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 study an optimum static element for efficient mixing. For this purpose, three static elements have been designed and 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 reduced operating costs and increased process 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 mixers are 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:**

![Experimental Setup Block Diagram](image)

Table.1 Specification of Static Mixer

<table>
<thead>
<tr>
<th>Specifications of Static Mixers</th>
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<tbody>
<tr>
<td>Diameter of the tube</td>
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<tr>
<td>Length of the tube</td>
</tr>
<tr>
<td>Length of the Static element</td>
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<tr>
<td>Diameter of the static element</td>
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<tr>
<td>Cut Spacing</td>
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<tr>
<td>Number of twist</td>
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<tr>
<td>Angle of the twist</td>
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<tr>
<td>Density of the flowing fluid</td>
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<td>Density of the manometric fluid</td>
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</table>

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. The optimum 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.
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.

Effect of Friction factor on Reynolds Number:

Fig.5 Friction 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 $Z(L/D)$:**

![Graph showing the relationship between $Z(L/D)$ and $N_{Re}$](image)

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.

**References:**

6. Hyun-Seob Song, Sang Phil Han, A general correlation for pressure drop in a Kenics static mixer, Chemical Engineering Science 60, 2005, Pages 5696 – 5704.