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poświęcone są publikacjom naukowym z zakresu teorii i badań doświadczalnych w dziedzinie mechaniki i termodynamiki przepływów, ze szczególnym uwzględnieniem problematyki maszyn przepływowych

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exist for the publication of theoretical and experimental investigations of all aspects of the mechanics and thermodynamics of fluid-flow with special reference to fluid-flow machinery

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WOJCIECH SPISAK, LEON TRONIEWSKI, ROMAN ULBRICH

Opole*

Experimental Investigations of the Froth/Annular Flow Transition in a Vertical Pipe**

An analysis of the boundaries of annular flow development as reported in the literature has been carried out on a single map with coordinates composed of the gas and liquid superficial velocities. A large divergence in the literature data has been found. The new transition line for the annular flow determined by means of analysis of the literature data has been compared with results of the authors experimental investigations.

In many industrial operations gases and liquids flow vertically upward through pipes. For the upflow some general types of flow pattern have been reported in the literature and correlated empirically as functions of the flow rates and flow properties.

The prediction of flow patterns is the central problem for the two-phase gas-liquid flow in pipes. Design parameters such as the pressure and the heat mass transfer are strongly dependent on the flow pattern. Hence, in order to accomplish a reliable design of gas-liquid systems such as pipelines, boilers and condensers an "a priori" knowledge of the flow pattern is needed.

One of the most important flow patterns is the annular flow which occurs in the thin film evaporator, thin film gas-liquid reactor and column with concurrent swirl trays. A general schematic diagram of a typical thin film evaporator or reactor is shown in Fig. 1.

For the annular flow considerable experimental and theoretical work has been done but no reliable general correlation has been established as yet, although correlations for specific flow systems have been published. Hence, besides direct observation the only way to determine the flow is to use flow maps.

Flow patterns are regarded as related to the physical properties of each phase, the geometry and dimensions of the channel, and particularly the flow rates or velocities of the gas and liquid phases and their ratio. A number of flow maps based upon these variables have been presented for the upflow and horizontal flow to predict the flow pattern.

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** This paper has been presented at the Colloquium EUROMECH 162 organized in 1982 by the Institute of Fluid-Flow Machinery, Polish Academy of Sciences, and the Technical University of Karlsruhe.

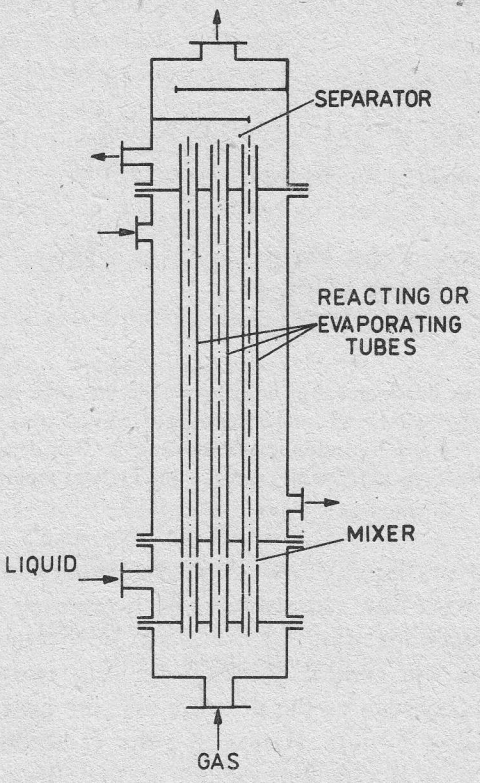

Fig. 1. General schematic diagram of a typical thin film evaporator or reactor

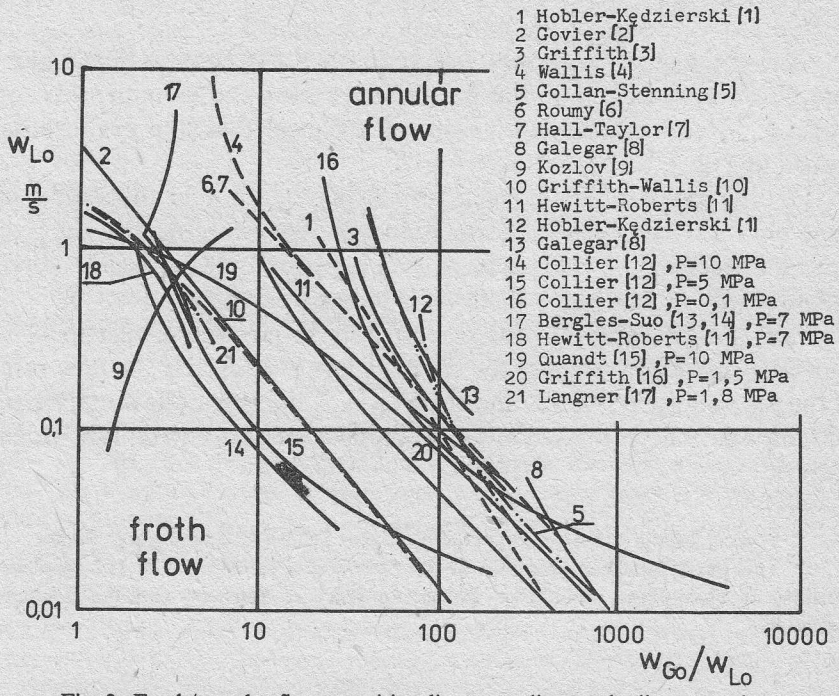

Fig. 2. Froth/annular flow transition line according to the literature data

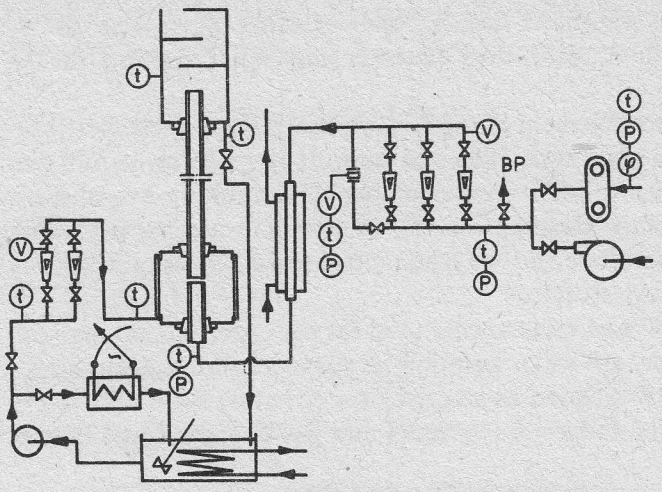

Fig. 3. The general arrangement of the flow system

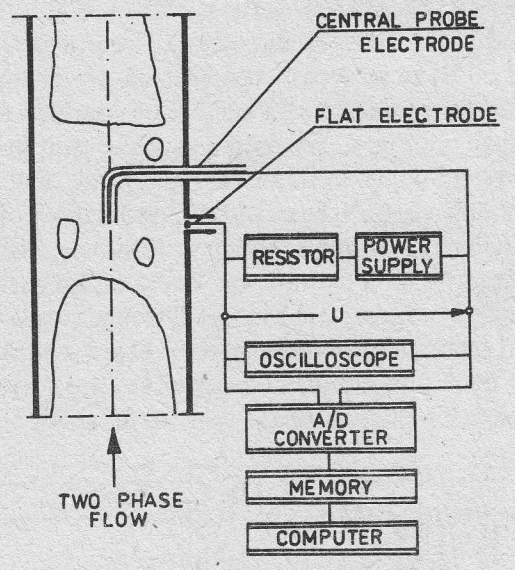

Fig. 4. Scheme of the probing system

Govier [2], Hewitt [11], Griffith and Wallis [10] and the others have produced two-phase flow maps with different co-ordinates.

Our own analysis of this border of annular flow formation as reported in the literature has been conducted on a single map with simple co-ordinates composed of the gas and liquid superficial velocities (Fig. 2). A large scatter in the literature data has been found.

As it was expressly mentioned, the annular flow is one of the most important in many industrial operations. So, we decided to correlate empirically the position of

the annular flow transition line. A series of experiments was made to investigate the effect of the inlet mixer, tube diameter and liquid viscosity on the annular flow boundaries.

The general arrangement of the flow system is shown schematically in Fig. 3. The test section was a glass tube 1800 mm long, of 18 or 25 or 36 mm diameter. The air and liquid were fed to the mixing chamber. The resulting two-phase mixture flowed upward in a conflow through the test section into a separator, where the air was vented to the atmosphere and the liquid returned via cooler or heater and a circulation pump to the mixing section.

Three kinds of inlet mixers were used for the experimental research of two-phase flows of air–water, air–water solution of sugar and air–oil mixtures . The annular flow border has been found as a conversion from the froth flow to the annular flow and vice versa. The ranges of the liquid and gas flow rates and flow properties were as follows:

$$x = 0.05 \div 0.82,$$
$$w_{G0} = 8.5 \div 30 \text{ m/s}, \; w_{L0} = 0.006 \div 0.4 \text{ m/s},$$
$$\varrho_G = 780 \div 1270 \text{ kg/m}^3, \; \eta_L = 0.7 \div 100 \cdot 10^{-3} \text{ Pa} \cdot \text{s},$$
$$P = 0.108 \div 0.128 \text{ MPa}, \; t = 25 \div 35^\circ\text{C}.$$

In all more than one thousand of experimental runs were made.

The determination of flow patterns was effected by visual observation and measurement of the two-phase mixture resistance. The conductance probe technique used is shown schematically in Fig. 4. We used a single central probe being able thus to detect differences between bubbly, froth and annular flows. The technique proposed was based on significant difference of the electrical conductivity of air and water. The probe was applied at different locations allowing to determine accurately the pattern. The method of identifying the flow pattern was based on an oscillograph trace that was obtained continuously on the screen. The oscilloscope traces were found to yield accurate and convenient pictures of the flow pattern based on their basic definitions. Representative runs for froth and annular flow patterns are presented in Figs 5 and 6. Thus, flow pattern maps for the two-phase upward flow can be constructed easily

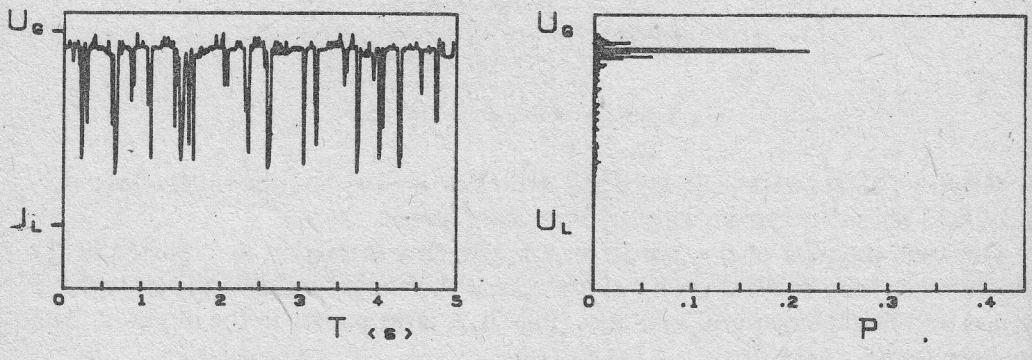

Fig. 5. Typical traces for the froth flow

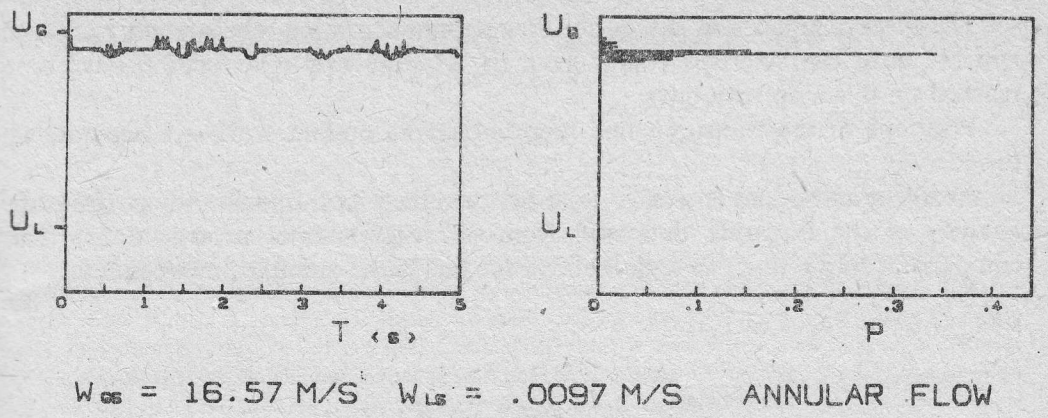

Fig. 6. Typical traces for the annular flow

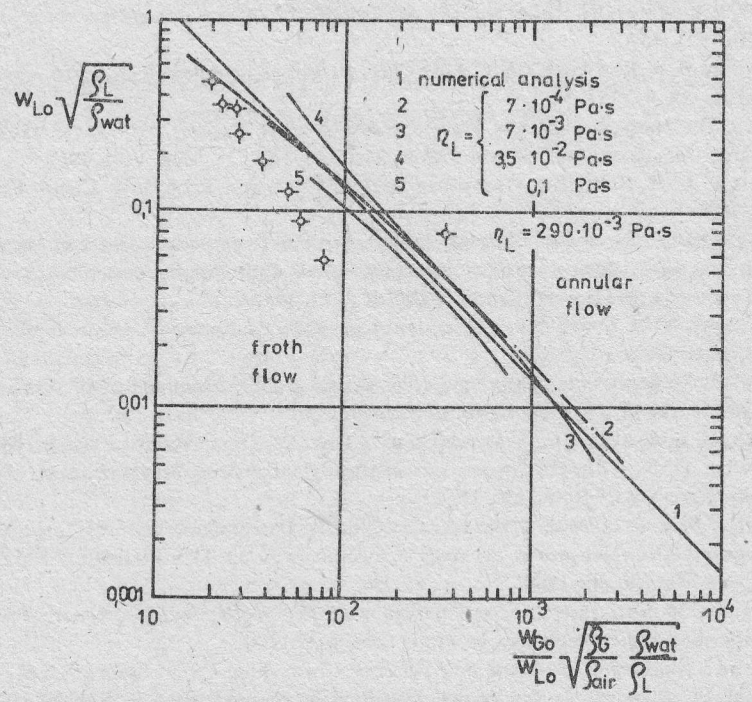

Fig. 7. Comparison between experimental investigation results and literature data

by using the direct information from the oscillograph trace provided by the conducting probe. The sensitivity of this method was sufficient for identifying the individual flow patterns also very close to the transition boundaries. The results of both independent ways of determining the flow patterns (visual observation and measurement of the two-phase mixture resistance) support the conclusion that the transition line should be interpreted as a band rather than a sharp line.

Results of a comparison between the experimental investigation results and those of literature data analysis are shown in Fig. 7.

The effect of liquid viscosity on the flow pattern transition was carefully examined and the most characteristic results from the experimental investigation have been marked on this map with lines.

Positions of the transition line reported in the present work are accurate up to $\pm 15\%$.

Excellent agreement is seen to exist between these two transition lines (from the analysis of the literature data and from our experimental investigations). This comparison shows that the region above the line is the annular flow region.

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Doświadczalne badania przejścia pomiędzy przepływem pionowym a pierścieniowym w pionowej rurze

Streszczenie

W pracy przedstawiono wyniki badań przebiegu granicy pomiędzy przepływem pierścieniowym i pionowym przy przepływie ku górze gazu i cieczy w rurze pionowej.

Badania prowadzono w celu wyznaczenia dolnej granicy zakresu pracy cienkowarstewkowego aparatu z hydraulicznie wytwarzanym filmem cieczy. Na podstawie przeprowadzonego porównania 21 cytowanych w literaturze map przepływu zaproponowano układ współrzędnych oraz — wynikającą z dokonanej analizy numerycznej tych map — linię oddzielającą przepływ pionowy od pierścieniowego. Przebieg tej linii potwierdzono własnymi badaniami, w trakcie których zmieniano średnicę rury (18, 25 i 36 mm), lepkość cieczy (0,7÷100 mPa·s), rodzaj układu zasilania, a także strumienie gazu i cieczy.

Badania prowadzono metodą wizualnej obserwacji oraz przez rejestrację zmian przewodnictwa elektrycznego płynącej mieszaniny dwufazowej.

Экспериментальные исследования перехода между вертикальным и кольцеобразным течениями в вертикальной трубе

Резюме

В работе представлены результаты исследований хода границы между кольцеобразным и вертикальным течениями, когда газ и жидкость текут вверх в вертикальной трубе.

Исследования проводились с целью определения нижней границы предела работы тонкопленочного аппарата с гидравлически образованной пленкой жидкости. На основе проведенного сравнения 21 цитированных в литературе карт течений предлагаются система координат и вытекающая из произведенного численного анализа этих карт линия, разделяющая вертикальное и кольцеобразное течения. Ход этой линий подтверждается собственными исследованиями, во время которых изменялись диаметр трубы (18, 25 и 36 мм), вязкость жидкости (0,7÷100 Па·сек), вид системы питания, а также потоки газа и жидкости.

Исследования проводились методом визуального наблюдения, а также путем регистрации изменений электропроводности протекоющей двухфазной смеси.