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Monitoring of Pumps and Valves in Fluidic Systems with Electro-Magnetic Flowmeters

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Summary:
A standard electro-magnetic flowmeter has been enhanced by dedicated electronics to allow access to the measured raw data. These unfiltered raw data contain further information on the fluidic system in addition to the volume flow. Analysis of these raw data reveals that important information such as pump rotation speeds or disadvantageous valve settings are clearly visible. Thus, this study enables future work to improve the control of fluidic systems by electro-magnetic flowmeters.

Keywords: Electro-Magnetic Flowmeter, Predictive Maintenance, Condition Monitoring

Introduction

Several devices to measure the volume flow of liquids are available. Due to its reasonable price, good accuracy, and sustainability the electro-magnetic flowmeter (EMF) is a very popular type of these measurement devices [1]. Basically, charge carriers of the liquid flowing through the EMF are redirected by a magnetic flied perpendicular to the flow direction. These redirected charge carriers result in an electric voltage between two electrodes perpendicular to the magnetic field. By measuring this voltage, the volume flow can be derived eventually. Although several disturbing electro-chemical potentials superpose this voltage, it is possible to obtain precise volume flow information by filtering the raw measurement data. A common practice is to derive the mean value over a constant period [2].

However, the eliminated electro-chemical potentials origin in changes of the temperature and pressure of the liquid, as well as of its conductivity. These eliminated information on the aforementioned parameters are of interest for the user and might prove to be valuable for many applications. Therefore, this work aims on enabling EMFs to not only provide the accurate value of the volume flow but to allow parallel access to the information hidden in the electrochemical potentials.

Technical Solution

In this work a standard EMF of type OPTIFLUX 3300C from KROHNE was used. As in all common EMFs this device samples and digitizes the voltage between the two electrodes with an analog-to-digital converter (ADC). The raw data values of the ADC are then processed by a microcontroller (µC) to obtain the precise volume flow. As the electronics of this device are optimized for this procedure, they do not offer the possibility to access raw data values directly for additional processing. Therefore, additional electronics have been implemented which allow direct access to the raw data of the ADC. Thus, the unfiltered raw data can be processed externally.

The additional electronics mainly consists of three components: a small single-board computer, a microcontroller, and the necessary power-supply. As single-board computer a Raspberry Pi 3B+ was chosen because it comes with a multi-core processor and enough computing power to allow for most experimental online data processing methods. Furthermore, lots of software is readily available for this component which significantly shortens development time. However, in the context of this work dedicated software had to be developed which accesses the raw data, prepares it for further analysis, and provides the data via a TCP/IP interface to the out-side world. Unfortunately, the Raspberry Pi as well as all other available small single-board computers do not come with the necessary hardware interface to directly access the raw data of the ADC. Therefore, a common ARM-core based µC was introduced between the ADC and the Raspberry Pi to perform fast recording of the ADC data and to provide these data to the Raspberry as a serial data stream.

Experimental Setup

The standard EMF with the additional electronics was integrated in an experimental setup to allow for recording of the raw data in a controlled environment. As experimental setup a basic pump circuit consisting of an impeller pump of type Stratos Giga 50/1-14 from WILO, a valve and the EMF was chosen. A schematic drawing of this setup is given in Fig. 1. The pump can be set to any rotational speed between 500 rpm and 3300 rpm. With the given pipe diameter of 100 mm this maximum rotational speed correlates to a maximum volume flow of approximately 30 m^3h^{-1}. The valve can be set to any value between fully opened and fully closed. For this experimental setup tap water was used as liquid. In addition, the static pressure of the liquid can be changed by adding water to or releasing water from the pipe system. With this setup various experiments with varying pump rotational speeds, varying valve settings, and different static pressures have been performed. The raw data were recorded using the attached computer. Afterwards, the raw data was analyzed what information on the fluidic system can be extracted from the raw data.

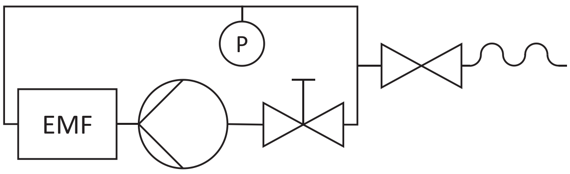

Fig. 1. Schematic drawing of the experimental setup

Results

The first analysis of the recorded data revealed that it contains a lot of noise as expected. However, in earlier work it was shown that some of this noise origins from periodic sources such as the impeller rotation of the pump [3]. Thus, analysis of the raw data was mainly performed in the frequency domain using a Fast Fourier Transformation (FFT).

In the spectral representation of the measured raw data the expected periodic signals are clearly visible. Fig. 2 shows the spectral results of measurements for pump rotational speeds of 3000 rpm and 3100 rpm at a constant static pressure of 2.4 bar and a constant volume flow of 5 m^3h^{-1}. Both curves show a clear peak at the frequency which correlates to the blade passing frequency at the pump outlet. As the pump has six impeller blades the frequency of 300 Hz correlates to the rotation speed of 3000 rpm and the frequency of 310 Hz correlates to the rotation speed of 3100 rpm. Furthermore, there are also peaks present at multiples of these frequencies, because the impeller blades do not produce a pure sinusoidal flow fluctuation.

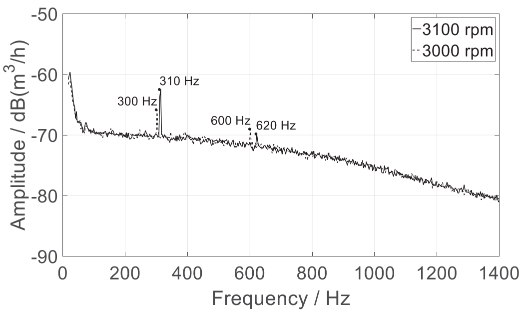

Fig. 2. FFT results derived from raw data of measurements with different pump rotation speeds

Repetitions of these experiments at different static pressures did not reveal any noticeable changes in the results. Thus, the static pressure can be neglected for future experiments.

However, valve settings at low static pressure causing cavitation are also clearly visible in the spectral representation of the raw data. They cause a drastic increase of the curve for lower frequencies. Therefore, disadvantageous valve settings can be detected by monitoring the raw data.

Conclusion and Outlook

The enhancement of an EMF by additional functionality to access the raw data has successfully been demonstrated. The first results prove, that impeller pumps and valve settings can be monitored by analysis of the raw data. Future work will deal with damaged pumps and valves to evaluate the use of such an EMF for predictive maintenance of fluidic systems.

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