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Brightness Beneficiation of Kaolin Clays by Magnetic Treatment

Abstract: A magnetic process for achieving clay brightness beneficiation by color body removal is introduced. The magnetic treatment does not employ sedimentation so that significant brightness improvement can be achieved without altering pigment-particle physical makeup or rheology. Coating studies are presented which illustrate the versatility and capability of magnetic processes in brightness beneficiation of kaolin clay. Employing available commercial magnetic treatment, standard clay grades can be processed with greatly reduced leach dosages. Magnetic beneficiation can also produce clays of exceptional brightness properties. The use of an experimental high brightness clay for partial replacement of titanium dioxide in a cylinder board coating is presented.

Keywords: Brightness · Whiteness · Beneficiation · Leaching · Clay · Kaolin · Processing · Magnetic properties · Magnetic separators · Separation · Impurities · Physical properties · Rheological properties · Coatings · Titanium dioxide

Clay is unmatched as a pigment raw material in the paper industry because of its economy and versatility of application. The adaptability of clay to paper coating and filler applications stems from many advantageous characteristics including, among others, desirable rheological and spectral properties.

Because of increased commercial interest in upgrading the optical properties of clay pigments, mineralogical means have been developed in recent years which augment traditional classification and chemical leaching in clay brightness beneficiation. These mineralogical methods have centered upon the removal of the discrete discolored mineral impurities which are found in small quantity in sedimentary kaolins.

The color bodies found in the Middle Georgia kaolins have been identified primarily as iron-stained titaniferous and micaceous minerals. These discolorants usually vary from yellow to dark brown, and their presence, even in small quantities, can have a significantly detrimental effect upon pigment spectral properties.

Two major methods of removing undesirable trace fractions from clays have been developed in recent years. Both methods reject the discolored mineral impurities either as an overflow fraction in froth flotation (*1*) or as a sedimentary deposit in differential flocculation (*2*). In both methods, the improvement in clay brightness is significantly greater than the best results obtainable with conventional processes.

This paper describes a new process which utilizes a magnetic force field to effect removal of certain naturally occurring discolorants. The process works to great advantage on sedimentary clays where most mineral color bodies are magnetic by virtue of the associated discoloring iron. Because of its unique capability and simplicity, magnetic beneficiation is finding widespread acceptance within the kaolin industry. The purpose of this paper is to illustrate the capability of this technology with examples of coating properties of pigments prepared by the new process.

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MAGNETIC SEPARATION

The principles of magnetic separation are well understood (*3*), and the method has long been used in industrial applications where ferromagnetic material is to be concentrated. Applications have ranged from upgrading of iron ore tailings to the removal of unwanted iron chips and filings from foodstuffs.

Magnetic beneficiation operates on the principle that the material to be concentrated is a discrete magnetizable component of a system composed of magnetic and nonmagnetic parts. The composite material is passed through a region permeated by a magnetic force field. The magnetic component is retained within the field-region while the nonmagnetic component passes over or through the field-region unhindered. The beneficiated product is either the magnetic or the nonmagnetic component, depending upon the application.

Previous commercial applications of magnetic separation have been confined to the concentration of coarse (generally larger than 100 mesh), strongly magnetic components. The development of an entirely new technology was necessary for the beneficiation of kaolin clays by magnetic treatment.

MAGNETIC PROCESSING OF KAOLIN CLAY

The principal mineral discolorant occurring in Middle Georgia kaolin clay has been identified as anatase, while rutile, mica, and quartz have also been observed (*4*). These dilute impurities are typically submicron in size and have magnetic properties which are some tens of thousands of times weaker than the strong ferromagnetism of iron (*3*).

Magnetic beneficiation processes are attractive to the clay industry because of their simplicity and capability. The fact that both flotation and sedimentation methods remove substantial amounts of these discolorants without alterations in the chemical nature of the final products indicates that some portion of the color bodies occurs as a discrete impurity which should in principle be removable by magnetic means. Even though pure kaolin can be expected to be magnetically inert, applications of prior art magnetic technology have hitherto been unsuccessful in brightness beneficiation of kaolin because of the small particle size and weak magnetism of the discoloring impurities.

Recent developments in magnetic separation have overcome the difficulties presented by small particle size and weak magnetism so that now the range of application of magnetic processing has been greatly extended. Indeed, the use of this new technology in kaolin brightness beneficiation represents the first successful commercial application of magnetic separation in the processing of weakly magnetic fractions generally finer than 400 mesh in size (5).

Processing with magnetic forces has the advantage of substantially enhancing the spectral properties of kaolin without significantly altering other clay pigment properties such as particle size distribution and rheological behavior. The dramatic effect which this beneficiation process can have upon clay spectral properties is shown in Fig. 1 where the relationship between color body concentration and pigment brightness and whiteness is illustrated.[1] The data were obtained by processing a No. 1 grade clay through a magnetic separator so as to achieve varying degrees of color body removal. The point of highest color body concentration corresponds to conventional clay processing without magnetic treatment.

Figure 1 shows that a 90% brightness, No. 1 grade clay cannot be made by conventional processing alone. Some color body removal is required to achieve this brightness, and this can be accomplished with a magnetic beneficiation process. Figure 1 further illustrates that quite significant improvements in brightness can be achieved by a magnetic treatment, and this can be accomplished without substantially changing the clay-particle makeup of the pigment.

The processes may be employed directly in the plant stream, and excellent color body removal can be achieved without addition of any foreign chemicals or agents other than those commonly employed in the processing of regular coating clays. Indeed, with the use of magnetic beneficiation technology, the standard clay grades can now be processed with greatly reduced leaching chemical dosages. Further, magnetic separation *per se* does not employ any physical or chemical process which affects clay-particle properties such as size, distribution, surface area, etc. Thus, beneficiation utilizing magnetic separations can yield a brighter and whiter pigment of unaltered physical, chemical, and rheological properties. Since magnetic separation affects the brightness properties of the pigment by color body removal only, it can be employed with independent methods to tailor overall pigment properties to the needs of the papermaker.

[1] Brightness was measured in accordance with TAPPI Procedure T 646 m-54. Whiteness factors were calculated from reflectance of the blue and green spectral components using the relation, 4B-3G. The blue and green wavelengths were 457 and 530 nm, respectively.

Table I. Comparison of Selected Pigment Properties of No. 1 and No. 2 Grade Clays Prepared by Magnetic and Conventional Processes

	No. 1 grade clay		*No. 2 grade clay*	
	Conventional treatment	*Magnetic treatment*	*Conventional treatment*	*Magnetic treatment*
Preparation				
Leach, %	100	0	100	0
Magnetic, %	0	100	0	100
G. E. brightness, %	87.0	86.8	86.0	85.8
Particle size, % <2 μm	91.5	91.2	80.7	80.9
Viscosity, 70% solids, content				
Brookfield, 20 rpm, cp	160.0	150.0	173.0	122.0
Hercules, dynes/1100 rpm	6.6	5.4	15.0	9.8

COATING PROPERTIES

Brightness beneficiation by magnetic separation will be illustrated by two examples which suggest improvements for paper coating applications. The first example shows that magnetic beneficiation can replace a large portion of the leaching chemical dosage normally employed in processing standard grades of clay. Thus, a process may be employed which will allow for the minimization of spurious effects of leaching chemicals. The second example demonstrates the ability of magnetic separation in preparing clays of truly exceptional optical properties. Both methods illustrate the important point that magnetic processing achieves color improvement without affecting physical properties of the clay. The effects which these physical properties will have upon coating characteristics will remain relatively unchanged by magnetic treatment.

Standard Clays

Brightness beneficiation employing magnetic treatment has been in limited commercial use since 1970. A significant increase in capacity for magnetically treated clays is expected in 1973 when several of the major suppliers of clay pigments are planning to have new high-capacity magnetic processing units on line. Because of this trend, it is expected that most coating clays produced in the United States will have been processed with magnetic separators within the very near future.

Clay pigments processed by a magnetic method are compatible with those processed in the conventional manner. This is illustrated in the following comparisons of pigment and coated properties of standard clay grades processed by the two independent methods. All the pigments employed in the comparisons to follow were prepared under commercial conditions.

Table I compares pigment properties of No. 1 and No. 2 grade clays prepared in the conventional manner by leaching with zinc dithionite and by a magnetic treatment without leaching. It is apparent from the elements of Table I that the pigment properties of the standard grades of clay prepared by a magnetic process fully match those of clays prepared by the conventional method. Although it is not shown here, this is true for other clay grades as well.

Table II. Viscosity Stability of Conventionally and Magnetically Processed No. 2 Grade Clay

Time at 50°C, days	*Brookfield viscosity, 20 rpm, cp, 70% solids content*	
	100% leach	*100% magnetic*
0	195	156
3	210	170
6	225	190
12	320	225

There is an indirect advantage implied in the pigment properties shown in Table I. Leaching chemicals are absent in the clay prepared by the magnetic treatment so that the effects of the presence of these spurious soluble ions have been minimized. The result is better overall viscosity stability.

Evidence of improved stability is shown in Table II where the Brookfield viscosity of clays prepared by a magnetic treatment and by conventional leaching are shown as a function of time stored at 50°C. Both favorable viscosity and stability are demonstrated for the magnetically prepared pigment.

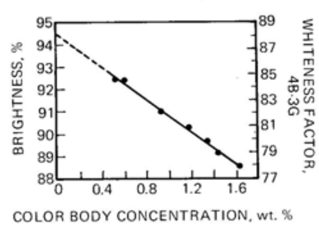

Fig. 1. Effect of color body concentration upon brightness and whiteness of a No. 1 grade clay.

Table III. Comparison of Color and Coated Properties of No. 2 Grade Clay Prepared by Magnetic and Conventional Processes

Preparation			
Leach, %	100	25	0
Magnetic, %	0	75	100
Color Properties			
Viscosity, 64% solids content Brookfield, 20 rpm, cp	6450	5600	5400
Hercules, dynes/1100 rpm	15.4	15.9	15.5
Coated Properties			
G. E. brightness, %	76.3	76.1	76.1
75° gloss, %	48.1	48.3	47.7
Opacity, %	89.1	89.1	89.0
Printed gloss, %	68.2	68.5	67.9
Whiteness factor	61.9	61.8	59.2
IGT, No. 5 ink, cm/sec	198.0	201.0	199.0
K&N ink absorption	72.7	72.9	73.6

Table IV. Comparison of Selected Coated Properties of High Brightness No. 1 Grade Pigments

	Pigment brightness, %	
	92.0	*90.0*
Brightness, %	79.6	78.6
Whiteness factor	67.2	66.0
75° gloss, %	53.7	54.1
Opacity, %	89.3	89.2
Printed gloss, %	68.4	68.6
IGT pick strength No. 5, ink, cm/sec	178.0	168.0
K&N ink absorption	67.5	67.4

The adverse effects of spurious ions upon rheology have long been recognized in the paper industry, and clay manufacturers have employed precautions to remove unwanted process chemicals from the finished product. Now, however, with the advent of magnetic beneficiation, there is the possibility of a commercial process for clay which employs reduced amounts of these undesirable chemical reagents while maintaining standard clay properties.

Table III shows a comparison of coating properties of magnetically prepared No. 2 grade clays applied to paper. These pigments were processed with varying and complementary degrees of magnetic separation and conventional leaching subject to the constraint that each would have pigment properties characteristic of those shown in Table I for a No. 2 grade clay.

For purposes of illustration in this and all coating applications to follow, a model coating color formulation of 100 parts of clay plus 4 parts of low-viscosity Delta protein with 12 parts of Dow 620 latex was chosen. For the paper applications, this formulation was applied at 8 lb/ream on the felt side of 46 lb/ream stock by a Keegan trailing blade coater.

The full coating evaluation of Table III is presented to illustrate that the coating properties of conventionally and magnetically processed standard clays are comparable. The clay-particle intensive properties of gloss, surface pick strength, and ink absorption are not substantially affected by magnetic processing.

The elements of the right hand column in Table III illustrate how clays prepared by a magnetic treatment alone can match the coated brightness of clays prepared by the conventional process. Modest amounts of chemical leaching can be employed along with magnetic treatment to control both brightness and whiteness. Accordingly, the elements of the middle column describe a clay prepared with only 25% of the normal leach dosage and show its coating properties to be fully equivalent to those of the clay prepared in the conventional manner.

The degree of color body removal required to achieve the standard No. 1 brightness is well within the range of magnetic processes, and much higher brightnesses and whitenesses can be achieved. The significance of this application of magnetic beneficiation lies in the demonstration that clays processed by a magnetic method employing a small amount of chemical treatment can be freely interchanged with those processed in the conventional manner requiring much higher levels of the chemical treatment.

High Brightness Pigments

Magnetic processing can yield clays of very high brightness. These pigments will be characterized by low color body concentrations and by clay-particle characteristics which have been unchanged by the magnetic separation.

To demonstrate this point, an experimental No. 1 coating grade clay having a brightness of 92% was prepared with a magnetic process and compared in a paper coating evaluation with a 90% brightness pigment of the same grade (Table IV).

A two-point difference in pigment brightness resulted in a one-point difference in brightness of the coated paper. This observation is consistent with normal relationships between pigment and coated brightness for No. 1 grade clays. The observed 1.2 points of difference in whiteness is significant and usually very desirable. Otherwise, the properties of gloss, opacity, printed gloss, pick strength, and ink absorption were essentially equivalent for the two samples of coated paper.

Board coatings have been made to further illustrate the effectiveness of high brightness pigments prepared by magnetic beneficiation. The same No. 1 grade clay having a 92% brightness employed in the preceding section was used in board coatings to determine the extent to which the 92% brightness clay can replace a portion of titanium pigments now commonly used in board coatings. For a comparison standard, we employed a mixture of 90% No. 1 grade clay and 10% TiO_2. The color formulation employed was identical to that used for paper coating except that the 100 parts of clay pigment was replaced by clay-TiO_2 blends. Coat weights of 4 lb/1000 ft^2 were applied to a cylinder board using a wire rod applicator. The boards were machine calendered.

The observed spectral properties of the coated boards are shown in Fig. 2. The brightness and whiteness intercepts of the comparison pigment containing 10% TiO_2 are shown as cross marks on the plot of experimental data. Arrows indicate the ordinate with which each cross mark is associated.

In applications where high brightness and whiteness are essential, a pigment such as the No. 1 grade clay of 92% brightness could offer a new possibility for upgrading coated characteristics. Figure 2 shows that direct substi-

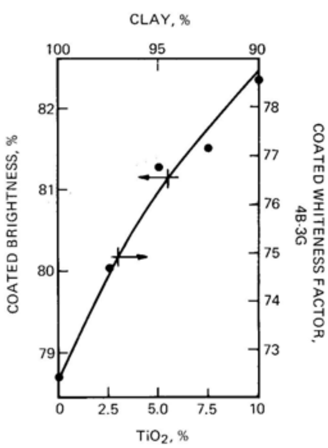

Fig. 2. Coated brightness and whiteness of 92% brightness clay-TiO_2 blends.

tution of the 92% brightness No. 1 clay for the 90% brightness clay resulted in an increase of 1.1 points in coated brightness and 3.8 points in whiteness factor.

Alternatively, these data suggest that a mixture containing between 3% and 5% TiO_2 with 92% brightness No. 1 clay can duplicate accepted spectral properties of the comparison pigment which contains 10% TiO_2. The possibility of replacing even a small amount of the expensive titanium dioxide pigment with clay is of obvious economic significance. Though high brightness pigments such as calcium carbonate, titanium dioxide, and aluminum hydrate will probably always find utility in paper and board products, the development of clays having brightnesses in excess of 92% offers a new opportunity for optimizing pigment performance.

SUMMARY

The application of magnetic treatment to upgrading brightness of sedimentary kaolin clay represents a significant advance in the commercial treatment of weakly magnetic submicron-sized minerals. Because of their simplicity, economy, and unique capabilities, magnetic separation processes hold great promise for the clay manufacturer and are finding widespread acceptance within the clay industry.

Magnetic separation is important to the paper industry in that it is a unique new technique for producing very high brightness clay pigments. Magnetic separation primarily affects spectral properties only and avoids the particle size distribution disruption inherent in some beneficiation processes currently used. Magnetic beneficiation can be used in conjunction with independent processes to tailor pigments to the papermakers' needs.

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