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THE EFFECT OF ELECTRODEWATERING ON THE FLOW CHARACTERISTICS OF BLACK COAL - WATER SUSPENSIONS IN PIPES

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ABSTRACT

The transportability and dewatering characteristics of suspensions of fine black coal particles (< 75 micron) and water may be enhanced by the application of a DC electric field. The effect of electrodewatering on the flow properties of a 42.0 % (v/v) coal-water mixture flowing in concentric and eccentric anode-cathode pipe arrangements is presented in this paper. Anodic wires (0.62mm & 3.0mm OD) are suspended in a 21.4mm and a 28.5mm pipe. Electric currents of between 1 and 7.5 amperes (at 72 volts), are applied in a 1 metre section of pipe to achieve typical reductions in pumping energy of 40-85 %.

INTRODUCTION

The production of fine coal particle wastes and by-products has increased as a result of the continuous mining methods and beneficiation processes relevant to the coal industry. An inherent problem with the production of fines is a relatively high moisture content which introduces technical and economic difficulties in the handling, disposal, water removal and reusability of coal fines. Tailings dams are a common method of disposal and storage of coal wastes produced by coal preparation plants.

The oil crisis that occurred during the 1970's generated further interest in coal slurry fuel technology [1] and the economics of alternative fuels, renewable energy [2] and coal slurry transport systems [3-6]. Contemporary ethical issues such as sustainable resource development [7] has directed political and economic pressure on the mining industry and government bodies to improve the utilisation of current resource levels and to limit any detrimental effects on the environment. There are also economic and environmental benefits in closing plant water circuits.

Chemical, biological and natural sedimentation methods used in the dewatering of concentrated suspensions of fine particles are generally inefficient and economically unfavourable. The use of electrokinetic techniques for the purpose of dewatering slurries has been applied to mineral slurries [8,9], mill tailings, slimes and coal wastes [10-12]. In the presence of a DC electric field ionic species and solid particles possessing a net electrostatic charge relative to the aqueous phase in a solid-liquid suspension, will migrate towards the oppositely charged electrode. As opposed to hydraulic flow, this externally induced flow is driven by electrokinetic forces which is primarily a surface phenomenon and is essentially independent of pore size and its distribution.

The transportability and dewatering of coal-water mixtures flowing in a pipe may be enhanced by the application of electrokinetic techniques. Previous experimental work [13,14] shows a significant reduction in the wall shear stress, and consequently a decrease in pumping energy requirements for the flow of coal-water mixtures combined with electrodewatering. In this process a 3mm tube (anode) is centrally aligned in a 12.62mm pipe (cathode).

EXPERIMENTAL

A slurry reservoir of 25 litre capacity was modified to function as a pressure vessel (fig.1). The flow rate in the tube rheometer is controlled by an air pressure regulator (0-250 kPa) which is attached to the inlet of the slurry pressure vessel. The cumulative mass flow

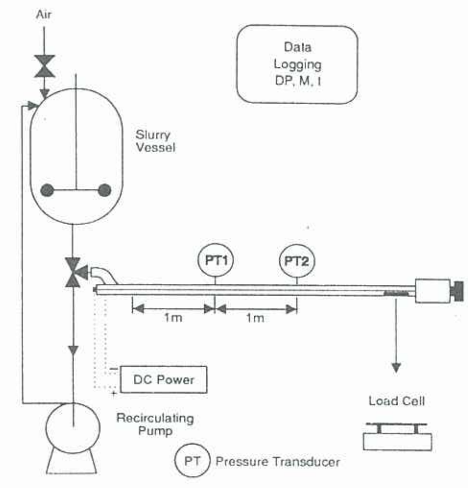

Fig. 1 Experimental Set-Up of Tube Rheometer.

rate through the system is measured by computer logging data from a top-pan weighing balance (0-30 kg). Pressure drop is also determined by interfacing the pressure transducers connected to the various tapping points on the pipe with the data acquisition system.

A variable DC power supply (72V,10A) is connected to the tube rheometer which is electrically insulated from the other components of the experimental apparatus. In all experiments the pipe wall acts as the cathode and the various concentric and eccentric anode arrangements shown in figure 2 are positioned and maintained by a tensioning device.

An Australian low rank bituminous black coal is used in all experiments. Particle sizes above 75 micron were removed by screening which produced a material of coal fines (D(50) = 20 micron). Coal-water mixtures are prepared in the slurry reservoir to a homogeneous state and are used immediately to minimise ageing effects.

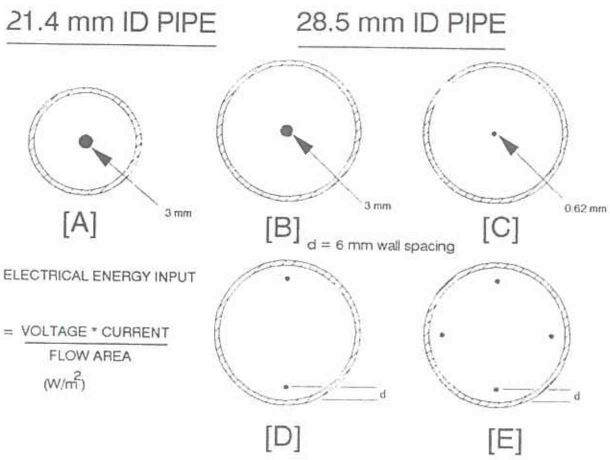

Fig. 2 Concentric (A-C), eccentric (D,E) anode-cathode pipe arrangements.

DISCUSSION OF RESULTS

The effect on fluid properties such as apparent viscosity when an electric field is applied was examined by Duff [15] almost a century ago and then by Winslow [16] in 1949 and is today commonly referred to as the electrorheological effect. In disperse systems Klass and Martinek [17] suggested that the polarisation of the particle double layer is the primary mechanism responsible for this observed phenomenon.

A rotational electro-viscometer which is similar to the one used by Winslow, provided electrorheological data and observations for concentrated coal-water suspensions [18]. In this system the formation of a highly cross-linked structure within a suspension subjected to an electric field, produced an observable increase in apparent viscosity which is attributed to the induced formation of particle dipoles and the migration of coal particles towards the anode. When the polarity of the electro-viscometer is reversed the rate of coal migration towards the anode is shown to be dependent on the electric field strength applied. A microscopic study of a dilute coal-water suspension in the presence of an electric field, revealed the formation of coal particle chains which is consistent with a mechanism based on particle polarisation.

The effect on the pressure drop in the electrodewatering section of the tube rheometer for variations in the electric field strength and mass flow rate is shown in figures 4 to 8. At a constant slurry vessel pressure a reduction in the pressure drop and a simultaneous increase in mass flow rate is measured when an electric field is applied. This effect is enhanced as the electric field strength is increased and at low flow rates where the initial residence time in the tube rheometer is maximised. The maximum electrical power measured for each of the anode-cathode arrangements is limited by the size and position of the anode(s) within the pipe.

The reduction in pumping energy is expressed in terms of a pressure drop ratio at the 'dewatered' flow rate (fig.3). The electric field strength in a concentric annulus is non-uniform and related to the radial distance. In the eccentric systems the electric field strength is also dependent on the radial angle. The mean electric field strength is represented as the rate of input of electrical energy based on the flow area.

Figures 9 to 11 show the effect of electrical energy input on the reduction in pumping energy at initial velocities of 0.3, 0.2 and 0.1 m/s respectively. The degree of electrodewatering for all the anode-cathode designs is dependent on the initial residence time and the input of electrical energy. System [E] shows a reduction in pumping energy of 85 % at an initial velocity of 0.1 m/s (fig.11). A comparison between this system and the twin-anode system [D] reveals that the frictional losses associated with the anodic area become significant at high initial velocities. Scaling-up the pipe diameter at constant anode size (A and C) enhances the electrodewatering effect however an increase in electrical power requirements due to the increase in annular gap, is measured (fig.9-11).

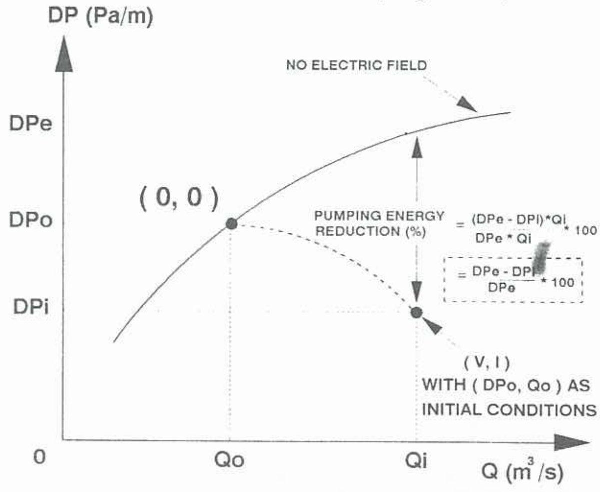

Fig. 3 Reduction in Pumping Energy (%)

A comparison between the electrical power requirements and the reduction in pumping energy suggests that the economic feasibility of a slurry pipe system using a concentric or eccentric anode-cathode arrangement is related to the stability of the water layer at the wall downstream of the dewatering section. Previous experimental work has confirmed the stability of flow conditions in a 12.62 mm [13] and a 21.43 mm [19] pipe system with a centrally aligned anode. The maximum ratio of the length of the non-dewatering to the dewatering sections in the tube rheometer was limited to 1.5 in both of these cases. During scale-up the eccentric systems [D] and [E], will minimise the increase in electrical energy requirements by maintaining a constant anode-cathode distance.

CONCLUSIONS

The use of a modified tube rheometer has demonstrated that a significant reduction in wall shear stress is possible when an electric field is applied to a coal-water slurry flowing in a pipe. The effectiveness and stability of the electrodewatering technique is shown to be dependent on the residence time in the dewatering section, electric field strength and the anode-cathode pipe design. Reductions in pumping energy requirements of 40-85 % are measured. Further research into the economic feasibility of this process and the stability of flow conditions in other anode-cathode arrangements is required.

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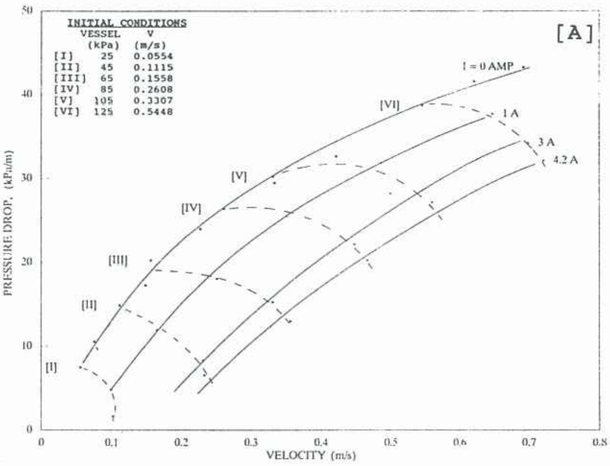

Fig. 4 Electrodewatering of a coal-water suspension (42.0 % v/v) in [A].

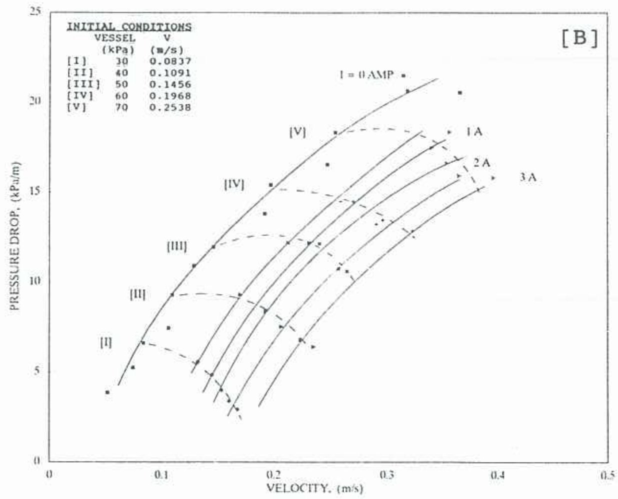

Fig. 5 Electrodewatering of a coal-water suspension (42.14 % v/v) in [B].

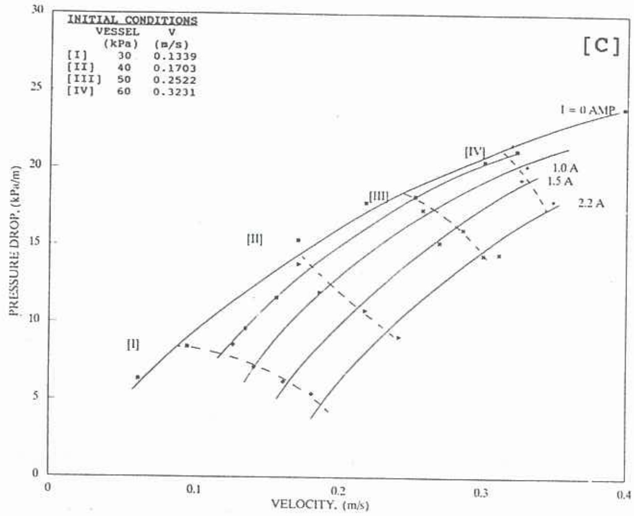

Fig. 6 Electrodewatering of a coal-water suspension (42.25 % v/v) in [C].

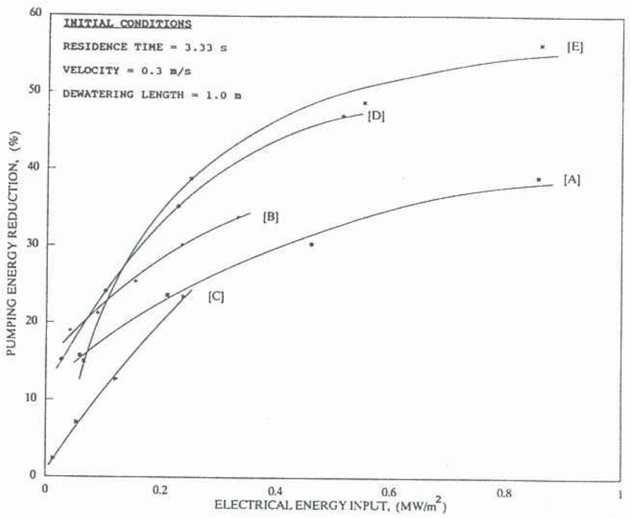

Fig. 9 Reduction in Pumping energy for (A-E). Initial Velocity = 0.3 m/s

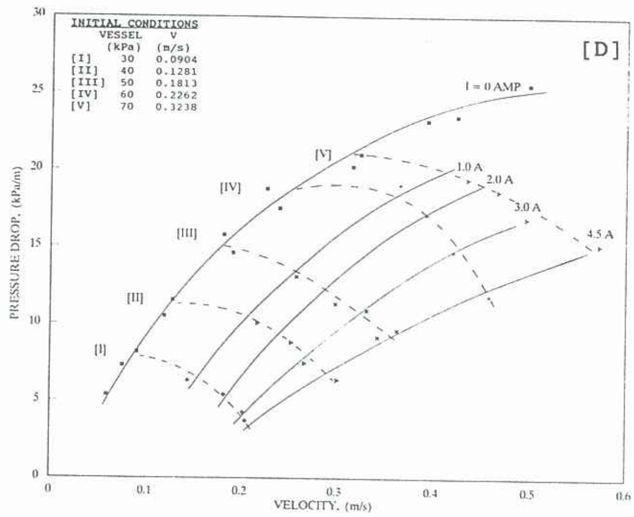

Fig. 7 Electrodewatering of a coal-water suspension (42.25 % v/v) in [D].

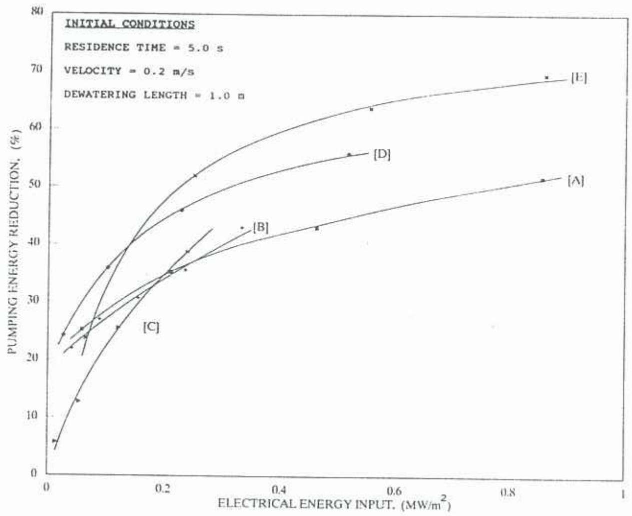

Fig.10 Reduction in Pumping energy for (A-E). Initial Velocity = 0.2 m/s

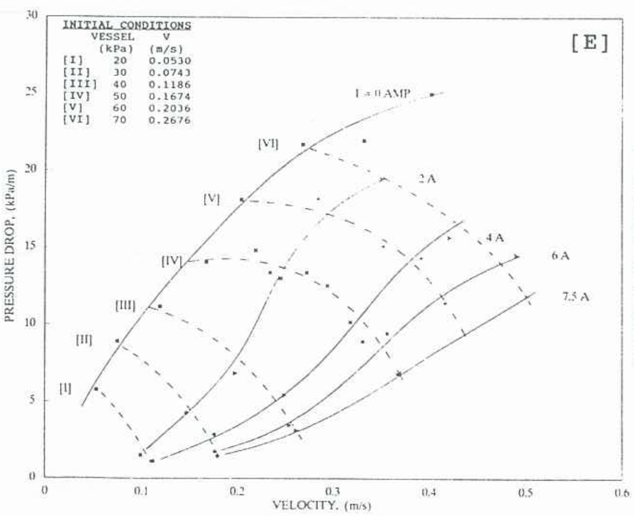

Fig. 8 Electrodewatering of a coal-water suspension (42.25 % v/v) in [E].

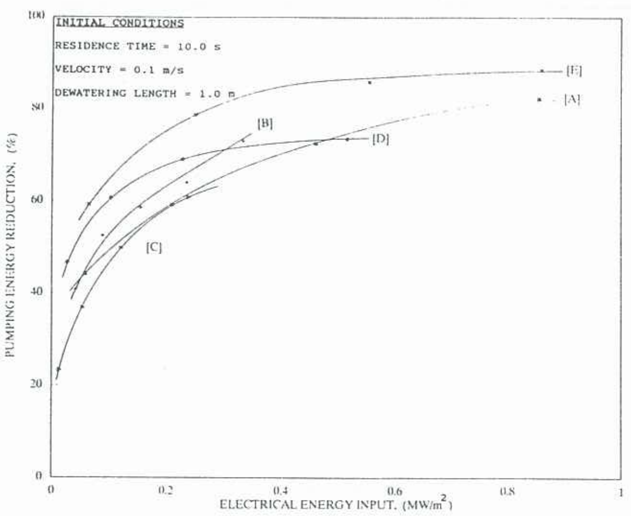

Fig.11 Reduction in Pumping energy for (A-E). Initial Velocity = 0.1 m/s