CHAPTER I
INTRODUCTION

1.1 Turbulent Drag Reduction: Definition

Turbulent drag reduction, DR, is a flow phenomenon in which a small amount of additive induces a drastic reduction of skin friction in turbulent flow. However, this turbulent drag reduction may be manifested in as a decrease in pressure drop for the same flow rate, or a decrease in wall shear stress of fluid at constant flow rate, resulting in a decrease in energy required to pump a fluid or propel an object through a fluid (Kulicke *et al.*, 1989).

1.2 Types of Drag Reducing Additives

Drag reduction has been reported for several solvent/additives systems, including dilute solutions of high molecular weight soluble polymers, surfactants, suspensions of insoluble particles such as fine grains or fibers. It has also been found that modified surfaces, such as compliant surfaces, heated surfaces, and surfaces covered with riblets (small triangle ribs) aligned with the flow can provide drag reduction of varying degrees.

To date, polymer solutions are the most widely studied and most often employed in the drag reducing systems (Lumley and Kubo, 1985). A partial listing of polymeric drag reducing fluids is found in Table 1.1. (Virk, 1975)

Table 1.1 Drag reducing polymer fluids

Water-soluble polymers	Poly(ethylene oxide) (PEO)
	Polyacrylamide and hydrolyzed polyacrylamide (PAM)
	Guar gum (GG)
	Xantum gum (XG)
	Carboxymethyl cellulose (CMC)

Water-soluble polymers	Hydroxyethyl cellulose (HEC)
Hydrocarbon-soluble polymers	Polyisobutylene (PIB) Polystyrene (PS) Poly(methyl methacrylate) (PMMA) Polydimethylsiloxane (PDMS)

1.3 Applications

The fields of application listed in Table 1.2 are a few examples to indicate the potential for utilizing the drag reduction effect (Kulicke *et al.*, 1989).

Table 1.2 Areas for the technical application of drag reducing additives

Field of application	Advantages
Transport of crude oil	Saving in energy and investment costs (pump and construction costs)
Sewage and irrigation systems	Protection against overloading by dosage of flow accelerators, reduction of the danger of cavitation, saving in pumping energy
Fire fighting and hydrostatic cutting tools used in textile, food and mining industries	Higher efficient due to increased jet velocity and beam focusing
Shipping industries	Increased velocity and fuel saving
Aircraft refueling	Reduction of fuel atomization and risk of explosion

Field of application	Advantages
Medicine	Addition to the blood circulation system during treatment of arteriosclerosis
Solid fuel transport	Increased throughput in pipelines

1.4 Objectives

(1) To compare drag reduction effectiveness between the solutions of PEO, HTAC and PEO/HTAC complex.

(2) To compare drag reduction effectiveness of HTAC and PEO/HTAC aqueous solutions with and without salt addition.

(3) To establish correlations between drag reduction effectiveness and PEO molecular weight, PEO and HTAC concentration, and salt concentration.