OC-16: Modification of the Ultrasound Induced Activity by the Presence of a Liquid Flow in the Acoustic Field. Study at Two Low Frequencies (20 and 40kHz) : Mapping Flow Velocities by Particle Image Velocimetry (PIV) and Electrochemical Mass Transfer Measurements

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Chemical and electrochemical applications carried out in presence of power ultrasound (between 20 and 100kHz) are widely used. Concerning applications in electrochemistry (Touyeras (2001)), Walton (1996) or cleaning processes (Mazue (2011)), the presence of a surface, inside the reactor, interacts with the ultrasound field and thus disturbs the hydrodynamic flow. Both description of induced disturbances and knowledge of the active zones distribution are useful for the reactor design. Many studies were carried out under static conditions i.e. without presence of flow circulation which would affect the ultrasound field. These studies enabled to obtain distribution of active zones, using electrochemical mass transfer measurements (Trabelsi (1996)), laser tomography (Mandroyan (2009)) or Particle Image Velocimetry (Mandroyan (2009)).

The present work deals with interactions between ultrasonic fields and liquid flows. Different operating conditions were investigated: two ultrasound frequencies (20 and 40kHz) various ultrasound power, liquid flow rate (1700<Reynolds Number<17000) and liquid viscosity (range from 10^{-3} to $2.25.10^{-3}$Pa.s). The active zone characterization was achieved using two metrology methods: electrochemical mass transfer measurements and Particle Image Velocimetry.

1. Materials and methods

1.1. Ultrasound generation

The 40kHz acoustic transducer used in our experiment was a MW800 from SODEVA (France). Vibrations from the probe are coupled and intensified with the titanium tip. The probe vibrates in a longitudinal direction and transmits this motion to the titanium horn (25mm diameter) immersed in the solution.

For 20kHz experiments, a probe (Sonics and Materials, Dabury, USA) was used with a 25mm diameter titanium probe to transmit ultrasound to the liquid.

1.2. Cell's measurement

A reactor was especially design for these experiments. It consisted in a polypropylene plane-parallel cell (40cm in length, 4cm in height and width). The transducer was fixed underneath the reactor (cf. Fig. 1). Three electrodes were necessary for electrochemical measurements and they were located on the upward face to the cell. For PIV measurements, specific optical windows were used for emission/reception parts. The liquid's circulation inside the experimental setup was insured by a magnetic pump (flow rate between 0 and 40L.mn^{-1}).

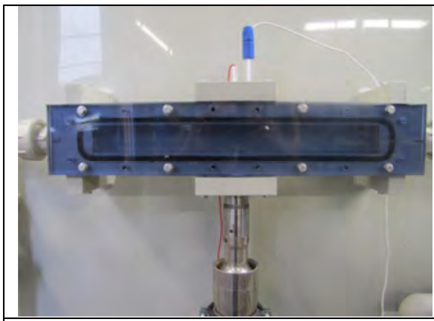


Fig 1: cell's measurement

1.3. Mass transfer measurement

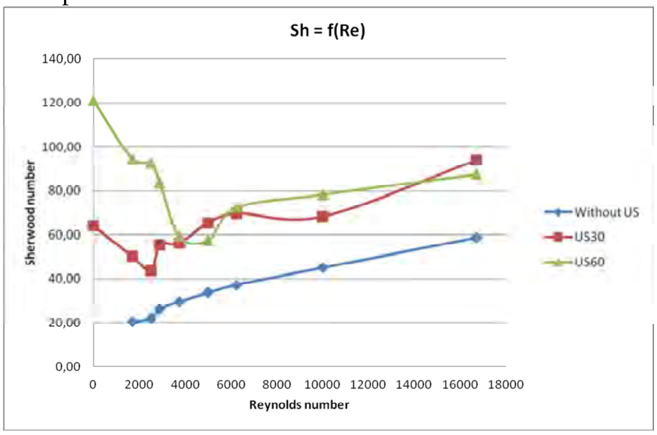
All electrochemical experiments were performed using a conventional three electrodes assembly linked to a potentiostat (PGP 201) and controlled by a computer for data acquisition. The working electrode was a platinum disk (1 mm diameter). Its surface was face to face with the horn. A simple platinum wire was used as a quasi reference electrode, the counter electrode consisted of a platinum plate and was designed and located so as to be outside of the ultrasonic field. The redox couple $Fe(CN)_6^{3-}$/ $Fe(CN)_6^{4-}$ was used for the mass transfer measurement. The solution was made of potassium ferri/ferrocyanide (5.10^{-3} mol. L^{-1}) in sodium hydroxide (0.2 mol. L^{-1}).

1.4. Particle Image velocimetry

Particle Image Velocimetry is a non intrusive optical method of velocity measurements. The test liquid was seeded with micrometer particles. A double pulsed Nd Yag (532nm) laser created a sheet of light which illuminated a two-dimensional plane in the flow. For each laser pulse, an image was recorded using a CCD camera. Thus two images, separated with a small time interval, were obtained. Inter correlation process was applied to these pairs of images. Thus displacements between the two images for the entire visualization area were calculated. Then instantaneous flow velocity vectors fields were obtained. For each operating condition (Re, viscosity, US power, US frequency), a set of at least 100 pairs of images was recorded. Thus 100 instantaneous fields were obtained from which an average velocity field was calculated. An example of such a field is given on figure3.

2. Results

The figure 2 shows, for the 20 kHz transducer, the Sherwood numbers versus Reynolds number obtained for different electric power (0%, 30% and 60%). In silent conditions, Sherwood number increased with the flow rate. In ultrasound presence, a transition zone (in which the Sh number increased) was observed for little flow rates and beyond Reynolds=6000. Even if the ultrasound flow was completely disturbed by the circulation of liquid (fig. 3), we observed the influence of ultrasound on the Sherwood number. This contribution seems to be independent of the ultrasound power.



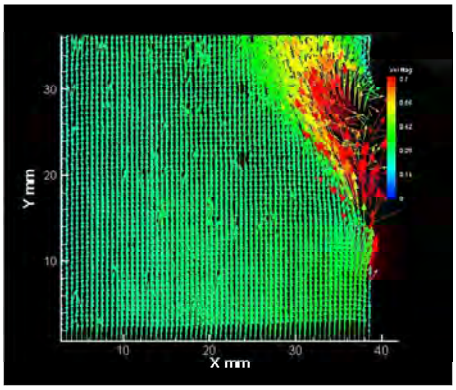


Fig 2: Sherwood number versus Re in silent conditions and various electrical powers applied to the sonotrode.

Fig 3: Velocity vectors field (velocities from 0 to 0.7 m/s), Re = 10000, electric power 60%.

References

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