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Pipeline Transportation of High Concentration Ironore Water Slurry Using Sodium Dodecylsulphate

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ABSTRACT

The iron and steel industry in India has grown substantially during the last two decades, with output predicted to exceed 180 million tonnes by 2022-2023. To fulfill this expected demand, the yearly output of run-of-mine (ROM) iron ore would need to grow from roughly 220 million tonnes to over 500 million tonnes. As a consequence, for the Indian iron and steel industries to survive, long-term continuous availability and supply of iron ore to processing sites at high rates are critical, and the emphasis is now on constructing environmentally friendly ore transportation through slurry pipelines in the future years. The slurry pipes will help to reduce pollution and traffic congestion. Transporting iron ore slurry with a high solids concentration might be considered a novel way to minimize specific water consumption per tonne of steel produced. The goal of this research is to investigate the impact of sodium dodecyl sulfate as a dispersing and stabilizing agent for the pipeline transport of iron ore particles in the form of iron ore water slurry. A viscosity test is used to assess the ability of sodium dodecyl sulfate as a dispersion agent. On the rheological behavior of iron ore water slurry, the impacts of sodium dodecyl sulfate dosages, IO concentration, temperature, and the shear rate-shear stress connection were explored. The slurries demonstrate Bingham plastic behavior within the concentration range studied. The change in electrostatic force caused by the surface charge on each particle resulted in improved dispersion behavior for the surface-modified particles in the aqueous solution.

Keywords: *Iron ore particle; Fe_2O_3;* sodium dodecyl sulfate*; Surfactant.*

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1. Introduction

The stability of highly concentrated iron ore slurry has become a leading research topic in the field of mineral processing[1]. The traditional way of transporting IO (iron ore)[2], which is harmful to the environment, has been looked into, but slurry pipeline transport is also a long-term option that has been looked into well. IO is usually moved by road, rail, or both. The amount of dust in the air is affected by how iron ore is loaded and unloaded at sidings[3–6]. Different physical [7–9]and chemical [10–12]ways of changing slurries are used to reduce particle-particle interactions and improve their rheological properties. Because of this, the surface of the IO particle was changed to improve its rheology. Most people know that the additive (dispersant or surfactant) makes a slurry more stable by reducing the contact between particles and increasing the electrostatic or steric repulsions of iron. This is what the DLVO hypothesis says[13].In 2018, Malorie and Kaushal[10,14]looked into the effects of different amounts of sodium hexametaphosphate on the yield point and viscosity value of slurry. They found that both of these properties were significantly affected. It was seen that the pH of the suspension and the amount of charge density on the particle surface had a big effect on how many surfactants stuck to the iron particle surface. In order to evaluate the adsorption on the surface and action mechanism of the surfactants sodium oleic(SO) and sodium-dodecyl-benzene-sulphonate on magnetite, Wang et al. [15]employed infrared spectral data, thermogravimetric and zeta potential analyses. The findings of the experiments demonstrated that SO molecules were able to form chemical bonds with the magnetite particles, and they also demonstrated that SDBS has been covered with a coating of SO-coated magnetite particles thanks to the Vander Waals attraction. Significant adsorption occurs across a range of pH values below the isoelectric point as a result of electrostatic interaction between the positively charged sodium dodecyl-benzene-sulphonate and the negatively charged magnetite particles (pI). Mabuza and his colleagues [16,17] utilized a polymeric dispersant (DP001) with varying quantities to make the ferrosilicon and magnetite dispersion less dense. The viscosity of the solution was reduced by around 20% even at low polymer concentrations, and it decreased by even more than 50%as the density and the amount of slime varied. For this experiment, a commercial ingredient such as SDS is used to stabilise the iron-ore water slurry (IOWS).

2. Materials and Methods

2.1 Iron Ore Sample

The Gandhamardan IO mines in Odisha, India, provided the sample of IO that was examined. Table 1 displays the chemical composition of IO measured by XRF (Zentium, Malvern Pananalytical). Fig.1. depicts the particle size distribution (PSD) of the IO sample as evaluated by a Laser Scattering Particle Size Analyzer (LA-960, HORIBA). The surface morphology of the IO sample was analyzed by using JEOI, JSM-7100F as shown in Fig.2.

Table 1.Chemical component analysis of IO (XRF).

Compound	Fe_2O_3(%)	Al_2O_3(%)	SiO_3(%)	Others (%)
Concentration	80.23	6.24	6.33	7.20

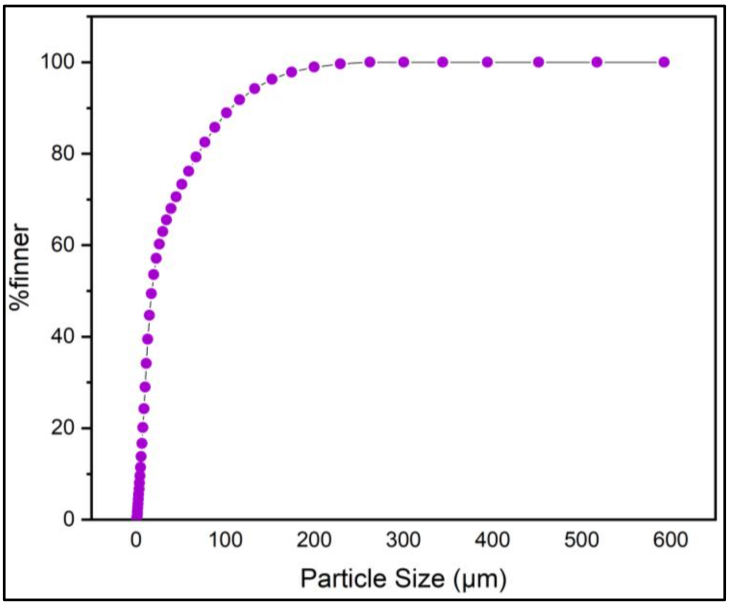

Fig. 1. Particle size distribution of iron ore sample.

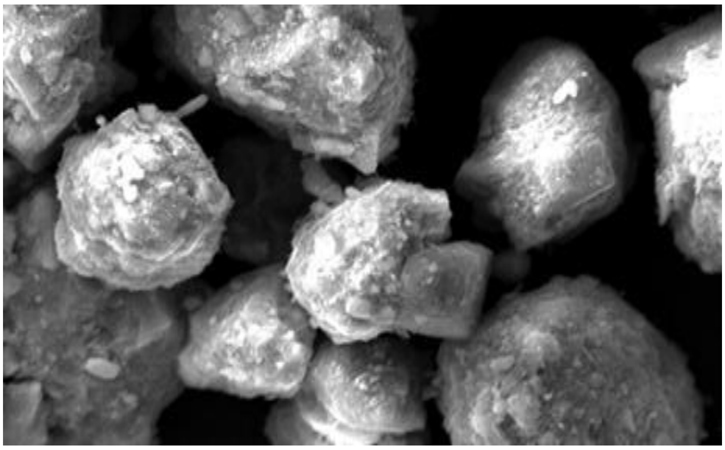

Fig. 2. SEM image of iron ore.

2.2. **Preparation of Sodium DodecylsulphateSolution**

Merck India Ltd. was provided the surfactant, Sodium Dodecylsulphate (SDS). Various concentrations of additive solution were prepared for the rheological behavior investigation of IOWS. These solutions had concentrations of 2 mM, 4 mM, 6 mM, 8 mM, 10 mM, and 12 mM respectively.

2.3. **Measurement of Rheological Behavior:**

For the rheological investigation of FAS, a Thermo Scientific HAAKE RHEOSTRESS rheometer was used. The MV I sensor system is used to monitor rheology. For two minutes, the shear rate was adjusted from 10 to 200 s^{-1} to determine the related viscosity at various temperatures. The slurry was passed through a circulating bath with a constant temperature that was connected to the viscometer to maintain a temperature variation of 0.1°C. Different FAS concentrations ranging from 45 to 65 percent were prepared by swirling continuously for 10 to 15 minutes. To perform a rheological test, a 30 mL volume sample of slurry was placed into a clean rheology cup.

2.4. **Measurement Static Stability of Iron Ore**

The static stability of IOWS was assessed using the rod penetration technique. Different concentrations of IO and SDS were used to prepare IOWS, which were then transferred to a 100 mL-capacity glass cylinder. The cylinders' tops were sealed, and they were kept at room temperature. For the penetrating technique, a glass rod of 5 mm in diameter and weighing 19 grams was used. Once every day, this glass rod was then inserted into the slurry. The emergence of soft sediment over time served as a sign of the stability of static stability.

3. Results and Discussion

3.1. Impact of SDS Concentration on the Apparent Viscosity

The influence of SDS dosage on the apparent viscosity of the IOWS was investigated by increasing the quantity of SDS dosages in the slurry mixture of 2 mM, 4 mM, 6 mM, 8 mM, 10 mM, and 12 mM. The findings revealed that SDS had a considerable influence on viscosity decrease. In Fig.3, as the concentration of SDS rises, the apparent viscosity of the slurry drops from 980 mPa.s, the quantity of SDS that generates the greatest obvious fluidity, to 240 mPa.s at 10 mM. The increased electrostatic and steric repulsions between the adsorbed molecules (starch, SDS, and tannin) at the IO interface seem to be the reason for decreased viscosity of IOWS [18,19].

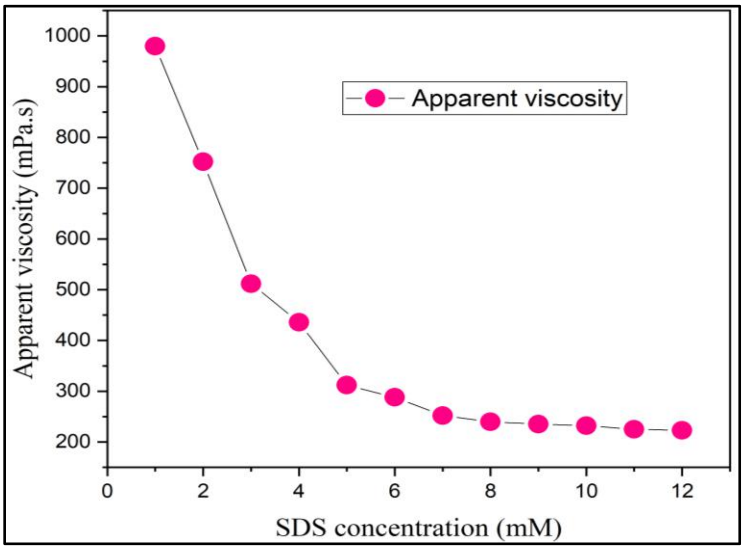

Fig. 3. Influence of SDS concentration on apparent viscosity.

3.2. Influence of Iron Ore Concentration on Apparent Viscosity

The amount of IO in IOWS is one of the most important aspects influencing slurry effectiveness. In the study of suspension rheology, solid concentrations are typically stated as a percentage of total volume. As the volume proportion of IO in the mixture increases, the capacity of the slurry to flow freely declines gradually but progressively. To avoid sedimentation caused by gravity, the viscosity of the concentrated slurry should be high. However, the viscosity of the slurry should be low during transit to allow it to flow more easily. As a result, a thorough knowledge of viscosity as a function of IO content is particularly important. The rheological properties of IOWS, a triple combination of IO, water, and surfactant, are primarily determined by viscosity values, which rise with increasing IO load. Fig. 4 depicts the variation of apparent viscosity with IO concentration in the presence of optimum SDS solution. Because of the production of hard IO sediment, the apparent viscosity increases over 64.6 wt.% of IO in the slurry. The apparent viscosity of IOWS rises with the volume percentage of IO in the slurry, reaching a maximum of 64.6% at an optimum SDS of 10 mM. As a consequence of significant interparticle interaction in the concentrated sample, the slurry becomes unworkably thick at 64.6 %. As a result, preparing 65% IOWS is not recommended owing to the development of stiffness in the IOWS sample.

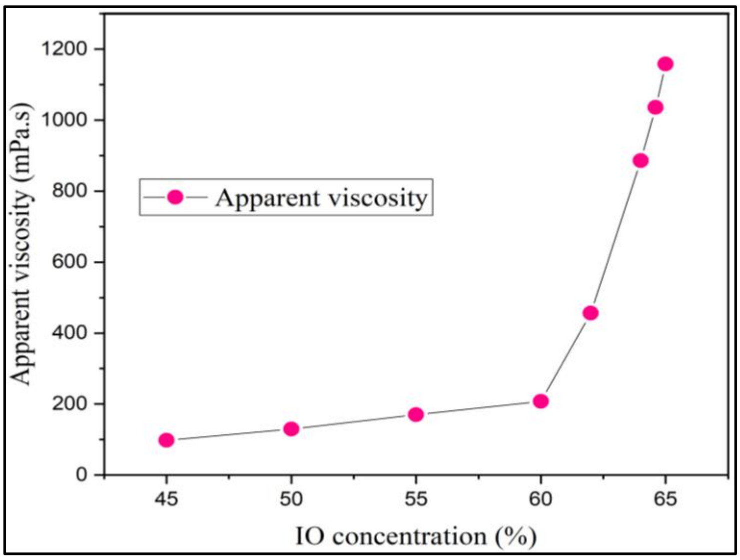

Fig. 4. Influence of iron ore concentration on apparent viscosity.

3.3. Rheological Analysis of IOWS at Different IO and SDSConcentration

Since transporting IOWS through a pipeline requires it to flow easily, it is important to understand how it flows and how its viscosity changes as it flows. The shear stress was measured as a function of the shear rate to figure out what IOWS was. This is shown in Fig. 6, where we studied the relationship between shear rate and shear stress at the optimal concentration of SDS with IO concentrations of 50% and 65%. In the Y-intercept of the plot, it can be seen that the IOWS can hold up to a certain amount of shear stress (initial shear-stress threshold value). Yield stress is the value of the shear stress at this point. For the slurry to move freely, the shear rate should be higher than this yield stress value. After the point of yield stress, the shear rate changes in a straight line with the shear rate. The plot of shear stress versus shear rate with an initial threshold shear stress gives a straight line, which shows that IOWS is acting as non-Newtonian Bingham plastics fluids and following the equation below,

$$\sigma = a.\gamma + b \qquad \dots (1)$$

Where, a = Dynamic viscosity, b = yield stress, and γ = applied shear rate.

The yield stress of slurry is given by the intercept of these linear plots. The yield stress goes up as the percentage of IO in the slurry goes up at the optimal concentration of SDS (10 mM). It has also been seen that (Fig. 5) as the IO concentration goes up, the yield stress value (Y-intercept) goes up considerably. This may be because the IO particles stick together strongly at higher concentrations. When the slurry passes a certain level of shear stress, called yield stress, it changes from an elastic to a plastic state. When the applied stress is less than the yield stress, the material deforms elastically, and the slurry doesn't move. But when the applied stress passes the yield point, the sample flows because it deforms.

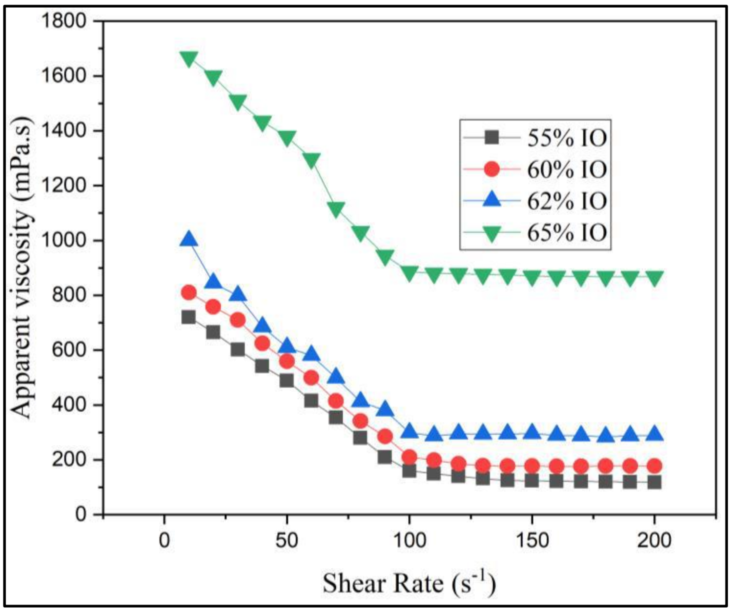

Fig. 5. Shear rate on apparent viscosity at various IO percentages.

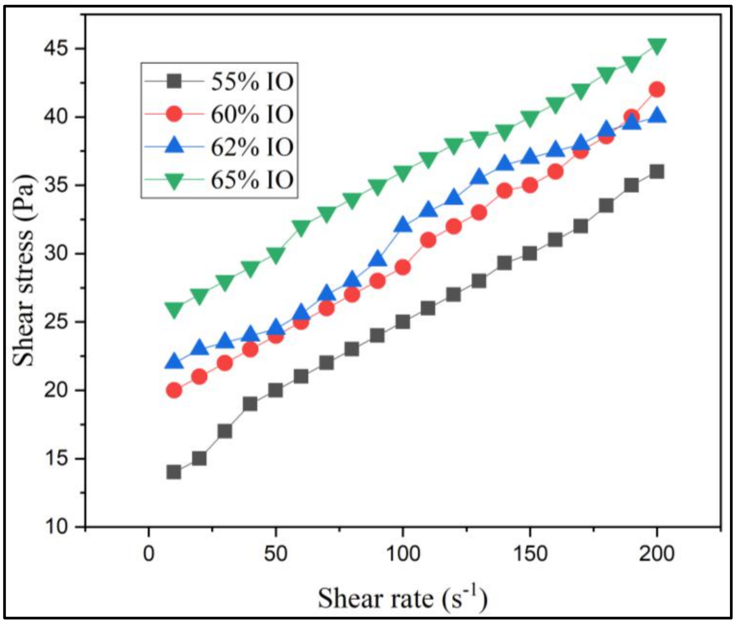

Fig. 6. Shear rate on shear stress at various IO percentages.

3.4. Effect of Temperature on the Rheology of Iron Ore

The influence of temperature on apparent viscosity was studied at temperatures ranging from 298K to 213K. The temperature of the slurry suspension was changed by 5° at a concentration of 60% IO. Fig.7 depicts how the viscosity of a slurry suspension varies with temperature. The number of solid particles and surface area per unit volume of slurry suspension decrease as the temperature rises. This reduces shear stress. As a result, all slurry suspensions have lower viscosity. The kinetic energy of the particles increases as the temperature of the slurry rises. This causes the particles to travel quicker, making it simpler for molecules in separate levels to cease interacting. Also, as the temperature rises, the activity of the surfactant to spread increases. All of the test shear rate settings indicate a slight decline in relative viscosity as the temperature rises from 208K to 213K. The authors also investigated the rheology of coal-water slurry[20],limestone-water slurry, and fly ash slurry[21], and discovered the same results regardless of temperature[22].

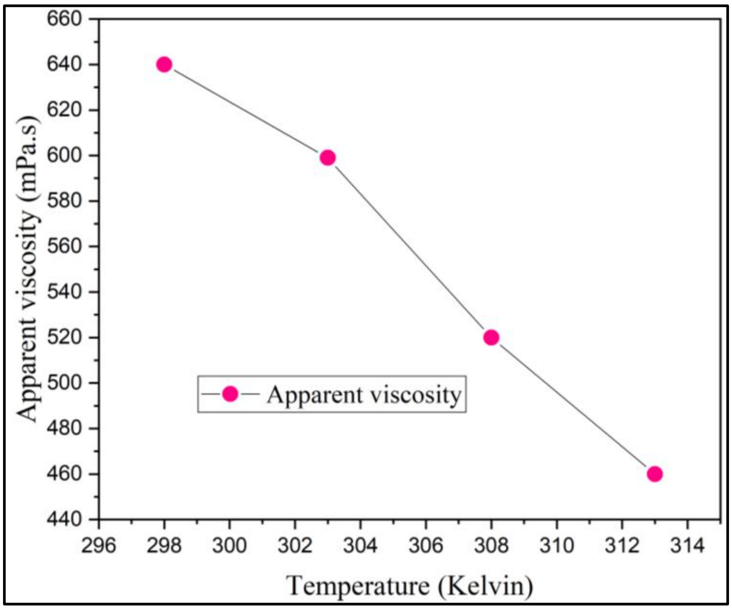

Fig. 7. Effect of temperature on apparent viscosity.

3.5. Static Stability of FAS

Because the transportation of IOWS from the mining unit to the dumping place is delayed for many days owing to an obstruction in the pipeline, the static stability of the slurry requires research. The stability of IOWS was studied at various weight concentrations (50%, 60%, and 65%) and SDS concentrations (2 mM,4 mM,6 mM,8 mM,10 mM, and 12 mM). The stability of the slurry was measured by the movement of a rod within the slurry containing the beaker over days. (Fig.3) demonstrates the influence of IO and SDS concentration on the stability of IOWS. The appearance of soft sediment by day was used as an indicator of static stability in the study. As shown in Table 2, increasing the SDS content from 2 to 12 mM enhanced the static stability of the IOWS until a plateau value was reached after 12 days. Nonetheless, it was believed from this investigation that above the optimal concentration of the SDS limit, the static stability remained unaffected, which was supported by published studies. According to the basic principle of surface chemistry, the stability of slurry depends upon the number of functional groups or groups containing lone pairs of electrons in the additive which gets adsorbed on a solid surface and the functional group gets hydrated extensively. From the experiment, it is displayed that IOWS has maximum stability and can be kept for up to 10 days.

Table 2.Results of static stability of IOWS at various IO and SDS concentrations.

IO concentration (wt.%)	Stability (days)				
	2 mM of SDS Conc.	4 mM of SDS Conc.	6 mM of SDS Conc.	8 mM of SDS Conc.	10 mM of SDS Conc.
45	04	05	07	08	08
50	05	07	09	09	09
55	07	08	11	12	12
60	08	10	14	15	15
62	10	12	15	16	16
65	13	14	16	17	17

4. Conclusion

SDS was used to reduce viscosity in the stabilization and pipeline transportation of high-concentration IOWS. As the SDS concentration was raised, the slurry viscosity and yield stress value decreased. The greatest viscosity decrease (980 to 240 mPa.s) was observed with 8 mM SDS Conc. With an acceptable range of viscosity, a maximum IO concentration of 64.6% was attained. When the temperature is increased from 208K to 213K, the relative viscosity decreases somewhat for all of the test shear rate values. The analysis illustrates the appropriate and successful use of SDS for improving IOWS pipeline transportation.

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Credit authorship contribution statement

Mandakini Behari: Conceptualization, Validation, Data curation, Visualization, Writing -original draft. A.M. Mohanty: Conceptualization, Supervision, Formal analysis. Debadutta Das: Conceptualization, Methodology, Investigation, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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