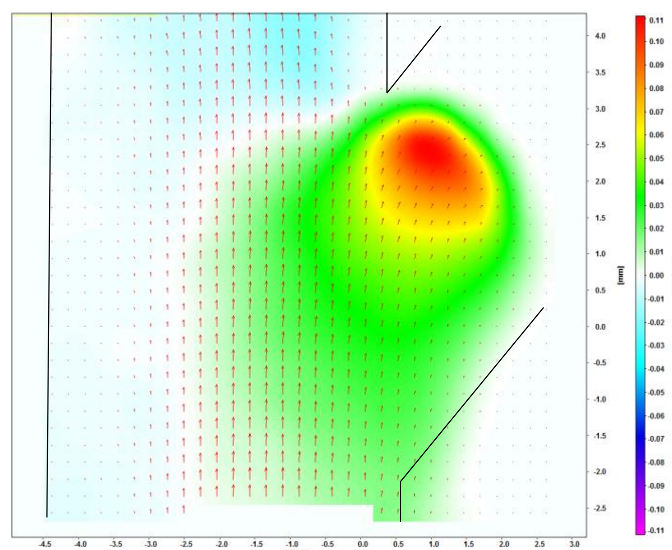

Fig. 7. Velocity field of a 60° branch in the x-direction

Conclusion

In order to analyze the flow behaviour of welded pipe connections, a new method was created, which allows optical accessibility to the object of investigation. The samples were investigated from a fluid dynamical perspective by means of particle image velocimetry.

Tests carried out so far have already shown good results. The influence of the weld is very low in comparison to various branch angles. However, further parameters (for example the flow rate and the time interval between the images of the cameras) can be optimized to provide assured results.

The experiments show that, in addition to simple welds, complex parts can also be molded and investigated. It was shown that it is possible to mold and compare manifolds with different branching angles.

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