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Slip Rheology Test in Searching a Good Casting Slip Clay in Producing Ceramic Product

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ABSTRACT

Slip casting is one of the methods used in forming ceramics. In this method, clay in liquid form is casted in a plaster mould to get an enhanced product. It is a process of using clay in liquefied form and poured into a mould, which is usually made of Plaster of Paris. Slip casting becomes stiff when attach to plaster mould. It is because mould is made of Plaster of Paris which absorbs water from casting slip. Rhodes (2000) also explained slip casting as a process of casting that requires fluid suspension clay in water which flows readily and does not settle in the mould. The clay slip must be poured out smoothly from the mould, leaving a surface free from lumps or roughness and it copies every detail in the mould. With this method, potters can make various forms and textures that could not be produced by other ceramics forming techniques. The advantage of slip casting is it can produce extremely complex shapes which are impossible to make by other methods. Slip casting may open a completely new world to both the adventurous and the hesitant potters. It offers an opportunity to overcome difficulties in making complicated, precise and bizarre forms. Besides, the equipment and expenses are economical. Production by slip casting technique can also produce products of the same size and form. Based on these advantages, slip casting has become one of the major industrial making processes.

***Keywords**: Slip casting, Slip rheology,Deflocculant, Sprcific Gravity,Slip Fluidity*

INTRODUCTION

Clay is defined as a fine –grained mineral which, when suitably crushed and pulverized, becomes plastic when wet, fragile when dried and on firing is converted to a permanent rock like mass. Chemically, clay is Hydrated Silicate of Alumina, having a theoretical clay crystal structure with the formula Al2O3.2SiO2.2H2O. The process of decomposition takes place when rocks are exposed to the mechanics of nature, namely water and glacial erosion, plant growth and heating by sun. The mechanics change granite into small particles of clay. The process is continuous over billion of year. Lightwood (2000, p.17) noted, *clay is created by the decomposition of rocks which have been thrust up by the action of volcanoes to form mountain. The process takes a long term and is continues.*

Preliminary clay in its purest form after decomposition takes place from parent rock is known as primary clay. Besides granite, diorite is also a material in parent rock which can turn to primary clay. Kaolin and bentonite are two types of clay from the decomposition process of granite and diorite. Kaolin or China Clay has fine texture, non-plastic and white. Bentonite clay contains montmorillonite as a mineral basis. It has fine texture and is plastic. Primary clay is also known as residual clay. It can be found at the nearest place where the decomposition process occurred.

Secondary clay can be found far from the site where the process of decomposition took place. It is transported by water, ice and wind to another place. During the migration process, the secondary clay

picks different minerals which give different colors, textures and characteristics to the clay compared to primary clay. Secondary clay behaves more plastic, is darker in colour and smelly in odour because it blends with carbon from organic matter. Secondary clay is also referred to as sedimentary or deposited clay.

SLIP CASTING

The History of Slip Casting

According to Hoppers (2000), slip casting originated idea come from press mould techniques that have been used less than 300 years ago. The development of forming clay by pressing and squeezing clay using fingers was a natural process in developing clay form technique. The Assyrians practiced writing on clay slab and preserve it by firing in a kiln. Slip casting approach came later when the use of clay slurry to make ceramic forms was introduced. Frith (1992) also said the first author who wrote about slip casting was Simeon Shaw. He wrote about ceramic production in Stafforshire around 1829. However, more detailed articles were written by The Rev. Dionysius Lardner, an American, in 1832. In the article, the details on casting process were explained.

The early casting slip was not a good slip for casting because too much water was used to generate clay slip. William Burton (in Frith, 1992) had pointed out the problems of casting which plagued potters of early times. Until 19th century potters preferred to use press mould technique instead of slip casting. After deflocculant material was found, slip casting became an important method for mass production of ceramics. Frith (1992) also said the success of using slip casting at that time was because of two factors. Firstly, the development of Plaster of Paris replaced fired clay as the material for making mould. Secondly, slip suspension was solved by adding deflocculant agent.

HOW TO DETERMINE A GOOD CHARACTER OF CASTING SLIP.

In order to determine the character of casting slip, it is necessary to carry out a Slip Rheology test. According to Doraiswamy (2002), rheology is concerned with the description of the flow behavior of all types of matter. Slip rheology test is defined as the study of the deformation and flow of clay slip. This test is important to decide on the suitability of a clay slip to be used and at the same time to ensure a good slip condition that can be maintained. In searching for a successful casting slip, Frith (1992) suggested three factors to control the slip. These factors are the amount of deflocculant, the specific gravity and the viscosity of a slip. According to Ryan and Radford (1987), there are three parameters used for industrial control of casting slip. The parameters are fluidity, thixotropy and specific gravity.

Based on the works Frith (1992) and Ryan and Radford (1987), in searching the suitable of casting slip, the test of deflocculant, specific gravity, viscosity, fluidity and thixotropy are important factors to determine the character of casting slip.

Deflocculant

Deflocculates is the action of dispersing clay particle in a slip to make clay slip more fluid. Deflocculant breaks the bonds that hold clay together and change a stiff clay or clay body into a liquid slip. Deflocculant introduces electrical charges, causing particles to repel one another (Pitelka, 2001). Casting slip must remain fluid and pourable for at least one hour (Speight and Toki, 2004). For this reason, special formulated casting slip must contain deflocculant. Slip is a combination of clay and water, while casting slip contains clay and water with the additional deflocculant (Birks, 1988).

According to Kenny (1976), clay mixed with water makes slip, but this is not the best material for casting. The water content of the mixture is high: usually 100 percent of the dry weight of the clay, since equal parts of clay and water are required to make slip which will pour. Consequently, there is a large amount of shrinkage. This is not so bad in simple drain molds; but in more complicated mold,

casting with ordinary slip is extremely difficult. Some way must be sought to make a casting slip with less water. The answer is deflocculation. (p. 150)

Deflocculant agent is one of the materials that have been used to make casting slip for many decades now. According to Frith (1992) deflocculant material was found by M. Bettignies from France and Goetz from Germany who applied to get patent in October 22, 1891. The introduction of deflocculant agent has made ceramics casting technique widely used in its production. This is because using deflocculant agent reduces the ingredient of water in casting slip. Too much water content in casting slip may cause high shrinkage and defect to the ceramic products. There are books revising the needs for deflocculant.

Pitelka (2001) cited that all casting slips must have deflocculated which would improve the character of flow of clay slip and also reduce its water content. Then, water is less absorbed by the mould, reducing shrinkage and problems at drying stage. It made fewer casting flaws and quickened the release of casting output from the mould.

Deflocculant is an important material in preparing casting slip as its function is to reduce the need for water to make slip flows. Deflocculant was added to slip to keep the clay particles in suspension and to reduce the amount of water to make slip. The type of clay made the difference in properties of deflocculant and water.

According to Rhodes (2000), the need for deflocculant in casting slip is between 0.3% - 1.5% of the slip weight. While Kenny (1976) stated that a well deflocculated casting slip should have the same percentage of water as plastic clay, i.e. 35% to 45 %. The water needed is reduced by 50% compared to clay slip without deflocculant. Rhodes (2000) said casting slip without deflocculant would need 35% to 50% more water. Whereas Frith (1992) stated, the ratio of water content to dry clay could range from 25% to 45%. Reducing the amount of water could reduce shrinkage to clay body. Speight and Toki (2004) also said that casting slip that contained too much water made fluxes content settled in the bottom of the container. This brought uneven structure to clay body output. Other than that, high water content would cause mould to be wet rapidly and produced high shrinkage to the products.

Some of the types of deflocculant listed by Wardell (1997) are:

1. Sodium Silicate
2. Soda Ash/ Sodium Carbonate
3. Calgon
4. Dispex (manufactured combination of Sodium Silicate and Soda Ash) usually used to adjust slip.
5. Darvant 7 (American Equivalent of Dispex)

However, Sodium Silicate and Soda Ash were the most commonly used deflocculant in casting slip. Kenny (1976) stated the best deflocculants used in slip were Sodium Silicate and Soda Ash, which worked well together. According to Ibrahim Mat Dom, Sodium Silicate is the most suitable deflocculant for slip casting process using plaster mould. However, too much deflocculant could be bad for casting slip. It could cause casting slip flow too slow and the cast dense and brittle. According to Pitelka (2001), for clay body deflocculant caused particles to repel rather than adhere, thus decreasing its plasticity.

Sodium silicate is made from Sodium Carbonate and Quartz. Sodium silicate is also known as water glass. Normally, sodium silicate used in making casting slip is in the form of clear, thick and sticky liquid. It is read in Twaddle degrees (°TW). The thickness of sodium silicate needs to be set so that the usage does not influence the composition of slip. At the same time, tests on standard materials can be carried out to all composition throughout the experiments. The viscosity of sodium silicate is calculated using the following formula.

$$°TW = (\text{specific gravity} - 1) \times 200$$

Specific Gravity

The definition of specific gravity is the ratio of the density of any substance to the density of any some other substance taken as standard. In this study, specific gravity for casting slip refers to the standard for liquids. Specific gravity is expressed as a number for each substance. It is best considered as the number of times by which a substance is heavier than the same amount of water. According to Frith (1992), specific gravity is determined by the accuracy of weighing. It is another way of measuring slip besides watching the slip run off from the fingers or by feeling, which that only can be done by clay experts. From the specific gravity test, the exact amount of water for casting slip is known.

Ryan and Radford (1987) stated that if the unit chosen was gram/milliliter, the numerical value of the density would be the same as the appropriate specific gravity value. Density test is the term used in this research. For specific gravity test, there were three instruments used to measure the weight of liquid and the right amount of water. The instruments were

Hydrometer

Hydrometer is a glass tube weighted by lead. It floats vertically in liquid. A reading from the device is recorded based on the position when it is floating in the slip. The higher the position the hydrometer is floating, the higher is the reading of the specific gravity of the slip.

Plate 1: Hydrometer

Specific Gravity Bottle

Another technique to measure the specific gravity of slip is using the specific gravity bottle. To get specific gravity reading using the calibrated volume bottle, the device needs to be filled with clay slip and weighed. Then, the weight of the clay slip filling, in the specific gravity bottle is recorded. The reading is then divided by 100 or any recorded volumes of the bottle for example 10, 25 and 50ml.

Plate 2: Specific Gravity Bottle

Specific Gravity Cup

The method of using specific gravity cup (s.g. cup) is the same as using the specific gravity bottle. An s.g .cup is an aluminum cylinder container with a tight cover. On the cover is a small hole for the purpose of removing air trapped in the s.g. cup so that the slip can be measured accurately. According to Ibrahim Mat Dom, the easiest way to measure slip density is by weighing a batch of slip accurately. This means using an s.g. bottle and an s.g cup are the best and the most accurate methods to measure slip density.

Plate 3: Specific Gravity Cup

Frith (1992) cautioned on the accuracy of measuring the specific gravity of a slip. He stated that it is difficult to interpret the correct reading on the scale of the hydrometer. Hydrometer can undoubtedly be used successfully only if the possible variations are controlled. The person with an established routine in mixing casting slip and testing the slip with a hydrometer undoubtedly would be able to set standards that can be interpreted correctly.

According to Frith (1992), weighing a batch of slip is much more reliable. He said that it is important to weigh and measure accurately the correct proportion of clay and water in deflocculated slip. In determining a good slip, Ryan and Radford (1987) set the standard density to achieve was 1.8 to 1.85g/ml. While Birks (1988) remarked, the density of a good slip was at least 1750 grams to a liter. According to Frith (1992), if casting slip is heavier than standard, it means the slip has too much clay. If lighter, the slip contains too much water.

Viscosity

Viscosity is the property of a fluid that resists the force tending to cause the fluid to flow. Hammer (2004) defined viscosity as the resistance to flow due to internal frictions in a fluid. In casting clay slip, measuring viscosity is used to determine the suitability of a clay slip for casting. High viscosity may cause casting output to be thicker and to crack after drying. Measuring viscosity helps in searching for the ideal slip for casting. According to Hammer (2004), viscosity is the opposite of fluidity.

Viscosity can be measured by timing. The instrument use is made by plastic tube with a closed bottom mounted on a stand. The bottom of the tube has a small hole in that controls the speed of a liquid passing through the tube. This instrument measures by the speed of liquid that passing through the tube. The result is related between pressure and time. Another tool that is used in measuring viscosity is digital viscometer or Brookfield viscometer. The unit for viscosity is poise.

Plate 4: Brookfield Viscometer

Fluidity

The word fluidity originate comes from fluid; it refers the ability of a substance to flow. Fluidity is a property of a liquid to be able to flow or move freely without the hindrance of a friction. Slip fluidity is one of the characteristics of a slip for casting. Fluidity is important during casting slip, especially when it is poured out from a mould for hollow casting. Rhodes (2000) said the process of casting requires a fluid suspension of clay in water, which flows readily but does not settle in the mould. A good clay slip flow produces an even thickness in a product. The instrument used in measuring fluidity is Torsion Viscometer. The unit measure for fluidity is degree over swing (°over swing). According to Ryan and Radford (1987), the standard for fluidity test is between 270° – 330°overswing.

Thixotropy

Slip becomes thicker when it is undisturbed for some time. It is called thixotropy. Thixotropy of slip casting is referred to as the characteristic of slip which becomes thicker when it is not stirred for some time and becomes fluid when stirred. Hammer (2004) defined thixotropy as the property of a slip to change its fluidity when left undisturbed. Similarly, Ryan and Radford (1987) referred thixotropy to the thickening of a slip when it is at rest and its reversal when it is stirred. Thixotropy test is the continuation of fluidity test. The thixotropy of a slip is measured with a Torsion Viscometer. According to Ibrahim Mohd Dom (2011), data from a thixotropy is measured in 2, 5 and within10 minutes of undisturbed time. Ryan and Radford (1987) said the standard reading for the thixotropy test is 10 – 60 degrees in one minute.

Plate 5: Torsion Viscometer

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