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Methods and Materials Characterization of Sodium Carboxymethyl Cellulose

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Abstract: **Four test solutions of 0.05% 0.1% 0.15% and 0.2% sodium carb-oxymethyle cellulose (CMC) are used for the experiments. The Sodium Carboxymethyle Cellulose is a whitish powder which is odourless tasteless and non toxic binder and it is used in several industries because of easy solubility in water. Other properties of Carboxymethyle Cellulose are film forming ability, effective thickenning action in water solution, an anionic and Rheology agent. Chemical properties of Carboxymethyle Cellulose are: pH=7.25 , Viscosity=1080 C.P. at 25^{o}C, and sodium content=8.23%**

Keywords: **viscosity, flow behavior index, power law model & cellulose**

1. INTRODUCTION:

Extensive work have been carried on non Newtonian fluids by many authors in recent years both experimentally and theoretically. In our present study,0.05% & 0.1% CMC Test Solutions have shown Newtonian behavior, On other hand 0.15% & 0.2% CMC Test Solutions behaved as non Newtonian fluids.

The classification of non-Newtonian fluids is as follows[1]:

A. Time Independent Fluids like yield stress fluids - Bingham, Herschel Bulkley, Casson etc.

B. Time Dependent Fluids - Thixotropics, Rheopectics & Viscoelastics

The following mathematical correlations [2] can be used to evaluate the Rheological parameters as:

1.Linear Equation: If shear stress vs shear rate is plotted ,the graph is known as flow curve. Thus model show the Newtonian ($\tau = \mu\ (\dot{y})$ where $\tau(o)$ approaches to zero.) and Bingham (with $\tau(o)$ being the yield point) flow behavior.

2.Basic equation is given as:

$$\tau = \tau\,(o) + \mu\,(\dot{y}) \qquad (1)$$

3.Power Law Equation: This model quantifies the rheological flow behavior for Newtonian pseudo-plastic and dilatants fluids

$$\tau = \mu\,(\dot{y})^{n} \qquad (2)$$

where n is called flow behavior index and shows the degree of the non-Newtonian flow behavior where n=1 Newtonian , n > 1 dilatants , n < 1 pseudo-plastic It is also called Ostwald model which is widely used to verify the rheological behavior effect on the velocity and thermal flow fields . This model gives better results compared to other models available.

If % concentration of the Test solution versus flow behavior index (n) is plotted, it can be noticed, from the following Fig.2.1, that there is a change in flow behavior depending on the concentration.

4.Herchel Bulkley Model**:**

$$\tau - \tau\,(o) = \mu\,(\dot{y})^{n} \qquad (3)$$

When yield limit as in case of plastic flow is known, the above equation can be used as power law equation. To evaluate the yield limit, one can use the Casson model first and then calculate the change in shear stress from the above equation.

5. Casson Model :

$$\sqrt{\tau} - \sqrt{\tau(o)} = \sqrt{\mu(\dot{y})} \qquad (4)$$

This model is extensively used for solid suspensions to verify the flow behavior.

6. Exponential Model:

$$\tau = \mu.\exp\,(n.\dot{y}) \qquad (5)$$

Examples of shear thinning are polymer slurries with fine particles suspended in water and Sodium Carboxymethyle Cellulose solutions . Corn starch, clay slurries and solutions of certain surfactants.

Another type of non-Newtonian fluid is a viscoplastic fluid. When a small shear stress is applied to this fluid, it will not flow until it approaches to a limiting value known as yield stress for the flow to take place. These fluids behave both as elastic and viscous. Some examples are blood, toothpaste, mud and nuclear fuel slurries.

Bingham plastics exhibit a linear relationship between shear stress and shear rate indicating a yield stress behavior. One can learn more about behavior of non-Newtonian fluids from literature [2]

2. METHODS & MATERIALS

Hawke VT500 Viscometer [3] has been used to evaluate the viscosity of 0.05%CMC,0.1%CMC,0.15%CMC and 0.2%CMC test solutions. It has RS-232 interface with data interoperation system and preset adjustment for shear rate in the range 1 to 600 rpm. For our study the Ostwald model regression method is taken into consideration and the model equation is taken as $\tau = \mu.\ (\dot{y})^{n}$ where τ=shear stress, μ=viscosity factor, n= flow behavior index $\dot{y}$=shear rate. The ranges for different concentrations: Viscosity Range: 1000-1100 C.P. and Shear Rate Range: 1-200 s^{-1} Temperature difference for each reading = 5^{0} C .

3. RESULTS & DISCUSSION

The 0.05% & 0.1% CMC Test Solutions are showing constant trend lines compared to 0.15% & 0.2% CMC Test Solutions as shown in Fig 1.The Viscosity of the fluid flow varies as temperature gradients increases.

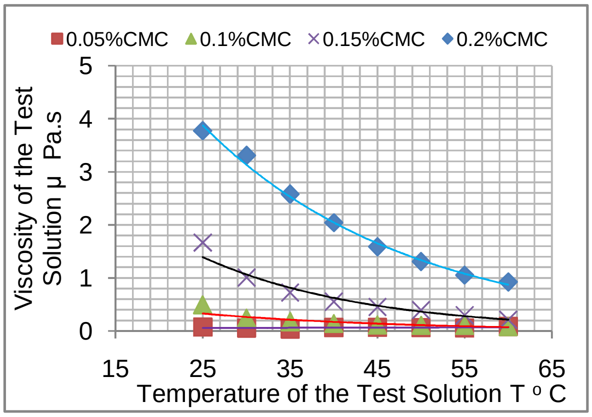

Fig 1 relation between viscosity and temperature 0.05%,0.1%, 0.15% &0.2% CMC test solutions

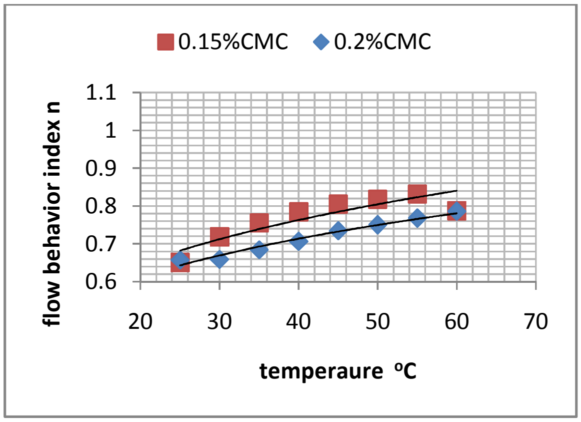

Fig 2 relation between flow behavior index and temperature for 0.15% &0.2% CMC test solutions.

Fig 2 shows the flow behavior index (n) of 0.15%CMC slow increases form 0.65 to 0.85 as temperature gradient gradually increases from 25^0 C to 60^0 , where as 0.2%CMC Test Solution slowly increases flow behavior index(n) form 0.65 to 0.78 as temperature increases further. It can be inferred from the graph of flow behavior index(n) Vs temperature, that flow behavior index (n) is a strong function of viscosity.

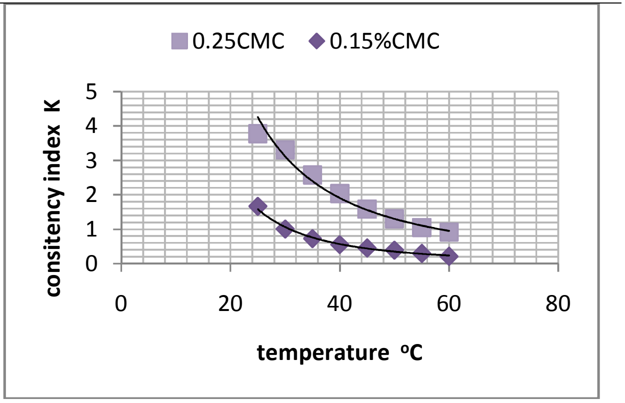

Fig 3 relation between consistency index K and temperature for 0.15% &0.2% CMC test solutions

Fig 3 indicates the dependence of consistency index(K) on temperature of the test solutions. The consistency index(K) decreases form 1.6 to 0.3as temperature rises from 25 to 60^0 C for 0.15% CMC, whereas for 0.2%CMC, as temperature trend line increase ,the consistency index(K) comes down from 3.8 to 0.9.

It is evident from the Fig 4, the shear stress of the sodium carboxymethyle cellulose becomes constant for 0.05% & 0.1% test fluids as temperature trend line increase , where as the shear stress moves down ward direction from 34 to 8Pa as temperature rises from 25 to 60^0 for 0.15% test fluid. Similarly, the shear stress trend line decrease from 45 to 22Pa for the same temperature gradient for 0.2% test fluid.

It is evident from the graphs drawn for characterization of test solutions gives very good relation with power law model comp are with other available models. The results shows validation form the data represented in the following graphs. The fact lies about the experimental equipment calibration in these data presented.

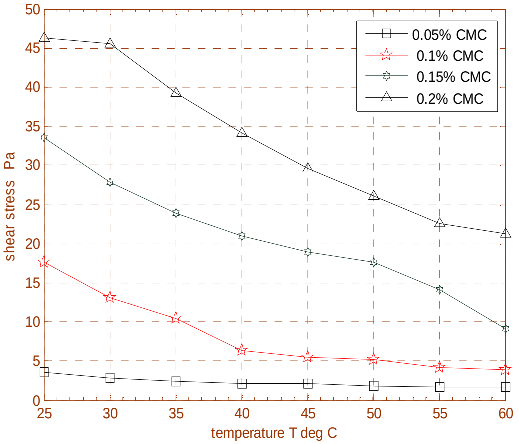

Fig 4 dependence of shear stress on temperature of the 0.05%,0.1%, 0.15% & 0.2% CMC test solutions

IV.APPLICATIONS OF NON NEWTONIAN FLUIDS

A non-Newtonian fluid is a fluid whose viscosity is variable based on applied stress or force. The most common everyday example of a non-Newtonian fluid is starch dissolved in water. Behavior of Newtonian fluids like water can be described exclusively by temperature and pressure. However, the physical behavior of non-Newtonian fluid depends on the forces acting on it from second to second.

If you punch a bucket full of non-Newtonian fluid such as cornstarch, the stress introduced by the incoming force causes the atoms in the fluid to rearrange such that it behaves like a solid. Your hand will not go through. If you shove your hand into the fluid slowly, however, it will penetrate successfully. If you pull your hand out abruptly, it will again behave like a solid, and you can literally pull a bucket of the fluid out of its container in this way. Non-Newtonian fluids help us understand the wide variety of fluids that exist in the physical world. A search for non-Newtonian fluid on the internet brings up some interesting results. When combined with a oscillating plate, non-Newtonian fluids demonstrate other unusual properties, like protruding "wingers" and holes that persist after creating them. An oscillating plate applies stress on a periodic basis, rapidly changing the viscosity of the fluid and putting it in an odd middle ground between a liquid and a solid. At the same time, there are examples wherein one can place a bowl of cornstarch near a vibrating speaker to see the interesting patterns that are created on the surface of the mixture.

The mathematical model suggested by Hiraoka could be used to evaluate and compare the experimental data for viscosity, velocity and shear stress distribution with power law fluids. It was concluded that Mezter-Otto constant ks cannot be approximated in the average deformation rate equation . Shear stress reveals that the deformation is weak at the vessel wall and it is easier to obtain relations with apparent viscosity.

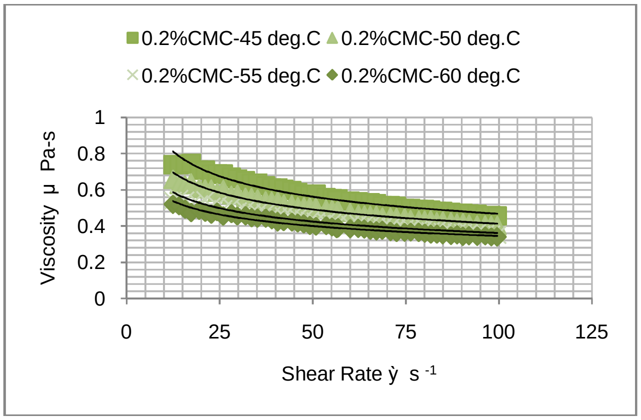

Fig 5 dependence of shear rate on viscosity of the 0.2% CMC test solutions at different temperatures

There are many real fluids which if tested in simple shear, would appear not to flow at all until the magnitude of the applied shear stress surpassed a fixed finite value termed the yield stress. Many other real fluids show an apparent yield stress as well. One type of constitutive equation which is used to describe fluids which appear to display a yield stress is the Bingham model . In simple shear of a Bingham fluid, there is no motion unless the magnitude of the applied shear stress is above a threshold, in which case, the material behaves like an incompressible Newtonian fluid. The non-Newtonian fluids can be quantified by a nonlinear shear stress and shear rate models developed by several investigators. The applications are vast to describe the rheological properties of polymers, paints and solid suspensions etc., which are extensively used in chemical industry . The equation developed for Newtonian and power law model cannot be used to predict the flow streamlines for viscoelastic fluids which was justified by Jahangiri [4] who demonstrated hydrodynamic experiments through LDA for visualization of velocity profiles in the transition flow regime i.e 35<Re>1800.By modifying blade angle of Rushton turbine, one can asses for mixing high shear rates. Magnofloc LT 27 Polyacrylamide solution mixed with glycerin/water was used as a test fluid. It was concluded that radial and tangential components were found to be independent of agitation in the vessel. The theoritical models were developed by Bose experiments through LDA for visualization of velocity profiles in the transition flow regime i.e 35<Re>1800.By modifying blade angle of Rushton turbine, one can asses for mixing high shear rates. Magnofloc LT 27 Polyacrylamide solution mixed with glycerin/water was used as a test fluid. It was concluded that radial and tangential components were found to be independent of agitation in the vessel. The theoritical models were developed by Bose and Carey[5], Renardy[6], Massondi and Phuce[7] , Derksen and Prashant[8] and Jahangiri [9] for non-Newtonian fluids. The purpose of this work has been to evaluate the performance of heating and cooling rates in a mixing vessel for non-Newtonian fluids.

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