Design of Greener Chemicals

Breakthrough Formaldehyde-Free Coating for Ceiling Tiles

December 30, 2011

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Title: Breakthrough Formaldehyde-Free Coating for Ceiling Tiles

Description: Armstrong World Industries has developed a formaldehyde-free coating which can be applied to the surface of any fibrous panel such as a ceiling tile to prevent product sagging as shown in Figure 1. This new patent pending technology was first successfully tested in production in August 2010. In October 2010, Armstrong's Leadership Team approved the funding to implement this new technology globally. Conversion to this new technology is underway and several key products have been changed over successfully.

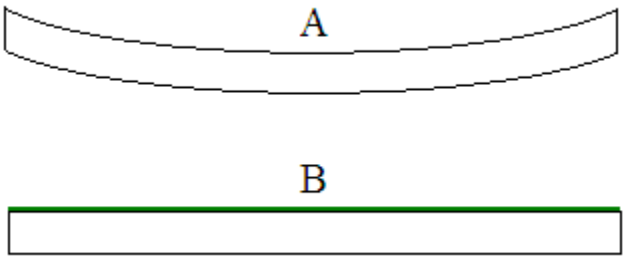

Figure 1. Ceiling tile A depicts deflection (sagging) that occur when tiles are not engineered to resist humidity and ceiling tile B depicts a non-sagging tile with has been engineered to resist humidity and associated sagging.

Small Business Statement: This project is not eligible for the small business award or the academic award

EPA Award Focus Area: This technology is consistent the following focus area: Design of Greener Chemicals.

Location of work: All of the research, development, and related aspects of this technology were developed by Armstrong World Industries, Inc. at their Corporate Headquarters located in Lancaster, Pennsylvania. Full-scale testing of this technology has been carried out at Armstrong manufacturing facilities located in Marietta, Pennsylvania, Macon, Georgia, and St. Helens, Oregon. Full scale implementation will include the remaining five (5) manufacturing facilities in United States, Europe and in China.

Abstract: Armstrong World Industries has developed a formaldehyde-free coating which can be applied to the surface of any fibrous panel such as a ceiling tile to prevent product sagging. This invention is the result of an extensive research effort to develop a new coating technology with the following four (4) performance parameters: 1) capable of hydroscopic expansion at high humidity to resist sag, 2) can maintain a high modulus even at high humidity 3) is compatible with other coatings and/or fillers and 4)

a water borne coating system. By implementing this new technology, which contains renewable bio-based materials, Armstrong will eliminate the use of 8,300,000 pounds of formaldehyde resins globally, 416,000 pounds of formaldehyde emissions to the air, and 134,000 pounds of triethylamine emissions annually.

Formaldehyde is a classified as a "known" carcinogen by International Agency for Research on Cancer (IARC) and as "reasonably anticipated to be a human carcinogen" by the National Toxicology Program. Formaldehyde is a key ingredient in a wide variety of building products including pressed-wood products, such as particleboard, plywood, and fiberboard; glues and adhesives; permanent-press fabrics; paper product coatings; and certain insulation materials. Historically, Armstrong and other ceiling tile manufacturers have applied a formaldehyde resin based back coat to prevent ceiling tiles from sagging, because of formaldehyde resin's unique hydroscopic properties.

Armstrong will use this newly invented coating technology to replace all formaldehyde resin ceiling tile applications as the new coating provides for hydroscopic expansion at high humidity while maintaining a high modulus to prevent sag, is compatible with other coatings and/or fillers and is a water borne system. The benefits of eliminating the use of formaldehyde resin include the:

1. avoidance of employee formaldehyde and triethylamine exposure risk at four (4) Armstrong manufacturing facilities in the United States and five (5) international facilities,

2. elimination of formaldehyde and triethylamine stack emissions associated with the ceiling tile back coat that resulted from the melamine formaldehyde cross linking process,

3. removal of potential formaldehyde emissions from finished products after they are installed.

4. reduction in life cycle assessment impacts associated with upstream production of formaldehyde and triethylamine.

Detailed Description:

Chemistry:

Ceiling tiles have a tendency to sag when exposed to high humidity environments due to the hydrophilic nature of certain components of the core substrate (i.e. binders (e.g. starch), cellulosic fibers (e.g. newsprint)). For this reason, a hydroscopic coating is applied to the back surface of the substrate. The hydroscopic coating absorbs moisture (due to high humidity) and expands its' volume and dimension, creating an expansion

force on the back surface of the substrate. The expansion of the back results in a force vector upward in the opposite direction of gravity when the ceiling tile is in its' normal face down position. The expansion differential at high humidity is what provides sag resistance to acoustic ceiling tile. Sag resistance is valued for aesthetic reasons, but more importantly it is directly related to acoustic, seismic and fire performance of ceiling tiles.

In addition to being hydroscopic, the coating must also maintain a high modulus and be compatible with other coatings and fillers. In order to be compatible with other coatings and fillers, and to prevent corrosion of processing equipment, the binder must have neutral to slightly basic pH. Our extensive research effort has developed a unique new, cost effective water based coating that is capable of hydroscopic expansion at high humidity while maintaining high modulus to prevent sag, and has a neutral to slightly basic pH which is compatible with most other coatings and with typical processing equipment.

The invented coating system includes a binder based on a combination of dextrose (sugar) and an ammonia neutralized polyacrylic acid. This binder is thermally crosslinked by the reaction of the acrylic's carboxylic acid groups with the sugar's hydroxyl groups. This reaction is shown in Figure 2.

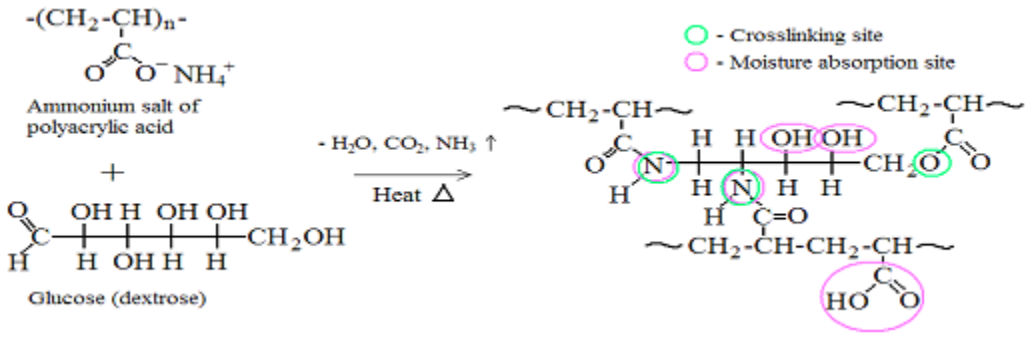

Figure 2. Coating binder reaction for new coating technology.

Note, however, that this binder alone would not provide the sag resistance required by typical acoustical ceiling tiles. In our invention, this binder is used as part of a coating where the pigment selection, the pigment to pigment ratio, the pigment to binder ratio, and the coating viscosity combine with the binder to provide the strength and expansion at high humidity needed to give excellent sag resistance to acoustical ceiling tiles. This unique coating solution relates directly to Armstrong patent # US 7,851,052 B2 in which

the differential expansion at high humidity between the face coating and back coating provides for sag resistance of the ceiling tile on which they are applied.

Problem

This patent pending ceiling tile coating technology will have a significant positive global impact. This technology offers a practical, cost-effective approach to eliminating formaldehyde resin application on ceiling tiles to reduce human exposure to formaldehyde. This technology may be applied to other processes where formaldehyde resins are used. This technology eliminates the use of formaldehyde resins which results in formaldehyde emissions that are classified as a Group 1 carcinogen by IARC.

Also, this technology eliminates globally the use of triethylamine which is used as a coating stabilizer for melamine formaldehyde based coatings from nine (9) Armstrong manufacturing facilities. Triethylamine is not classified by IARC, but is a highly flammable irritant that is listed in Section 313 of the Emergency Planning and Community Right-to-Know Act and reported a part of the Environmental Protection Agency's annual Toxic Release Inventory (TRI). Once this technology is fully implemented, Armstrong will no longer have any triethylamine emissions; therefore Armstrong will no longer be required to report triethylamine emissions as part of the TRI process.

The elimination of formaldehyde resin and triethylamine results in 1) avoidance employee formaldehyde and triethylamine exposure risk at four (4) Armstrong manufacturing facilities in the United States and five (5) global facilities, 2) elimination of potential formaldehyde off gassing from products installed in buildings, 3) removal of free formaldehyde stack emission and triethylamine emissions that results from cross linking of the formaldehyde back coat, and 4) reduction life cycle impacts associated with upstream production of formaldehyde and triethylamine.

Technology Comparison:

Technologies that were studied to eliminate formaldehyde in ceiling tiles include:

1) Latex and Starch Binders - Neither latex nor starch binders alone could directly replace the formaldehyde binder in the ceiling tile back coat. Both latex and starch had to be coupled with additional high strength materials such as mineral wool to prevent board sagging. This solution resulted in higher manufacturing costs and larger negative product

environmental impacts such as higher carbon footprint and embodied energy.

2) Sugar with Carboxylated Compound Binders - Sugar with carboxylated compound binders alone would not provide for sag resistant ceiling tiles without the unique formulation that was created for this new coating technology. This is because the binders alone would not provide the differential expansion needed for good sag resistance.

3) Additional Substrate Strengthening Materials Without Special Binders - The formaldehyde binders could be completely eliminated by making the ceiling tiles stronger by adding reinforcing materials. These high strength materials resulted in ceiling tiles with higher embodied energy and carbon footprints than ceiling tiles manufactured with our unique coating system technology. This new coating technology eliminates the ceiling tile sagging without the addition of expensive reinforcing materials and without the use of a formaldehyde resin back coat.

Life Cycle View

This technology solution does not have any known drawbacks from a cradle to grave life cycle perspective. This solution will result in a reduction of the ceiling tiles carbon footprint. This reduction is the result of replacing the melamine urea formaldehyde resin. As shown in Table 1, 100% solid form melamine urea formaldehyde resin has a carbon footprint based on 100-year timeframe (IPCC 2007[1]) of 2.9581 kg-CO2 equivalents[2]. The formaldehyde resin used in ceiling tiles is approximately 60% solid; therefore it has a carbon footprint of 1.775 kg-CO2 equivalents. The technology solution will allow the formaldehyde resin to be replaced with a chemical that has a carbon footprint based on 100-year timeframe (IPCC 2007 and CML 2001[3]) of 1.014 kg-CO2 equivalents when appropriately proportioned. So, the total carbon footprint reduction with the new technology will be reduced by 1,719,015 kg-CO2 equivalents annually.

Table 1. The Carbon Footprint given in kg-CO2 equivalent (eq) for 100% solid melamine urea formaldehyde resin[4].

[1] Intergovernmental on Climate Change

[2] Wilson, John B., Resins: A Life-Cycle Inventory of Formaldehyde-Based Resins Used in the Wood Composites in terms of resources, emission, energy and carbon, Wood and Fiber Science, Vo. 42, March 2010.

[3] Center of Environmental Science of Leiden University

[4] Wilson, JB. Resins: A Life-Cycle Inventory of Manufacturing Resins Used in the Wood Composites Industry. Consortium for Research on Renewable Industrial Materials (CORRIM, Inc.). University of Washington, Seattle, WA. January 2009.

Greenhouse gas (GHG)	GHG Contribution kg/kg resin 60% solids	CO_2 equiv. multiplier	Carbon Footprint kg-CO_2 eq/kg resin 100% solids
CO_2	1.677934	1	2.7966
Methane (CH_4)	0.00374	25	0.1558
Nitrous oxide (N_2O)	0.0000114	298	0.0057
Total			2.9581

In addition to a carbon footprint reduction, the end of life for the ceiling tiles will be enhanced, because they will no longer have potential for containing residual added formaldehyde which means that residual formaldehyde will not enter the recycling stream.