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EXPERIENCES OF PULP FLOW MEASUREMENTS WITH ELECTRO-MAGNETIC FLOWMETERS

Esa Luntta, Harri Nystedt, Jouko Halttunen, Tampere University of Technology, Tampere, Finland
Juha Kortelainen, UPM-Kymmene Oyj, Valkeakoski, Finland

Introduction

Electromagnetic flowmeters are today practically the only meter type used in the measurement of pulp flows in paper mills. Usually, these meters have the required accuracy (or at least they are believed to have), the price of them is reasonable, and they are almost maintenance-free. However, electromagnetic flowmeters are usually calibrated in water flow and the effect of the change of the flowing medium to pulp on the accuracy has been investigated rather little [1], [2], [3]. The possible error sources in pulp flow measurements can be for example non-uniformity of conductivity or air content of pulp suspension. Incomplete mixing of dilution water may also affect the measurement accuracy. Moreover, the position of the flowmeter has to be selected often after the process plant has been built up. Therefore, the disturbance-free pipe lengths upstream and downstream of the meters can be too short. This paper presents the results of the experiments carried out with five electromagnetic flowmeters of different manufacturers with different water and pulp flows.

Test process

A pulp line of a paper mill was rebuilt so that it was possible to pump water or pulp to a reference tank, and then recirculate the same batch back to the feed tank, Figure 1. The nominal size of the pipe was 168,3x2 mm. The reference volume of about 29 m^3 was formed with two level switches installed on the wall of the reference tank. A data acquisition system capable to measure both the pulse output signal and the current output signal of all flowmeters was constructed.

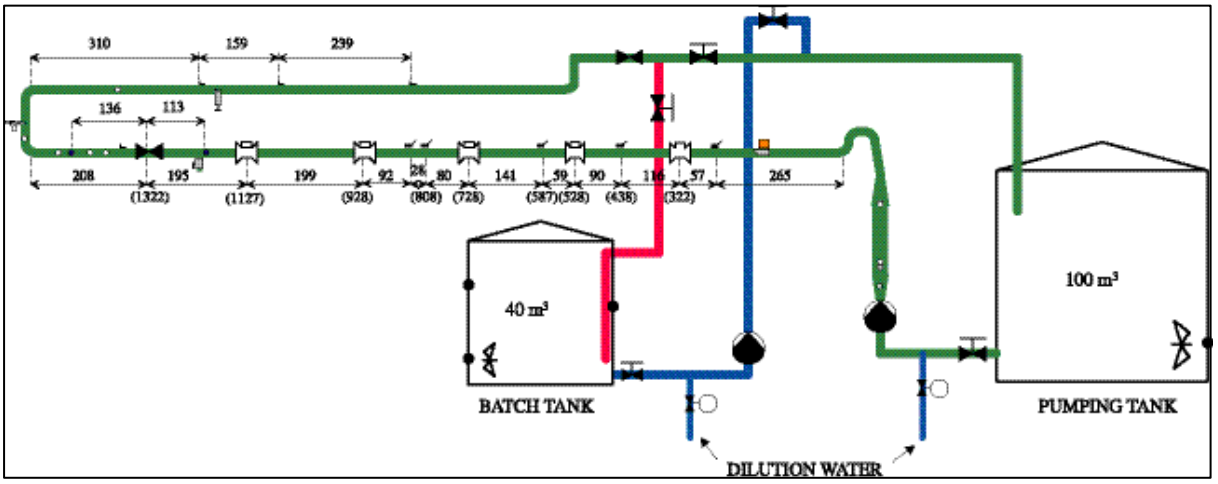

Figure 1. The test process and the positions of the flowmeters. The distances are in centimetres. The reference volume 29 m^3 was formed with two level switches on the wall of the batch tank.

The waters used in the tests were clear filtrate and white water of the paper machine, and also lake water. The pulps used in the measurements were mechanical pulp from a TMP-plant, bleached softwood chemical pulp, and the machine stock of a paper machine, which was a mixture of the mechanical and chemical pulp with about 28 % ash content. The consistency of the pulps varied from about 1 % to about 4,5 %. Properties of the fluids are shown in Table 1.

Table 1. Properties of the fluids used in the tests.

Fluid	Temperature [°C]	pH	Conductivity [µS/cm]	Solids content or consistency	Ash content [%]	CSF [ml]	Mean fibre length [mm]
White water	35-40	5.4	790	1300 mg/l	69		
Clear water	43	6.8	85	24.7 mg/l			
Lake water	7 -15	6.5	36	9 mg/l			
Machine stock	50 - 52	4.3	1150	3.4 %	28	43	1.5
Chemical pulp 1	50 - 59	5.6	950	3.5 %, 1.8 %, 1.0 %		700	2.3
Chemical pulp 2	47 - 53	8.6	2150	3.4 %		700	2.3
Mechanical pulp 1	50 - 64	4.7	950	4.5 %, 3.7 %, 2.8 %		43	1.5
Mechanical pulp 2	58	5.2	850	4.2 %		38	1.43

Meters

Five electromagnetic flowmeters of different manufacturers were tested. The nominal size of all meters was 150 mm. The form of the magnetization signal and its frequency was different in different meters. Some specifications of the meters are shown in the Table 2.

Table 2. Specifications of the tested electromagnetic flowmeters.

Meter	Magnetization method	Magnetization frequency [Hz]	Accuracy, pulse output	Accuracy, current output
EMF1	Pulsed AC	10.0	0.5 % of rate ±0.1% of range (12m/s) ±0.2% repeatability	Pulse +0.1%
EMF2	AC	50	1.0% of rate Q>0.05 Qmax, 0.0005 Qmax Q<0.05 Qmax	Pulse ±0.1% of rate
EMF3	DC (square wave current)	16.7	0.2% of rate ±1mm/s	Pulse ±5µA
EMF4	Dual frequency	NA	0.1% of span below 20 %, 0.5% at 20% or more (span 1-10 m/s)	NA
EMF5	Bipolar, pulsed DC (square wave current)	25	0.3% of MV, v> 1m/s, 0.2% of MV + 1 mm/s, v< 1m/s	Pulse ± 10 µA

Results

The results of the experiments performed with white water of the paper mill showed that two of the meters were clearly outside of the accuracy specifications, Figure 2. The repeatability of every meter in total volume measurement was quite good. However, there were sharp peaks and fluctuation in the current output signal of some flowmeters. Increasing the time constant of the signal filters can in principle eliminate these phenomena. However, this may disturb the function of control loops, because it will slow down the responses of the meters.

After the white water tests, mechanical and chemical pulp and machine stock of the paper machine were used in tests. Mechanical pulp was pumped into the test process in a consistency of about 4,5 % and it was diluted in several stages to the consistency level 2,7 %. Chemical pulp used in the tests was unbeaten long-fibered softwood pulp in consistency from 3,5 % to 1 %. It was found that with both mechanical and chemical pulp the consistency affected the error of the flowmeters, Figures 3 and 4. The effect seemed to be different on different meters, Figures 5 and 6. Ash content of machine stock seemed not to affect the measurement, because the errors measured with machine stock of the paper machine were of the same order as the errors with mechanical and chemical pulp of the same consistency, Figure 7.

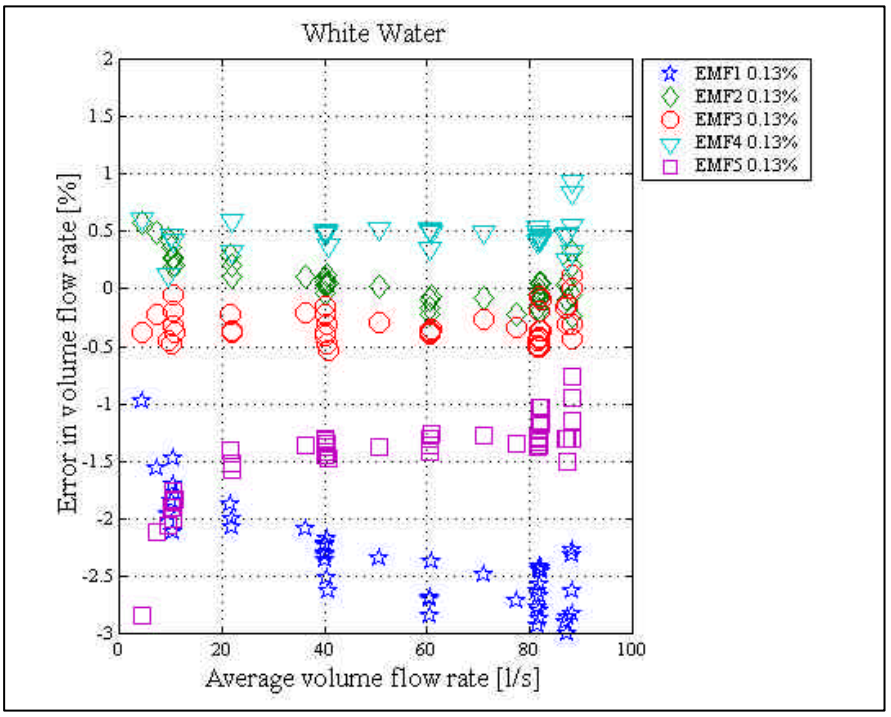

Figure 2. Errors of the five electromagnetic flowmeters in white water tests compared with the reference volume. The errors of the meters 2, 3 and 4 are less than 1 %, but the meters 1 and 5 have significant negative errors, which are outside of the specifications. The errors of these meters seem to be flowrate dependent, too. The repeatability of all meters at a specific flowrate is quite good.

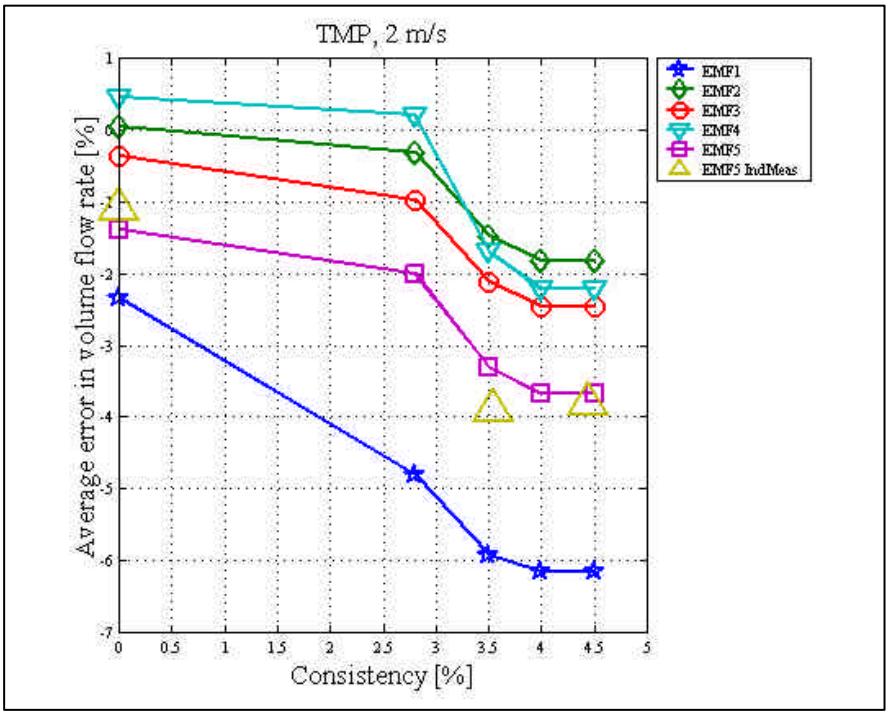

Figure 3. Consistency dependency of the averaged errors of the flowmeters in mechanical pulp tests at a mean flow velocity of about 2 m/s. The errors measured with the radiotracer method for the electromagnetic flowmeter 5 are shown, too.

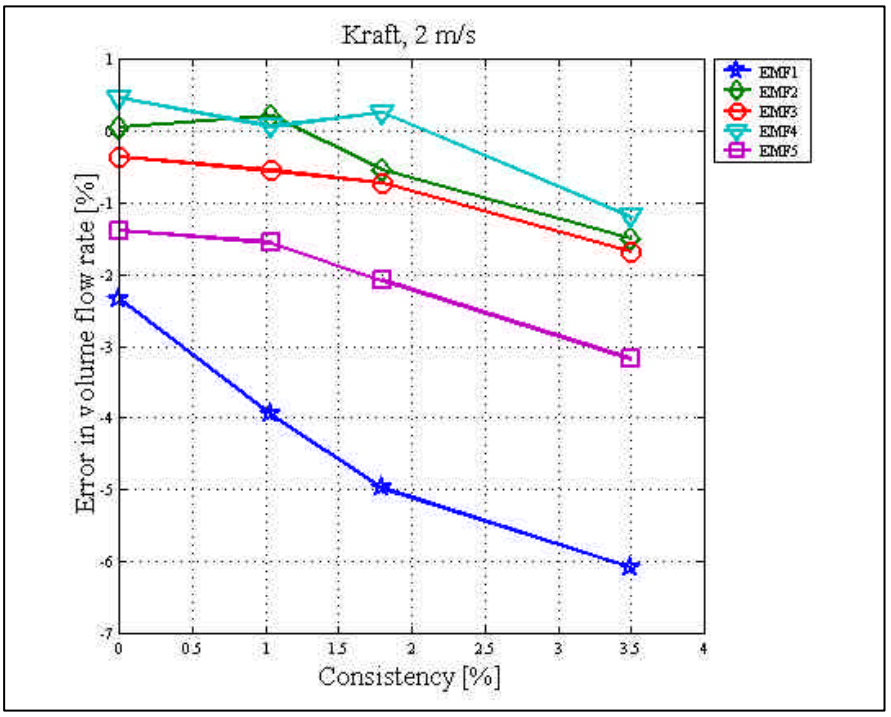

Figure 4. Consistency dependency of the averaged errors of the flowmeters in chemical pulp tests at a mean flow velocity of about 2 m/s.

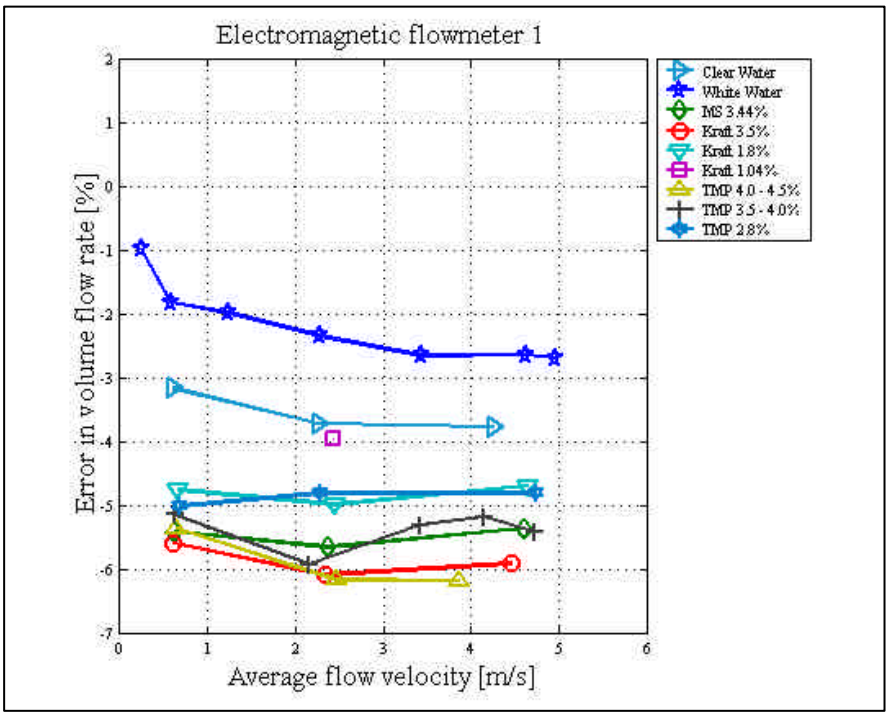

Figure 5. Averaged errors of the electromagnetic flowmeter 1 with water and different pulp flows at different flowrates. This meter showed biggest errors in all tests.

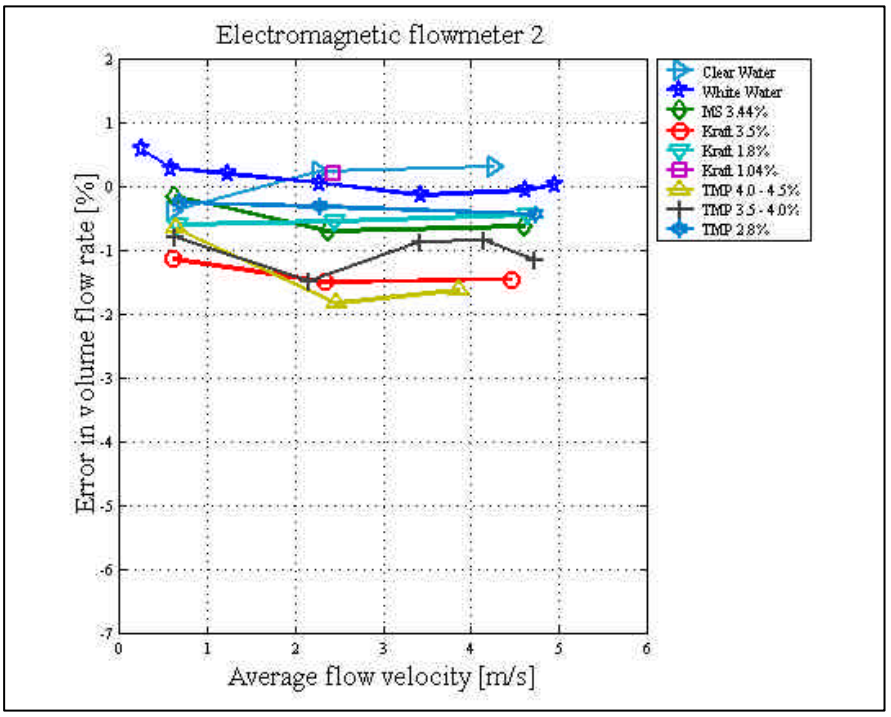

Figure 6. Averaged errors of the electromagnetic flowmeter2 with water and different pulp flows at different flowrates. The errors of this meter were found to be closest to the specifications given by the manufacturer.

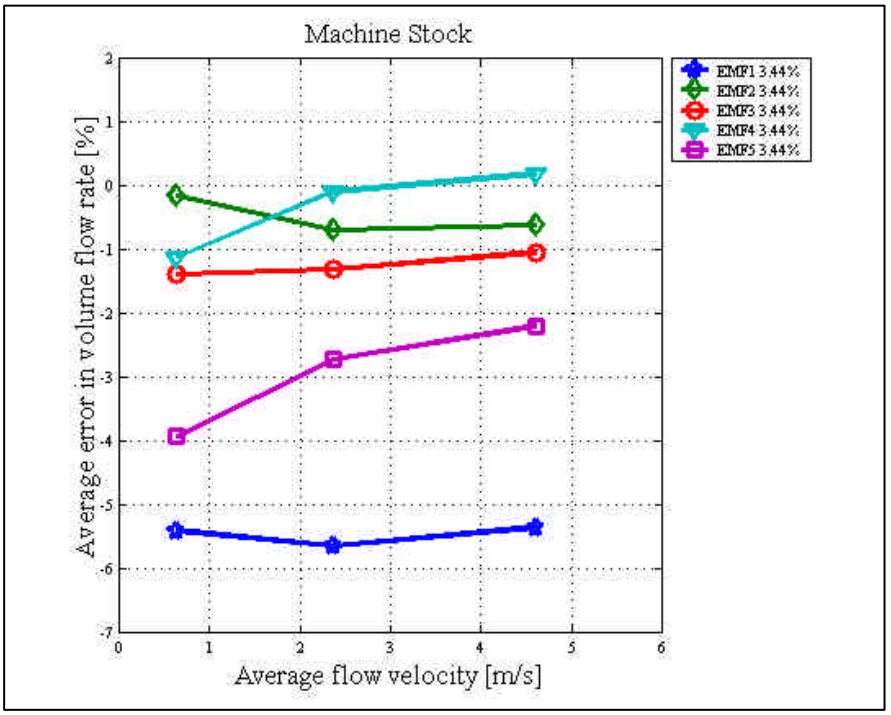

Figure 7. Averaged errors of the five electromagnetic flowmeters in machine stock tests. The error curve of every meter has shifted to the negative direction compared with the white water tests.

Effect of magnetization frequency

In clear filtrate tests it was found that the current output signal of the flowmeter 5 fluctuated very strongly, Figure 8. The magnetization frequency used during the white water and pulp tests of this meter was 25 Hz and the output signal of the meter was very stable compared with other meters. When the frequency was turned to 8,33 Hz in clear filtrate tests, the fluctuation disappeared, but the output signal was still very noisy. It is assumed that this phenomenon was due to the combined effect of low conductivity and internal signal processing of the meter.

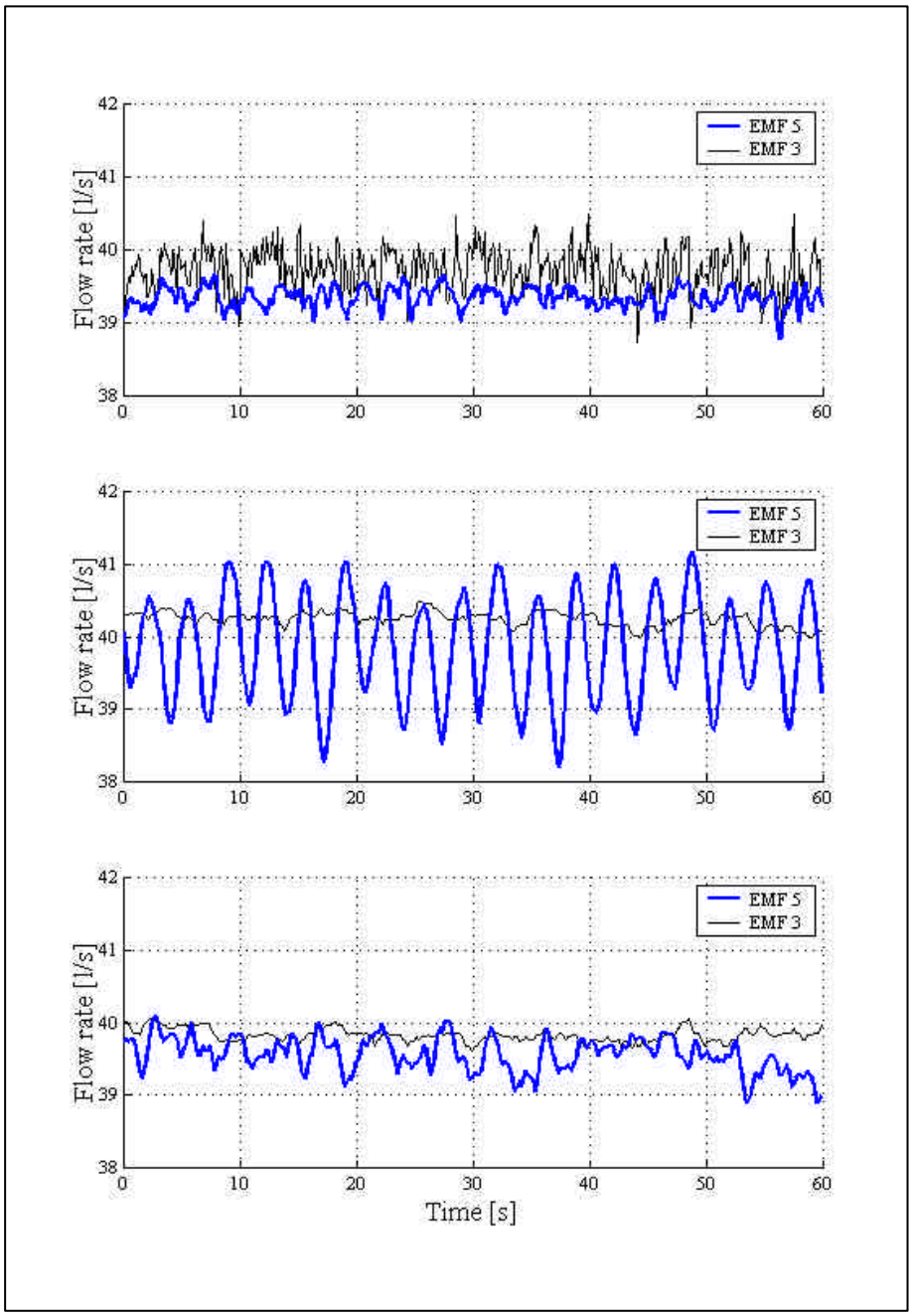

Figure 8. In white water tests the output signal of the flowmeter 5 was very stable (up), but when the fluid was changed to clear filtrate, there was a strong fluctuation in the output (middle). When the magnetization frequency was changed from 25 Hz to 8.33 Hz, the fluctuation disappeared, but the noise level was rather high compared with the output of the flowmeter 3 (down). On the contrary, in white water tests the output of the flowmeter 3 was noisier than the output of the flowmeter 5.

Comparison with an accredited calibration laboratory

Four of the electromagnetic flowmeters were calibrated after the paper mill tests in an accredited calibration laboratory. The results of the calibration laboratory were similar to the paper mill tests except with one meter. Its error curve shifted to the negative direction about 1 %, Figure 9.

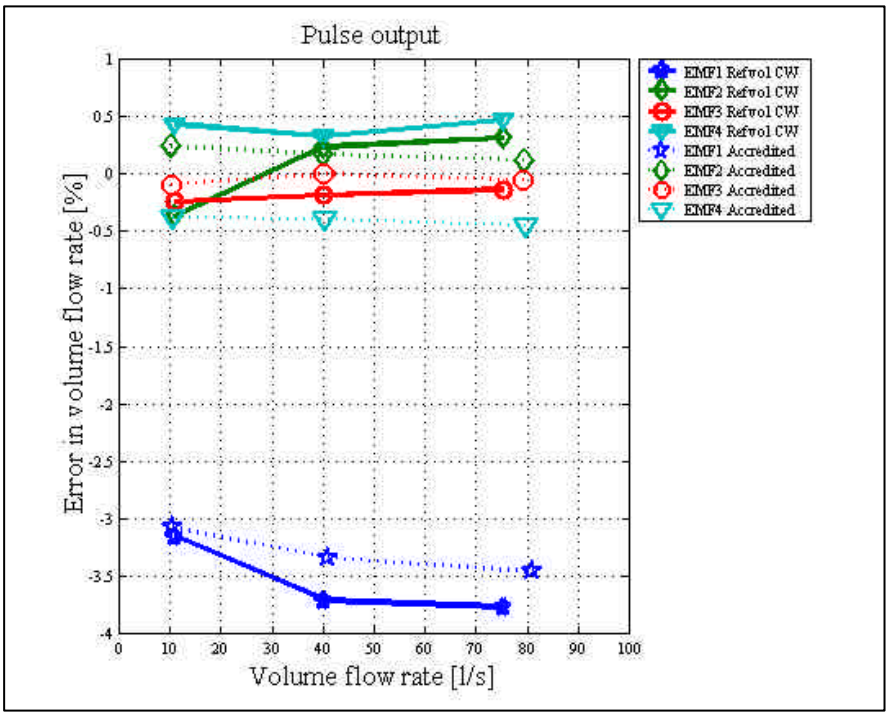

Figure 9. Averaged errors of the four electromagnetic flowmeters determined in an accredited calibration laboratory (dotted line) and with paper machine clear water (solid line). The error curve of the flowmeter 4 shifted to the negative direction about 1 %.

The possible error sources in the tests performed in the paper mill were the determination of the exact reference volume and the possible air content of the pulp suspension. The function of the level switches used in the determination of the reference volume might be non-ideal because of the wavy action of the level of the reference tank with water flows, or the unevenness of the level in pulp tests. The air content of the flow was measured during some test runs with a density meter, which showed no or very little density changes. Anyhow, calibration measurements performed with a radiotracer method for one flowmeter showed an error shift of the same order as the reference volume method.

Conclusions

Two of the five electromagnetic flowmeters were outside the accuracy specifications in all flow tests. The consistency of the flowing fluid was found to affect the reading of all flowmeters tested. The reason to this phenomenon has not been investigated. The possible reasons could be the non-uniformity of conductivity of pulp flows or the velocity profile effects. The electromagnetic flowmeters are usually calibrated in water flow with a turbulent velocity profile, whereas pulp is expected to flow as a plug with a thin water film near the pipe wall. The results achieved in the tests should be investigated more deeply, because the accuracy of flow measurements affects directly the calculation of mass balances of a paper mill and maybe in some cases the functioning of special sub-processes.

References

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