Manufacure of a ceramic paper for art applications

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Abstract. Ceramic paper products are mostly used as high temperature ceramic insulation products. They offer an effective solution for most demanding heat management and insulation applications. The objective for this research project was to create a ceramic paper like product that combines the advantages of paper fibers, ceramic filler, and a clay product into one product, which can be produced on a continuous basis with a paper machine. The produced ceramic paper product had a ceramic filler level between 59.68% and 78.8% with a basis weight between 322.9 g/m² and 693.7 g/m², and a final moisture content of 58.6% to 44.7% respectively. The wooden fiber served as a support medium for the ceramic filler material during production on the paper machine and during the conversion process into art pieces. During firing in a kiln, the fiber material combusted and the ceramic filler material mixture acts as common pottery clay, holding the desired shape of the art pieces produced.

1. Introduction

Since its invention by the Chinese Inventor, Ts’ai Lun, in 105 C.E., paper has made significant contributions to the advancement of society. Today paper products can be found everywhere in modern societies and its consumption is an indicator of the wealth and advancement of society. To save production cost filler material are added, because they are less expensive than fiber materials [1]. Paper products today range from newsprint, printing paper, tissue or hygiene paper, board and packaging paper, to specialty paper materials. Many paper products that are currently produced incorporate an inorganic material called fillers, designed to accommodate the individual customer needs. Filler materials are normally incorporated into the paper web during the formation process on the papermaking wire. This is achieved by mixing filler material and wooden fibers with water into a suspension during a preparation process. The water from the suspension is then drained out on the papermaking wire while suspended fiber and filler particles are retained in a fibrous web that is formed on the papermaking wire [1].

Today’s primary filler materials in the paper industry are precipitated calcium carbonate (PCC) and ground calcium carbonate (GCC). Fillers are less expensive than fibers, allowing reduced production costs, improved optical paper properties, dimensional stability, better sheet formation and printability of the paper product. Filler content in today’s paper products in North America is normally between 15 to 20%, but can reach up to 30% by weight in specialty paper products. Other filler materials such as titian dioxide, calcined clay and silica are incorporated in paper materials when specific properties are required such has abrasion, and hardness [1, 2]. The literature states that a paper can be produced with a filler content of over 70%. However, it is not being implemented because the paper product
loses its integrity and required mechanical and physical properties if the filler contents is above 20%.
[1-5].
The bases of ceramic materials are mineral fillers. These fillers are also the base component of
graphic paper to increase the printability, surface and optical properties. Typical fillers are Kaolin,
Talc, Ground Calcium Carbonate (GCC) or Titanium Dioxide. By incorporating these ceramic
materials into a paper product results in reduced strength properties and run ability problems on a
paper machine [6].

If a ceramic paper with a thickness below 2 mm and ceramic filler content above 40% can be
manufactured, a paper-like composite material with a wide range of applications in industry and art
products would result. At present time, a ceramic paper like product is available for insulation purpose
[7, 8] but not for art or other applications.

Currently artists and sculptors add paper fibers to the clay body giving it important and unusual
working characteristic such as enhanced surface and binding qualities in the green stage of the
building process. It allows the production of large thin objects without cracking. [9, 10]. Paper fibers
added to the clay body burn away early in the firing, leaving a durable ceramic product virtually
unrecognizable from conventional ceramics, except for the lost weight of the fired paper ceramic [11].

The objective for this research project was to create a ceramic paper product that combines the
advantages of paper fibers, ceramic filler, and clay product into one product that can be produced on a
continuous base with a paper machine. The ceramic paper product should contain about 60% to 80%
filler content with a moisture content level of 40 % to 50%, allowing the final product to be cut, rolled
and molded and then finally fired in a kiln to produce a ceramic art piece.

2. Methodology
The methodology section describes the equipment, procedures and materials used for this project at
the State University of New York (SUNY), College of Environmental Science and Forestry (ESF),
department of Paper and Bioprocess Engineering (PBE). As part of this study several test methods
were applied. These are described in detail in the following subsections. All tests were performed and
reported according to TAPPI standards or as noted otherwise. Repeatability of the results stayed in
between the allowable margins of the TAPPI testing standards.

2.1. Fiber materials
For the ceramic paper development paper machine run a total of 6 kg fibers were used. The pulp fiber
mixture consisted of 2/3 Northern Bleached Softwood Kraft (NBSK) and 1/3 Eucalyptus Bleached
Hardwood Kraft (EBHK). Both fiber fractions were used unrefined and had an initial Canadian
Standard Freeness (CSF) of 600 ml and 400 ml respectively. The fiber mixture was pulped at a
consistency of 5% and then diluted to 3% and stored in the paper machine chest. From the paper
machine storage chest, the pulp fiber mixture was pumped to the headbox with prior dilution to 1.5%
fiber content.

2.2. Ceramic filler materials
20.0 liter of a ceramic filler material suspension with a final solids content of 65.5% was prepared.
The suspension had 32.0% Kaolin, 18.0% Feldspar, 18.0% Silica, 1.5% Ball Clay and 25.5% water.
Content based on weight. 0.25% sodium silicate was added to improve dispersion. The ceramic filler
suspension was stirred in the holding tank with a mixture to keep the solids in suspension while the
suspension was pumped with a peristaltic pump into the headbox supply line.

2.3. Paper machine conditions
A 12 inches wide pilot Fourdrinier Paper Machine (FPM) at the PBE department (figure 1) was used
for this research. The FPM was operated at a speed of 0.9 m/min. The fiber flow to the headbox was
set at 5.6 l/min. at a consistency of 1% solids content. The ceramic filler flow started at set at 140
ml/min. and was increased during the run to 900 ml/min. To minimize ceramic filler loss, water
removed from the fourdrinier section of the paper machine was used as dilution water for the paper fibers. The fourdrinier section was operated without a dandy roll. The vacuum boxes of the fourdrinier section were operated at maximum vacuum to remove as much water as possible from the suspension containing the fiber and ceramic filler material.

Figure 1. Fourdrinier pilot paper machine [12].

The press section was operated under no pressure. The Yankee dryer had an operation temperature of 190°C. The finished ceramic paper product was rolled up between the first two top drying cans as shown in figure 2.

Figure 2. Rolled up ceramic paper [13].

2.4. Testing
Testing needed for preparation of the pulp fibers and ceramic filler slurry, the paper machine run and for final testing of the ceramic paper product was carried out using TAPPI testing standards. Ceramic paper samples were conditioned according to T 402 sp-13, Standard conditioning and testing
atmospheres for paper, board, pulp handsheets [14]. The grammage was determined by T 410 om-08 “Grammage of Paper and Paperboard (weight per unit area)” [15]. Moisture content of ceramic paper and ceramic filler slurry was determined by T412 om-06 “Moisture in pulp, paper and paperboard” [16], the freeness of pulp was measured as Canadian Standard Freeness (CSF) according to T 227 om-09 “Freeness of pulp (Canadian standard method)” [17]. The ash content of the ceramic paper product was determined by T-211 om-02 “Ash in wood, pulp, paper and paperboard: combustion at 525°C” [18].

2.5. Firing of ceramic paper product
The ceramic paper product was fired at gas kilns at the Syracuse University Art Facility in Syracuse New York. The bisque and the glaze firing was at cone 10 (1300°C/2380°F), typically used for proclaim products.

3. Discussion of Results
In this section, the production process of the ceramic paper product and its conversion into origami art applications is discussed.

3.1. Ceramic paper production
For the ceramic paper machine run the grammage or basis weight and the ceramic filler content were targeted as the ceramic paper specifications. The goal of the paper machine run was to produce various grammages of ceramic paper that can be used as working material to produce a ceramic art object. Earlier preliminary tests showed that a moisture content between 40% and 60% is desirable for the conversion of the ceramic paper product, allowing the artist enough time to convert the ceramic paper product into an art object before the ceramic paper product becomes too dry and stiff before it can be converted into art pieces.

Figure 3 represents the different ceramic paper products that were produced during the 3-hour paper machine run. Sample 1 was the paper sample with no ceramic filler, a dry basis weight of 130 g/m² and a moisture content of 22%. Sample 2 had a basis weight of 322.9 g/m², a ceramic filler content of 58.6% and a moisture content of 58.3%. Sample 3 showed a basis weight of 352.8 g/m², a ceramic filler content of 65.5% and a moisture content of 55.7%. Sample 4 had a basis weight of 322.9 g/m², a ceramic filler content of 59.6% and a moisture content of 58.3%. The production of sample 5 revealed a basis weight of 495.4 g/m², a filler content of 73.3% and a moisture content of 48.0%. The basis weight of sample 6 was 633.6 g/m², with a filler content of 76.2% and a moisture content of 43.1%. The produced sample 7 had a basis weight of 693.7 g/m², a filler content of 78.8% and a moisture content of 44.7%.

Figure 3. Ceramic paper product production sample.
The produced ceramic paper product was rolled up and the specific sample marked with paper strips as shown in figure 2. After the production was finished the produced roll was wrapped in a plastic bag to prevent moisture to escape. The finished ceramic paper product is stored in a cold room till it is used.

3.2. Conversion into origami art
The finished ceramic paper product from sample 7 with a basis weight of 693.7 g/m² and a moisture content of 44.7% was first cut into smaller sheets of 20.0 cm by 20.0 cm. The cut sheets were air dried for 30 minutes at room temperature achieve best folding results. The sheet was then folded into the origami structure shown in figure 4a. After air drying for 24h the green ware origami structure was bisque-burned in a gas fired kiln at 1300°C. After the bisque-burn a 20% reduction in size was noted (figure 4a). The origami ceramic product was glazed (figure 4b), followed by another burn at a 1300°C. After the second burn no shrinkage was observed (figure 4c).

![Figure 4. a) Ceramic paper origami after 1st firing, b) glazed, c) ceramic paper origami after 2nd firing with glaze [19].](image)

The second approach using the ceramic paper sheet from sample 7 was the application as wall for a small drinking cup shown in figure 5a to c. As shown in figure 5b the wall thickness after glazing was about 1.6 mm. The production of the small cup included a bisque-burn in a gas fired kiln at 1300°C, followed by another burn after glazing at a 1300°C. A shrinkage of 20% after the first bisque-burn was observed. No shrinkage was observed after the second burn. The ceramic paper product showed excellent folding and forming capabilities during the creation of the two art objects shown in figure 4 a-c and figure 5 a-c. During firing of the ceramic paper art pieces in a kiln, the fiber material combests and the ceramic filler material mixture acts as common pottery clay holding the desired 3-dimmensional shape of the art piece during the first bisque-firing and at its final state after the second firing for setting the glaze.

![Figure 5. a) Ceramic paper cup after firing, b) wall thickness glazed 1.5 mm, c) paper clay cup after 2nd firing with glaze [20](image)
4. Conclusion

Production of a ceramic paper product for art applications using a paper machine is feasible. The ceramic paper product had a ceramic filler level between 59.68% and 78.80% with a basis weight of 322.90 g/m² and 693.70 g/m², and a moisture content of 58.6% to 44.7% respectively. The wooden fiber served as a support medium for the ceramic filler material during production on the pilot paper machine and the conversion process into art pieces using origami folding methods. During firing in a kiln, the fiber material combusts and the ceramic filler material mixture acts as common pottery clay holding the desired shape of the art piece during firing and at its final state after the first bisque firing. After the second firing for setting the glaze no changes in shape have been observed.

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[12] Image by Klaus Dölle, Fourdrinier pilot paper machine jpg-file
[13] Photo by Klaus Dölle, Rolled up ceramic paper jpg-file
[14] TAPPI T 402 sp-13 “Standard conditioning and testing atmospheres for paper, board, pulp handsheets”
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[17] TAPPI T 227 om-09 “Freeness of pulp (Canadian standard method)”
[18] TAPPI T-211 om-02 “Ash in wood, pulp, paper and paperboard: combustion at 525°C”
[19] Photos by Klaus Dölle, a) Ceramic paper origami after 1st firing, b) glazed, c) ceramic paper origami after 2nd firing with glaze jpg-file
[20] Photo by Klaus Dölle, a) Ceramic paper cup after firing, b) wall thickness glazed 1.5 mm, c) paper clay cup after 2nd firing with glaze jpg-file