XX IMEKO World Congress
Metrology for Green Growth
September 9–14, 2012, Busan, Republic of Korea

CONTACT-FREE FLOW RATE MEASUREMENT IN WEAKLY CONDUCTING ELECTROLYTES USING LORENTZ FORCE VELOCIMETRY

A. Wegfrass, C. Diethold, M. Werner, C. Resagk, F. Hilbrunner, B. Halbedel and A. Thess

Ilmenau University of Technology, Department of Mechanical Engineering, Germany,
andre.wegfrass@tu-ilmenau.de

Abstract: The feasibility of Lorentz Force Velocimetry for flow measurement of poorly conducting electrolytes is demonstrated using experimental results on salt water flow exposed to a permanent magnet system. The results provide a linear relationship between the measured Lorentz force and flow velocity, consistent with the theoretical scaling laws. Further measurements are currently being performed on a new experimental setup. The new experiments are aimed at investigating the effect of flow dynamics on the measured force.

Keywords: Lorentz force, weakly conducting electrolytes, flow rate measurement

1. INTRODUCTION

There are several well-known techniques available to accomplish the various required measurement tasks in industry. But in some special applications the fluids are extremely hot, corrosive or abrasive and classical methods would not withstand the rough environment for a sufficiently long time, because the sensor in each of these techniques interacts with the surrounding fluid or with the pipe wall. Examples for these fluids include metal melts and acids. In order to avoid these interactions a novel contact-free flow rate measurement device has been developed – the Lorentz Force Flowmeter.

The basic idea of the measurement device relies on the interaction between a magnetic field and the moving conducting fluid. When an electrically conducting fluid moves through the magnetic field a Lorentz force is generated and acts on the measurement system. This method has been studied and verified by Thess et al. [1, 2] only for molten metal and is known as Lorentz force velocimetry (LFV).

2. EXPERIMENT AND RESULTS

To understand the capabilities of LFV for weakly conducting fluids, we perform experiments (Fig.1) with salt water which has an electrical conductivity of up to 6.2 Sm^{-1} at room temperature. The fluid flows in a duct with rectangular cross-section (30 mm x 50 mm), whose design is based on the numerical results of Werner et al. [3].The flow velocities are in the range of up to 3.5 ms^{-1}. In order to generate a high magnetic field strength, we apply a magnet system which is equipped with high-energy magnets made of NdFeB. The magnet system is suspended on thin tungsten wires resembling a pendulum and the entire system is mounted on a frame of aluminium profiles. The generated Lorentz force causes a deflection of the magnet system which is detected with a laser interferometer. Both the aluminium frame and the laser interferometer are mounted on a granite block with a mass of about 400 kg in order to suppress vibrations. The Lorentz force is calculated from the dimensions of the pendulum and the measured deflection. These elements are crucial for measuring the Lorentz force which is expected by numerical simulations to be in the range of $F_{Lorentz} \leq 10^{-5}$ N.

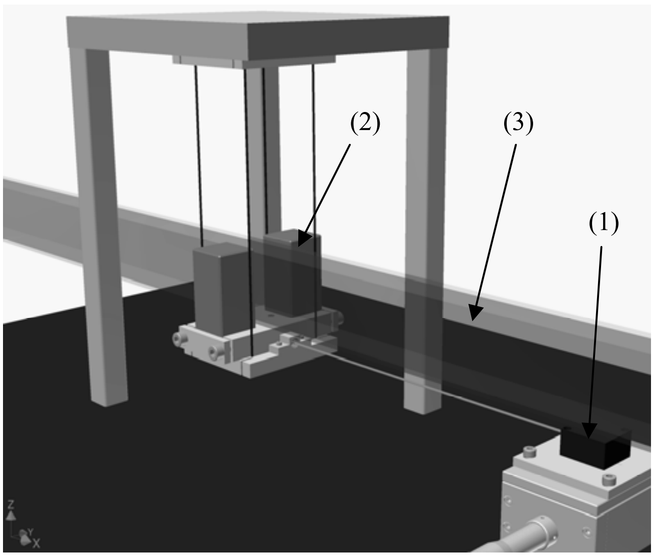

Fig. 1: Sketch of the experimental setup. The main components are the interferometric measuring device (1), the Lorentz force flowmeter (2) and the rectangular shaped fluid flow channel (3) close to the flowmeter.

In order to evaluate the sensitivity of LFV, we perform experiments at various fluid velocities and three different electrical conductivities of 2.3 Sm^{-1}, 4.0 Sm^{-1} and 6.2 Sm^{-1}. The experimental results are compared with numerical simulations. The results are in good agreement with each other except for the case with a conductivity of 6.2 Sm^{-1}

(Fig.2). Furthermore, it can be seen that there is a linear dependence of the Lorentz force on the flow velocity in both experiment and numerical simulation. This is consistent with the theory of Thess et al. [1]. The most encouraging aspect of the experimental results is the feasibility of LFV for flow measurement of poorly conducting electrolytes.

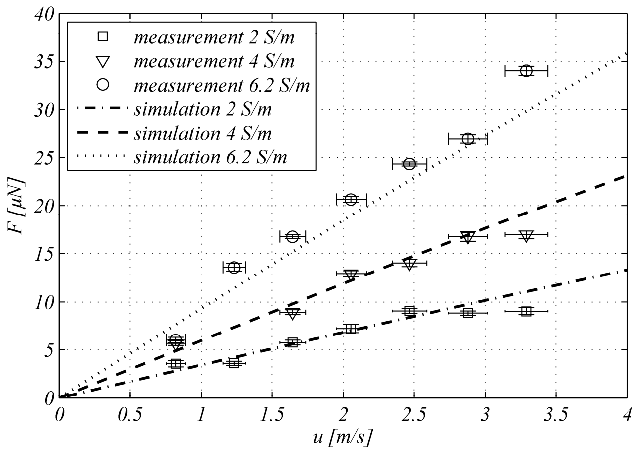

Fig. 2: Measurement results of the experiment. The graph shows the relationship between the velocity of the fluid and the generated Lorentz force. The different line types and symbols represent different electrical conductivities from 2.3 Sm^{-1} (cuboid), 4.0 Sm^{-1} (triangle) and 6.2 Sm^{-1} (circle).

It must be emphasized that this preliminary experimental setup is not an optimized fluid flow design and does not provide any information on the flow dynamics inside the duct. In order to overcome these disadvantages, a new measurement system has been built. This improved setup is designed using extensive CFD simulations and provides better control on flow velocities at the inlet and outlet of the duct. This is essential in creating a constant velocity profile before the region of the magnetic field (turbulent mean profile or a laminar profile). The new setup helps to understand the effect of the flow profile on the total Lorentz force.

4. ACKNOWLEDGMENT

The authors are grateful to the Deutsche Forschungs-gemeinschaft for financial support of the present work in the frame of the Research Training Group “Lorentz force velocimetry and Lorentz force eddy current testing”.

5. REFERENCES

[1] A. Thess, E. Votyakov, B. Knaepen, O. Zikanov: Theory of the Lorentz force flowmeter. New J. Phys., Vol. 9, 299, 2007.

[2] A. Thess, E. Votyakov, and Y. Kolesnikov. Lorentz Force Velocimetry. Phys. Rev. Lett., 96 (16), 2006.

[3] M. Werner, B. Halbedel, E. Rädlein: Numerical study of magnet systems for Lorentz Force Velocimetry in electrically low conducting fluids. International Scientific Colloquium “Modelling for Material Processing”, 2010, Riga.