DRAG REDUCTION BY POLYMER AND FIBROUS ADDITIVES

by

RADHEY SHYAM SHARMA
Applied Mechanics Department

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CERTIFICATE

This is to certify that the thesis entitled "Drag Reduction by Polymer and Fibrous Additives" by Mr. Radhey Shyam Sharma being submitted to the Indian Institute of Technology, Delhi, for the award of the Degree of Doctor of Philosophy in Applied Mechanics, is a record of bonafide research work carried out by him. He has worked under our guidance and fulfilled the requirements for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted in part or in full to any other University or Institution for the award of any Degree or Diploma.

R.C. Malhotra
12/9/77

(R. C. Malhotra)
Applied Mechanics Deptt.
Indian Institute of Technology,
New Delhi-110029.

V. Seshadri

(V. Seshadri)
Applied Mechanics Deptt.
Indian Institute of Technology,
New Delhi-110029.

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ABSTRACT

In the present investigation, drag reduction studies have been conducted with hydropropylmethyl cellulose, HPMC (a derivative of the cellulose series) and with Turner Brothers asbestos fibres. Experiments with these additives have been conducted in tubes of 7-mm and 19-mm diameter.

Pipe flow experiments with different solutions of hydropropylmethyl cellulose having concentrations ranging upto 2500 ppm(weight) show that this polymer is a better drag reducer than CMC. Degradation studies show that HPMC is shear resistant. The pipe diameter and polymer concentration are found to influence the onset Reynolds number for drag reduction as well as the extent of drag reduction at any Reynolds number. The effect of polymer addition on the process of transition has been investigated with the help of a specially constructed water-table apparatus. The formation and growth of turbulent spots in polymeric solutions of different concentrations has been studied at various plate inclinations. Addition of this polymer to water is found to affect the process of transition from laminar to turbulent flow.

A functional relationship for the onset of drag reduction in polymeric solutions has been derived analytically by assuming Denn's model for the viscoelastic behaviour of the solution. This analysis indicates that the inception of drag reduction is a function of the

tube diameter, the velocity gradient in the wall region and the first normal stress difference in the polymeric solution. Experimental results on the onset of drag reduction, that are reported in the literature as well as the present results, are explained on the basis of this analysis.

In order to overcome the difficulty of mechanical degradation of the highly effective Turner Brothers asbestos fibres, injection technique has been adopted to introduce the fibres into the flow. It is found that injection of these fibres at the boundary and at the centreline of the pipe carrying water results in the realization of drag reduction even with the trace quantities of the fibre. The onset phenomenon is found to be absent with the injection technique. A comparison of the present results with those obtained with a homogeneous system of fibre suspensions indicates that the injection technique is superior in terms of drag reduction. Further, on comparing the two alternate modes of injection one finds that the boundary injection of large aspect ratio hair-like asbestos fibres results in better drag reduction under identical conditions of flow.

Synergism has been investigated with a mixed polymer-fibre system. Injection of fibres both at the boundary and at the centreline of turbulent flow of a carrier fluid containing dilute concentration of hydropropylmethyl cellulose exhibits the existence of the synergistic effect. This effect is found to be more pronounced with the boundary injection method.

The mechanism of drag reduction by TB asbestos fibre suspensions has been investigated. The velocity profiles have been measured, in fibre suspensions as well as in a mixed polymer-fibre system, using a purge impact probe. These measurements indicate that the presence of the chrysotile asbestos fibres in water reduces the momentum transfer ability of the flow in the turbulent core thereby exhibiting drag reduction. However, the region between the pipe wall and the outer layer of the buffer zone is found to remain unaffected. The measured velocity profiles indicate that this reduction in momentum transfer, due to the presence of the fibres, is greater in the case of the boundary injection method for the same conditions of flow.

The measured velocity profiles for a mixed polymer-fibre system show that the presence of the polymer has no effect on the momentum transfer ability of a given fibrous suspension in the turbulent core. In fact, the combination of the polymer and fibres in a mixed system results in further thickening of the viscous sublayer. This indicates that the effectiveness of the polymer has been enhanced by the presence of the fibres.

Experimental data on the flow characteristics of different drag-reducing systems have been compared in order to make some quantitative conclusions regarding the mechanism of drag reduction in different systems.

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