Development of Gliding Arc Plasma Jet with a Bent Nozzle for Pre-Treatment of Inkjet Printing in Roll-to-Roll Processing

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Abstract

The polymer film used as food packaging has time limit information printed by an inkjet printer. This information is susceptible to erasure during product distribution. Therefore, ink adhesion to the film needs to be improved. In the present study, the gliding arc (GA) was used to treat the surface where the time limit information is printed on food packages at the end of a roll-to-role processing line. Tension checks and rubbing tests were carried out to evaluate the performance of the treatment. The GA with a normal exit nozzle was tested. It was found that the treatment was uneven along the film feed direction and high-speed observations revealed why the GA plasma jet sometimes exited in the direction of the film feed and sometimes against it. Therefore, a bent-nozzle GA with a deflection plate was developed to control the outflow direction of the plasma jet, and improved treatment performance. Furthermore, in order to attain better adhesion, a flow guide cover was added to the bent nozzle GA. When the flow guide cover curved along the shape of the roll, there was better ink adhesion because multiple treatments were performed without separation of the plasma from the treated surface.

Keywords: Gliding arc plasma jet, Surface treatment, Polymer film

1. Introduction

Time limit information such as the consumption expiration date, best before date, and freshness date is typically displayed on food packaging. The transcription is usually printed out directly onto the packaging using an industrial inkjet printer[1,2]. A polymer film such as polypropylene (PP) is generally used as the packaging material. However, ink adherence is weak because the surface is inactive and the surface energy is low[3]. Therefore, the printed information sometimes disappears during product circulation. As a preventative measure, the film surface is treated to improve the ink adhesion. Examples of dry surface treatments are irradiation with ultraviolet rays[4,5] and plasma irradiation[3,6]. The latter is roughly divided into the vacuum plasma[7,8] and atmospheric pressure plasma[9,10] categories.

Atmospheric pressure plasma is attractive to the industry due to its various advantages such as simple equipment, low running cost, and high-speed continuous processing. Atmospheric pressure plasma generation methods include corona discharge[9–13], atmospheric pressure glow discharge[9,10,14], dielectric barrier electric discharge[9,10,15–20], RF electric discharge[9,10,21], and arc discharge[9,22,23]. The corona discharge process[9–13] is mostly used to treat the surface of a resin film. The corona discharge system is comprised of a high voltage electrode and a ground electrode. It is necessary to sandwich an object between the electrodes. Therefore, it may not be easy to deploy the system in existing production lines.

The gliding arc (GA)[24–30] is an electrical discharge between two electrodes under forced gas flow. The conventional GA device has a free open end at the exit of the arc plasma jet. The arc starts at the smallest electrode gap. The arc column is then pushed downstream with the plasma plume by the forced gas flow, slides towards the wider gap between the electrodes, and exits from the end. After the arc extinguishing, a new arc starts at the smallest gap. The plasma jet appears to be flat. It therefore has some advantages compared to other treatment technologies: wider treatments can be achieved compared with cylindrical plasma jets and easy installation on existing production lines since no sandwiching is necessary. In prior work, we showed a preliminary demonstration of the GA plasma jet on frozen food packaging film and the consequent improvement in ink adhesion[30]. In this study, we tested the GA jet system in a practical production line. We observed the change of the GA jet flow by difference in the structure of the jet exit for stable and efficient surface treatment on the practical production line. A new GA device was developed to address them.

2. Experiments with a GA with a Simple Nozzle

2.1 Experimental details

A GA with a conventional rectangular exit nozzle was tested in an actual roll-to-roll print line as shown in **Fig. 1**. The APW-602f GA system was used