FLOW ASSURANCE: A NEW CHALLENGE FOR CHEMICAL ENGINEERS

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Abstract

Flow Assurance (FA) in the Oil & Gas Industry is the discipline which deals with the transmission of oil, gas and water in the same pipeline, from the reservoir to the receiving facility. The emergence of this discipline in the last 20 years has been driven by the inherent complexity of multiphase flow systems, combined with the hostile environment found in deep-water oil and gas production systems. The main challenges of FA and, in general, of Subsea Process Engineering are:

- Lack of reservoir pressure required to ensure the expected production.
- Onset of unsteady flow conditions, characterized by the formation of long liquid slugs (terrain slugging).
- Formation of gas hydrates or build-up of solid deposits (wax, asphaltenes, scale, sand).
- Formation of high viscosity liquid-liquid or solid-liquid emulsions.
- Erosion and corrosion phenomena.

All these potential problems have negative effects on the expected hydrocarbon production and in some cases may lead to pipeline blockage or may oblige to interrupt the production, with an enormous financial loss.

Multiphase flow in hydrocarbon pipelines represents the basis of Flow Assurance and the establishment of FA as a new technical specialty in the Oil and Gas Industry has been supported by the development in the early 80's of the dynamic gas-liquid flow model, OLGA (1). This flow simulator was originally developed to face one of the major FA problems, the onset of severe slugging in a subsea pipeline. OLGA was also able to describe slow transients, typical of pipeline transport operations, such as variable production rates, pipeline start-up and shut-in, pigging operations. The code then evolved into a three-phase gas-liquid-liquid flow model, able to describe hydrocarbon flow in complex pipe networks, in presence of valves, separators and pumps. At the same time the date base of the code was extended with field data and laboratory data taken close to field conditions, as far as fluid properties and pipe diameter concern. Unfortunately, for confidentiality reasons, after the first paper, very little has been published on the data base, the empirical correlations and the numerical structure adopted by the code. According to available information, OLGA is similar to the dynamic nuclear reactor codes from which it was derived. In particular, the code is based on the solution of one-dimensional transient mass and momentum conservation equations for the gas and liquid phases and on a set of empirical closure relations derived from the technical literature. However, due to the limitations of the hardware available and the numerical schemes adopted, OLGA is still obliged to use a very rough description of the different flow patterns and of the transitions among them. To this it may be added that the slug flow model adopted by OLGA is very poor, even if compared with the slug flow models available when the code was first developed (2). As slug flow is the most common flow pattern in hydrocarbon transmission lines, this defect of OLGA is a serious one.

Notwithstanding its major limitations, over the years OLGA became the reference tool for commercial FA studies. The absence of serious competitors probably prevented any significant evolution of this flow simulator, whose main core still appears to be very similar to its first version. In recent years the situation changed because, due to the increasing interest towards the FA applications of multiphase flow and the clear inadequacy of OLGA, the Oil Industry invested consistent resources into the development of an alternative commercial code, LEDA, (3) and also of a new, advanced model of gas-liquid pipe flow, MAST, (4), whose main characteristics are described in this paper. Regarding LEDA, it is difficult to detect appreciable differences with OLGA. In industrial applications it has been found that the results obtained with LEDA most of the time are very similar to OLGA's results (5). This may be due to the fact that the two codes are based on the same data base. In any case, LEDA presents the same problem as OLGA: for confidentiality reasons the user is not allowed to access the numerical schemes, the data base and the closures adopted by the code. This certainly helps in hiding any possible flaws of the code, but makes it very difficult to evaluate the code reliability.

In this paper it is shown that the use of a fine grid allows the onset of large waves or liquid slugs at a gas-liquid interface to be detected by the direct solution of the transient two-fluid model equations (4). This result can be coupled with a set of closure equations derived from the open literature (5-8) which allow the friction factor at the gas-liquid interface (5), the gas entrainment at a slug front (6), the void fraction in liquid slugs (7) and the rates of droplet entrainment and deposition (8) to be computed. The final result is a fully dynamic code which does not require transition rules among flow patterns, as these transitions directly arise from conservation and closure equations. This approach allows all flow patterns, stratified, dispersed, bubble and in particular, slug flow to be described as transient flow patterns which continuously evolve along the pipeline also when the flow, on the average, is steady. As a major difference with OLGA, the code computes the slug length and velocity distribution at pipe exit. This result, which is very useful in industrial applications, represents a substantial change with respect to the conventional slug unit model proposed by Duckler and Hubbard(2) and partially adopted by OLGA.

Finally, model equations, numerical schemes and the data base adopted by MAST have been and will be published in the open literature and in the present phase of code assessment, MAST is freely released and open to the contribution of Universities and Oil/Service companies.

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