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AN INEXPENSIVE METHOD FOR SEPARATING QUARTZ FROM CLAY

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Abstract

A magnetic method is described using conventional laboratory apparatus and non-toxic liquids, which permits the separation of quartz from crushed pottery. The efficiency of the described method of separation is in excess of 90% which compares favourably in performance with commercial magnetic separators.

Introduction

Commercial magnetic methods have been developed by metallurgical engineers for separating magnetic and non-magnetic mineral components in powders and slurrys. Flotation methods, although often having the disadvantage of requiring the use of toxic liquids, have also been developed. A description of these methods as applied to mineral processing have been described in a variety of text books - one particularly recent being that by B. A. Wills, "Mineral Processing Technology", Pergamon Press, Oxford, 1979. A method of particular importance in separating quartz grains is the magnetohydrostatic method described by U. Andres (Minerals Science Engng. 7, (1975)).

The above commercial techniques have been used to separate quartz from pottery samples and have been described by S. Fleming in his recent book on Thermoluminescence Techniques in Archaeology, Clarendon Press, Oxford, 1979. A more recent development is that of the application of the magneto-hydrostatic method of Andres by J. H. James and H. Junger which is to appear in the publication by PACT of the Oxford T.L. seminar (1980). We wish to describe in the present note an efficient magnetic method of separating quartz from pottery which requires conventional laboratory apparatus thereby requiring a modest capital outlay for a separator of comparable usefulness as those commercially available.

Method

A schematic plan of the apparatus is shown in figure 1(a) with the the various components identified in the figure caption. The method of operation consists of:

(i) crushing the pottery in a v-shaped metal trough placed between the jaws of a machinist's vice.

(ii) passing the crushed pottery through a series of sieves, the finest being 45 μm.

(iii) when the sieved particles are poured into the top of the apparatus the magnetic field gradient holds back the strongly paramagnetic material in the upper chamber and the diamagnetic material drops directly through to the bottom chamber. (In order not to have the liquid surface tension hold the particles, a wetting agent, such as commercial detergent, is added to the water column.) The dividing valve is then closed off, the bottom chamber removed, and the particles and liquid separated by filtering through a Gouch crucible. The particles are then dried in a small laboratory oven.

(iv) If a greater degree of separation is needed, then the above process can be repeated before drying the particles. It was found that after three passes there was little increase in the percentage of quartz content.

Experimental Requirement of the Method

The major piece of equipment involves the permanent magnet. In order to determine what minimum magnetic field is required a series of separations as a function of field were carried out. This was accomplished by using an electro-magnet with a variable pole gap. In order to "estimate" the minimum field necessary for the method to function effectively, consider the forces acting on a paramagnetic particle in a viscous liquid. When the falling particle has reached a terminal velocity the various forces can be represented as shown in Fig. 1(b). Substituting values for the vectors we have:

$$4/_3\ \pi\ r^3\ (k_q - k_w)\ H\ \frac{\partial H}{\partial y} = 4/_3\ \pi\ r^3\ g\ (\rho_q - \rho_w) - 6\ \pi\ \eta r V_t$$

where the subscript q and w refer to quartz and water respectively. In the present case the particles were found to reach terminal velocity after travelling 2 cms of the tube length.

k - volume magnetic susceptibility

ρ - density

V_t - terminal velocity of falling particle

η - viscosity of water

r - average radius of the particle

$H\ \frac{\partial H}{\partial y}$ - value of constant magnetic field intensity and field gradient in the vertical direction

Rearranging terms we have as an estimate for the product of field strength and gradient

$$H\ \frac{\partial H}{\partial y} = \left(\frac{1}{k_q - k_w}\right) g\ (\rho_q - \rho_w)\ \frac{-9\eta\ V_t}{2r2} \sim \frac{10^2}{k_g - k_w} \left(\frac{\text{Gauss}^2}{\text{cm}}\right)$$

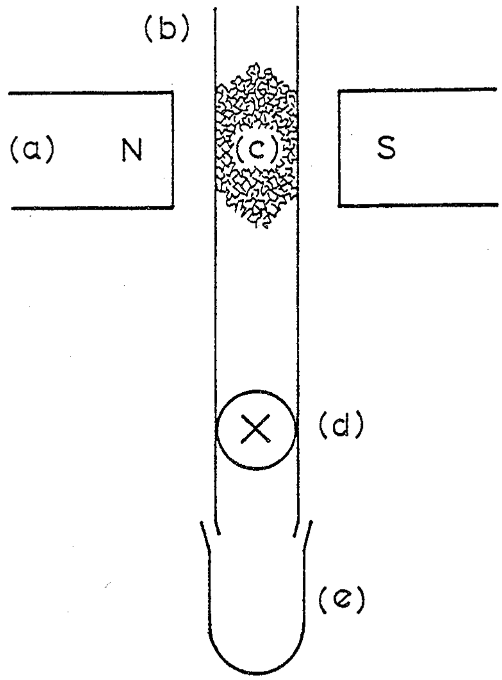
If one uses the value of the susceptibility of Fe_2O_3 as the major magnetic component in the clay then a minimum value of ^{3}4 x 10 Gauss ^{2}/cm is estimated, i. e. a field of 4 kilogauss and a gradient of 10 Gauss/cm. These values can be obtained from large yoked permanent magnets, the gradient being produced either by tapering the pole caps of the magnet of by using steel wool in the pass tube. Magnetron permanent magnets are ideally suited. One note of caution if the latter method is used: the density of steel wool should be sufficiently low that it does not act as a sieve in filtering the particles. In fact, the density of packing should be adjusted until tapping the tube in the presence of the field does not yield further increase in the mass of collected particles in the lower tube. Some experimentation is required in this regard but we found best results when a mass of 0.6 gms of number 422 stainless steel wool was teased to a length of 10 cm in a tube of 2.6 cm cross section.

Results

Ten 1.5 samples of crushed and sieved pottery from the same source were run through the apparatus at three different magnetic field strengths. After each run the samples were etched 20 minutes in an aqua regia solution and then for 10 minutes in a 10 N hydrofluoric solution in order to remove feldspars and calcites. After the particles were dried, a microscopic count was made of the percentage of quartz particles in the calibrated grid. The results are summarized in Table 1 where it can be seen that smaller fields are nearly as effective as larger ones provided the number of passes is increased. In order to judge the efficiency of this method of separation, a comparison with a commercial apparatus (Franz separator) indicated an efficiency of 90% for crushed and sieved pottery from the same source.

Maximum field	Original weight of sample(gr.)	No. of Runs through system	Final weight of sample(gr.)	Particles Counted	Percent Quartz
5K gauss	1.40225	1	0.78370	1220	66 %
	1.67535	2	0.8281	869	62
	1.57617	3	0.36712	956	80
10K gauss	1.40623	1	0.79033	944	70 %
	1.42163	2	0.45087	686	81
	1.47751	3	0.30045	1047	85
15K gauss	1.7276	1	0.99753	563	80 %
	1.488195	2	0.42946	869	88
	1.55681	3	0.2408	438	95

Table 1 —— Weight and percentage of quartz as a function of uniform magnetic field. The percentage of quartz as counted in the untreated sample used in this experiment was 30%.



(A)

Fig.1(a) Schematic figure of apparatus

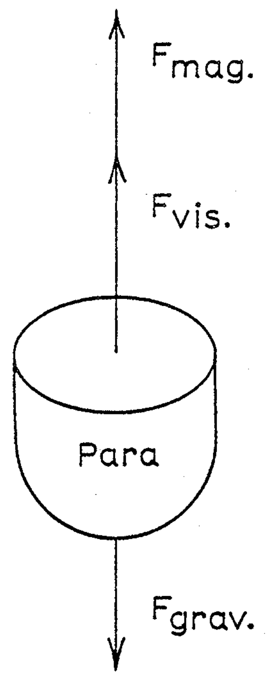
(a) Pole pieces of magnet

(b) Copper tube 1" diameter 12" long (also possible to use glass if preferred)

(c) Steel wool

(d) 1" Gate valve - brass

(e) Removable chamber



(B)

Fig.1(b) Forces exerted on a paramagnetic particle

$F_{grav.} = mg = {}^4/_3\ \pi r^3$ (ρ quartz-ρ water) g

where r is the radius of the particle, ρ the density and g the acceleration due to gravity.

$F_{vis.} = 6\ \pi\eta r\ v_t$ (Stoke's law)

where η is the viscosity of the fluid and v_t is the terminal velocity of the particle.

$F_{mag.} = (k\text{ quartz} - k\text{ water})\ v\ H\ \frac{\partial H}{\partial y}$

where k is the volume susceptibility, v the volume of the particle, H the magnetic field strength and $\frac{\partial H}{\partial y}$ the magnetic field gradient in the vertical axis.