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Experimental Equipment for an Electrical Resistance Tomography of a Gas Lift Flow

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Abstract. The article describes design of an experimental equipment for an electrical resistance tomography (ERT) of an air-water bubble multiphase flow. It reuses most of a circuit from a previous PIV experiment, with an exception of a measurement segment and adjacent pipes. The core components are two electrode rings each with 16 stainless steel electrodes smoothly embedded to its walls. The design is made modular, so it is possible to easily swap or modify its parts in case of need.

INTRODUCTION

Electrical resistance tomography is a method of visualization of distribution of electrical resistance in a cross section of a volume. The electrical resistance can be distributed for example according to a multiphase morphology, as each phase has different resistivity, or according to a concertation of dissolved substances, which also changes resistivity. This method works only for flow with continuous conductive (if only weakly) fluid phase (in other cases for example electrical capacitance tomography, or ECT, has to be used). The measurement is done by introducing an electric current to the flow and measuring the electrical resistance. For circular cross sections this is usually done by 16 electrodes. The electrical resistance is measured for all possible pairs of electrodes with an exception of neighboring ones. A map of electrical resistance is then reconstructed (which can be translated to map of the parameter in question, like a distribution of phases). In the case of multiphase flow, the velocity can be determined by cross-correlating images from two cross sections. More detail about Electrical Resistance Tomography can be found for example in sources [1] and [2]. Some useful general information about this method can also be found in [3] and [4].

Both software and hardware are available in the market, however measurement via ERT also requires custom made electrodes. This article will present design of the electrode carrier, in this case a ring, for an existing gas lift flow circuit located at University of West Bohemia in Pilsen. The experiments are planned to be recorded by a use of a dual channel tomographic system with adjustable frequency of 75 to 153.6 kHz.

Gas lift flow circuit

The previous status of the gas lift flow circuit is depicted in Fig. 1. The gas, air in this case, is injected by a set of 10 nozzles placed around the perimeter of a pipe (1) just below the measurement segment (2) into water. The air is injected in sufficient quantity to cause net flow of the fluid component in a direction opposite to gravity –

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acting as a pump. The gas phase is then separated in a large tank on top of the circuit (3). The tank is topped with a lid to prevent accidental ejection of water from the circuit. The fluid phase from the tank, now devoid of any gas, is fed back by a return pipe (4) through a second measurement segment (5) to a heater tank (6). The heater tank contains electrical coil capable of increase in temperature of the water up to boiling point.

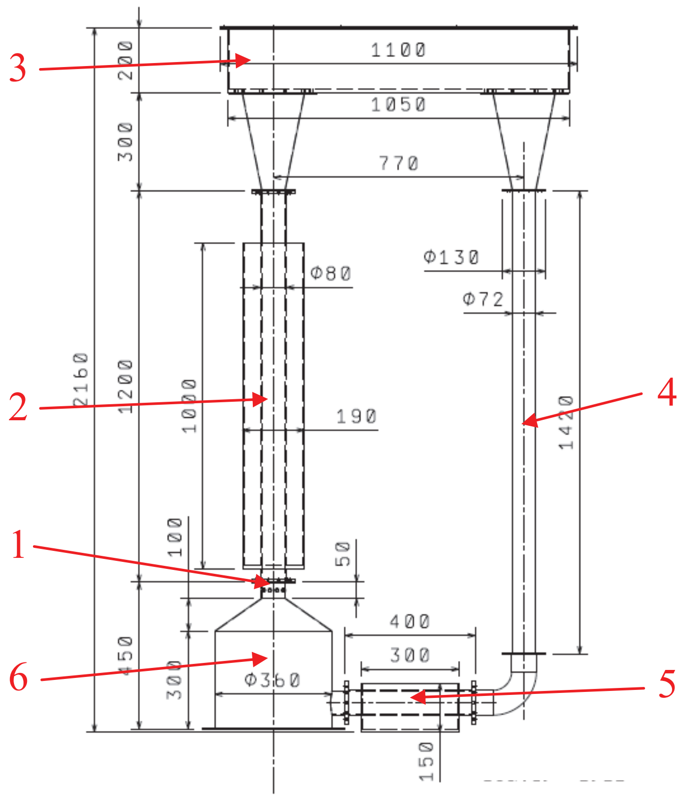

FIGURE 1. Gas lift flow circuit

DESIGN OF THE EXPERIMENTAL EQUIPMENT

The vertical PIV measurement segment of the gas lift flow circuit ((2) in Fig. 1) was replaced by a segment consisting of three pipe segments and one ERT measurement segment – as is shown in Fig. 2. The core components of the measurement segment are two electrode rings. Each ring contains 16 stainless steel electrode smoothly embedded in the circular channel. The segments are joined by flanges and sealed by O-rings. This gives an option of easy disassembly and assembly without risk of subsequent leakage. All the segments are center aligned by a use of geometrical features. All materials, with the exception of the electrodes themselves are from electrically insulating materials.

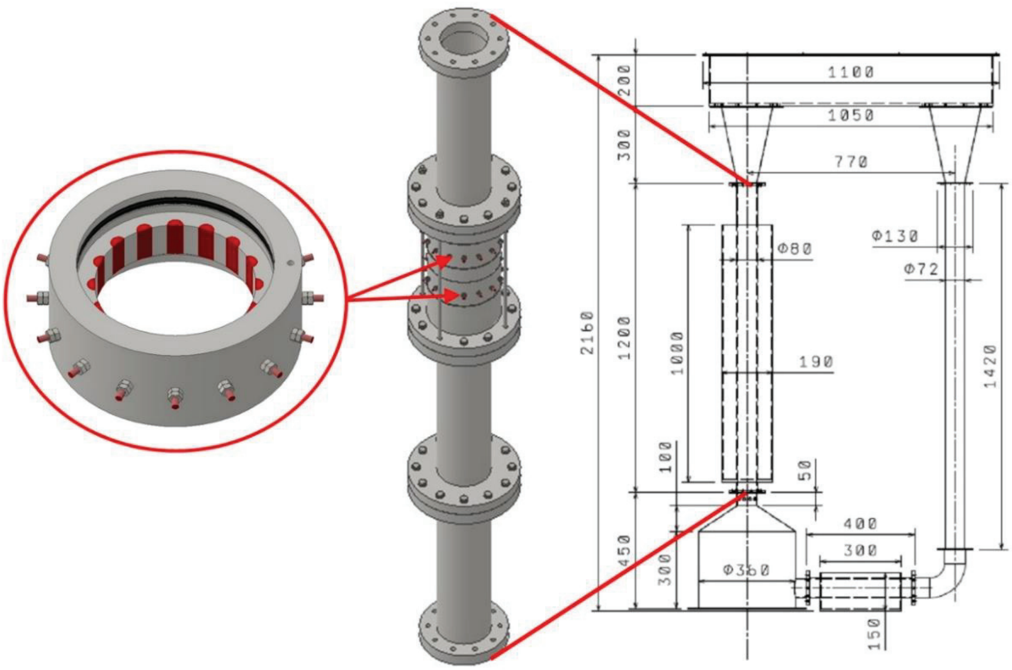

FIGURE 2. Designed experimental equipment - electrode ring (on the left), ERT measurement segment (in the middle), repurposed PIV circuit (on the right)

Electrode rings and electrodes

Figure 3. shows an electrode ring. It holds 16 semicircular electrodes (each electrode is soldered together with a threaded rod) which are tightly pulled to their slots by a nut. The second nut on each threaded rod is present only as a means to fix connectors (which will be sandwiched between the two nuts). The electrode ring also contains two slots for O-rings (top and bottom) and two holes for aligning pin (top and bottom). The top pin hole is circular and the bottom one is oval (it only removes rotational degree of freedom), since all segments are already center aligned.

The electrode rings are made out of polyoxymethylen (or polyacetal or POM-C), a material which is easily machinable (so the components are accurately made and no bumps are present on the walls), has decent mechanical properties (to ease up the manufacturing of the electrodes) and low water absorption (so the geometry and electrical properties do not deviate too much). The electrodes are made of stainless steel – specifically ČSN 17 349 (equivalent to DIN 1.4404 or AISI 316) to ensure electrochemical resistivity to water. The threaded rods are also made of stainless steel. The electrodes and the threaded rods are joined by a silver based solder.

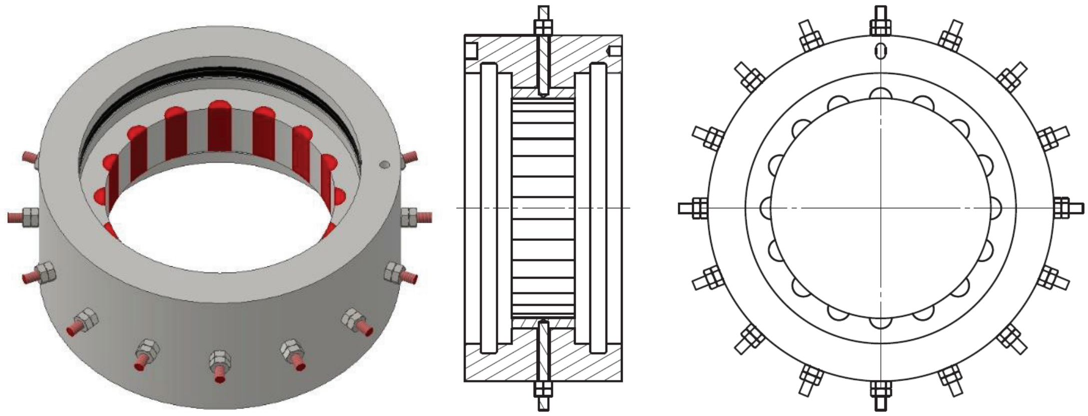

Figure 3. Electrode ring

Measurement segment

Figure 4. shows a measurement segment. It consists of two electrode rings, three distancing pipes and two flanges. The measurement segment is held together by threaded rods as can be seen in Fig. 2 (sandwiched between two pipe segments). At the top flange there is a slot for an O-ring. All the parts are rotationally aligned by pins, to ensure proper mutual position of the electrodes.

The distancing pipes as well as the flanges are made of polyoxymethylen (or polyacetal or POM-C). Flanges are glued to the distancing pipes.

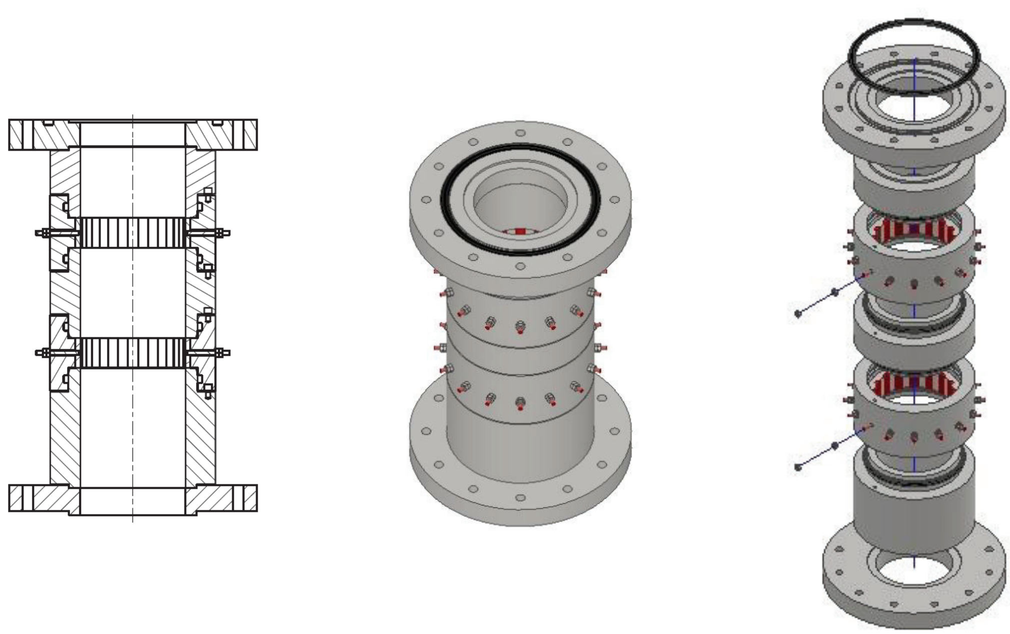

Figure 4. Measurement segment

Pipe segments

Pipes were made from acrylic glass (polymethyl methacrylate) to retain optical access for visual inspection or some form of optical measurement. Two flanges from polyoxymethylen were glued to each pipe. Acrylic glass and polyoxymethylen are materials which are not optimal for gluing with each other, however UV-hardened epoxy for acrylic glass were successfully used to create sufficiently strong bond, as long as the bonded surfaces were roughened with a use of sandpaper prior to the gluing process. For future projects small construction change could be made to make the gluing process easier and the bonding stronger – make a hole in the flange (slightly larger than a diameter of the pipe), insert the pipe into it and fill the resultant slit by the glue.

CONCLUSION

In the article setup of an ERT of gas lift flow was presented. It reuses gas lift flow circuit used in previous experiment and replaces the measurement segment. The main components of the new measurement segment are two electrode rings. Each ring contain 16 stainless steel electrodes smoothly embedded in the wall. The measurement segment is made of combination of acrylic glass and polyoxymethylen and is easy to disassemble. The experimental setup will be possibly modified in future - for example the gas injection nozzles might be replaced.

The equipment hasn't been finished yet, but in the near future measurements will be conducted. The measurements are intended to be conducted by a dual channel tomographic system with frequency of up to 153.6 kHz. The measurements will focus on a study of a bubbly flow and possibly on a slug flow. Mainly multiphase structure and bubble velocity will be observed.

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