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Original Article

Analysis of cracking potential and micro-elongation of linerboard

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ABSTRACT

Folding cracks of linerboards in relation to their micro-elongation and the forming conditions were studied using an industrial linerboard machine with a top former. The experiments consisted of the study of various forming conditions by manipulating the jet/wire speed ratio to produce linerboard with differences in fiber structures that were related to the cracked and uncracked products. The results showed that changes to the jet/wire speed ratio of about 0.01–0.02 to improve the tested folding endurance in the machine direction potentially produced folding cracks in the linerboard, which indicated an ambiguous interpretation of the foldability tests. The delaminated cracked layers were found to have a high folding endurance and tensile strength, while the decrease in the micro-elongation formulated in this study was found to be related to cracking. A lower micro-elongation of about 350–500 μm/N·g was found in a range of products with folding cracks.

Introduction

Cracking of corrugated containers under the folding process is a crucial problem producing defect products and reducing the production capacity of the converting process, as the folding cracks result from an inappropriate creasing condition, a low moisture content of the folded sheets (Whitsitt and Mckee, 1966; Whitsitt, 1974; Hartikainen, 1998; Gooren, 2006) and an inferior strength of linerboards (Mcgrattan, 1990).

In Asia, testliner is a major grade of linerboard produced from recycled fibers (Kaviranta, 2000). These fibers have a large variation in quality and cause instability in the board-making processes and consequently produce inferior products with the folding crack problem. The folding cracks regularly occur crossing the fiber orientation because this direction has a lower elongation under the tensile forces (Niskanen et al.,1998; Fellers, 2009). It has been reported that the folding cracks can be minimized by optimization of the linerboard-forming conditions to manipulate the fiber structures (Odell, 2001). However, the linerboards consist of various layers formed by the separate forming sections and various types of fiber sources (Kaviranta, 2000). The oriented fibers are also affected by many variables including the slice opening of the headbox, the stock consistency, the dewatering pressure and the velocity of the jet-to-wire speed (Baum, 1991; Nordström and Norman, 1994; Ullmar and Norman, 1997; Shakespeare, 1998; Gigac and Fiśerová, 2009). These make it difficult to maintain the quality of each layer in the linerboard structure, and potentially produce inferior foldability products. Industrially, the foldability of a linerboard is determined using laboratory folding tests. However, corrugated containers produced using linerboard with high folding endurance and strength properties still have cracking problems in the folding process.

In order to reduce the severe folding cracks on the linerboards, this study was setup to establish the correct properties to use in the determination of foldability in linerboards, and to examine the cracking potential in the forming operations by manipulating the jet/wire speed ratio to produce linerboard with different fiber structures and to relate these to the cracked and uncracked products. The relationship between the cracking regions and the forming conditions was used to confine the former operating window in order to avoid operations beyond the cracking zones.

Materials and methods

The experiment consisted of two parts. First, the sources of folding cracks were analyzed using industrial linerboard products. The second part of the study involved using the linerboard machine to produce linerboard samples with various structures and fiber orientations. The cracking potential of the trial linerboards under the former operating conditions were determined and related to their micro-elongation as formulated in this study.

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Analysis of cracked linerboard products

Industrial linerboards including the claimed and unclaimed products with a basis weight of 125–185 g/m^2 were sampled. The cracking line was observed using a stereo microscope and a scanning electron microscope. The top layers of samples were delaminated and analyzed to investigate the correlation between their mechanical properties and the cracking. The tensile strength was tested according to the ISO 1924-2 standard method (International Organization for Standardization, 2011). The folding endurance was determined according to the ISO 5626 standard method (International Organization for Standardization, 2011).

Analysis of cracking potential in paperboard machine operations

The production of linerboards was carried out using a four-ply Fourdrinier machine at Thaicane Paper PLC, Thailand. The top ply, which is a cracking layer, was produced with various structures while the other layers were kept constant. The major stock component of the top ply consisted of unbleached softwood kraft pulp and bleached hardwood kraft pulp having a freeness of 350 mL. The other layers were made from old corrugated container pulp. The linerboards were produced at a basis weight of 125 g/m^2 with the top ply having a basis weight of 40 g/m^2. The stock consistency was controlled at 0.3% with a headbox slice opening of 15 mm. The wire speed was operated at 625 m/min. The jet velocity was controlled in the range 563–656 m/min (jet/wire ratio 0.90–1.05) producing a top layer with various structures and fiber orientations. The dewatering pressure, pressing conditions and drying conditions were kept constant. The tested samples including the delaminated top ply and the whole sheet were analyzed. The tensile strength was determined according to the ISO 1924-2 standard method (International Organization for Standardization, 2011), and the folding endurance was determined according to the ISO 5626 standard method (International Organization for Standardization, 2011). The cracking potential under the operating conditions of the former was analyzed using the micro-elongation which was formulated in this study.

Results and discussion

Cracked product analysis

Cracking of the corrugated container samples was found during the folding process. The folding crack occurred on the top-ply of the linerboard crossing the machine direction (MD) where the fiber was oriented in this direction, as shown in Fig. 1. Microscopic examination of the cracking line showed that the fibers were broken without any loosening of their network indicating a sufficient bonding strength.

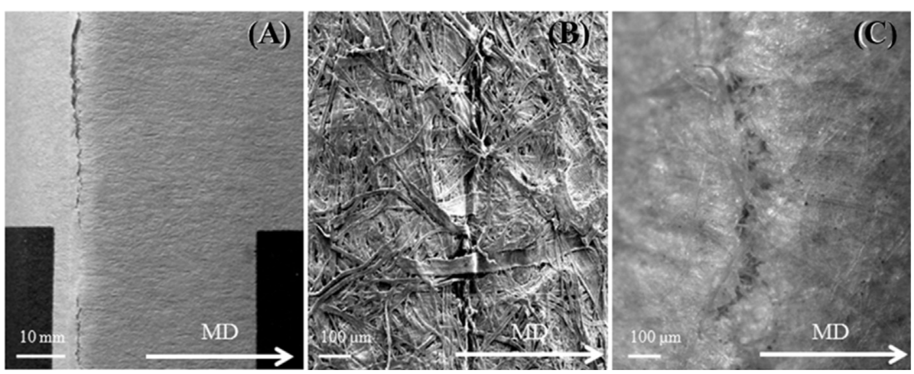

Fig. 1. Cracked product features (A) having a cracking line along the folding direction (B). The folding crack occurred on the weaken fibers and the top layer (C) of linerboard (MD = Machine direction).

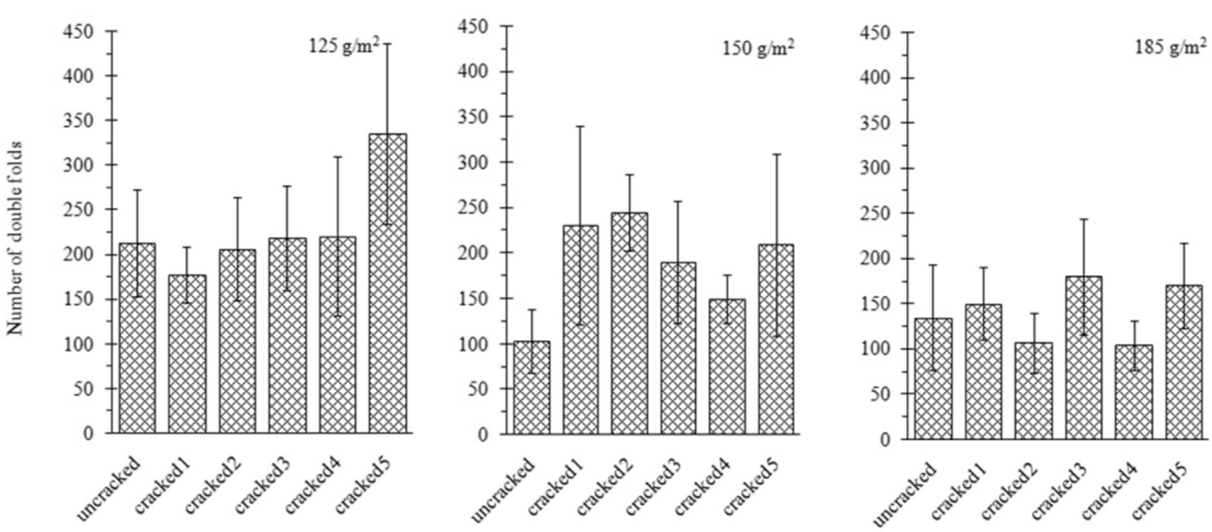

Fig. 2. Number of double folds of cracked and uncracked linerboard products tested in machine direction. Error bars indicate ± SD.