Poster Paper

Simulating Horizontal Wet Gas Flow Meters with CFD

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INTRODUCTION

The accurate measurement of the flow of wet gas production is a technically challenging feat. However, the ability to meter wet gas flows can have a significant impact, improving the economics of production, reducing the need for expensive measurement infrastructure and potentially making previously uneconomic gas reservoirs viable.

Experimental studies have gone a long way in improving the understanding wet gas meter performance. However, experiments are relatively slow and expensive and as most tests are performed at high pressures, to match conditions seen in the field, detailed information on the flow behaviour within flowmeters in sparse.

Computational Fluid Dynamics (CFD) flow simulation methods offer a potentially powerful tool for investigating wet gas flows in more detail. In this paper the predictions of a two-dimensional CFD modelling method has been compared against published test data to assess and extend its range of applicability. A second three-dimensional approach has been developed and assessed that more correctly represents the multiphase flow patterns seen in wet gas flows, particularly at lower velocities.

TWO-DIMENSIONAL CFD MODEL

The two-dimensional method was identical to that developed by Jeff Gibson at TUV NEL to study the effects of varying liquid properties on Venturis in wet-gas [1]. The aim of this work was to find out whether this approach was valid for cone meters and Venturis.

In essence, the flowmeter is represented as a two-dimensional axisymmetric model in the ANSYS Fluent 12.0 CFD software [2]. The liquid and gas are represented as separate phases using the Eulerian multiphase model. This represents the liquid as droplets suspended in the gas. Mist flow conditions are assumed at the inlet to the flowmeter for all flow conditions.

Initially simulations were run of a beta 0.6 Venturi in kerosene-nitrogen flow at different gas Froude numbers. The droplet size was adjusted until the predicted over-reading matched that measured in the tests.

Further models were then run of orifice plates and cone meters over a wide range of wet-gas flow conditions. In these models the droplet size for a given gas Froude number was set to be the same as that for the original Venturi model. Figure 1 shows a typical prediction of liquid fraction in a cone meter. It was found that this approach produced a close prediction of the meter over-reading in annular-mist flow and mist flow regimes. However, unsurprisingly, it under-predicted slightly for when the true flow regime was stratified.

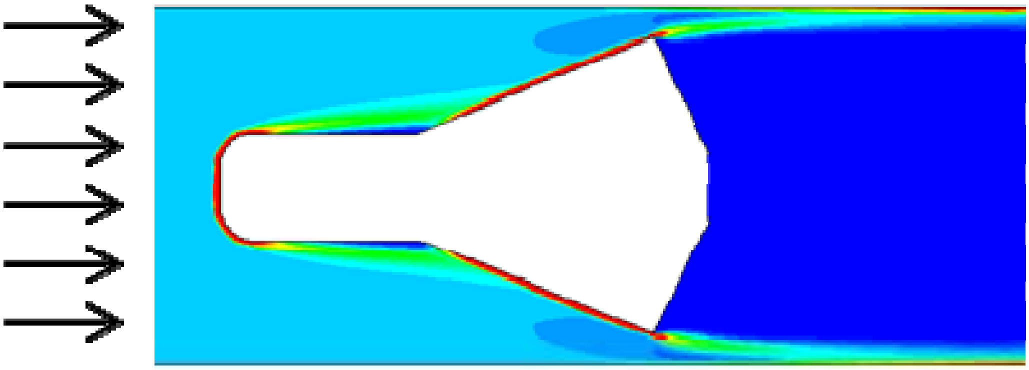

Figure 1 Contours of liquid fraction in the two-dimensional simulation of a cone meter

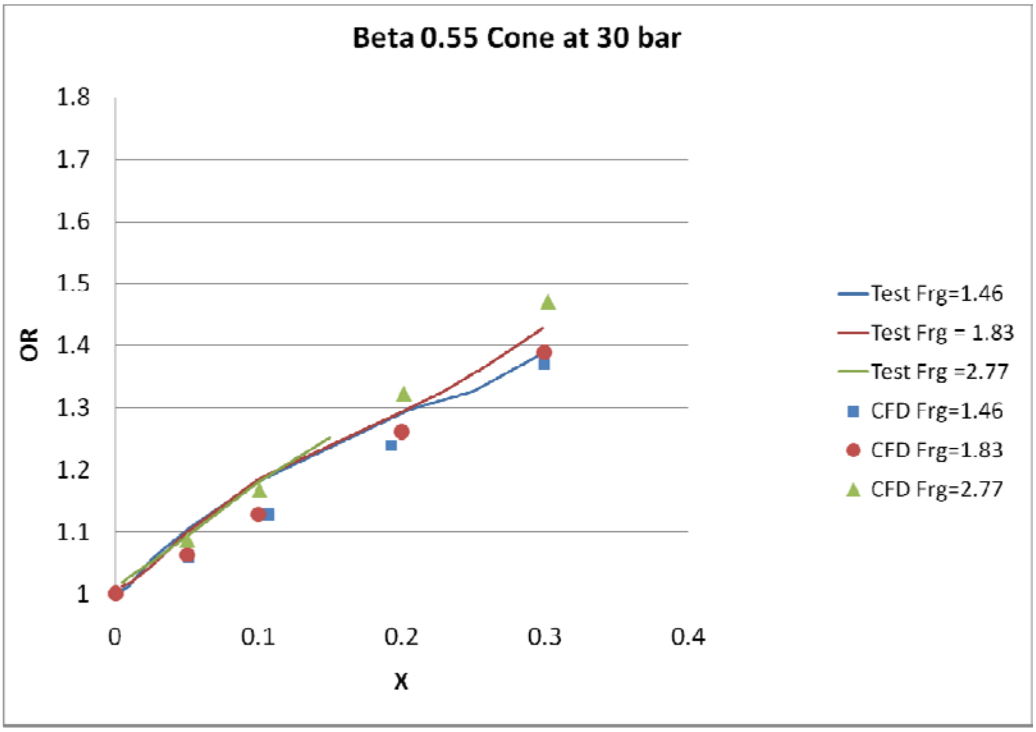

Figure 2 Comparison of test data and two-dimensional CFD predictions for a beta 0.55 cone meter

THREE-DIMENSIONAL CFD MODEL

The two-dimensional approach has the disadvantage that there is little physical basis for the choice of droplet size, other than it gives a reasonable prediction of over-reading. Also, features such as annular wall-films and stratified liquid layers are not represented in the model. A three-dimensional approach was therefore developed to address these issues.

The three-dimensional model used the immiscible Eulerian model. This is similar to the standard Eulerian model used previously, but it includes a surface-sharpening algorithm that helps to maintain liquid films and liquid layers, should conditions allow them to form. As the model was three-dimensional, the effects of gravity were included. The droplet size was based on a correlation developed by Azzopardi [3]. In all cases liquid was injected at the inlet in the form of an annular ring and droplets in the core. The fraction of liquid in droplet form was based on a modified version of the Shell flow regime map [4] as shown in Figure 3. In stratified flow the flow regime map dictated that all of the liquid would be injected as an annulus at the inlet. As flow velocities are low in stratified flow this annulus would collapse into a stratified layer upstream of the meter. Thus the flow regime experienced by the meter was reasonably realistic.

The model was used to simulate wet-gas flow through orifice plates, Venturis, cones and wedge meters over a range of different conditions. A typical liquid fraction contour plot is shown in Figure 4. Note that Figure 4 has been truncated and that the development length (necessary for the flow to stratify) is not shown. Figure 4 clearly shows liquid films on the pipe walls and on upstream-facing surfaces of the cone. Droplets in the core may also, just about be seen.
The three-dimensional method was found to account for stratified flow better than the two dimensional method. It also successfully reproduced behaviour measured in the TUV NEL and CEESI test loops, showing that it is not “tuned” to any one test facility.

CONCLUSIONS

It has been shown that CFD methods can be applied to model wet-gas flows. Two alternative approaches have been developed, and these will probably be used in tandem in any further studies. Potential applications of this technique include meter development, assessment of liquid properties effects and extrapolation of laboratory calibrations to field conditions.

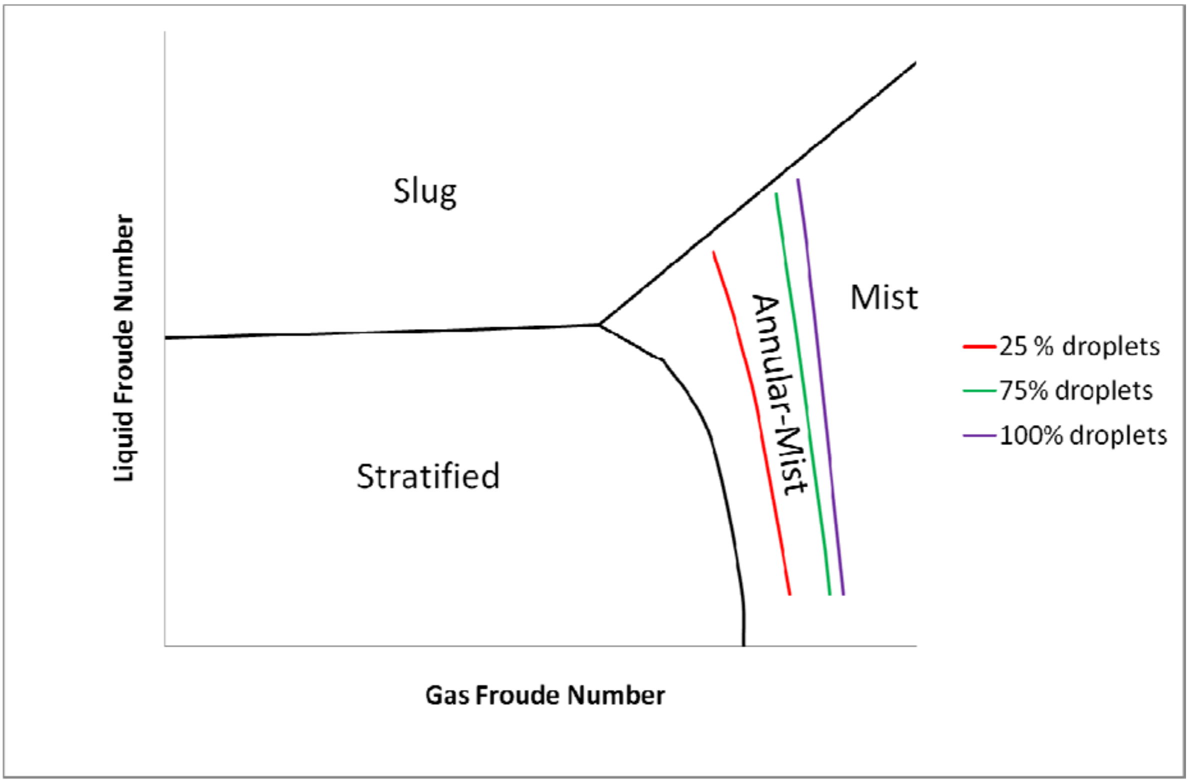

Figure 3 **Flow Map used in three-dimensional simulations (not to scale)**

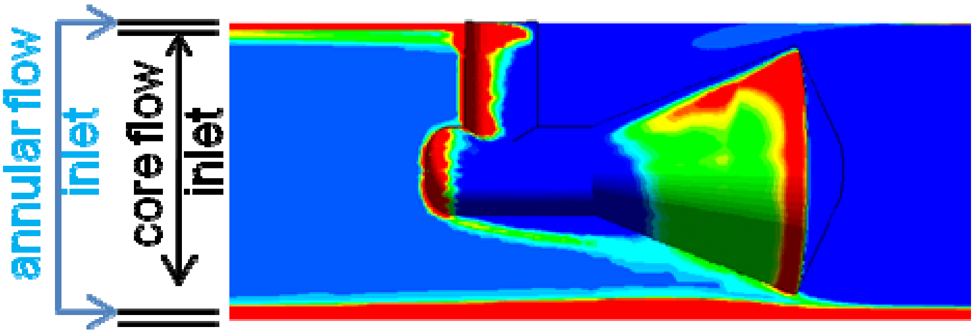

Figure 4 **Contours of liquid fraction in the three-dimensional simulation of a cone meter**

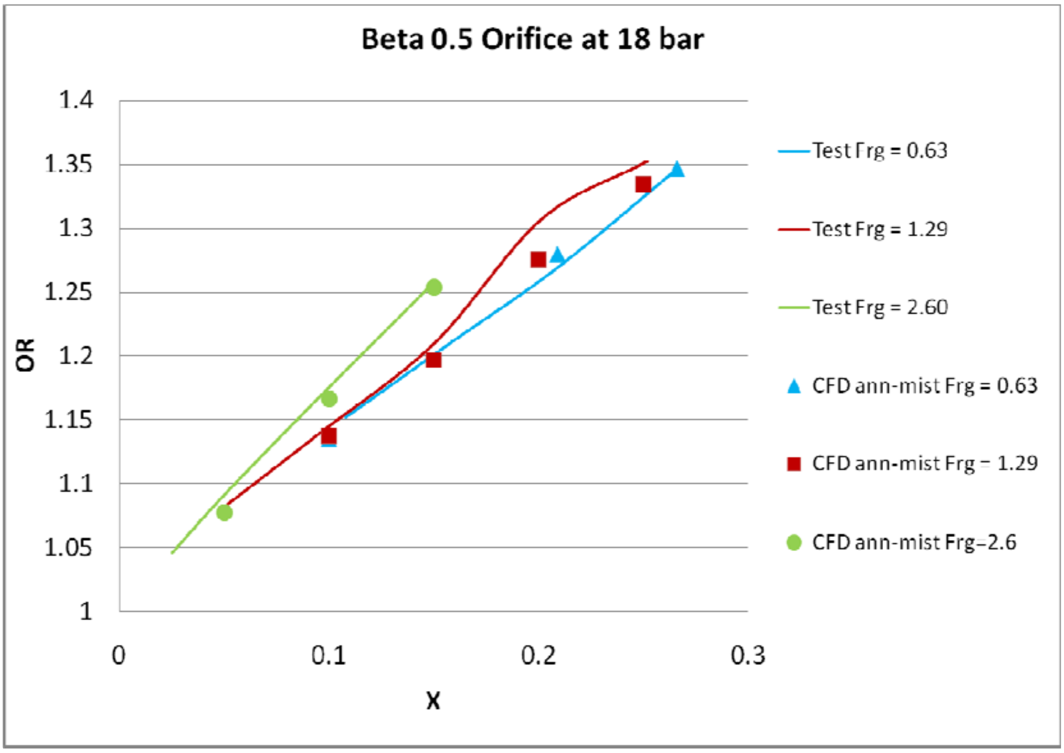

Figure 5 Over-reading for orifice plate tests at CEESI [5] (4 inch Orifice Plate)

REFERENCES

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