Analysis of cavitation noise at ultrasonic horn tip using an integrated sensor

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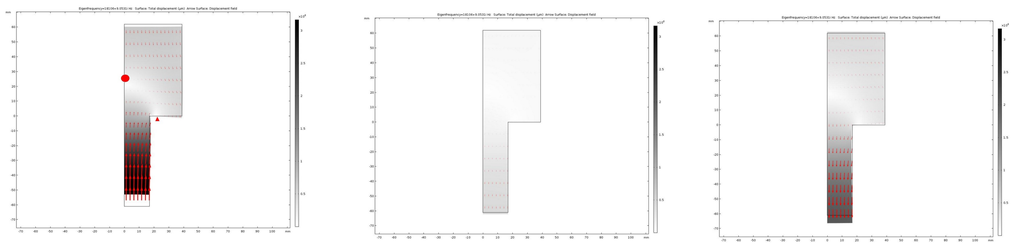
Introduction

Acoustic cavitation is an established process technology for homogenization, dispersion and sonochemical reactions in multiphase fluid systems. The analysis of the cavitation noise is providing the chance for a temporally high resolved insight to the dynamics of cavitation. For process monitoring suitable sensors with adapted analysis tools are required. Special challenges exist in the application of cavitation in turbid media, e.g. molten metals at high temperatures in an industrial environment [1].

This poster presents an improved cavitation sensor for power ultrasonic systems with advanced data analysis of cavitation noise. During investigations on a model system consisting of an operating ultrasonic horn in water acoustic emission signals were recorded and compared to high speed video recordings from the cavitation at the horn tip. From literature it is known, that the data analysis reveal characteristic signatures of „attached cavitation at a ultrasonic horn tip“ [2].

This work is discussing the recordings of an integrated cavitation sensor far away from the tip using the tools of advanced data analysis.

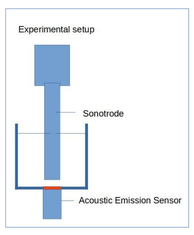
Integrated Cavitation Sensor

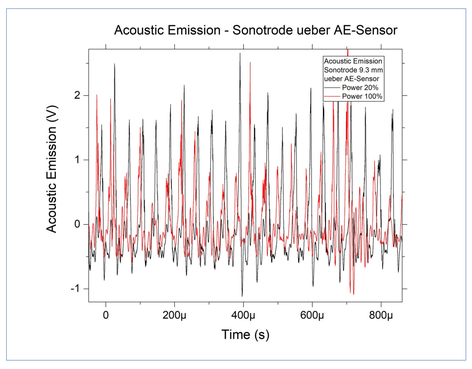


Cavitation Sensor: The Sonotrode works as an acoustic wave guide for the high frequency waves of cavitation. An integrated sensor is placed at a neutral point, denoted by a red point, where the displacement field of the exciting mode is zero [3].

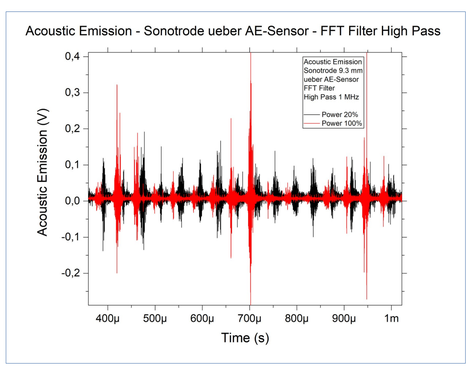
Acoustic Emission Sensor under Sonotrode

- Time series of Acoustic Emission of AE-sensor (Sonotec) sample rate = 62.5 MS/s
- UP200s Dr. Hielscher ultrasonic processor with sonotrode diameter d = 14 mm, electric power input 200W
- Distance to AE-sensor 9300 µm = 9.3 mm
- High-speed imaging: Photron FASTCAM Nova S16

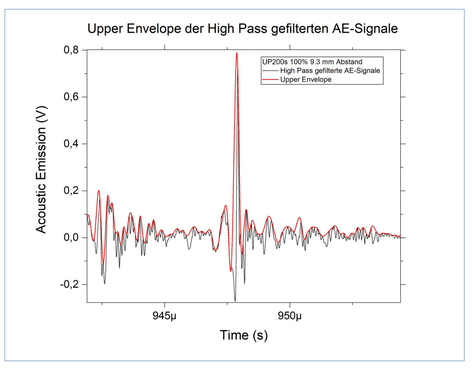




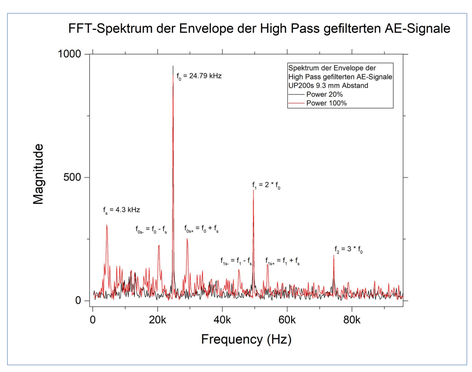
Acoustic Emission recorded from AE sensor in face to the Sonotrode. Power 20% and power 100%.



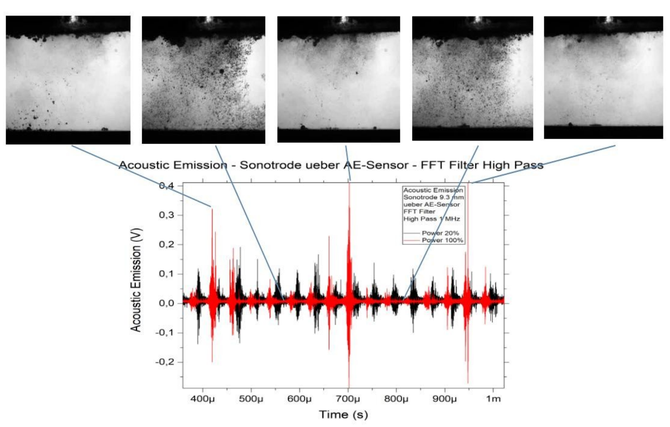
High pass FFT filter 1 MHz. High frequency signals of cavitation in fluid volume.



Upper Envelope of the high pass filtered AE signals.



FFT spectrum of the upper envelope of high pass filtered AE signals. The f_0 is the exciting frequency. f_s is shedding frequency with satelite frequencies f_{0-s} and f_{0+s}.

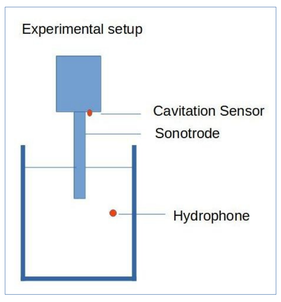


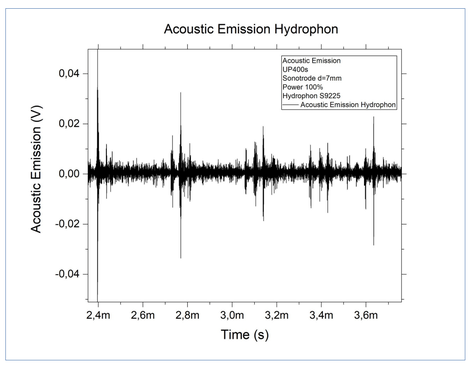
Synchrone display of high frequency signals (above 1MHz) together with high speed imaging. Sonotrode (ultrasonic horn) above and AE-sensor below. The shedding time is 5-6 times of the period of f_0.

Hydrophone Sensor and Integrated Cavitation Sensor

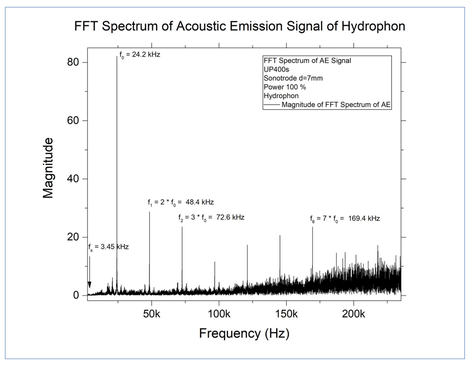
- Time series of Acoustic Emission of AE-sensor (Sonotec) with GMBU data logger 25 MS/s
- UP400s Dr. Hielscher ultrasonic processor with sonotrode diameter d = 7 mm, electric power input 400W

- Integrated cavitation sensor S9225 on a neutral point
- Hydrophone sensor also S9225 in model fluid water in the free fluid volume.

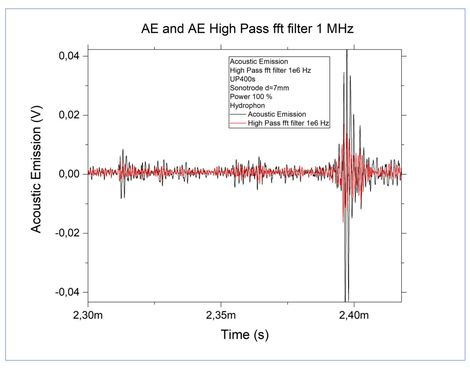




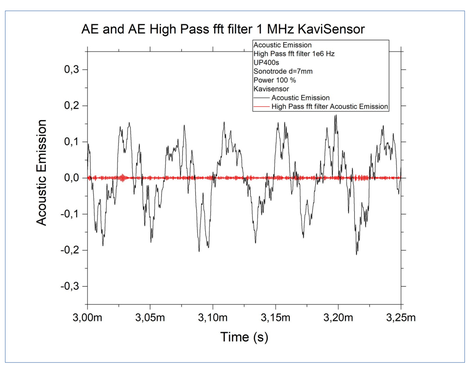
AE recorded by the Hydrophone Sensor (Power 100%)



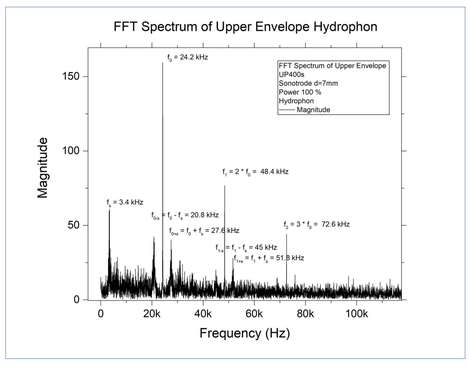
FFT spectrum of AE signal. No shedding frequency is visible.



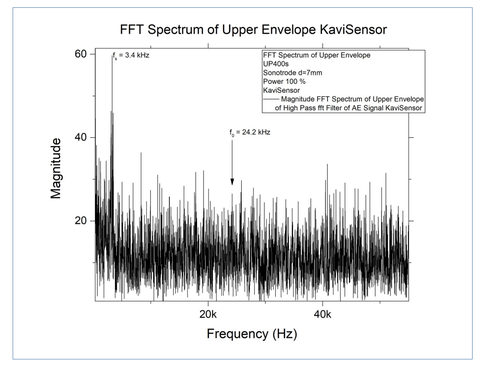
AE and AE high pass fft filter 1 MHz recorded by the Hydrophone Sensor.



AE and AE high pass fft filter 1 MHz recorded by the Cavitation Sensor.



FFT spectrum of upper envelope of high pass filtered AE signals. The f_0 is the exciting frequency. f_s is the shedding frequency with satelite frequencies f_{0-s} and f_{0+s} from the hydrophone sensor.



FFT spectrum of the upper envelope of high pass filtered AE signals of the cavitation sensor. The f_s shedding frequency is visible.

Conclusion

- The acoustic signature of shedding from cavitation clouds is the modulation of the high frequency amount of the overall acoustic emission signals.
- The shedding frequency is visible in the FFT spectrum of the envelope of the high pass filtered AE signal.
- The data analysis of the acoustic emission of the cavitation sensor shows the shedding frequency of the attached cavitation cloud on the tip of the sonotrode.

References

[1] Tzanakis, I., Lebon, G. S. B., Eskin, D. G., Pericleous, K. A., Characterisation of the ultrasonic acoustic spectrum and pressure field in aluminium melt with an advanced cavitometer, Journal of Materials Processing Technology, 229 (2016) 582-586

[2] Znidarcic, A., Mettin, R., Cairos, C., Dular, M., Attached cavitation at a small diameter ultrasonic horn tip, Physics of Fluids 26, 023304 (2014)

[3] Patent DE 10 2010 043 316 B4, Patent pending 10 2021 120 442.9

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