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METHOD OF PROVIDING DRY ADDITIVES FOR A GYPSUM BOARD MANUFACTURING PROCESS

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ABSTRACT

[0001] In general, the present publication is directed to a dry additive regulation and transmission system. In particular, the present system is an improved method of dispersing, mixing, and conveying dry additives to a wall board manufacturing process.

BACKGROUND

[0002] Gypsum board is commonly employed in drywall construction of interior walls and ceilings and also has other applications. Generally, these gypsum boards are formed from a gypsum slurry including a mixture of calcined gypsum, water, and other additives. In certain gypsum board manufacturing processes, dry additives are first added to a beater or pulper in batch form. The pulp batch solution, which contains a fixed ratio of dry additives, is subsequently pumped to a pin mixer, pin mixer appurtenances, or another part of the gypsum board manufacturing process. However, the pulp batch solution cannot be readily adjusted to accommodate changes in core recipe or process requirements. As a result, the pulp batch solution is subject to error and spoilage. These limitations may result in decreased availability of gauging water for stucco rehydration in the pin mixer and difficulty adjusting dry additive ratios for board line speed, product changes, and other process requirements. Alternatively, loss-in-weight (LIW) and volumetric feeders are sometimes used to meter dry additives into the main stucco system in dry form. However, it is known that some dry additives are more effective when delivered wet.

[0003] Thus, there is a need to provide an improved method of making a gypsum board so as to improve the control and delivery of the dry additives.

DETAILED DESCRIPTION

[0004] Generally speaking, the present publication is directed to a method of making a gypsum slurry and a gypsum board using a particular dry additive delivery system. The dry additive delivery system as described herein allows for the ability control the recipe and other process conditions in real-time, unlike standard batch processes.

[0005] Typically, gypsum board is made from a gypsum slurry, which includes at least stucco and water. In this case, the gypsum slurry also includes certain additives. For example, at least some of these additives may be supplied to the gypsum slurry using the dry additive delivery system as described herein. When making the gypsum slurry, the stucco and water are combined. In addition, any other additives as disclosed herein or known in the art may also be combined.

[0006] In general, stucco may be referred to as calcined gypsum or calcium sulfate hemihydrate. The calcined gypsum may be from a natural source or a synthetic source and is thus not necessarily limited. In addition to the stucco, the gypsum slurry may also contain some calcium sulfate dihydrate and/or calcium sulfate anhydrite. If calcium sulfate dihydrate is present, the hemihydrate is present in an amount of at least 50 wt.%, such as at least 60 wt.%, such as at least 70 wt.%, such as at least 80 wt.%, such as at least 85 wt.%, such as at least 90 wt.%, such as at least 95 wt.%, such as at least 98 wt.%, such as at least 99 wt.%, based on the weight of the calcium sulfate hemihydrate and the calcium sulfate dihydrate. Furthermore, the calcined gypsum may be α-hemihydrate, β-hemihydrate, or a mixture thereof.

[0007] In addition to the stucco, the gypsum slurry may also contain other hydraulic materials. These hydraulic materials may include calcium sulfate anhydrite, land plaster, cement, fly ash, or any combinations thereof. When present, they may be utilized in an amount of 30 wt.% or less, such as 25 wt.% or less, such as 20 wt.% or less, such as 15 wt.% or less, such as 10 wt.% or less, such as 8 wt.% or less, such as 5 wt.% or less based on the total content of the hydraulic material.

[0008] As indicated above, the gypsum slurry may also include water. Water may be employed for fluidity and also for rehydration of the gypsum to allow for setting. Water may also be employed to disperse, mix, and convey additives, include dry additives. The amount of water utilized is not necessarily limited.

[0009] In addition, the weight ratio of the water to the stucco may be 0.1 or more, such as 0.2 or more, such as 0.3 or more, such as 0.4 or more, such as 0.5 or more. The water to stucco weight ratio may be 4 or less, such as 3.5 or less, such as 3 or less, such as 2.5 or less, such as 2 or less, such as 1.7 or less, such as 1.5 or less, such as 1.4 or less, such as 1.3 or less, such as 1.2 or less, such as 1.1 or less, such as 1 or less, such as 0.9 or less, such as 0.85 or less, such as 0.8 or less, such as 0.75 or less, such as 0.7 or less, such as 0.6 or less, such as 0.5 or less, such as 0.4 or less, such as 0.35 or less, such as 0.3 or less, such as 0.25 or less, such as 0.2 or less.

[0010] In addition to the stucco and the water, the gypsum slurry may also include any other conventional additives as known in the art. In this regard, such additives are not necessarily limited. For instance, the additives may include dispersants, foam or foaming agents including aqueous foam (e.g. sulfates), set accelerators (e.g., BMA, land plaster, sulfate salts, etc.), set retarders, binders, biocides (such as bactericides and/or fungicides), adhesives, pH adjusters, thickeners (e.g., silica fume, Portland cement, fly ash, clay, celluloses, high molecular weight polymers, etc.), leveling agents, non-leveling agents, starches (such as pregelatinized starch, non-pregelatinized starch, and/or an acid modified starch), colorants, fire retardants or additives (e.g., silica, silicates, expandable materials such as vermiculite, perlite, etc.), water repellants, fillers (e.g., glass fibers), waxes, secondary phosphates (e.g., condensed phosphates or orthophosphates including trimetaphosphates, polyphosphates, and/or cyclophosphates, etc.), polymers (natural polymers, synthetic polymers), mixtures thereof, etc. In general, it should be understood that the types and amounts of such additives are not necessarily limited.

[0011] In general, each additive may be present in the gypsum slurry in an amount of 0.0001 wt.% or more, such as 0.001 wt.% or more, such as 0.01 wt.% or more, such as 0.02 wt.% or more, such as 0.05 wt.% or more, such as 0.1 wt.% or more, such as 0.15 wt.% or more, such as 0.2 wt.% or more, such as 0.25 wt.% or more, such as 0.3 wt.% or more, such as 0.5 wt.% or more, such as 1 wt.% or more, such as 2 wt.% or more based on the weight of the stucco. The additive may be present in an amount of 20 wt.% or less, such as 15 wt.% or less, 10 wt.% or less, such as 7 wt.% or less, such as 5 wt.% or less, such as 4 wt.% or less, such as 3 wt.% or less, such as 2.5 wt.% or less, such as 2 wt.% or less, such as 1.8 wt.% or less, such as 1.5 wt.% or less, such as 1 wt.% or less, such as 0.8 wt.% or less, such as 0.6 wt.% or less, such as 0.5 wt.% or less, such as 0.4 wt.% or less, such as 0.35 wt.% or less, such as 0.2 wt.% or less based on the weight of the stucco.

[0012] As indicated above, the additives may include at least one dispersant. The dispersant is not necessarily limited and may include any that can be utilized within the gypsum slurry. The dispersant may include carboxylates, sulfates, sulfonates, mixtures thereof, etc. For instance, in one embodiment, the dispersant may include a sulfate.

[0013] In another embodiment, the dispersant may include a carboxylate, such as a carboxylate ether and in particular a polycarboxylate ether or a carboxylate ester and in particular a polycarboxylate ester. In general, the carboxylate or polycarboxylate may be derived from an acrylic acid or a salt thereof, such as a methacrylic acid or a salt thereof. In addition, the polycarboxylate ether copolymer optionally has additional structural groups in copolymerized form. In this case, the additional structural groups may include styrenes, acrylamides, hydrophobic compounds, ester repeating unit, polypropylene oxide and polypropylene oxide/polyethylene oxide units. In addition, any comb-branched polycarboxylate dispersant may be useful in the slurry. In particular, the polycarboxylate dispersant may be one having polyether side chains. The polycarboxylate ester in some embodiments may be prepared by polymerization of a monomer mixture containing a carboxylic acid monomer as the main component. In other embodiments, it is advantageous if the formula (I) represents a polyether containing alkyl or vinyl groups. An aspect of many polycarboxylate esters is their anti-foaming, defoaming and/or surface active properties. Therefore in some embodiments where the dispersant component is such a polycarboxylate ester, the dispersant component can provide antifoaming and surfactant effects in addition to their dispersing effect. In some embodiments, the monomer mixture includes an (alkoxy)polyalkylene glycol mono(meth)acrylate monomer of the general formula (II):

[0014] In particular, the dispersant may include a sulfonate, such as a naphthalene sulfonate, a lignosulfonate, or a mixture thereof. In particular, the sulfonate may be a polynaphthalene sulfonate. The naphthalene sulfonate may have an average molecular weight of at least about 1000 g/mol, such as at least about 2000 g/mol, such as at least about 3000 g/mol, such as at least about 5000 g/mol, such as about at least about g/mol to about 40000 g/mol or less, such as about 30000 g/mol or less, such as about 25000 g/mol or less, such as about

20000 g/mol or less, such as about 15000 g/mol or less, such as about 10000 g/mol or less, such as about 8000 g/mol or less.

[0015] In this regard, the dispersant may include a sulfonate, a polycarboxylate ether, a polycarboxylate ester, or a mixture thereof.

[0016] As indicated above, the additives may include at least one accelerator. The accelerator is not necessarily limited and may include any that can be utilized within the gypsum slurry. The accelerator may include ground or unground gypsum such as from a ball mill accelerator, land plaster, sulfate salts, etc., as well as a mixture thereof. In one embodiment, the accelerator may include at least a ball mill accelerator (BMA).

[0017] The manner in which the components are combined is not necessarily limited. For instance, the gypsum slurry can be made using any method or device generally known in the art. In particular, the components of the slurry can be mixed or combined using any method or device generally known in the art. For instance, the components of the gypsum slurry may be combined in any type of device, such as a mixer and in particular a pin mixer. In this regard, the manner in which the additives is incorporated into the gypsum slurry is not necessarily limited. For instance, the additives may be provided prior to a mixing device, directly into a mixing device, and/or after the mixing device. Further, when provided after the mixing device, the additives may be provided to a canister or boot or by using a secondary mixer. In addition, the respective additives may be provided alone, as part of a mixture, or in a solution. For instance, it may be provided or added to a mixing device or another compound either alone or as part of a mixture. For instance, the additives may be combined directly with another component of the gypsum slurry.

[0018] In one particular embodiment, dry additives are provided to the gypsum slurry using a particular dry additive delivery system. For instance, the dry additive delivery system utilizes a liquid, such as water, a gas, or a combination of a liquid and a gas to simultaneously disperse, mix, and convey dry additives to a gypsum slurry and board manufacturing process. Typically, the dry additive delivery system utilizes water for dispersing the dry additives. In general, dry additives are respectively measured using techniques known in the art. These may include conventional loss-in-weight (LIW) and volumetric feeders to deliver prescribed amounts of one or more dry additives to an accumulator. The accumulator allows for accumulation of all of the dry additives provided to the slurry using this system. After accumulation, the dry additives are provided to an in-line disperser. In addition, a liquid, such as water, a gas, or a combination of a liquid and a gas (hereinafter “feed fluid”) is simultaneously conveyed to the same in-line disperser so that the dry additives are integrated into the feed fluid. The feed fluid is continuously metered using pumps and flow meters. The feed fluid serves as a medium to “pre-dissolve” dry powder additives and promote dispersion. In addition, the feed fluid provides the motive force to carry the resultant additive solution to a the gypsum slurry and board manufacturing process. The solution may then be introduced at various points of the manufacturing process, with respect to the mixer which mixes the gypsum, as indicated above. Using this method, it is possible to continuously deliver a solution comprising prescribed amounts of dry additives and feed fluid.

[0019] For instance, any method or device generally known in the art may be employed to combine the dry additive(s) and feed fluid. In particular, a Quadro® disperser may be employed to combine the dry additive and feed fluid and deliver the additive solution to a gypsum board manufacturing process wherein the additive solution may be combined with stucco, water, and other additives. Alternatively, an Arde-Barinco™ disperser may be employed to combine the dry additive and feed fluid and deliver the additive solution to a gypsum board manufacturing process wherein the additive solution may be combined with stucco, water, and other additives. The disperser is not necessarily limited and may include any that can be utilized with the additive solution disclosed herein for combining the dry additives and the feed fluid.

[0020] Additionally, the disperser may be employed to disperse a pre-hydrate thickener. In particular, the disperser may be employed to disperse a pregelatinized (pregel) starch. When used in combination with a disperser as defined herein, the dispersed pregel starch may allow for desired properties to be realized. For instance, the dispersed pregel may improve mix rheology, bubble structure, board strength, and nail pull values.

[0021] In addition, it should be understood that the flow rates and concentrations of the various feeds is not necessarily limited. For example, the rate of delivery of the respective dry additive(s) to the accumulator, the accumulated dry additives to the in-line disperser, and/or the feed fluid to the in-line disperser may be regulated to obtain the desired concentrations within the gypsum slurry. As mentioned herein, such delivery system allows for regulation of such additives and feed fluid in real-time in response to changes in manufacturing conditions (e.g., board line speed, product changes, etc.).

[0022] Compared to previous methods of delivering dry additives, the system mentioned herein has the advantage of providing dry additives already in solution, enabling gauging water to be fully available for stucco rehydration. The system, in comparison to traditional batch processes, allows for the delivery of dry additives to be instantly adjusted to ensure a proper mix in light of board line speed, product changes, and other process requirements. The disclosed system also reduces raw material costs because fewer dry additives may be required to achieve desirable board qualities. Furthermore, the supplied additives are more effective and more uniformly distributed throughout the gypsum slurry. Successful implementation of the system may eliminate the need for batch pulper systems in the making of gypsum boards. Additionally, by using the dry additive system disclosed herein, the resulting board may exhibit desirable mechanical properties and characteristics. For instance, properties such as mix rheology, bubble structure, board strength, and nail pull resistance may even be improved due to the use of the described method.

[0023] In addition to a method of making a gypsum slurry, the present disclosure also provides a method of making a gypsum board. The method may include the aforementioned step of combining stucco and water. In addition, the method may also include combining any of the other aforementioned components mentioned above with respect to the gypsum slurry using the dry additive delivery system as disclosed herein.

[0024] Once the gypsum slurry is prepared, the method may comprise a step of depositing the gypsum slurry onto a first facing material. The first facing material may be conveyed on a conveyor system (i.e., a continuous system for continuous manufacture of gypsum board). Next, a second facing material is provided on top of the gypsum slurry such that the gypsum slurry is sandwiched between the facing materials in order to form the gypsum board.

[0025] The facing material may be any facing material as generally employed in the art. For instance, the facing material may be a paper facing material, a fibrous (e.g., glass fiber) mat facing material, or a polymeric facing material. In general, the first facing material and the second facing material may be the same type of material. Alternatively, the first facing material may be one type of material while the second facing material may be a different type of material.

[0026] In one embodiment, the facing material may include a paper facing material. For instance, both the first and second facing materials may be a paper facing material. Alternatively, in another embodiment, the facing material may be a glass mat facing material. For instance, both the first and second facing materials may be a glass mat facing material. In a further embodiment, the facing material may be a polymeric facing material. For instance, both the first and second facing materials may be a polymeric facing material.

[0027] After deposition, the calcium sulfate hemihydrate reacts with the water to convert the calcium sulfate hemihydrate into a matrix of calcium sulfate dihydrate. Such reaction may allow for the gypsum to set and become firm thereby allowing for the boards to be cut at the desired length. In this regard, the method may comprise a step of reacting calcium sulfate hemihydrate with water to form calcium sulfate dihydrate or allowing the calcium sulfate hemihydrate to convert to calcium sulfate dihydrate. In this regard, the method may allow for the slurry to set to form a gypsum board. In addition, during this process, the method may allow for dewatering of the gypsum slurry, in particular dewatering any free water instead of combined water of the gypsum slurry. Such dewatering may occur prior to the removal of any free moisture or water in a heating device after a cutting step. Thereafter, the method may also comprise a step of cutting a continuous gypsum sheet into a gypsum board. Then, after the cutting step, the method may comprise a step of supplying the gypsum board to a heating or drying device. For instance, such a heating or drying device may be a kiln and may allow for removal of any free water. The temperature and time required for drying in such heating device are not necessarily limited.

[0028] In this regard, the present disclosure also defines a gypsum board. The gypsum board includes a gypsum core sandwiched between two facing materials. The gypsum board may comprise calcium sulfate dihydrate.

[0029] The thickness of the gypsum board is not necessarily limited and may be from about 0.25 inches to about 1 inch. For instance, the thickness may be at least 1/4 inches, such as at least 5/16 inches, such as at least 3/8 inches, such as at least 4/10 inches, such as at least 1/2 inches, such as at least 5/8 inches, such as at least 3/4 inches, such as at least 1 inch. In this regard, the thickness may be about any one of the aforementioned values. For instance, the thickness may be about 1/4 inches. Alternatively, the thickness may be about 3/8 inches. In another embodiment, the thickness may be about 1/2 inches. In a further embodiment, the thickness may be about 5/8 inches. In another further embodiment, thickness may be about 1 inch. With regard to the thickness, the term “about” may be defined as within 10%, such as within 5%, such as within 4%, such as within 3%, such as within 2%, such as within 1%.

[0030] The gypsum board may also have a certain void volume. In general, the void volume may refer to the volume of the board occupied by air and not any material. The void volume of the gypsum board may be 5% or more, such as 10% or more, such as 20% or more, such as 25% or more, such as 30% or more, such as 40% or more, such as 50% or more. The void volume may be 90% or less, such as 80% or less, such as 70% or less, such as 60% or less, such as 50% or less, such as 40% or less, such as 30% or less.

[0031] In this regard, the gypsum board may have a density of about 5 pcf or more, such as about 10 pcf or more, such as about 15 pcf or more, such as about 20 pcf or more. The board may have a density of about 60 pcf or less, such as about 50 pcf or less, such as about 40 pcf or less, such as about 35 pcf or less, such as about 33 pcf or less, such as about 30 pcf or less, such as about 28 pcf or less, such as about 25 pcf or less, such as about 23 pcf or less, such as about 20 pcf or less.

[0032] In addition, the board weight of the gypsum board is not necessarily limited. For instance, the gypsum board may have a board weight of 500 lbs/MSF or more, such as about 600 lbs/MSF or more, such as about 700 lbs/MSF or more, such as about 800 lbs/MSF or more, such as about 900 lbs/MSF or more, such as about 1000 lbs/MSF or more, such as about 1100 lbs/MSF or more, such as about 1200 lbs/MSF or more, such as about 1300 lbs/MSF or more, such as about 1400 lbs/MSF or more, such as about 1500 lbs/MSF or more, such as about 2000 lbs/MSF or more, such as about 2500 lbs/MSF or more, such as about 3000 lbs/MSF or more. The board weight may be about 5000 lbs/MSF or less, such as about 4500 lbs/MSF or less, such as about 4000 lbs/MSF or less, such as about 3500 lbs/MSF or less, such as about 3000 lbs/MSF or less, such as about 2500 lbs/MSF or less, such as about 2000 lbs/MSF or less, such as about 1800 lbs/MSF or less, such as about 1600 lbs/MSF or less, such as about 1500 lbs/MSF or less, such as about 1400 lbs/MSF or less, such as about 1300 lbs/MSF or less, such as about 1200 lbs/MSF or less. Such board weight may be a dry board weight such as after the board leaves the heating or drying device (e.g., kiln).

[0033] The gypsum board may have a certain nail pull resistance, which generally is a measure of the force required to pull a gypsum panel off a wall by forcing a fastening nail through the panel. The values obtained from the nail pull test generally indicate the maximum stress achieved while the fastener head penetrates through the board surface and core. In this regard, the gypsum board exhibits a nail pull resistance of at least about 25 lb_f, such as at least about 30 pounds, such as at least about 35 lb_f, such as at least about 40 lb_f, such as at least about 45 lb_f, such as at least about 50 lb_f, such as at least about 55 lb_f, such as at least about 60 lb_f, such as at least about 65 lb_f, such as at least about 70 lb_f, such as at least about 75 lb_f, such as at least about 77 lb_f, such as at least about 80 lb_f, such as at least about 85 lb_f, such as at least about 90 lb_f, such as at least about 95 lb_f, such as at least about 100 lb_f as determined according to ASTM C1396. The nail pull resistance may be about 150 lb_f or less, such as about 140 lb_f or less, such as about 130 lb_f or less, such as about 120 lb_f or less, such as about 110 lb_f or less, such as about 105 lb_f or less, such as about 100 lb_f or less, such as about 95 lb_f or less, such as about 90 lb_f or less, such as about 85 lb_f or less, such as about 80 lb_f or less as determined according to ASTM C1396. Such nail pull resistance may be based upon the thickness of the gypsum board. For instance, when conducting a test, such nail pull resistance values may vary depending on the thickness of the gypsum board. As an example, the nail pull resistance values above may be for a 5/8 inch board. However, it should be understood that instead of a 5/8 inch board, such nail pull resistance values may be for any other thickness gypsum board as mentioned herein.

[0034] The gypsum board may have a certain compressive strength. For instance, the compressive strength may be about 150 psi or more, such as about 200 psi or more, such as about 250 psi or more, such as about 300 psi or more, such as about 350 psi or more, such as about 375 psi or more, such as about 400 psi or more, such as about 500 psi or more as tested according to ASTM C473. The compressive strength may be about 3000 psi or less, such as about 2500 psi or less, such as about 2000 psi or less, such as about 1700 psi or less, such as about 1500 psi or less, such as about 1300 psi or less, such as about 1100 psi or less, such as about 1000 psi or less, such as about 900 psi or less, such as about 800 psi or less, such as about 700 psi or less, such as about 600 psi or less, such as about 500 psi or less. Such compressive strength may be based upon the thickness of the gypsum board. For instance, when conducting a test, such compressive strength values may vary depending on the thickness of the gypsum board. As an example, the compressive strength values above may be for a 5/8 inch board. However, it should be understood that instead of a 5/8 inch board, such compressive strength values may be for any other thickness gypsum board as mentioned herein.

[0035] In addition, the gypsum board may have a core hardness of at least about 8 lb_f, such as at least about 10 pounds, such as at least about 11 lb_f, such as at least about 12 lb_f, such as at least about 15 lb_f, such as at least about 18 lb_f, such as at least about 20 lb_f as determined according to ASTM C1396. The gypsum board may have a core hardness of 50 lb_f or less, such as about 40 lb_f or less, such as about 35 lb_f or less, such as about 30 lb_f or less, such as about 25 lb_f or less, such as about 20 lb_f or less, such as about 18 lb_f or less, such as about 15 lb_f or less as determined according to ASTM C1396. In addition, the gypsum board may have an end hardness according to the aforementioned values. Further, the gypsum board may have an edge hardness according to the aforementioned values. Such core hardness may be based upon the thickness of the gypsum board. For instance, when conducting a test, such core hardness values may vary depending on the thickness of the gypsum board. As an example, the core hardness values above may be for a 5/8 inch board. However, it should be understood that instead of a 5/8 inch board, such core hardness values may be for any other thickness gypsum board as mentioned herein.

[0036] In addition, it may also be desired to have an effective bond between the facing material and the gypsum core. Typically, a humidified bond analysis is performed for 2 hours in a humidity chamber at 90°F and 90% humidity. In this test, after exposure, the facing material is removed to determine how much remains on the gypsum board. The percent coverage can be determined using various optical analytical techniques. In this regard, the facing material may cover less than 50%, such as less than 40%, such as less than 30%, such as less than

25%, such as less than 20%, such as less than 15%, such as less than 10%, such as less than 9%, such as less than 8% of the surface area of the gypsum core upon conducting the test. Such percentage may be for a face of the gypsum board. Alternatively, such percentage may be for a back of the gypsum board. Further, such percentages may apply to the face and the back of the gypsum board. In addition, such values may be for an average of at least 3 gypsum boards, such as at least 5 gypsum boards.

FIGURE

[0037] Figure 1 below illustrates one embodiment of a dry additive delivery system as described herein. One or more dry additives are added to respective loss-in-weight and volumetric feeders. The feeders continuously meter and convey dry additive to an accumulator which accumulates the dry additives. The accumulated dry additives are then conveyed to an in-line powder disperser. Liquid pumps are used to convey a feed fluid to the in-line powder disperser where the additive(s) are dissolved or dispersed in the feed fluid. The feed fluid flow rate can also be regulated using a flow meter. The dry additives and feed fluid form a resultant additive solution which may be modulated to adjust the ratio of dry additive. The additive solution is then delivered to a gypsum board manufacturing process for incorporating into a gypsum slurry.