

Ultrasonic in-line rheology sensor for complex non-Newtonian liquid mixtures

P.L.M.J. van Neer¹, U. Stelwagen², E.N.P. Boer¹, L. Geers³, D. Piras⁴, E.J.M. Giling³

¹TNO (www.tno.nl), Oude Waalsdorperweg 63, 2597 AK the Hague, the Netherlands, email: paul.vanneer@tno.nl

²TNO, Anna van Buerenplein 1, 2595 DA the Hague, the Netherlands

³TNO, Leeghwaterstraat 44, 2628 CA Delft, the Netherlands

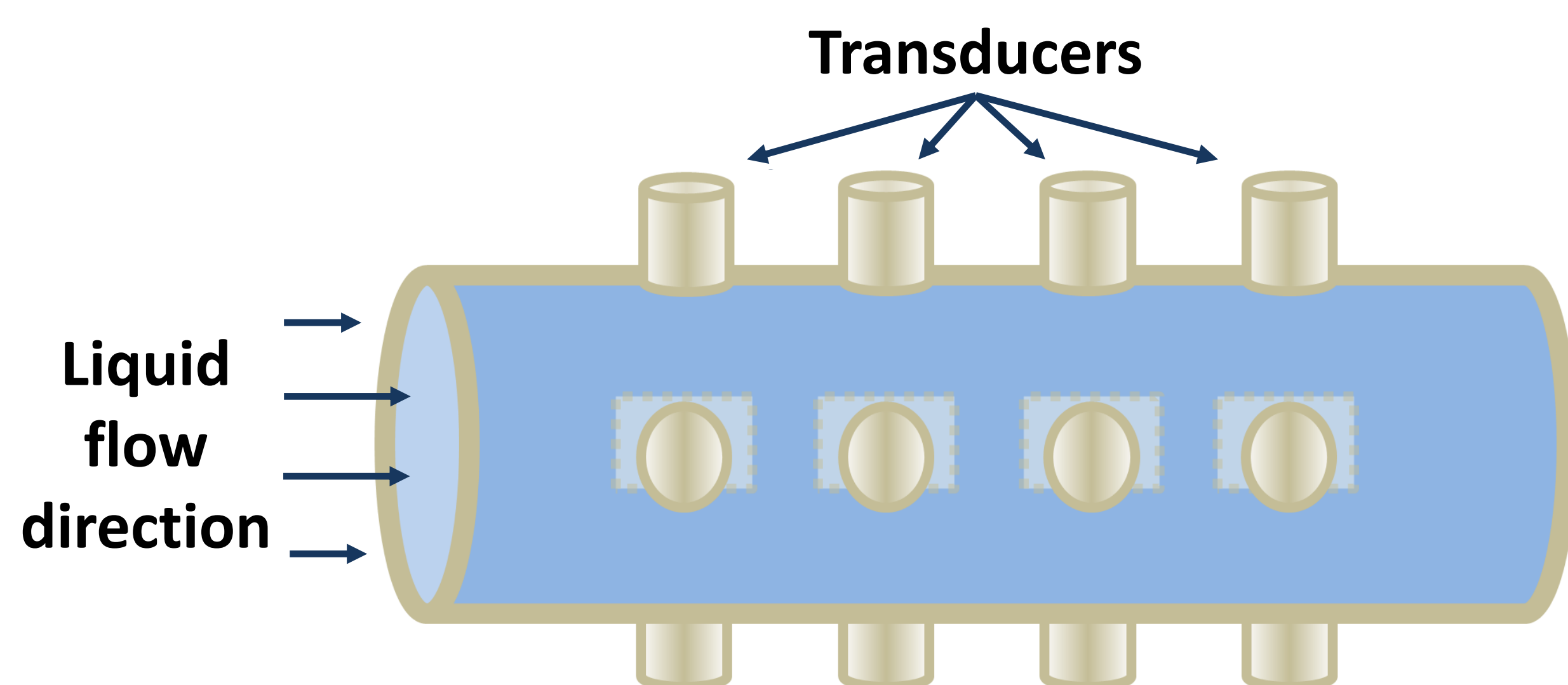
⁴TNO, Stieltjesweg 1, 2628 CK Delft, the Netherlands

Introduction

A large number of liquids used in the chemical industry exhibit non-Newtonian behavior. Examples of these are polymer-mixtures, emulsions and suspensions. These substances have a viscosity which depends on the shear rate. This property is a complicating factor in the mixing of liquids, the filling of packages and the dosing of specific amounts. The majority of in-line viscosity meters produce a single viscosity value, which is only correct for Newtonian liquids. Viscometers capable of describing non-Newtonian liquid behavior correctly are usually off-line, intrusive, or too slow for process control.

Sensor principle

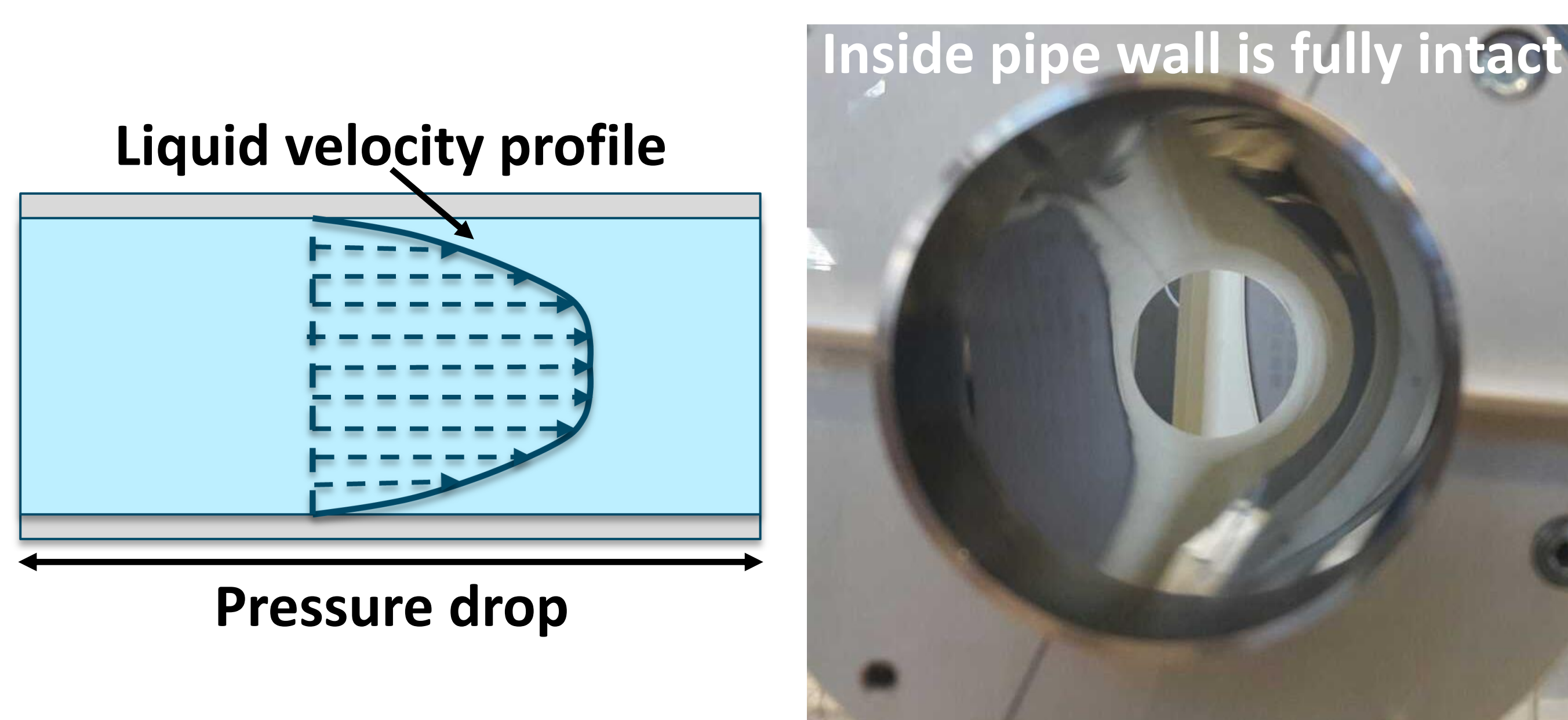
The rheology sensor is based on the propagation of ultrasound waves through the liquid of interest. By combining the measurements of several sensors using a tomographic algorithm the velocity profile can be measured. The velocity profile is then combined with a measurement of the pressure differential over the sensor to obtain the viscosity as function of the shear rate.



Sensor features

The sensor

- measures:
 - the viscosity as a function of shear rate
 - the velocity profile/volume flow
 - the pressure drop over the sensor
- works for Newtonian and non-Newtonian liquids,
- is in-line,
- is non-intrusive,
- works in the presence of gas bubbles and particles,
- has an upper shear rate limit depending on the liquid velocity.

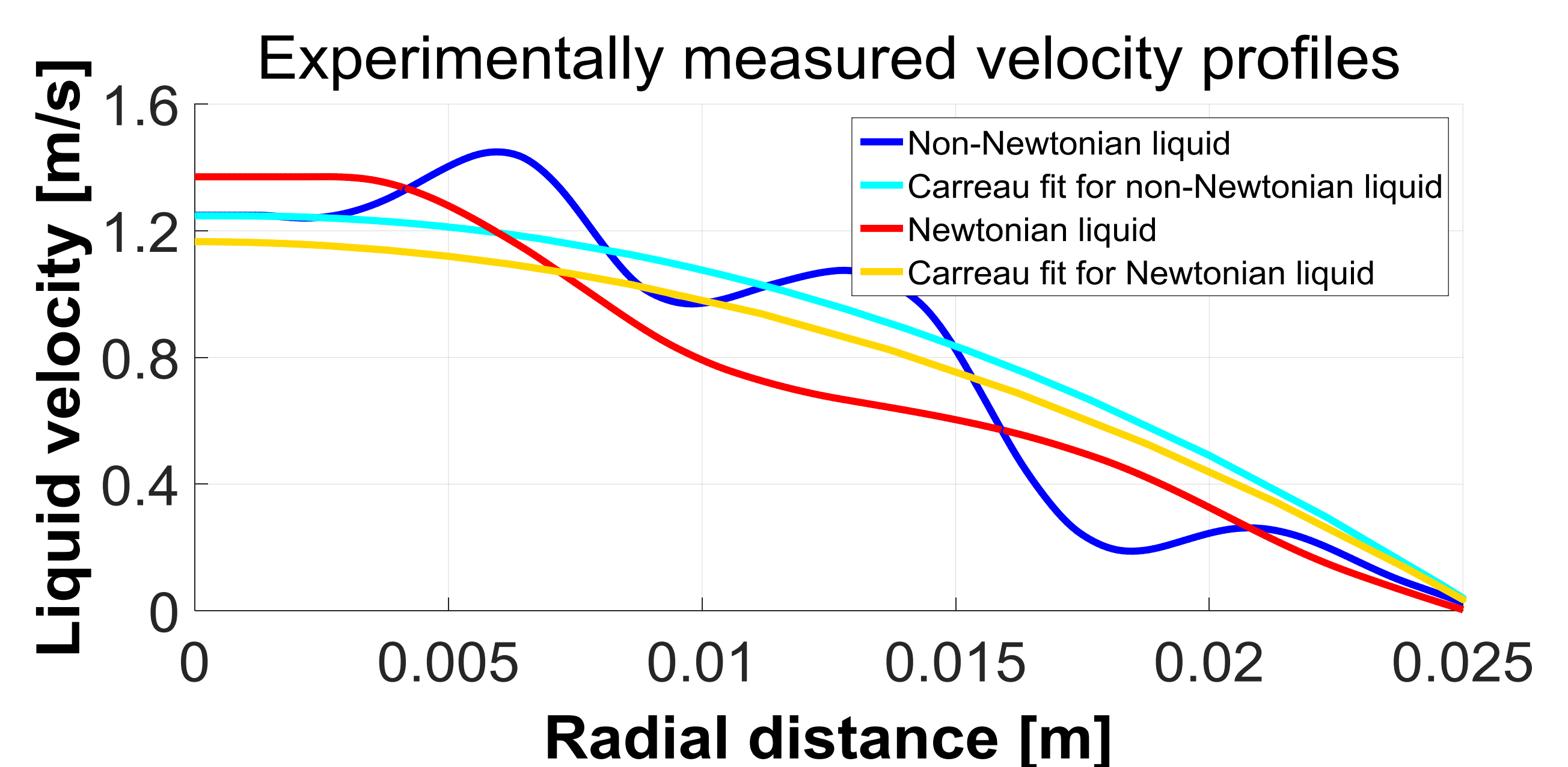


Results

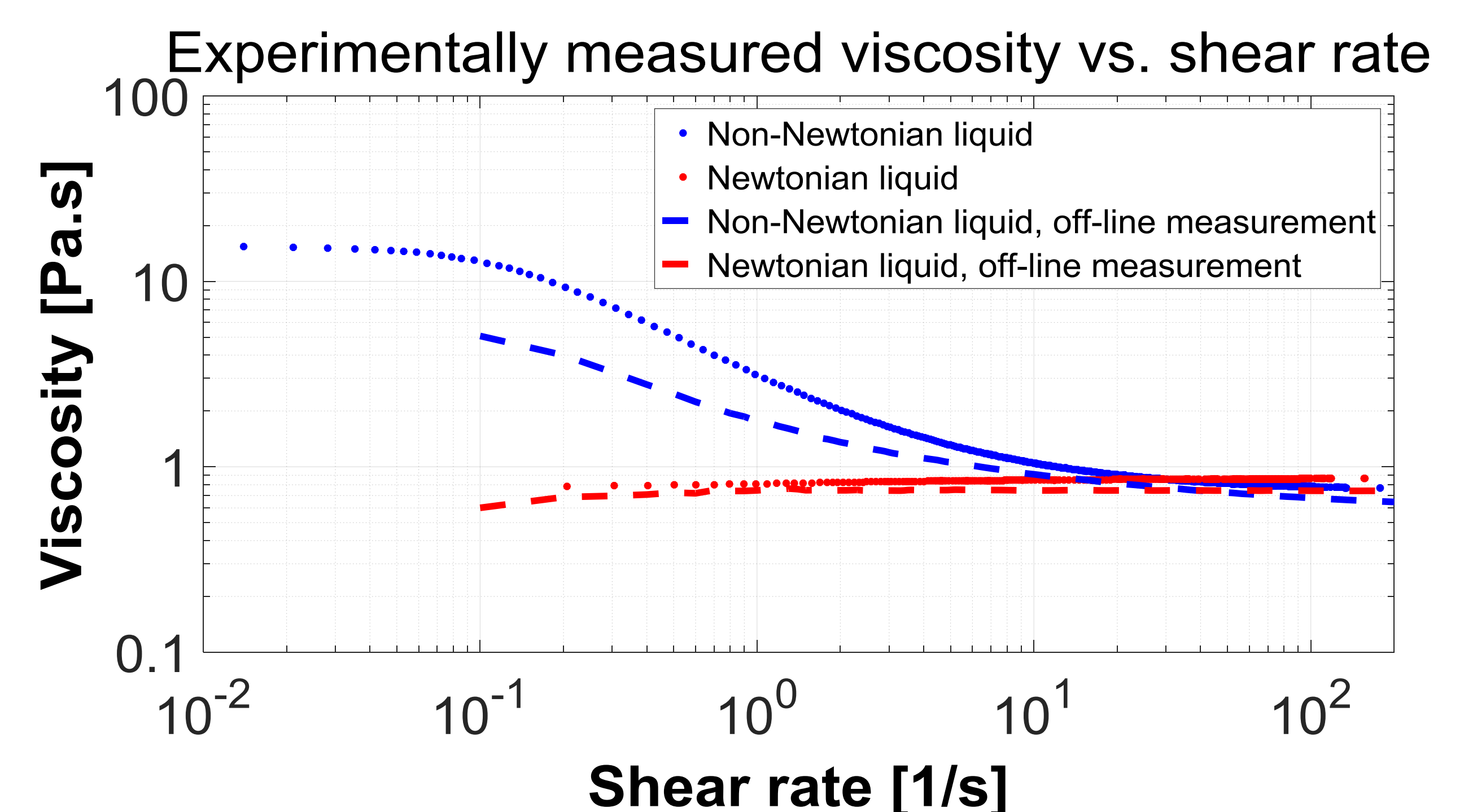
Initial experiments have been performed:

- with non-Newtonian mixtures (shear thinning),
- with Newtonian liquids,
- developed, laminar flow,
- at flow velocities of 0 – 2 m/s,
- at room temperature.

Some example results are shown below.



Note: the wobbliness in the velocity profile is partly caused by spurious wave modes in combination with spurious refractive effects. This will be solved in an updated design.



Conclusion

- A prototype of an inline rheology sensor has been designed, realized and tested at an industrial pilot site.
- The obtained experimental results verify the measurement principles.
- Potential for further accuracy improvements is identified.
- Patents pending.
- TNO is looking for partners for product development.

References and Acknowledgements

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