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Recent Advances in Chemical Engineering

Studies on Mixing Characteristics of Non Newtonian Fluids using Static Mixer

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Abstract: Mixing is one of the most common unit operations employed in chemical and allied industries. Mixing is the degree of homogeneity of phases and it plays a vital role in the quality of the final product. Continuous processing of viscous materials, most of which are Non-newtonian in character finds its application in chemical industries. Recent literature reveals that 80 percentages of the losses in the chemical and allied industries are due to improper mixing. Mixing is conventionally carried out by mechanical agitators and static mixers. In the present work, a systematic work has been undertaken to studyan optimum static element for efficient mixing. For this purpose, three static elements have been designedand tested in static mixer setup. Hydrodynamic parameters like pressure drop and power consumption was studied for the designed static elements.From experimental results it was found that the pressure drop for column with mixing elements is 16 to 18 times higher than empty pipe.The reduced pressure drop through static mixer results in reducedoperating costs and increasedprocess capacity.
Keywords–mixing; static mixer;hydrodynamic; Non-newtonian.

Introduction:

Mixing is one of the most common unit operations employed in chemical and allied industries. Mixing is the degree of homogeneity of phases and it plays a vital role in the quality of the final product. Mixing is conventionally carried out by mechanical agitators or static mixers. Static mixers are a series of geometric mixing elements fixed within a pipe, which use the energy of the flow stream to create mixing between two or more fluids.

Static mixers are installed in thousands of process plants worldwide, providing the highest standard of mixing efficiency, reliability and economy. Static mixersare used in different mixing tasks like blending, dispersing, contacting and heat exchange and reactions. Some of the advantages of static mixers over dynamic mixers are that they have no moving parts, small space requirements, low or no maintenance cost and a short residence time.

Continuous processing of viscous materials, most of which are Non-newtonian in character finds its application in chemical industries such as polymer, petroleum, food, rubber, detergents, cellulose manufacturing and cosmetics. In most systems involving highly viscous liquids, the Reynolds number does not exceed 10. Hence static mixer finds applications in the abovementioned industries were chosen for continuous processing of viscous materials.

In the present work, three static elements namely Helical, Kenics and X-Grid types were designed, fabricated and tested for its mixing efficiency. Based on the experimental results, optimum static element was found. For the optimized static element, hydrodynamic parameters like pressure drop and power consumption studies were carried out.

Experimental Setup and Procedure:

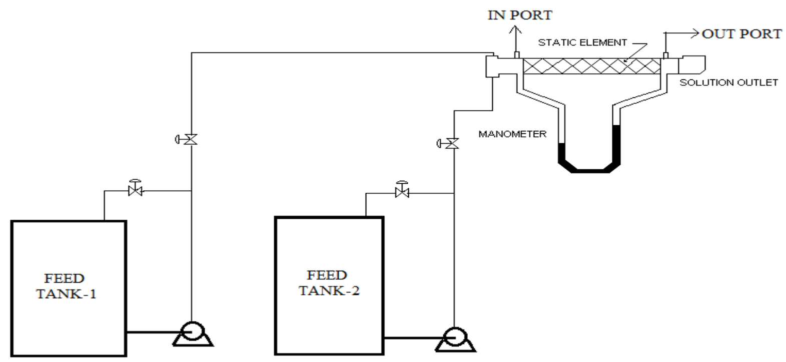


Fig.1 Experimental Setup Block Diagram

The experimental setup and its specifications are shown in Fig.1 and Table.1 respectively.Non-newtonian fluid used for this study is Carboxyl Methyl Cellulose (CMC, 1% wt) and Glycerol (1% wt).Centrifugal pumps are used to maintain the required head in the column. The pressure drop across the column was measured by a differential U tube manometer.Three static element designnamely Helical (A), Kenics (B) and X-Grid (C) types were designed, fabricated and tested in a static mixer. The optimum static element was recommended based on the pressure drop and power consumption as obtained from the experimental results. For the optimized static element the mixing efficiency is determined for different flow rates.

Table.1 Specification of Static Mixer

Specifications of Static Mixers	
Diameter of the tube	5.1 cm
Length of the tube	80 cm
Length of the Static element	76.5 cm
Diameter of the static element	5 cm
Cut Spacing	13 cm
Number of twist	6
Angle of the twist	180°
Density of the flowing fluid	1000 Kg/m3
Density of the manometric fluid	1595 Kg/m3

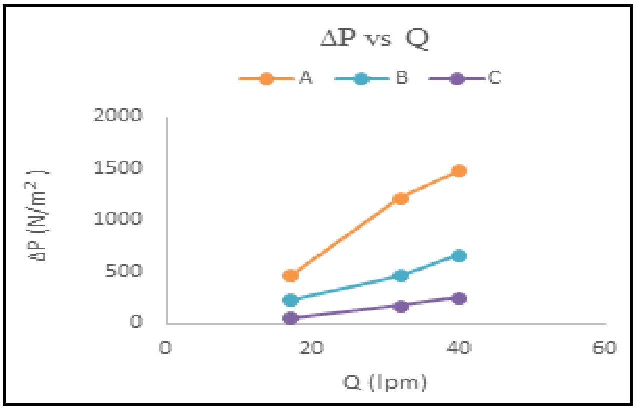
From the three new designs an optimum static element for mixing of Non–newtonian fluids was found out based on the hydrodynamic studies.

Results and Discussion:

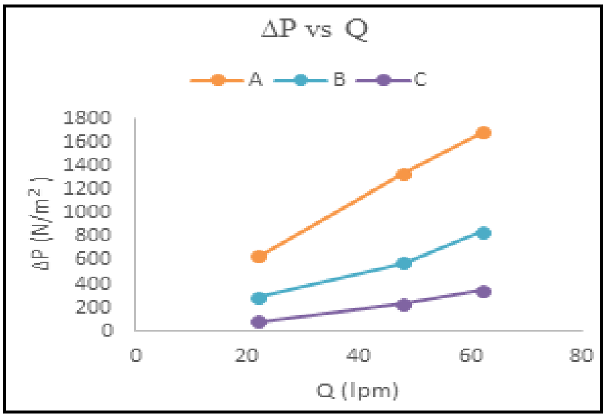
Pressure drop, friction factor and mixing efficiency determining parameter Z (L/D) were calculated for three designed static elements. Theoptimum static element design was found and hydrodynamic parameters were analysed for that optimized static element.

Effect of Pressure drop on Flow rates:

The effect of pressure on flow rate is shown in Fig. 3 for both Newtonian and Non-newtonian fluids (CMC and Glycerol). From this Fig. 3 it can be seen that the pressure drop increases with an increase in flow rate. However, the increase in pressure drop is more for Helical (A) design. The same observation was noted for Non-newtonian fluids.



For Newtonian Fluid

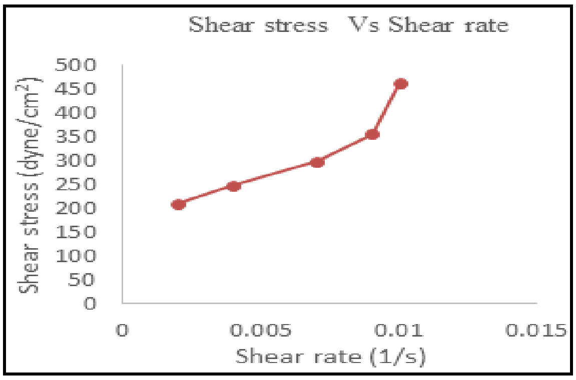


For Non-Newtonian Fluid

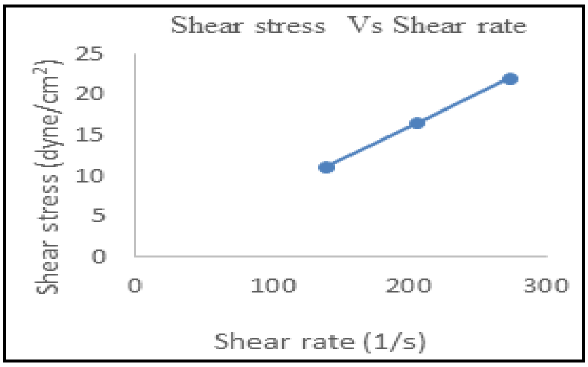
Fig. 3 Pressure drop Vs Flow rate

Rheological Properties CMC Solution and Glycerol:

The Rheological Properties (Shear stress Vs Shear rate for 1% wt) obtained for CMC solution and Glycerol solution are depicted in Fig.4.



For CMC solution



For Glycerol solution

Fig.4 Shear stress Vs Shear rate for 1% wt

Effect of Friction factor on Reynolds Number:

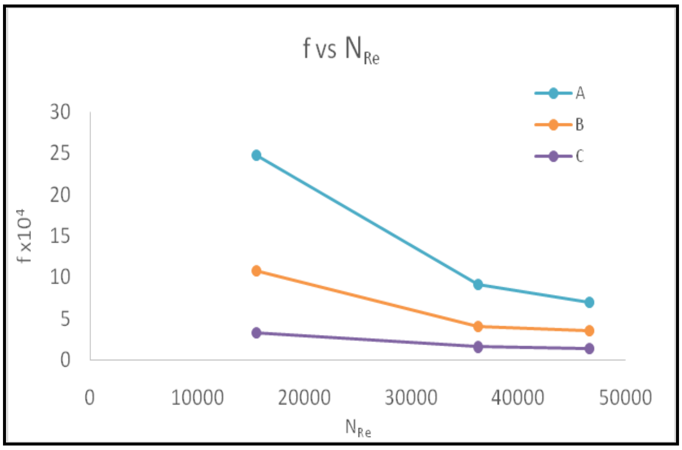


Fig.5Friction factor Vs Reynolds Number

The effect of friction factor on N_{Re} is shown in Fig.5. The friction factor decreases with an increase in N_{Re}. However, the increase in friction factor is more for Helical (A) than Kenics (B) and X-Grid (C), which may be due to larger pressure drop for Helical (A) mixing element in static mixer.

Determining Efficiency in Terms of Z(L/D):

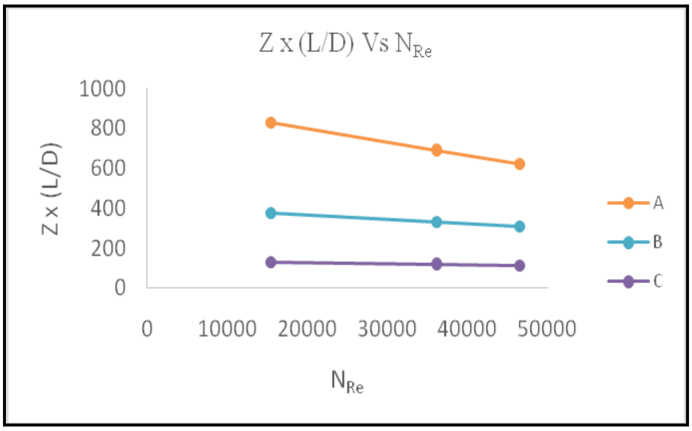


Fig.6Determining Efficiency in Terms of Z (L/D)

The effect of N_{Re} on Z (L/D) is shown in Fig. 6 for Non-newtonian fluids (CMC and Glycerol). From this Fig. 6 it can be seen that the Z (L/D) decreases with an increase in N_{Re}. However, Z (L/D) decrease is more for Helical (A) design than other two designs.

Conclusion:

- From the experimental observation it was found that Helical (A) design shows less pressure drop for the given flow rates.
- Pressure drop with mixing element is 18 times greater than bare tube. But mixing efficiency is more for column with mixing element.

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