Shape and Positioning of Ultrasonic Transducers in Flare gas Applications

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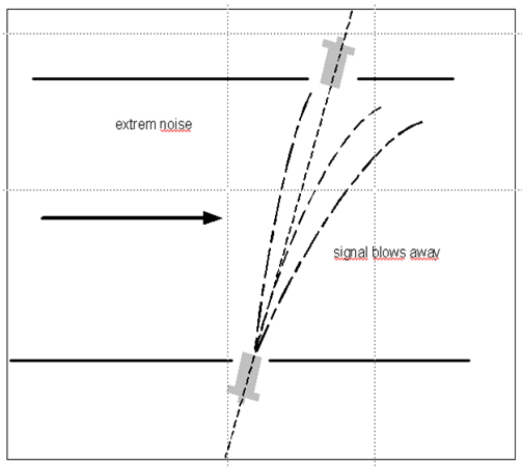
Introduction:

Over time ultrasonic flow meters became popular for flare applications because of the big turndown-ratio and it's capabilities of reading mass flow. By following "EPI Guidelines" or "EU Guidelines for Reporting CO2 Emissions" the mass CO2 emitted is calculated. To date the installation and positioning of the ultrasonic transducers is carried out in different ways. The installation is critical toward the performance of a flow meter.

An ultrasonic flow meter measures the time difference over an acoustic path in an angle toward the process. If however the flow velocities are getting over approximately 70 m/s the acoustic signal tends to bend off with the flow.



Even though these signals have a cone shape finally this will result in the signal not reaching the second transducer, which causes then signal loss. This signal drifting is the main cause of losing the measurement at these high flow velocities. Shaping and positioning of transducers can lead to major improvements in maximum measurable flow velocities. One of the main causes of signal drifting is turbulence in front of the sensor face.

Fig. 1 Beam drift

Another important parameter is the noise created by the process and the noise generated by the flow itself directly over the transducers.

Shape:

The reduction of beam drifting would lead immediately to higher measurable flow velocities. If we now introduce the "Joukowski profile" (fig. 2) from aerodynamics, which is in shape the wing of an aero plane, we can reduce turbulence in front of the transducer face as well as the noise generated by the flow over the transducer. Figure 3 shows the implementation of the profile onto the sensor head. In this case the pattern itself is made of a high density Teflon which has as positive side effect that Teflon has a reduced adhesive character towards pollution. Even though ultrasonic flow meters are in general not very sensitive to pollution we also should consider that flare gasses are generally not clean. Also liquid carry overs can cause a built-up of dirt.

The shape itself assists in extending the maintenance time for cleaning.

Fig.2 Jakowski Profile

Fig. 3 Shaped Transducer

The signal to noise ratio is increasing significantly by adapting this modification.

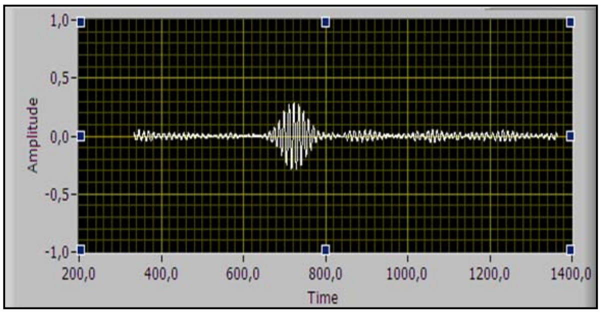


Fig.4 Standard Transducer

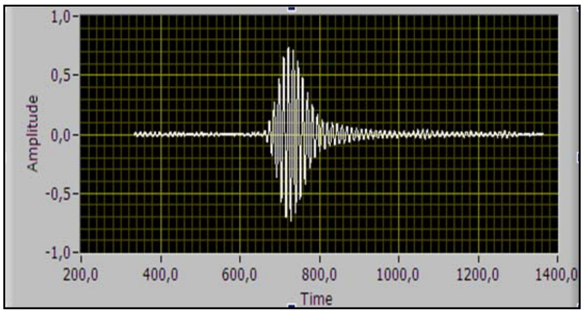


Fig 5. High Speed Transducer

The implementation of the “Joukowski Profile” on the sensor head reduces the noise level with 50% (~2X bigger amplitude) and the beam drift effect for about 30%. Higher flow velocities up to 120 m/s became feasible now, measured complete cross duct.

Considering now that pipelines are not always 100% accessible, measurements could also be performed by having a flow optimized body in the stream.

Fig 6. Probe Version

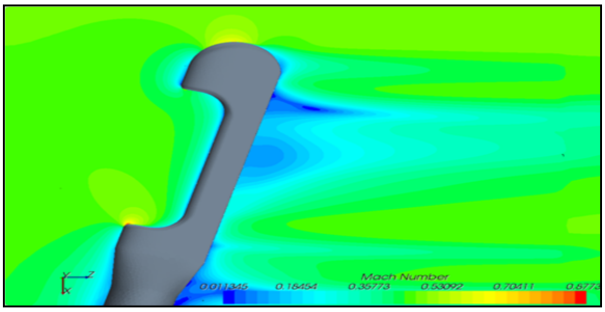


Fig 7. CFD animation

If installed under an angle to process transit time can be measured in the same way as cross duct solutions. CFD simulation shows that there is no major flow profile disturbance from this flow optimized body. Also here the “Joukowski Profile” is adapted. By having now a fixed distance in between the transducers in the flow optimized shape, the alignment in the field will also be easier when used in hottap installations as there is just 1 flanged connection to process and the transducers can be aligned in the production process.

Positioning:

The nozzle position for ultrasonic flow devices is important. Especially installation angles and axial distance between the nozzles within tolerances are important measures towards performance and accuracy. As cross duct transducer installations are flush with the inner wall of the pipe, they are quiet straight forward in their positioning. For this reason we will take a closer look at the probe version and it’s positioning.

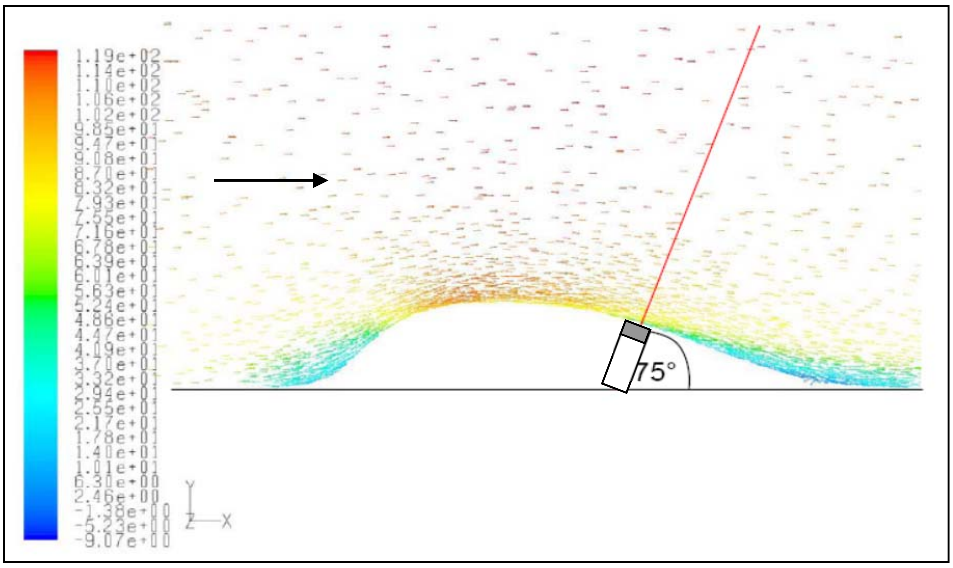


Fig 8. Simulation result

For both the high speed sensor design and the probe version, the optimal angle turned out to be 75˚ as per CFD simulation. At this angle the turbulence in front of the sensor face is the less.

Based on literatures and regulations (Gätke, Johann "Akustische Strömungs- und Durchflußmessung"; ISO DIS 7145) there is a nearly „stable“ area in the flow profile where no dependency on Reynolds number is present. The offset is constant 1,014. The position is 0.4 * Radius. Here the present flow velocity is representative for the area velocity.

The condition under which this applies is a developed flow profile. This means that the Reynolds number >3000 and a developed profile by isometrics. The advantage with that is primarily that the distance to the pipe wall is small. In an emergency situation the flow condition can be very high. By having a reduced insertion length this mechanical force will be reduced.

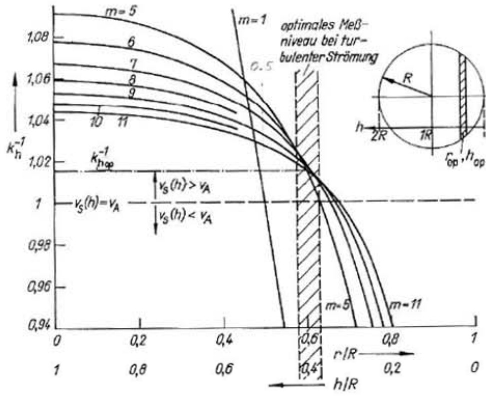


Abb. 8.16. Kalibrierungsfaktor bei exzentrischer Meßanordnung und optimales Meßniveau bei nur turbulenter Strömung

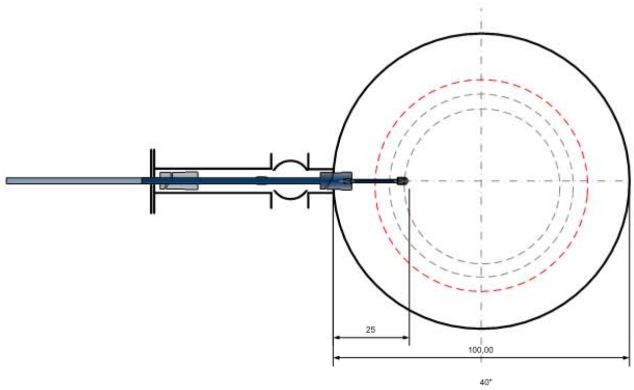


Fig 9. Optimized position for Reynolds number independency

Fig 10. Probe position

Field tests showed that there is a very good correlation between cross duct measurements and this probe installation. For increased accuracy or at very big flare stacks also 2 path probe solutions could be considered.