MILITARY TECHNICAL COLLEGE

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LOCAL PRESSURE LOSSES FOR SCMC AQUEOUS SOLUTIONS IN PIPE-FITTINGS

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ABSTRACT

Local pressure losses for Sodium Carboxymethyl Cellulose (SCMC), aqueous solutions in pipe-fittings were experimentally measured, for concentrations range from 0.03 to 1.1 wt.%. Pressure drop-flow rate relation has shown similar behaviour, (power expression), to that of pipe flow with the same power.

Correlations were predicted for the evaluation of pressure drop in different pipe- fittings, which enable to estimate the local losses for another pseudoplastic fluids if the behaviour equations are found.

INTRODUCTION

Many industrial processes involve fluids or fluid mixtures, which behave in various complex forms. In consequence specialized sets of operating and design rules have been developed. One particular group of fluids of interest is the so called non-Newtonian fluids. Most of slurries, suspensions and dispersions are non-Newtonian, as are melts of long chain polymers or polymers' solutions. Fluids of this type are encountered in almost all sections of chemical industries,/1/[§].

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§ Reference number.

From this view, the object of this work concerned with the study of non-Newtonian fluid flow through different pipe-fittings. Study has been carried out for Carboxymethyl cellulose, (SCMC), aqueous solutions of different concentrations.

A pilot scale piping system has been used to investigate, experimentally, the pressure losses in ball valve, 90^{o} bend, venturi-meter, orifice-meter, 90^{o} T-junction, sudden contraction and sudden expansion. SCMC concentrations range from 0.03 to 1.1 wt.% have been used.

HEAD LOSSES IN PIPE-FITTINGS

In process industries, it is sometimes necessary to pump non-Newtonian fluids over long distances. Therefore, it is essential to predict the head losses due to friction loss in pipes and local losses in pipe-fittings. For Newtonian fluids flow, numerical data, for these losses, may be found in standard references. Whereas, limited informations regarding the flow of non-Newtonian fluids are not sufficient to permit the developement of generally valid correlations.

Two qualitative conclusions have, however, been drawn from available studies. Firstly, for turbulent flow conditions the pressure losses in fittings do not depend significantly on the non-Newtonian character of the fluid, /2/. Secondly, for laminar flow conditions, the losses do depend on the fluid properties, and increase as Reynolds number decreases. They may reach twenty times that of Newtonian fluids at low Reynolds number, /2/.

Usually, the local losses are estimated by means of local loss coefficients or by equivalent length methods. The local loss coefficient (ζ), for a pipe-fitting may be calculated by knowing the pressure drop (Δp_1), and flow rate (Q). For mean flow velocity (v), the loss coefficient can be estimated by using the flow equation, /3/,

$$\Delta p_1 = \zeta . \rho . \frac{v^m}{2} ,$$

where (ρ) is the fluid mass density, and (m) is a constant has to be found, experimentally.

EXPERIMENTAL INVESTIGATION

Flow behaviour of SCMC aqueous solutions, as well as local losses in pipe fittings have been found, according to the following scheme,

1) Preparation of the SCMC solutions of different concentrations : 300, 450, 700, 1000, 3000, 5000, 7000, 9000, and 11000 ppm.

2) Measurement of the rheoligical properties of the prepared solutions.

3) Measurement of the pressure drop-flow rate relation for different fittings and concentrations.

Solution preparation has been carried out by using a mehanical mixer of 40 cm in diameter, and 100 cm in height. Preparation procedure, as well as the rheological measurement have been discussed in detail in reference /4/. The effect of mechanical degredation on the fluid apparent viscosity has been tested by measuring the rheometric properties of the solutions before and after two hours pumping. Negligable differences have been observed, /4/.

Experiment was carried out in the laboratory of fluid mechanics in the M.T.C., by using the C6-00 fluid friction apparatus, manufactured by the Armfield Technical Education Co. Ltd., England, Fig.(1).

Flow rates through the pipe-fittings have been measured by volume method, while the pressure drop across them were measured by using U-tube manometer, /4&5/.

RESULTS AND CONCLUSIONS

Local losses in the pipe-fittings for different flow rates and concentraions of SCMC aqueous solutions, have been investigated by plotting the pressure drop versus flow rate,

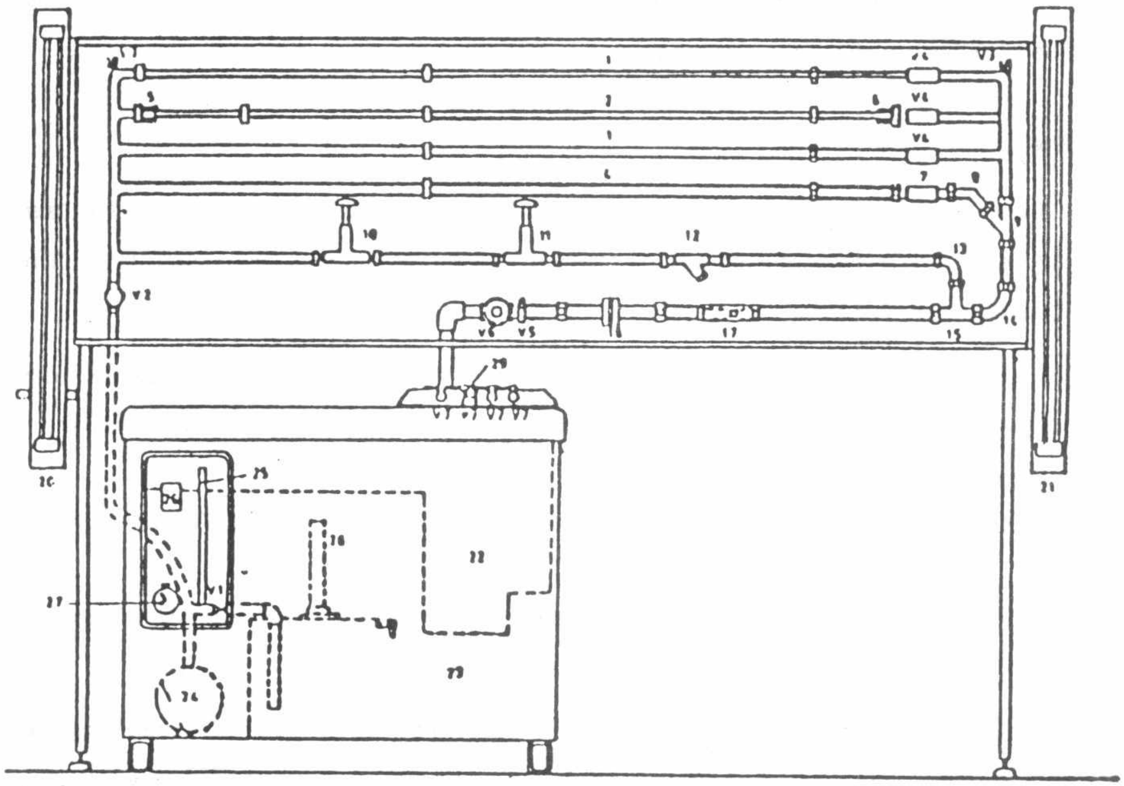

Fig.(1), Fluid Friction Apparatus

Examples of the pressure drop-flow rate behaviour for the tested pipefittings are given in Fig.(2) & (3). From these figures, it can be noticed that the slopes of the flow lines are identical to that of the pipe flow, for the same concentration. Tab.(1), gives the slopes of flow lines, (m), for different concentrations and flow regimes.

Tab.(2) & (3) summarize the local loss coeffecient ratio (ζ / ζ_o), for laminar and turbulent flow conditions. Coefficient (ζ_o) is held for water flow.

The relation between (ζ / ζ_o) and the concentration (c) may be given in polynomial form as :

$$y = a + b(x) + s(x)^2 ,$$

where $x = c$, and $y = \zeta / \zeta_o$. The values of a, b, and s are given in Tab.(4)

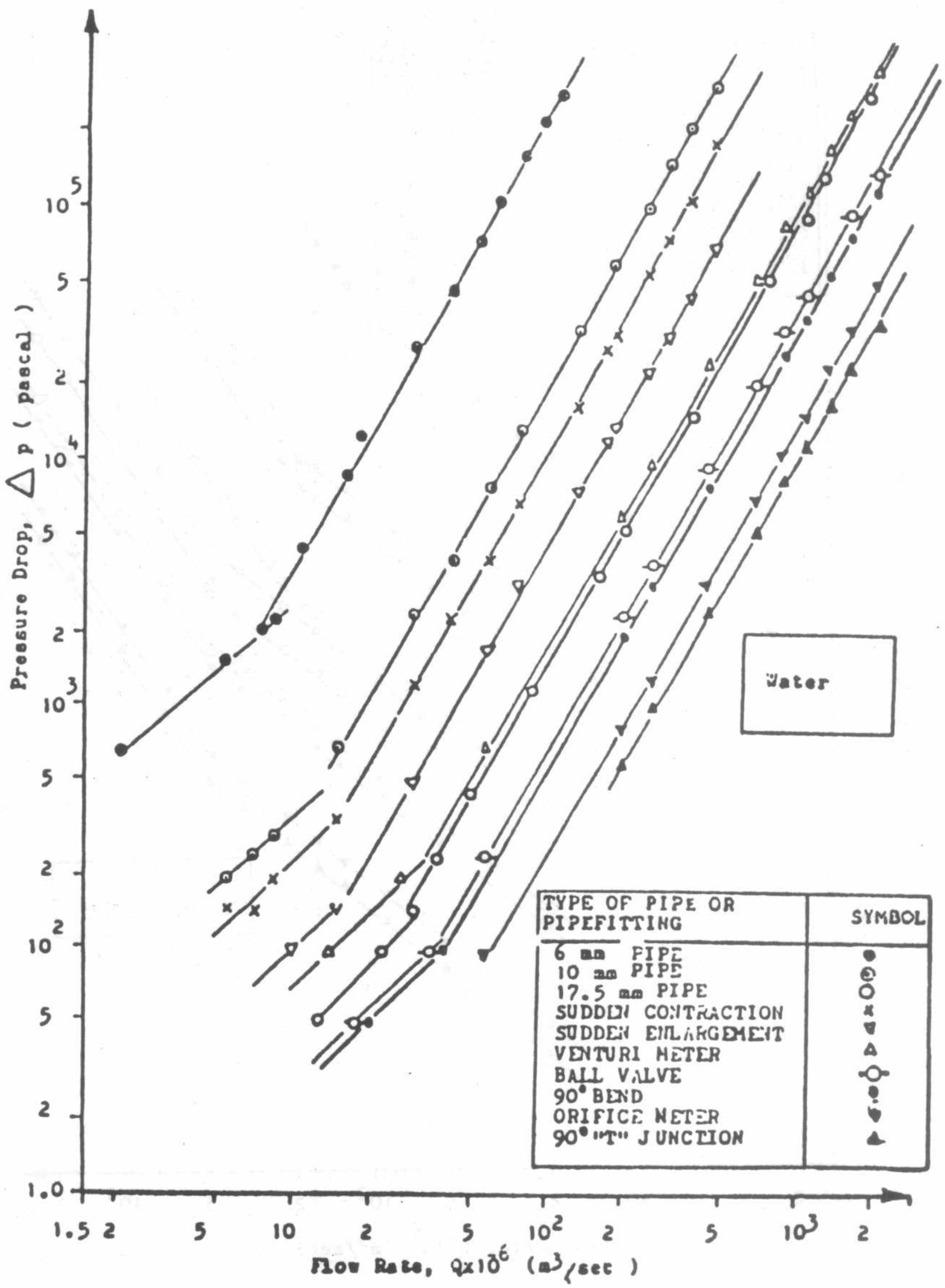

Fig.(2), Flow Lines for Water Flow in Pipes and Pipe-Fittings.

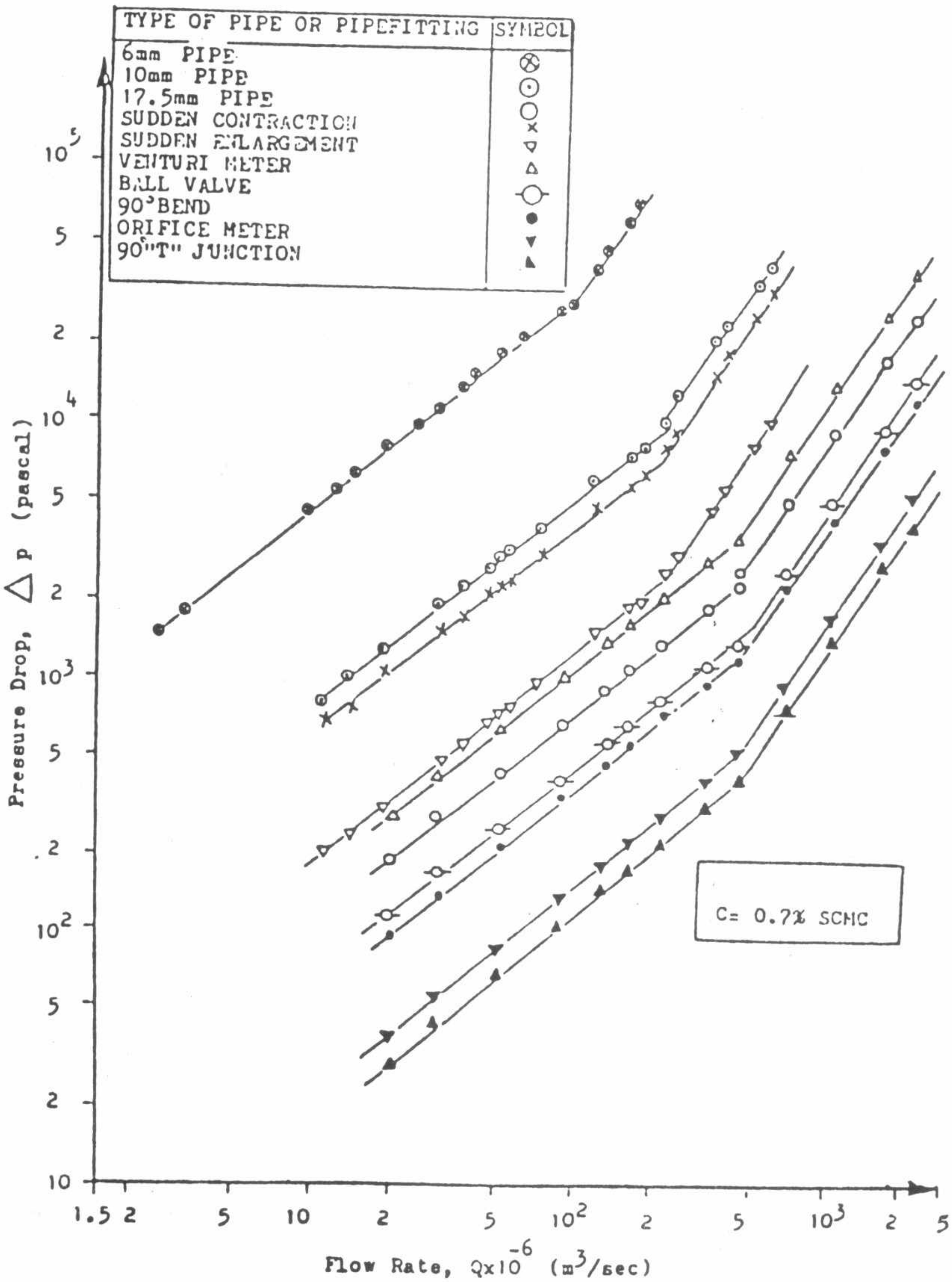

Fig.(3), Flow Lines for 0.7% SCMC Solution Flow in Pipes and Pipe-Fittings.

TYPE OF FLUID	m (dimensionless)	
	Laminar flow	Turbulent flow
WATER	1	1.788
0.1 % SCMC	0.925	1.625
0.3 % SCMC	0.9	1.56
0.5 % SCMC	0.86	1.5
0.7 % SCMC	0.825	1.4
0.9 % SCMC	0.785	1.32
1.1 % SCMC	0.74	1.283

Tab.(1), Slopes of Flow Lines (m).

Concentration (%C) / Type of fitting	0	0.1	0.3	0.5	0.7	0.9	1.1
BALL VALVE	1	4.0278	6.8327	8.7584	12.684	15.031	19.599
90° BEND	1	3.78	7.114	8.6174	12.85	15.962	18.278
VENTURI METER	1	3.3414	5.1909	7.8942	12.557	17.77	24.35
SUDDEN CONTRACTION	1	4.5258	9.1295	11.901	17.856	25.089	35.18
SUDDEN ENLARGEMENT	1	3.1895	6,261[illegible]	8.5552	13.381	22.096	28.7[illegible]

Tab.(2), Local Loss Coefficient, Laminar Flow.

Concentration (% C) / Type of fitting	0	0.1	0.3	0.5	0.7	0.9	1.1
BALL VALVE	1	1.3451	1.5944	1.6788	1.8357	2.0913	2.45
90° BEND	1	1.1632	1.5799	1.6364	1.9347	2.2036	2.294
VENTURI METER	1	1.1077	1.4047	1.5348	2.1987	2.4832	2.882
ORIFICE METER	1	1.1521	1.2705	1.5044	1.9633	2.3357	2.643
90° "T" JUNCTION	1	1.1367	1.3787	1.5063	2.1308	2.4775	2.659
SUDDEN CONTRACTION	1	1.4355	2.0515	2.1261	2.7461	3.377	4.41
SUDDEN ENLARGEMENT	1	1.01	1.3168	1.9164	2.0394	2.8921	3.489

Tab.(3), Local Loss Coefficient, Turbulent Flow.

TYPE OF PIPEFITTING	TYPE OF FLOW	POLYNOMIAL EQUATION
BALL VALVE	LAMINAR FLOW	$y = 1.82 + 14.25\ x\ 1.37\ x^2$
90° BEND	LAMINAR FLOW	$y = 1.49 + 17.07\ x\ \ x + 1.56x^2$
VENTURI METER	LAMINAR FLOW	$y = 1.78 + 8.23\ x + 10.85x^2$
SUDDEN CONTRACTION	LAMINAR FLOW	$y = 2.29 + 12.74\ x + 14.96\ x^2$
SUDDEN ENLARGEMENT	LAMINAR FLOW	$y = 1.75 + 6.7\ x + 16.39\ x^2$
BALL VALVE	TURBULENT FLOW	$y = 1.13 + 1.12\ x + 0.014\ x^2$
90° BEND	TURBULENT FLOW	$y = 1.02 + 1.64\ x + 0.42\ x^2$
VENTURI METER	TURBULENT FLOW	$y = 0.99 + 1.14\ x + 0.56\ x^2$
ORIFICE METER	TURBULENT FLOW	$y = 1.01 + 0.82\ x + 0.64\ x^2$
SUDDEN CONTRACTION	TURBULENT FLOW	$y = 1.18 + 1.52\ x + 1.18\ x^2$
SUDDEN ENLARGEMENT	TURBULENT FLOW	$y = 1.04 + 0.19\ x + 1.91\ x^2$

Tab.(4), Local Loss Coefficient Concentration

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