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Using Microbubbles to Improve Transmission Oil in Pipes

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Abstract

Drag reduction (DR) techniques are used to improve the flow by spare the flow energy. The applications of DR are conduits in oil pipelines, oil well operations and flood water disposal, many techniques for drag reduction are used. One of these techniques is microbubbles. In this work, reduce of drag percent occurs by using a small bubbles of air pumped in the fluid transported. Gasoil is used as liquid transporting in the pipelines and air pumped as microbubbles. This study shows that the maximum value of drag reduction is 25.11%.

Key Words: Drag, gasoil, microbubbles, turbulence

Introduction

Microbubbles is considered as a method to reduce friction between wall pipes and the liquid that flows by squirt small bubbles into the turbulent confines layer[1]. In a large ship, skin friction causes 80% saving of total drag. This explains why this type of drag reduction is significant for applications on maritime transportation .In this experiment total drag can be reduced by microbubbles, and if gas generation rate increases, drag reduction increases [2]. In the 1980s systematic studies were conducted in water tunnels to study the effects of drag reduction on a flat wall by using microbubbles which were generated by porous plates[3] . According to merkle and deutsch[4], the size of the bubbles is significantly important. The trajectories of the bubbles are affected by their diameters. As a result, both the concentration and the location of the bubbles in the boundary layers will be affected as well. When the bubble sizes are measured, it indicates that the bubble size decreases if free stream speed is increased, but it increases if airflow rate is increased. However, it seems that the injection technique has little effect. Merkle and Deutsch [4] showed that the sizes of the bubbles are between 500 – 1200 µm. This shows that the range is larger than the thickness of the sublayer which is about 10 µm and smaller than the size of the boundary layer which is about 10 mm. Sayyaadi, Nematollahi [5]observed that when the speed is high , high injection rate of bubbles is needed. The reason is that high speed pushs the bubbles outside the boundary layer , while at low speed, the bubbles will be near the boundary layer. Madavan et al [6] stated that allowing the viscosity and density to vary locally as a function of a prescribed bubble concentration profile simulates the action of bubbles. These results of the model show that if the microbubbles are present, the substantial skin friction reductions can be obtained. This support the idea that microbubbles can be used as an agent to not only reduce skin friction but reduce overall drag as well.

Description of Experiment

1- Flow system

The schematic of the flow system is depicted in figure 1. The diameter of the pipe is 1 inch while the test section of three meters carbon steel pipe with roughness equal 0.0018, gasoil was used as liquid transporting, and the testing temperature was about 35 °C.

2- Procedure of experiments

The procedure will be followed: a-In the pipe, the gasoil is permitted to flow. Bypass section is used to control the flow rate of the liquid. b-The flow rate of the air is changed c-Transmitter which is connected to the computer is used to measure the pressure drop. d-Procedures a, b and c are repeated for different flow rates of gas oil and air.

3- Calculations

To measure velocity, drag reduction percentage, Reynolds number , friction factor, skin friction factor and α ,the following equations are used respectively.[7,8]

$$V = Q/\ A \quad \dots (1)$$

$$\%DR = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \times 100 \quad \dots (2)$$

$$\mathrm{NRe} = \frac{\rho \cdot V \cdot d}{\mu} \quad \dots (3)$$

$$C_f = 0.455/(\log \mathrm{NRe})^{2.58} \quad \dots (4)$$

$$f = \frac{\Delta P \cdot d/4L}{\rho \cdot V^2/2} \quad \dots (5)$$

$$\alpha = Q_L \ / \ Q_{Air} \quad \dots (6)$$

Where:
V= velocity (m/sec) , Q=flow rate (m^3/hr)
A= inside area of pipe(m^2), DR=drag reduction , ΔP_a =pressure drop after air injection(psi), ΔP_b= pressure drop before air injection(psi), NRe=Reynolds number(dimensionless), μ= dynamic viscosity(c.p) , ρ=density(m^3/hr), C*f*: skin friction factor, *f*=friction factor, L=test section length(m), Q_{Air}=air flow rate(m^3/hr), Q_L=liquid flow rate (m^3/hr)

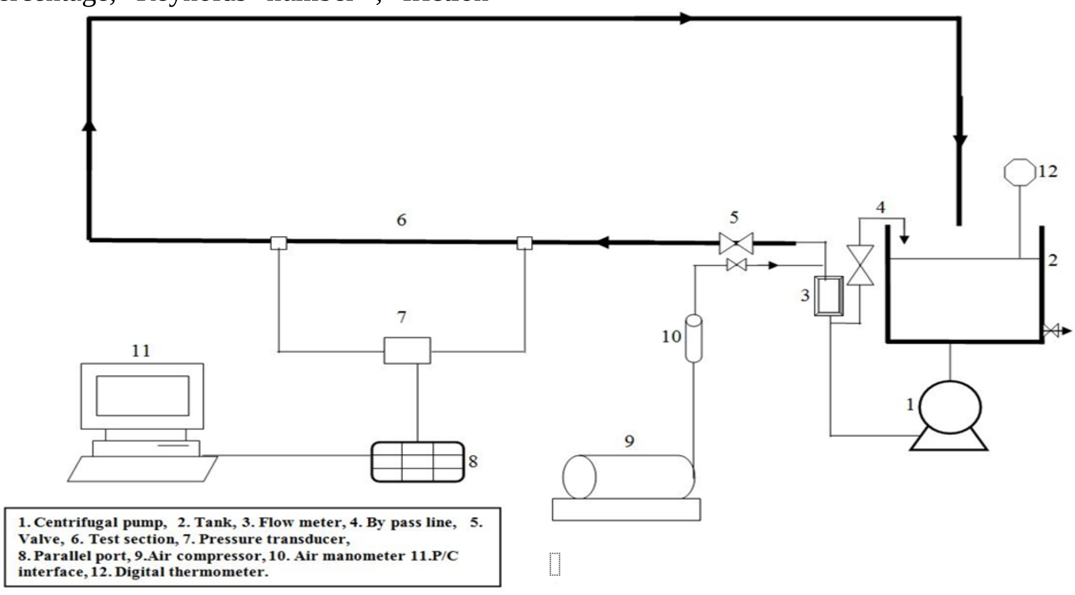

Fig. 1, Schematic layout of flow system

Results and Discussion

1- Effect of Reynolds number

Fig. (2) shows that the drag reduction increases when Reynolds number is increased. The reason behind this is that increasing Reynolds number leads to increasing turbulence in the pipe. The figure also shows that for each curve, increasing the air flow rate results in increasing drag reduction. This happens because of the increase in the void fraction in the boundary layer in the pipe. The maximum drag reduction is 25.11%.

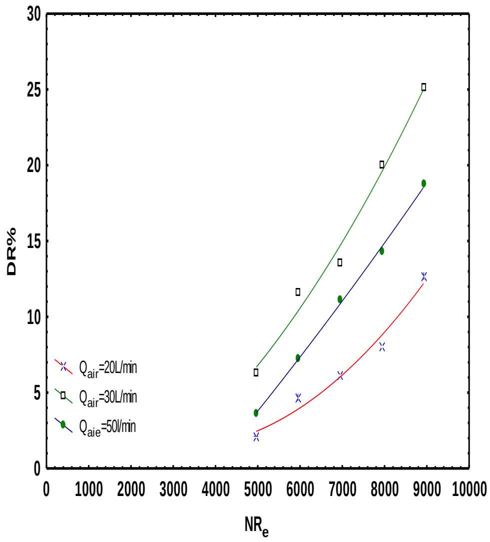

Fig. 2, Effect of Reynolds number on drag reduction

2- Friction factor versus Reynolds number

Fig. (3), shows that the friction factor decreases when Reynolds number is between 5000 and 6000. Then, it starts to increase when Reynolds number is 7000. It starts to decrease at 8000 and increase again at 9000.This ripple is due to interaction between microbubbles and the liquid, as the microbubbles interaction results in reducing the friction factor. The increasing of friction factor happens because the effect of microbubbles are low due to the changes in turbulence. This figure also shows that friction factor decrease significantly when the air flow rate increases to 50 L/min.

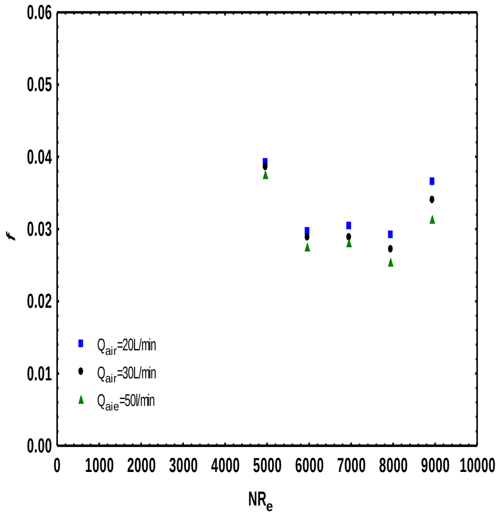

Fig. 3, Friction factor versus Reynolds number

3- Effect of air flow rate

Fig. (4) shows drag reduction increases when air flow rate increases for the different liquid flow rate values. When the liquid flow rate is low, the increase DR% will be graduated. However, when the liquid flow rate increases, a sudden drag reduction can be observed because of the increasing of turbulence.

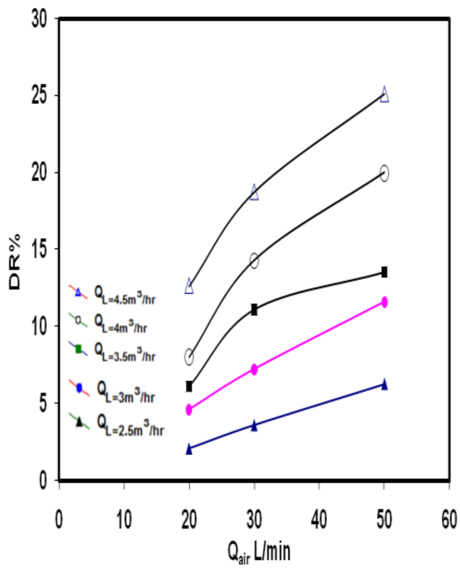

Fig. 4 Effect of air flow rate on drag reduction

4- Skin friction factor

Fig. (5) shows that when air flow reaches the highest point which is 50 L/min, the skin friction will be at the highest point as well. The figure also shows that the slope of lines in the chart decreases when the air flow increases. This happens due to the increase of microbubbles which are injected. This leads to the decay of turbulence area at the boundary layer area.

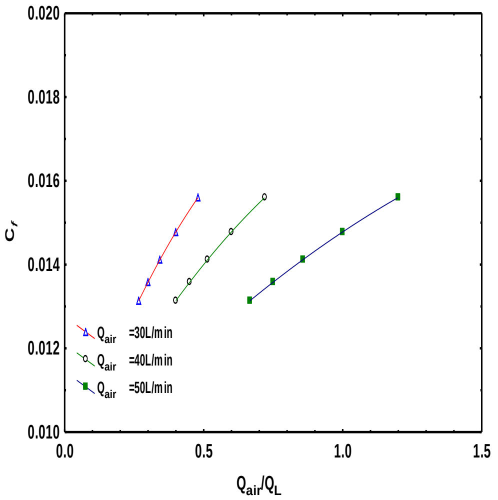

Fig. 5, skin friction factor versus α

Conclusions

- Good results have been obtained with the present technique besides the economic limit.
- Increase air flow rate leads to increasing drag reduction.
- The friction factor ripple attributed to change turbulence resulting Reynolds number changed.
- The maximum value of drag reduction is 25.11%.
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Nomenclature

A: inside area of flow pipe
DR: drag reduction
C*f*: skin friction factor
NRe: Reynolds number
Q,Q_L: liquid flow rate
Q_{Air}: air flow rate
V: velocity
f : friction factor

Greek Symbols

ΔP_a :pressure drop after air injection
ΔP_b: pressure drop before air injection
α:Q_L/Q_A
ρ: Specific gravity
μ:dynamic viscosity

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