Effect of Binder on Viscosity with Shear Rate

Vishal Phaugat, Hari Mohan Rai, Subham Gupta and Rohit Thakran[4]

Abstract: This paper represents the effect of binder on viscosity and its experimentation. The experimental result briefs:

1. **With no binder added, the initial viscosity of the slurry was 35mpas.**
2. **As the percentage by parts of the binder was increased to 3 and then to 6 ,the viscosity of the slurry decreased to 32m pas which was the minimum viscosity value reported**
3. **After further increasing the binder content, the viscosity again started to increase and increased upto the binder content of 16(by parts),and thus achieved the value of viscosity 40mpas. The same trend was observed for both the mean value of viscosity and also the peak value of viscosity at maximum shear rates.**
4. **The peak value also decreased first from 35mpas to 32mpas, on increasing the binder content from 0 to 6. After that it increased to 40 mPas on further increasing the binder to 16.**

Key words: Rheology, Binder, Viscosity, Shear Rate.

I. INTRODUCTION

This reports starts with the study of effect of varying the binder and then dryness fraction on the viscosity of c-60and c-90 coating emulsion by varying the temperature. This effect is especially important for the paper coatings that have to undergo a wide range and high values of temperature particularly in dryness fraction. So considering the rheological behaviour of the coating at different temperatures, the optimum and maximum permissible temperature for working with paper coating can be determined. After this the behaviour of the viscosity with different compositions and contents of coating slurry is observed. This gives the dependence of the rheology of the coating on the type and shape of the particles. Viscosity is a measure of a fluid's resistance to an applied shearing force [1]. In a coating, viscosity is a measure of the ease with which the continuous phase deforms and allows the pigment particles to slide over each other [2]. If the volume of the continuous phase is large, the particles of the solid phase move more independently and slide past each other more easily [3]. Increasing the volume of the continuous phase thus reduces coating viscosity. When a coating is put under shear, only the continuous phase is subjected to that shear; the solid phase just reduces the area available for shearing [4].

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II. RHEOLOGY

It is defined as the science of the deformation and flow of matter that is how the materials respond to the stress applied to them [5].

There are two types of deformation:

1. Reversible (Solid like behaviour): it is also known as elastic deformation .In which the internal structure remains intact.

2. Irreversible (Liquid like behaviour): it is also known as flow deformation .In which the internal structure is destroyed.

3. Reversible + Irreversible (frequency dependent behaviour): it is also known as visco-elastic deformation.

For solid materials, the elastic properties are most important while, for liquid materials, the flow properties are most important. Materials can also exhibit viscoelastic behaviour in which there is both elastic and flow deformation. For viscoelastic materials, there is a limited degree of recovery once the stress is removed-in fact, the material will have fading recovery of its prior state [6]. This highlights another aspect of rheology, namely, the time dependent or dynamic behaviour of materials. Paper coating formulations have complex time dependent rheological behaviour. During the coating process, the coating formulation experiences a wide range of shear stress lasting from a few microseconds upto several minutes .As a result, paper coating rheology is complicated and remains an active area of research. The capability to forecast a material's performance provides the materials designer with an significant tool in developing future products [7].

Despite its complexity, understanding the rheology of paper coatings is important for two reasons.

1. The rheological behaviour of the paper coating formulations is a key factor influencing runnability, water retention and coating holdout. Understanding how to control and classify the coating rheology is critical for achieving good runnability and optimum placement of the coating [8].
2. Second rheology is a powerful tool for characterizing the interactions between the different components of a paper coating formulation. It also serves as a quality control measurement. Understanding the different types of information from rhelogical measurements can greatly speed up and improve the design of new coating formulations [9].

Shear rate dependent rheology:

- Typically, shear stress versus shear rate is plotted on a linear scale while viscosity versur shear rate is plotted on a log scale. On a log-log scale, the plot for the viscosity versus shear rate is often a straight line [10].

- Known as POWER LAW fluid and is quite common for polymer fluids and colloidal systems of paper coatings.
- The equation for the viscosity versus shear rate is:

$$\tau = Kpow(\gamma, n)$$

III. TYPES OF NON-NEWTONIAN FLUIDS

A. PSEUDOPLASTIC or SHEAR THINNING

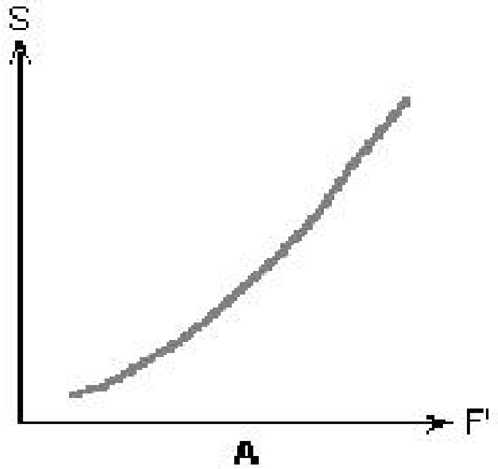

Fig.1. Shear Versus force

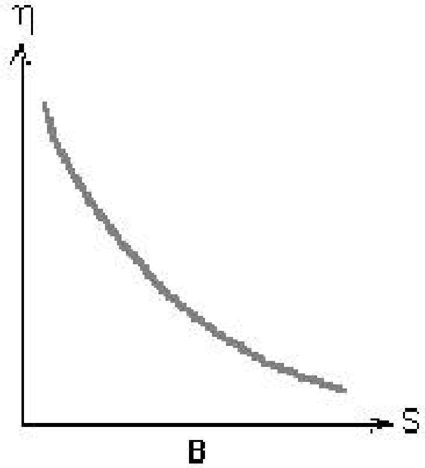

Fig. 2. Viscosity versus Shear Rate

- The Viscosity decreases with increasing the Shear Rate (fig 1).
- The Shear Thickening Index n (<1) is less than One (fig 2).

B. DILATANT or SHEAR THICKENING

- The Viscosity of these fluids increases with the Shear Rate (fig 3).
- The Shear Thickening Index n (>1) is less than One (fig 4).

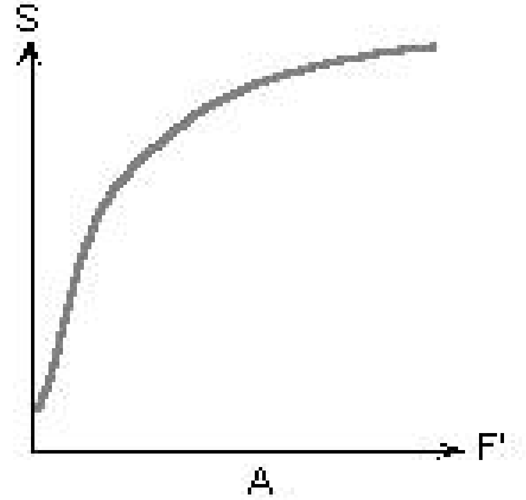

Fig.3.Shear versus Force

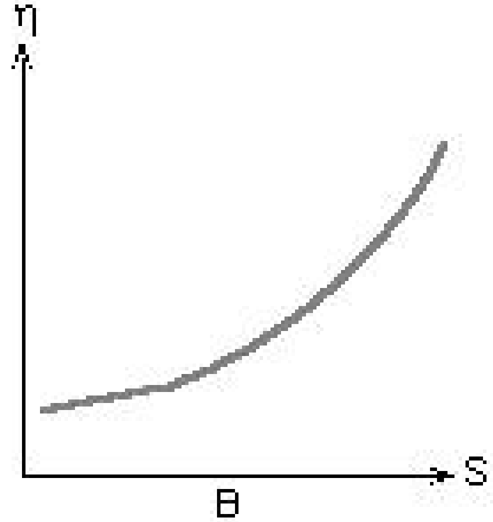

Fig.4.Viscosity versus Shear Rate

IV. RESULT AND DISCUSSION

At low binder concentrations, the viscosity first decreases on addition of the binder. However, at higher binder concentrations, that is when the amount of binder in the coating becomes significant, the viscosity starts to increase with the increase in the binder content. This may be attributed to the fact that as at lower concentrations, the binder particles enter the crystal lattice of the coating pigments and disturb the regular structure. The binder particles are not contributing much to the joining of different particles by their glueing ability, due to their small amount as compared to the pigment particles. So, the viscosity initially decreases.

It is observed that from figure 5, the viscosity increases later on, at higher binder percentages, due to increasing the binder content. This is due to the more thick and viscous (tacky) nature of the binder than the pigment particles. So, the binder makes the pigment particles to stick together in a much better way due to its gluing ability and thus increases the viscosity of the coating. More is the amount of binder, more is the resistance to motion offered by the particles of the coating and thus, more is the viscosity.

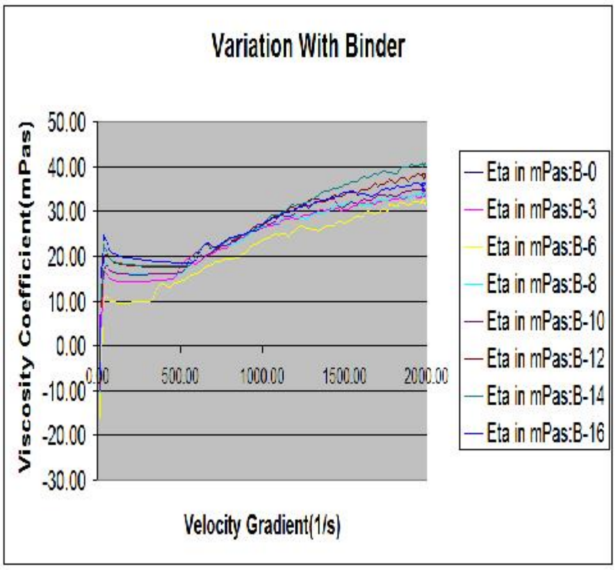

Fig.5. Variation of viscosity with dryness

It should be taken into account that for each individual case, as the velocity gradient is increased, the viscosity of the coating first decreases with increasing shear and on further increasing the shear rates, the viscosity then starts increasing which is shown in table 1.

Binder Content (% by parts)	Viscosity Coefficient (mPas)
0	29.78
3	29.10
6	28.67
8	31.67
10	32.69
12	35.06
14	37.29
16	37.86

V. RESULTS

From the benchmarking tests we performed for different softwares we came to know that the softwares having the large file size tend to use more CPU than the ones having file size lower than them. This can be seen as all the games which were used in the tests (i.e Sleeping Dogs,FIFA 2013, CS-Global Offensive) have large area than other softwares and as a result they use more CPU. Which we can clearly study from the graph above that the Instructions Processes per Second (FLOPS-Floating Point Operations Per Second) for these games is higher. Comparison between CPU usages And MFLOPS (Million Floating Point Operations per Second) for various applications have been shown in fig. 4.

Whereas this is does not hold true for the memory used. As CS-Global Offensive uses the most CPU but the memory usage of the same is comparatively quite low. So we found out that File size of the software being used and the memory it uses to process the data are not the only reasons which determine the speed of the CPU. Thus along with these reasons the type of file being processed plays an important role in determining the speed and efficiency of the microprocessor.

As it was found during the experiment that the Paper Coatings followed a different pattern in their variation with the Shear Rate (rotation speed of job)

- The viscosity of slurries and suspensions is dependent of the arrangement of individual particles, on the solids volume fraction and the maximum packing volume.
- At low shear rates, there are two possible situations; for low solids and non interacting particles, the particles have a random arrangement due to BROWNIAN MOTION.
- And in this case, it will exhibit Newtonian flow behaviour with low shear viscosity ή°.
- If the particles interact to form large aggregates or a network structure, the yield behaviour results and the viscosity becomes infinite as shear rate approaches zero ή.
- As the shear rate increases, the suspension exhibits Pseudoplastic(Shear Thinning) behavior. Under shear, particles orient themselves into layers that can flow past each other, causing a decrease in the Viscosity.
- Once the suspension particles are aligned into layers (Shear Layers), the suspension again has a constant Newtonian viscosity of ή.
- At high solids fraction or high shear rates, these shear layers can become distorted and disoriented thereby increasing the viscosity (Shear Thickening) behavior.
- The overcrowing and disorder in the particles leads to increase in the viscosity.

VI. CONCLUSION

It was observed during all the experiments that the viscosity varied in a definite pattern with the shear rate. The curves for Viscosity versus the Shear Rate (which was the job speed for the experiment) were all of the same shape. As the shear rate (job rotation speed) was increased, for all the cases, the viscosity first decreased with the increasing shear and achieved a minimum point. After this minimum value of viscosity, if the shear rate was increased further, the viscosity showed to rise with the increasing shear rate.

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