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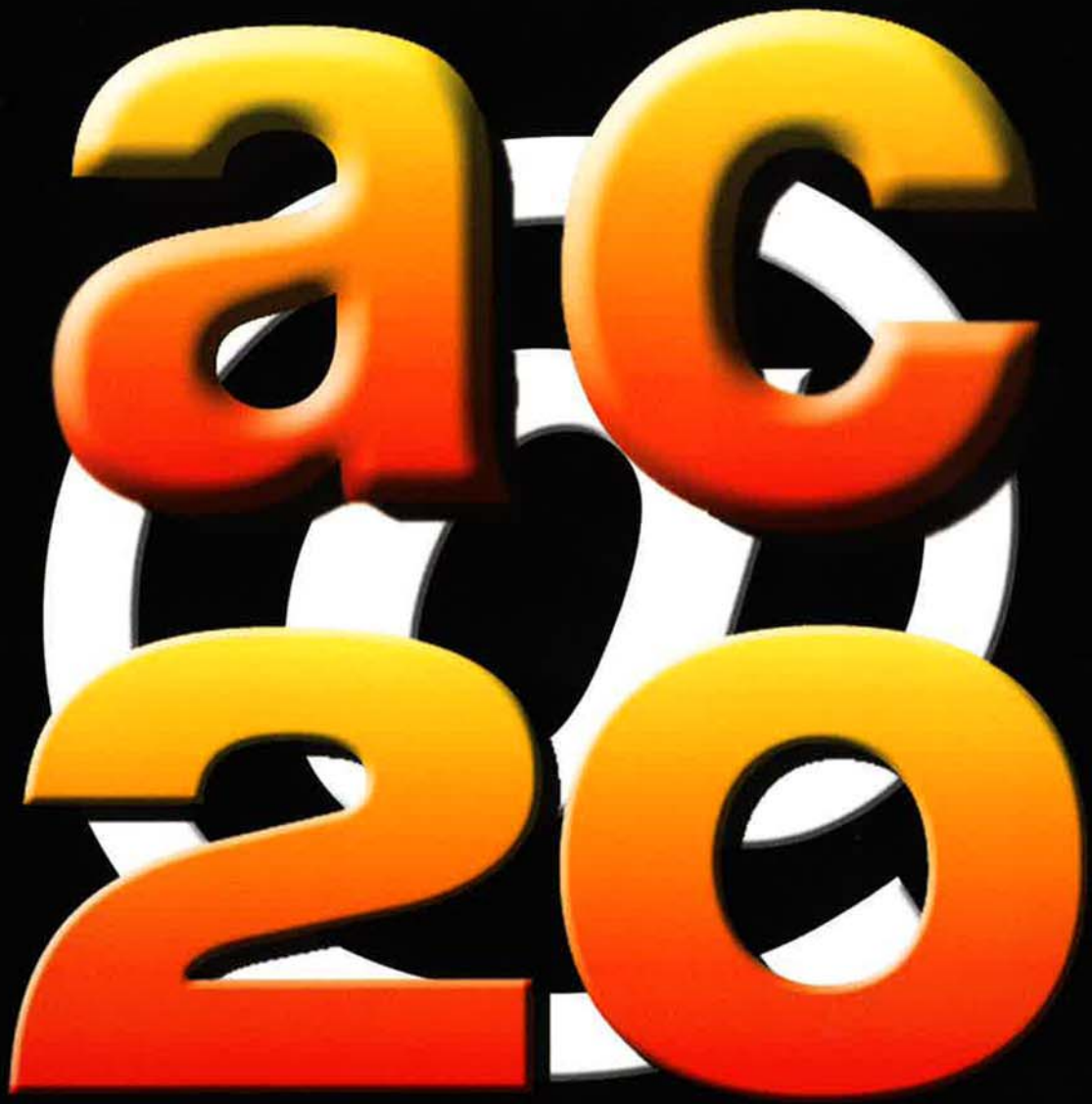

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Combining Kaolins and ball clays to enhance your sanitaryware production yields

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The evolution from traditional plaster casting, such as bench, battery or capillary casting techniques to high pressure casting using polymer moulds results in a more demanding sanitaryware production. Most manufacturers use various combinations of the above techniques to produce their full range of pieces; some are now pressure casting heavy, complex, and truly one-piece water closets using automated de-moulding. In this environment, raw material properties are key to manufacturers who create more complex formulations to obtain the maximum benefit from each technique.

Basic principles of casting techniques

Whichever forming technique is used, the basic principles are the same. The mix of raw materials, known as the body, is prepared as an aqueous slip with a specific degree of deflocculation. Water is extracted through a mould that is specifically shaped to form the final piece. The casting process starts with the formation of a thin body surface against the mould, as a filter cake, and from this point on, the characteristics of the cake ultimately drives the cast rate and other properties. The cake increases in thickness until the desired thickness is achieved.

In traditional casting systems (i.e. plaster based), the mould has a constant suction pressure of about 1.5 to 2 bar, however the increasing thickness of the cast build up means that the cast rate is not constant and actually reduces over the casting period. As a consequence, the cast body has to generate and maintain a high degree of permeability. Therefore the pore size distribution has to be developed so that the flow of water remains at the highest level possible. In high pressure casting, the mould is actually acting as a support and the process of cake build up is governed by the water movement under constant, higher pressure, through the cast piece; hence a different pore distribution can be managed, allowing production of more demanding pieces.

Adjusting slip parameters to control casting properties

To optimise performance of the different techniques, manufacturers need to adjust recipes and slip parameters specifically to the piece being produced and to how it is produced. Typically, all bodies are based around various percentages of ball clays, kaolins, quartz and flux (typically feldspar or nephylene syenite). Auxiliary materials, such as dolomite, talc or chamotte can be added in small quantities to adjust specific parameters, such as the point of vitrification or coefficient of thermal expansion. Therefore the mineraology of the system is set up to allow the correct firing characteristics and in basic terms, the body formulae are relatively similar in overall composition. The key to success is choosing suitable materials and adjusting parameters to control the cast piece properties. This is often achieved by using a number of ball clays or kaolin with different characteristics.

The raw materials play a key role in determining the majority of the casting body performance. The clays, often termed "the plastics", provide the main properties of the cast piece, contributing to plasticity, particle size distribution, fluidity, shrinkage and strength. The non-plastics, quartz and feldspar, are less complex and contribute mainly via particle size distribution, fusibility and coefficient of thermal expansion.

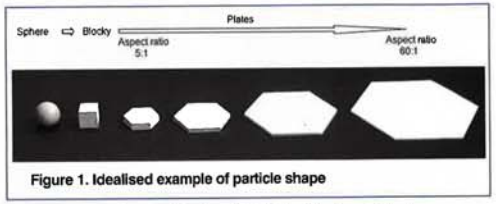

Figure 1. Idealised example of particle shape

In addition to the particle size distribution itself, particle shape and electrical charge density of the particles should be considered. In terms of particle shape, particles can resemble spheres, blocks, known as blocky clays, or more plate shaped (Figure 1).

Each example has a different Aspect ratio and a different surface charge density which affects how the particles interact. These parameters also influence rheology, casting rate and particle packing.

Whilst establishing the correct balance of raw materials is vital, so is the slip setup itself. Subsequent control of slip density, fluidity, thixotropy and temperature interdependently influence the overall performance. Indeed, the setup of the casting slip influences the casting rate, particle packing, permeability, drainage and drying characteristics of the ware. Casting rate is important in terms of productivity, but particle pack, permeability and drying characteristics control the strength and ultimate firmness of the piece in both cast and dry conditions, shrinkage and deformation. Hence it controls the overall quality and yield.

Understanding and utilising the different properties of the raw materials is key. Imerys Ceramics has developed a number of different clays over the years which incorporate all the above factors and enable the manufacturer to manipulate the body performance.

Kaolin range product for the Sanitaryware industry

Imerys Ceramics Thailand's kaolins are primary in origin and derived from a granite source. They are composed of a mixture of kaolin and halloysite, together with some mica, feldspar and a small amount of quartz. This kaolin product range has a naturally coarse particle size distribution, around 18% of the particles being finer than 1 micron. By combining the selection of the kaolin matrix in the mine with a modern wet refining process, Imerys Ceramics Thailand is able to offer a range of kaolin products for the sanitaryware industry (Table 1). The particle size and the specific particle shape, resulting from the mineralogy allow manufacturers to obtain a high permeability and increase the productivity of the casting shop. However, due to their nature, they provide a narrow range of fluidity.

Imerys Ceramics' kaolins from United Kingdom are also primary in origin and derived from a granite source. They are composed of mainly kaolinite, together with some mica, feldspar and a small amount of quartz. The UK kaolins are more platy in nature and more fluid. Due to more intense processing, they are available in a wider range of particle sizes.

Ball clay product range for the Sanitaryware industry

Imerys Ceramics Thailand's ball clays are relatively low in carbon and composed of kaolinite, illite, mica and quartz. They are characterised

TYPICAL DATA		Prosper	NSC	Acrobond	SP 412	MRD Cast	MRD/SW Cast	MRD Standard SW
CHEMICAL ANALYSIS (mass %)	SiO_2	49.0	48.0	48.0	48.0	48.0	48.0	48.0
	Al_2O_3	35.5	36.5	36.5	36.5	36.0	36.0	36.0
	Fe_2O_3	1.40	0.98	1.01	0.80	1.20	1.10	1.30
	TiO_2	0.05	0.06	0.05	0.03	0.04	0.04	0.05
	CaO	0.06	0.06	0.07	0.07	0.01	0.01	0.01
	MgO	0.25	0.30	0.30	0.20	0.01	0.01	0.01
	K_2O	2.80	2.80	2.00	1.70	1.90	1.90	2.10
	Na_2O	0.10	0.10	0.10	0.03	0.01	0.01	0.01
	L.O.I.	10.2	11.9	12.0	12.3	12.50	12.5	12.5
PARTICLE SIZE ANALYSIS (mass %)	> 53 µm	0.8	max. 0.15	max. 0.25	max. 0.04	max. 3.0	max.2.0	max. 3.0
	< 2 µm	28	40	39	68	24	27	30
MoR	Dried at 110 °C (MN m^{-2})	0.9	1.4	1.1	3.0	0.4	0.5	0.7
CASTING DATA	Casting concentration (mass % solids)	65	63.0	66.5	63.5	61	61	62
	Casting rate (mm^2 min^{-1})	7.5	0.8	1.9	0.6	21	14	11.0
	Deflocculant demand (mass %)	0.34	0.45	0.48	0.55	0.56	1.06	1.06
FIRED AT 1180 °C	Water absorption (wt%)	10.4	13.9	16.5	10.0	18.0	18.0	17.0
	Brightness (%)	32	80	82	87	82	82	80
	Contraction (%)	7.7	7.5	7.0	7.5	6.5	7.5	7.5
APPLICATION	Vitreous - Conventional casting	√	√	√	√	√	√	√
	Vitreous - Pressure casting	√	√	√	√		√	√
	FFC		√	√			√	√

Table 1. Properties of selected Thai and UK kaolin's from Imerys Ceramics sanitaryware range

by exhibiting high strength, combined with a fine particle size distribution, where approximately 50% of particles are finer than 0.6 microns (measured by sedigraph). These characteristics endow the ball clays with good properties for the production of sanitaryware; such as reasonable fluidity and rheology, medium permeability, high plasticity and high dry mechanical resistance combined with controlled shrinkage. They are available in both blended and refined forms: the blended forms are produced under specific selective mining conditions, whilst the refined forms are prepared by wet processing and provide more fluid options combined with better slip stability and lower levels of contaminants.

Imerys Ceramics' sanitaryware ball clays from United Kingdom are more kaolinitic and contain mica rather than illite. They are finer, with d50 around 0.3 to 0.4 microns, more fluid and contain more carbon than blended Thai clays.

TYPICAL DATA		Hycast VC	Hycast UK	Hycast Rapide	Thalcast S1	Modiscast S4
CHEMICAL ANALYSIS (mass %)	SiO_2	53	53	53	63	63
	Al_2O_3	30	30	30	22.5	23
	Fe_2O_3	1.2	1.2	1.1	1.95	2.0
	TiO_2	1.0	1.1	1.1	0.75	0.8
	CaO	0.2	0.2	0.2	0.3	0.25
	MgO	0.3	0.4	0.3	0.7	0.5
	K_2O	2.0	2.2	1.7	2.2	2.0
	Na_2O	0.2	0.2	0.2	0.1	0.15
	L.O.I.	12.2	12	12.5	9.0	8.5
	Carbon	2.2	2.5	2.0	0.7	0.7
PARTICLE SIZE ANALYSIS (mass %)	> 125 µm	1.5	0.7	2.0	3.0	0.5
	> 53 µm	2.5	1.5	3.0	5.0	3.0
	< 5 µm	91	90	87	90	89
	< 2 µm	77	76	70	70	65
	< 1 µm	67	65	60	55	53
	< 0.5 µm	54	54	45	45	42
SPECIFIC SURFACE AREA	M.B.I. (mg g^{-1})	25.0	24.5	18.0	39.0	37.0
MoR	Dried at 110 °C (MN m^{-2})	5.5	5.5	3.5	7.0	8.0
	Dried at 110 °C (p.s.i.)	780	780	500	994	1135
CASTING DATA	Casting concentration (mass % solids)	66.5	67.0	70.0	64.0	66.5
	Deflocculant demand (mass % 0.7 Pa.s)	0.75	0.75	0.50	1.00	1.05
	Deflocculant demand (mass % 0.5 Pa.s)	1.05	1.05	0.80	1.20	1.40
FIRED AT 1180 °C	Water absorption (mass %)	5.5	6.5	8.0	0.5	0.7
	Brightness (%)	62.0	61.5	68.0	45.0	43.0
	Contraction (%)	13.0	12.0	11.5	9.5	9.6
APPLICATION	Conventional Casting	√	√		√	√
	Pressure Casting	√	√	√	√	√
	FFC	√			√	

Table 2. Selection of Thai and UK ball clays from Imerys Ceramics' sanitaryware range

Combining kaolins and ball clays to improve production yield.

Using combinations of Thai and UK kaolins and ball clays can help the manufacturer to improve performance. For example, with a traditional casting formulation for plaster casting, initially based on a Thai kaolin and ball clay system, Imerys Ceramics can improve product yield, particularly when producing more complex, heavier one-piece water closets by using their ability to influence slip density and particle packing (Table 3).

The first example, Slip 1 used a combination of NSC kaolin from the UK with Thai kaolin to increase slip density, improve packing and produce cast pieces with higher wet strength at a lower critical moisture content and higher green strength. The cast rate decreased slightly, but can be offset by increased yield.

The second example, Slip 2, took this concept further by using some Hycast VC ball clay, combined with fully refined Modiscast S4 Thai ball clay, to further increase slip density, reduce critical moisture content and increase wet and dry strength. The cast rate decreased again.

The third example, Slip 3, used a combination of Prosper kaolin from the UK with Thai kaolin and ball clay to increase slip density and improve overall wet and dry strength. In this case the casting rate was maintained.

In all cases production yield of one-piece water closets increased.

Table 3. Body performance using combinations of Imerys UK kaolin and ball clay

	Reference	Slip 1	Slip 2	Slip 3
Thalcast S1	30%	30%	0%	30%
Modiscast S4	0%	0%	20%	0%
Hycast VC	0%	0%	10%	0%
MRD Cast	26%	16%	16%	16%
NSC	0%	10%	10%	0%
Prosper	0%	0%	0%	10%
Feldspar	27%	27%	27%	27%
Quartz	17%	17%	17%	17%
Slip density (gcm-3)	1.800	1.820	1.825	1.815
Viscosity (poise)	6.2	6.7	7.0	6.8
TTV Fluidity (overswing)	315	314	311	312
TTV 5 min thixotropy (overswing)	75	80	82	79
Cast thickness (mm/hour)	9.0	8.6	8.5	8.9
Cast MoR Dry (kgcm-2)	32	35	39	34
Critical Moisture Content,CMC (%)	17.0	16.6	16.0	16.7
MoR at CMC (kgcm-2)	6.8	7.7	8.0	7.4

Manufacturing sanitaryware is more demanding due to the gradual transition from standard plaster casting to full pressure casting. It enables time saving, reduced reliance on skilled labour and improvements in yield and product quality. This transition results in the diversification of demands, better understanding of traditional casting systems and more focus on raw materials.

Imerys Ceramics offers solutions to help assist manufacturers improve performance thanks to its wide product portfolio combined with detailed understanding of the properties of the plastic materials.

Whilst the example quoted was based on traditional casting, it demonstrates the importance of understanding both how clays work within the body and how the process itself is driven. In this way it can demonstrate how certain properties can be manipulated to give advantages.

Imerys Ceramics is confident that building on these fundamentals with a new, novel, laboratory scale pressure casting test rig will enhance their understanding of the process as well as their customers' and improve performance in the future.