Reconsidering the Concept of Dry Surface Treatment of Cellulosic Paper to Produce Coated Paper Products

Fei Yang,[b] and Jing Shen [a]*

The concept of dry surface treatment for paper coating applications has been available for more than ten years. Different from conventional coating methods such as extrusion coating and suspension coating, dry surface treatment involves a combined process of non-contact deposition of coating materials and surface smoothening of the coated paper. Pronounced features of this concept include avoidance of the need for paper drying and elimination of various negative consequences related to rewetting of the paper with water, *etc*. However, to date the concept has not been commercialized. Some significant challenges remain. Commercializable technologies for production of size-controllable coating particles and their electrostatic deposition onto paper are the key. Reconsidering this interesting concept may at a minimum shed light on the technological advancement in the area of pulp and paper.

Keywords: Dry surface treatment; Cellulosic paper; Coating; Concept

*Contact information: a: Key Laboratory of Bio-based Material Science and Technology of Ministry of Education, Material Science and Engineering College, Northeast Forestry University, Harbin 150040, China; b: State Key Laboratory of Pulp and Paper Engineering, South China University of Technology, Guangzhou 510640, China. *Corresponding author: jingshen.china@hotmail.com*

Conventional Methods of Surface Treatment of Cellulosic Paper with Coating Materials and Some of Their Drawbacks

To meet the requirements of end-uses and post-processing, cellulosic paper usually needs to be engineered by various methods, among which surface treatment is important in a number of ways. For instance, surface treatment can improve the surface properties, printability/writability, and convertability of paper, as well as delivering unique functionalities such as barrier properties to paper. Conventionally, the application of coating materials at the paper surface can be implemented by extrusion coating, emulsion/dispersion/suspension coating, or solution application (Putkisto *et al*. 2004a).

When the coating materials are in the form of emulsions/dispersions/suspensions or solutions, the coating methods can be referred to as emulsion/dispersion/suspension coating or solution coating. As a typical example of such coating methods, pigment coating has been widely used to improve the critical properties of paper. These methods enable the application of low coat weights and the use of materials that are not extrudable; however, they have such drawbacks as an energy-intensive evaporation and drying stage after application as well as handling of media in liquid forms (Putkisto *et al*. 2004a). The interaction of previously dried paper with such liquids as water may impair its properties.

On the other hand, as an established processing technology resulting in the production of multilayer flexible structures, extrusion coating involves melting of thermoplastic materials (*e.g.*, polyethylene and polylactic acid) to be applied onto paper (Manjure 2011). This method has been traditionally used to impart such properties as water/oil resistance to paper, so that the products can meet the requirements of liquid

packaging, for instance. However, due to the dependence of coating efficiency on the adhesion properties of the melt and the draw strength, the extrusion coating process usually requires specially manufactured machinery when processing different materials or operating at specified tension levels; also, temperature-sensitive coating materials may suffer from chemical changes during the melting process (Putkisto *et al*. 2004a).

Concept of Dry Surface Treatment and Its Unique Features

The innovative concept of dry surface treatment of cellulosic paper was initially proposed and demonstrated by researchers in Finland (Maijala *et al*. 2002, 2004a,b,c, 2005; Putkisto 2004; Putkisto *et al*. 2003, 2004a,b,c,d, 2006), and was later followed and evaluated by researchers in China (Yang *et al.* 2012; Zhu *et al.* 2008). According to Putkisto *et al*. (2006), this concept was initially devised in 1999. In this concept, essentially paper coating and surface smoothening are achieved in a combined process (as briefly illustrated in Fig. 1 (Maijala *et al*. 2004c, 2005)) involving the following sequential steps:

- An electric field is used to direct charged coating particles (pigment coatings or polymer coatings) onto paper, and the deposited layer attaches to paper *via* electrostatic interactions.
- Subsequently, during the heating and compressing (fixing) phase, the coating materials soften to form a coherent structure, so that the paper surface can be smoothened.

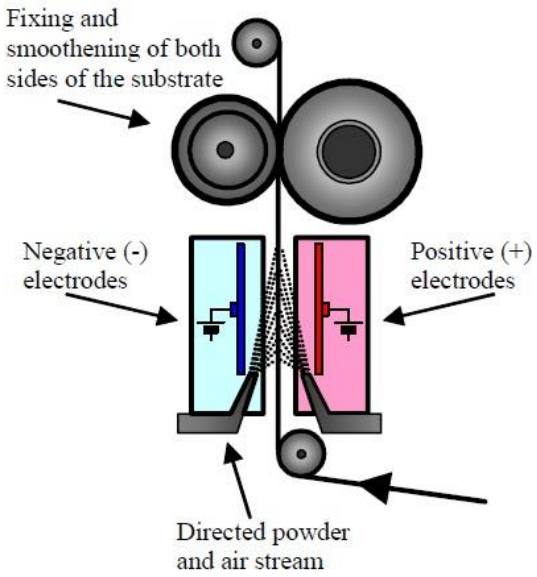

Fig. 1. Schematic illustration of simultaneous two-sided dry surface treatment of cellulosic paper

In contrast to the conventional paper coating techniques mentioned earlier, the interesting concept of dry surface treatment has several unique features that are advantageous to the paper industry (Putkisto *et al*. 2004a):

- As the process may gain in being more or less solvent-free, no drying is needed after application of the coating. Thus, the drying-related energy consumption is eliminated, and the negative impact of interactions of solvents (*e.g.*, water) with paper is at least partly avoided.

- The non-contact application of coating materials onto paper might be favorable for reducing the wet stress and minimizing the need for collection and circulation of materials. As a result, the adoption of the concept may improve the machine runnability.
- In the fixing phase, the fusing and homogenization of the coating layer is achieved in a nip at low tension (*i.e.*, low elongational shear rate in comparison to the stretching of the melt in extrusion coating), resulting in the possible consequence that such a process might be less material-dependant than extrusion coating.
- As the processing temperature in this process is lower than that of extrusion coating, the chemical degradation of coating materials and the spreading of volatile decomposition products into the surrounding air would be less.

Challenges and Future Possibilities

To our knowledge, although the concept of dry surface treatment of cellulosic paper has been available for more than ten years, it has not reached the real commercial scale. This may be due to its possible intrinsic limitations, such as:

- The charging of coating particles and generation of electric field involves huge capital investment.
- The commercial production of water-free, powdery nano-sized or micro-sized coating particles (*via* such routes as freeze/spray drying of coatings and *in-situ* polymerization of monomers in supercritical carbon dioxide) may be challenging.

These limitations may pose big challenges for the commercialization of the concept. The economic feasibility of the application of this new concept still needs systematic evaluation. It is likely that the well-established commercial practices of extrusion coating and pigment coating may at least temporarily discourage the implementation of a completely different concept of paper coating.

On the other hand, the technical progress in high solids coatings for paper surface treatment may compete with the implementation of this new concept. Once the solids content is increased, the energy consumption during the drying process can be significantly decreased. To date, the highest obtainable solids content of pigmented coatings can be close to 70 wt.%.

However, it may still be meaningful to reconsider the concept of dry surface treatment of cellulosic paper. It may be expected that once successfully optimized, this concept may have certain potential of real commercialization. In particular, the significant benefits related to drying elimination and non-contact-based advantages (*e.g.*, improved machine runnability) are rather encouraging, and these may function as the driving motivations for future interest on the part of industrialists. In this sense, the commercializable technologies related to size-controllable synthesis of coating particles and simplified/streamlined particle deposition onto paper are the key. Future research and developmental work related to economic/technological analysis, process optimization, and concept modification may lead to improved commercializability. At a minimum, this interesting concept may shed light on the configuration modification, new coating formulation development, or other related research and development in the area of pulp and paper. The explorations into this concept may also help to devise alternative approaches to the surface engineering of cellulosic paper for both traditional and value-added applications.

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