Preferred citation: R.W. Hoyland and M.P. Neill. The effect of AKD on paper friction – Prepared contribution. In **The Fundametals of Papermaking Materials**, *Trans. of the XIth Fund. Res. Symp. Cambridge, 1997*, (C.F. Baker, ed.), pp 1617–1631, FRC, Manchester, 2018.
DOI: 10.15376/frc.1997.3.1617.

Prepared Contribution
The effect of AKD on paper friction

R.W. Hoyland and M. P. Neill
Department of Paper Science, UMIST, P0 Box 88, Manchester M60 1QD, UK.

Introduction

Recent years have seen the increasing change from acid to neutral papermaking sizing systems~ Neutral systems allow the use of calcium carbonate and have necessitated a change in the sizing system from rosin/alum systems to neutral sizing agents. Alkyl ketene dimers (AKD) are commonly used nowadays. However it has been noted that AKD sizes have a detrimental effect on paper friction, resulting in a lowering of the coefficient of friction (1,2).

Measurement of the coefficient of friction

The horizontal plane method was used to determine the frictional properties. This method allows measurement of both the static and kinetic coefficient of friction and measures the force required to move a sledge over the sample surface at a predetermined speed. Based on previous experience in the Paper Science Department, the method employed by Massey (3) was used in this work. A metal sledge was attached via a nylon thread and frictionless pulley to the load cell of an Instron tensile tester.

Measurement of the initial force required to create the onset of sliding allows calculation of the static coefficient of friction. Once sliding has commenced measurement of the average force over a sliding distance of 15cm determines the kinetic coefficient of friction. All friction values were paper to paper with the top side of the sheet on the sledge being moved over the wire side of the sheet on the base plate. In all cases the direction of movement was along the machine direction of the sheet.

Preparation of the papers used for testing

The paper for the experiments was made on the pilot papermaking machine at UMIST employing a 30% bleached softwood (pine) and 70% bleached hardwood (birch) ftirnish, beaten to 35 deg. SR. The paper was manufactured to a grammage of 80 g/m2 and conditioned for two days at 23 deg C and 50 % RH before testing. For the papers contalning AKD, the emulsions were added to the paper stock in the mixing box prior to the headbox on the papermaking machine. The addition levels quoted are the dry solids weight of the AKD expressed as a percentage of the oven dry fibre weight. Typical industrial addition levels are in the range 0.05-0.25%.

Preparation of the AKD emulsions

In reality commercial AKD's are a mixture of ketene dimers, where the side chains could be of the same length and or be different lengths, depending upon the natural fatty acid sources from which they are manufactured. Also they may contain residues of the fatty acid and this could even be a mixture of different fatty acids. To mimmise this source of variability, emulsions were prepared according to the scheme shown in Table 1. All emulsions contaimed a small amount of dispersant, appoximately 4% of the total solids.

Results

C16AKD series emulsions

Figures 1 and 2 show the effect of the Cl6AKD emulsions on the static and kinetic coefficients of friction respectively. With the Cl6AKD emulsion the static coefficient of friction decreases as the addition level increases. The kinetic coefficient of friction exhibits a larger change over the same addition range. The Cl6AKD 4% emulsion produces a dramatic decrease in both the static and kinetic coefficient of friction once an addition level of 0.1% has been exceeded. At higher addition levels the values of the static and kinetic coefficient of friction appear to be levelling out.

In the case of the emulsion with the highest fatty acid content, C16AKD 8%, the decrease in both the static and kinetic coefficient is immediate and remains at this level at the higher addition levels of the emulsion.

Cl8AKD series emulsions

Both the static and kinetic coefficient of friction decrease with the increase in addition of C18AKD as shown in Figures 3 and 4. In this case the introduction of the fatty acid, Cl8AKD 4% and Cl8AKD 8%, results in little or no change in the value of the static or kinetic coefficient of friction when compared to the C18AKD.

C22AKD series emulsions

There is a dramatic decrease in the friction coefficient values with increasing AKD addition level as shown in Figures 5 and 6. There is an immediate decrease in both the static and kinetic coefficient of friction even with the addition of the pure AKD emulsion. The kinetic coefficient of friction decreased at the same rate for all the three emulsions with the increase in AKD addition level.

The effect of the AKD side chain length on the coefficient of friction

Only the results of the pure AKD emulsions are considered, as the addition of fatty acid could distort the analysis. The results are presented in Figures 7 and 8. The results show that the side chain length of the AKD molecule has a significant effect on the decrease of the friction coefficient. The longer side chain lengths produce a greater decrease in the friction coefficients.

The reason for the decrease in the friction is probably due to the collapse of the hydrocarbon chains under the pressure of the test conditions. With the action of the sledge sliding over the surface, the hydrocarbons would probably be orientated in the direction of the slide, thus providing a lubrication of the fibre surface. The longer chains would be more likely to collapse and orientate under the sliding conditions, as a result of their greater flexibility allowing them to bend more easily than the shorter chains. The longer chains would also be able to cover the fibre surface more effectively, simply due to the greater length of the molecule. These combined effects would result in the longer chain lengths having a much lower friction value.

Surface energy measurements

The surface energy of all the manufactured papers was measured using the contact angle method devised by Owens and Wendt (4). The results are presented in Figures 9 and 10. The graphs include the data from all the papers which were made. The surface energy values around the 60 ergs/cm2 value are the zero AKD addition samples.

Initially the surface energy value remained constant whilst the surface energy value decreased, this is associated with the initial addition of the AKD. The frictional level then decreased sharply, whilst the surface energy only decreased slightly. The friction value then levelled out, whilst the surface energy contined to decrease. The overall effect is that there is an apparent 'step' decrease in the friction coefficient with the decrease in the surface energy. The 'step' feature of the plot between friction and surface energy values can be seen in the results of work by Inoue et al (2) although Inoue did not comment on this feature.

Conclusions

In general terms, the addition of AKD to the paper reduces the static and kinetic friction coefficients.

For the C16AKD emulsion, both the static and kinetic coefficient of friction decreased as the addition level of MW was increased, with the kinetic coefficient exhibiting a larger change over the same addition range.

The addition of fatty acid to the emulsion (Cl6AKD 4% and Cl 6AKD 8%) produced a larger decrease in both the static and kinetic coefficient of friction, the higher the fatty acid content the more dramatic the effect, which appears to be approaching a minimum value.

Both the C18AKD and C22AKD emulsions produced an effect similar to the C16AKD emulsion. However the addition of fatty acid did not produce any flirther reduction in the value of the static or kinetic coefficient of friction.

The side chain length of the AKD molecule has a significant effect on friction, the longer the side chain the greater the decrease in the friction coefficients. The addition of AKD decreases the surface energy of the paper, as well as the friction coefficients. The decrease in the friction coefficients had a 'step' relationship to the decrease of the surface energy of the paper. It was found that there was a critical surface energy value, below which there was a dramatic reduction in the friction coefficients.

References

1. Bach, E. L., Proceedings Tappi International Physics Conference, 49 (1991).
2. Inuoe, M., Gurnagul, N. and Aroca, P., Tappi, 73(12), 81(1990).
3. Massey, A. M., M. Sc. Thesis, University of Manchester, 45 (1979).
4. Owens, D. K. and Wendt, R. C.,·J. Appl. Polymer Sc. 13, 1141(1969).

Emulsion Designation	Side Chain Length		AKD Content as % of total solids	Fatty Acid	Fatty Acid Addition Level as % of total solids	Starch Content as % of total solids	Total Dry Solids Content %
	R	R'					
Tetradecyl ketene dimer							
C16AKD	14	14	78.9	Palmitic	0	17.1	7.1
C16AKD4%	14	14	74.9	Palmitic	3.9	17.1	7.4
C16AKD8%	14	14	70.9	Palmitic	7.9	17.2	7.2
Hexadecyl ketene dimer							
C18AKD	16	16	76.8	Stearic	0	19.2	7.5
C18AKD4%	16	16	73.1	Stearic	3.8	19.1	7.5
C18AKD8%	16	16	69.3	Stearic	7.7	19.0	7.5
Didecyl ketene dimer							
C22AKD	20	20	76.9	Arachidic	0	19.2	8.7
C22AKD4%	20	20	76.3	Arachidic	3.8	19.2	9.1
C22AKD8%	20	20	69.2	Arachidic	7.7	19.2	8.0

Table 1. Contents of the AKD emulsions

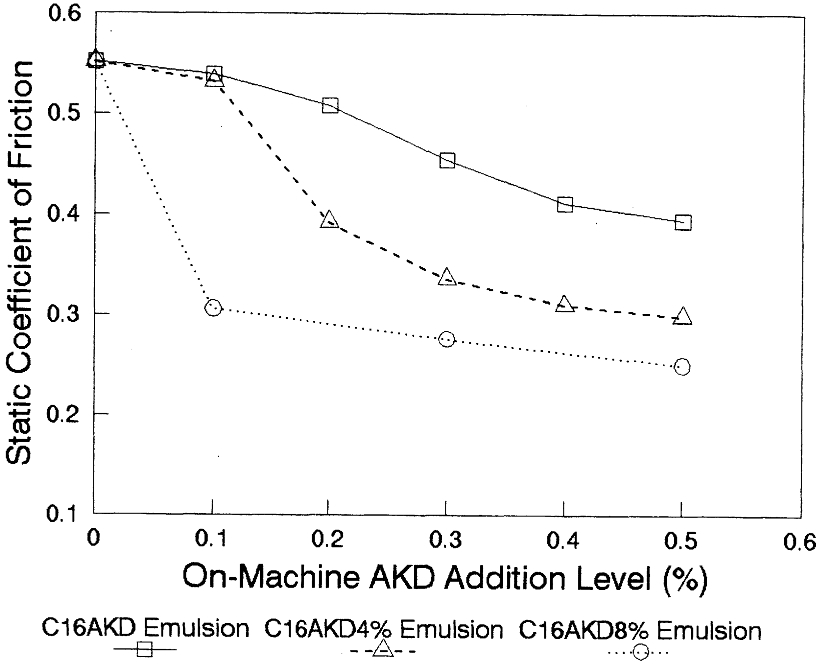

Figure 1 : The effect of the C16AKD emulsions on the static coefficient of friction

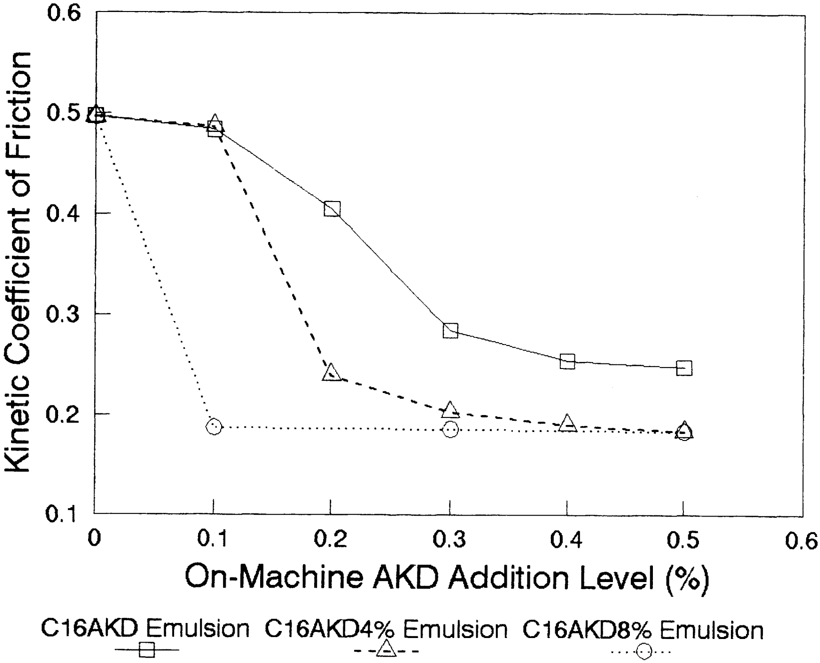

Figure 2 : The effect of the C16AKD emulsions on the kinetic coefficient of friction

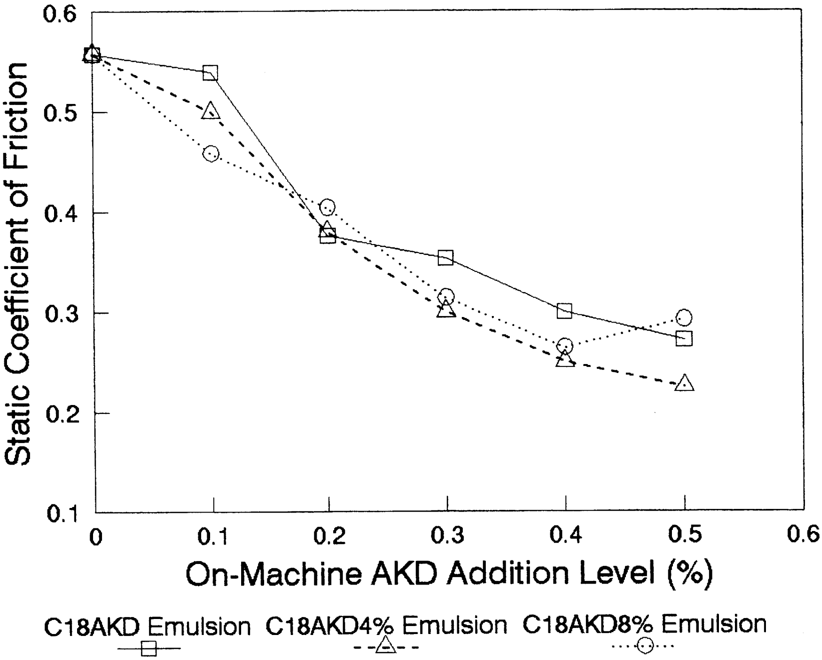

Figure 3 : The effect of the C18AKD emulsions on the static coefficient of friction

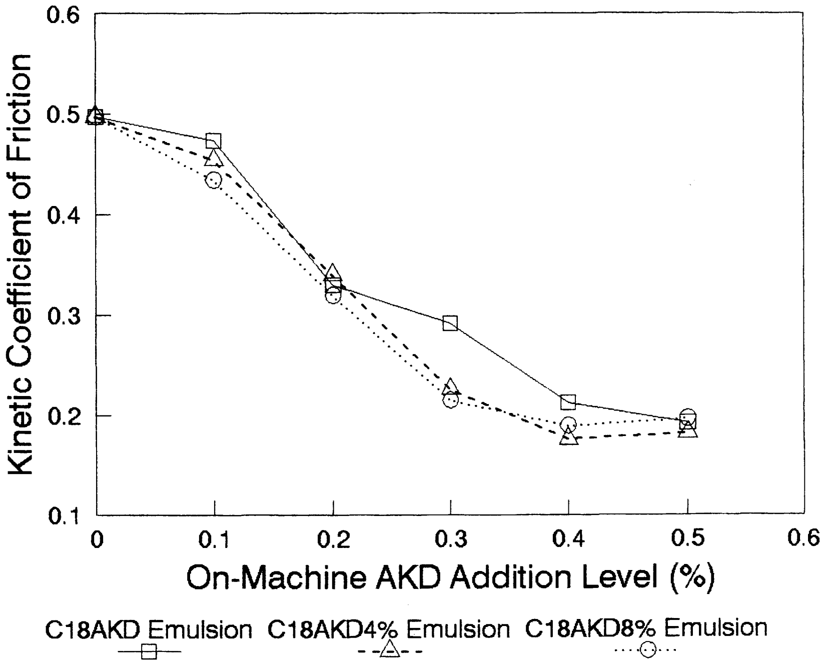

Figure 4 : The effect of C18AKD emulsions on the kinetic coefficient of friction

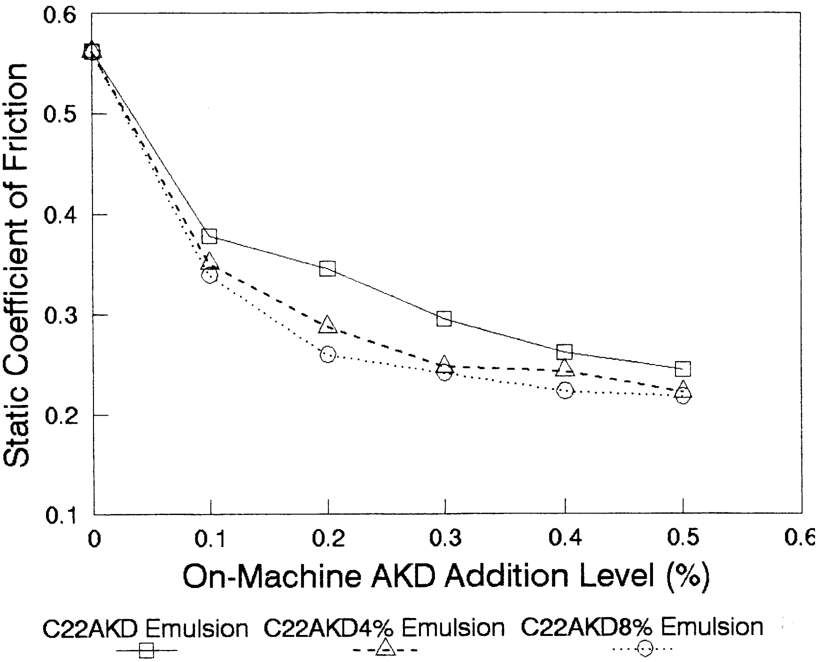

Figure 5 : The effect of the C22AKD emulsions on the static coefficient of friction

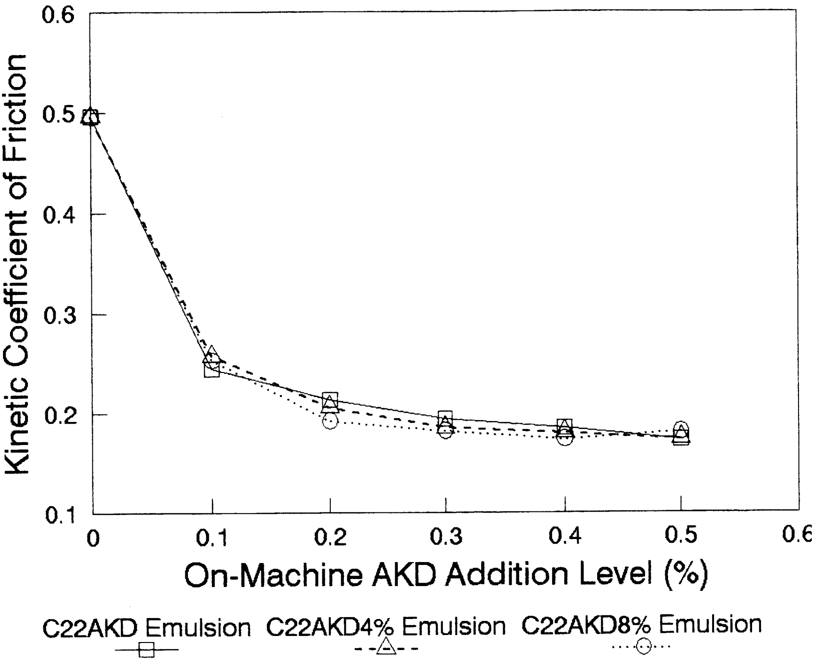

Figure 6 : The effect of the C22AKD emulsions on the kinetic coefficient of friction

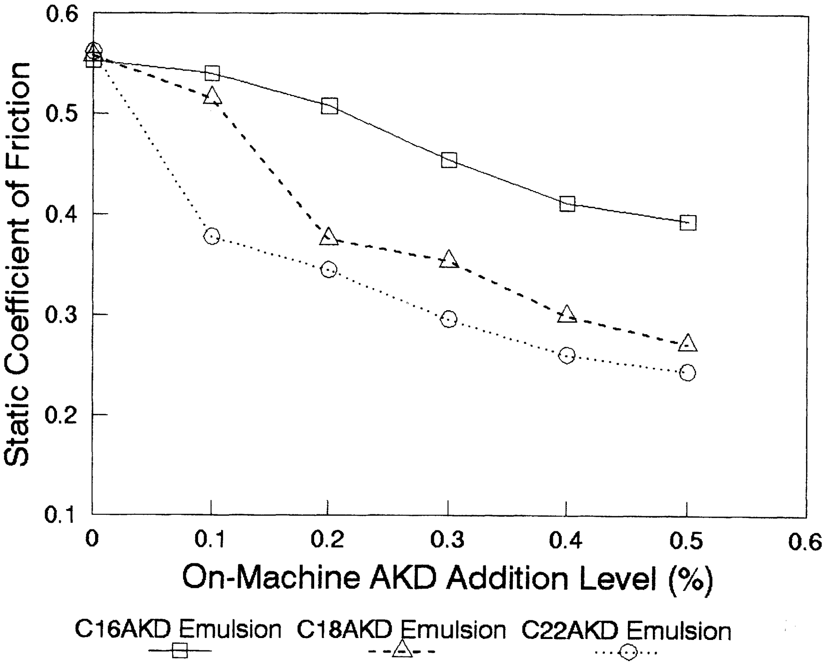

Figure 7 : The effect of AKD side chain length on the static coefficient of friction

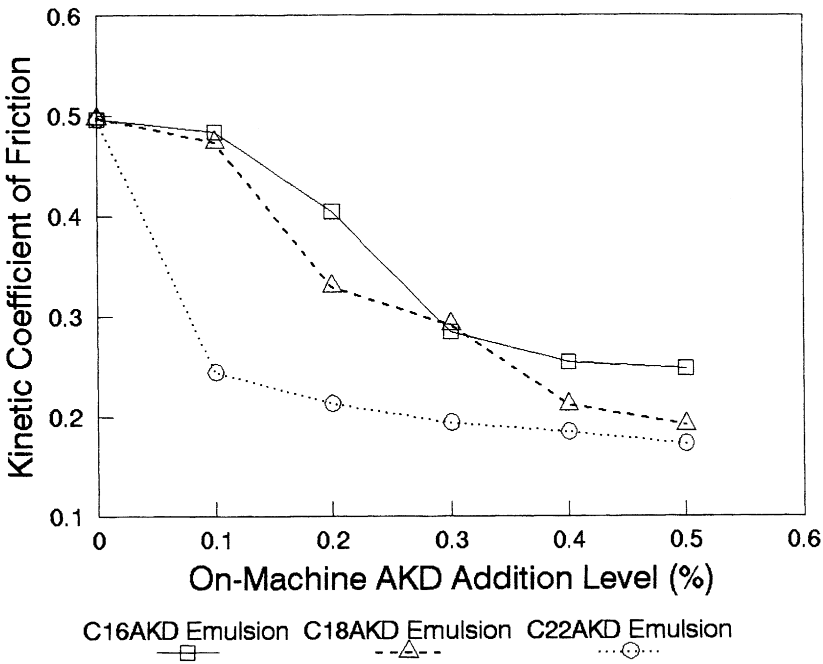

Figure 8 : The effect of AKD side chain length on the kinetic coefficient of friction

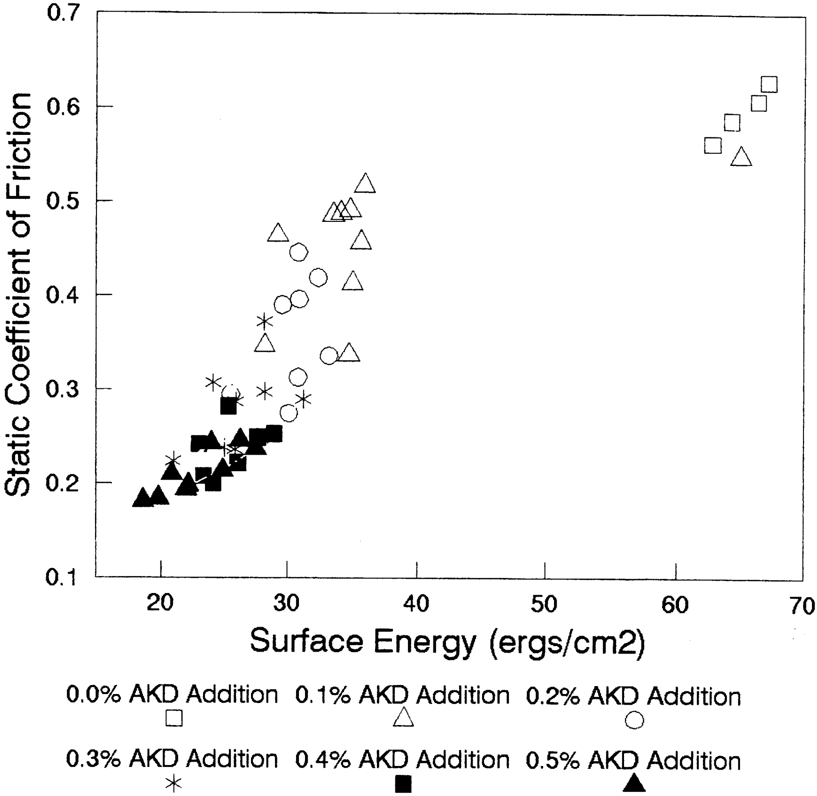

Figure 9 : The surface energy values plotted against the static coefficient of friction

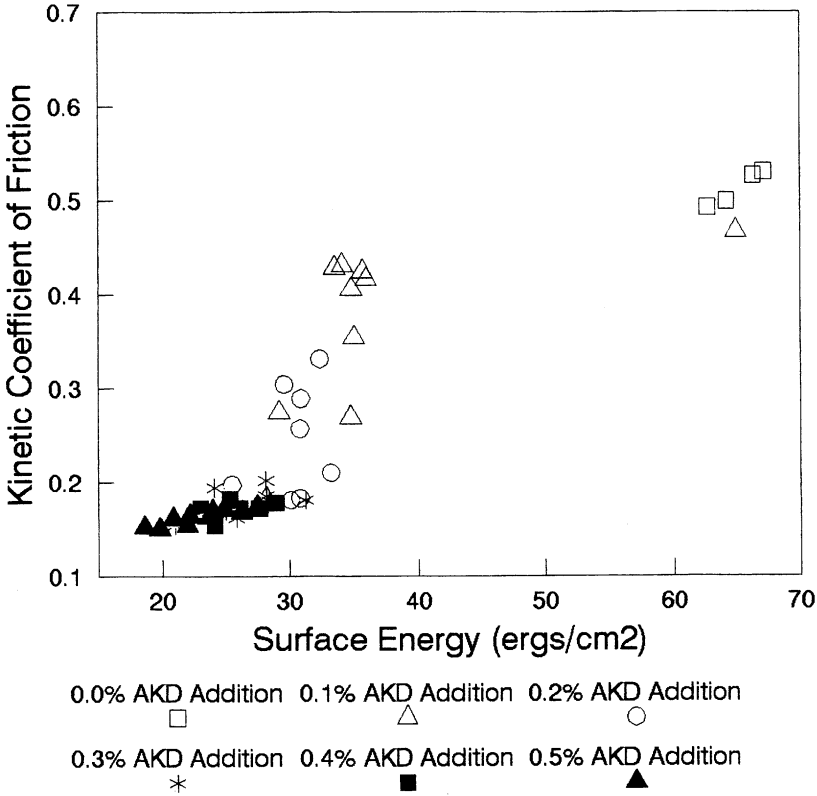

Figure 10 : The surface energy values plotted against the kinetic coefficient of friction