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Original Research Paper

Engineering

MICRO-PERFORATION OF POLIETHYLENE FILM USING AN IGNITION COIL

Federico Hahn Irrigation, Universidad Autonoma Chapingo, Texcoco, México.

Jorge Colin IAUIA, Universidad Autonoma Chapingo, Texcoco, México.

Francisco Marin IAUIA, Universidad Autonoma Chapingo, Texcoco, México.

ABSTRACT Modified atmosphere packing increases the shelf life of fruits and vegetables. Plastic films for modified atmosphere packing (MAP) requires of a cheap technology that can produce orifices with diameters ranging between 50 and 200 µm. A micro-perforation equipment used an electric high voltage discharge between two electrodes that crosses the static polyethylene film to make the holes. An ignition coil generates high voltage and the size of the hole is dependent on the spark time, distance between electrodes and film thickness. It was found that for a thin 0.02 mm film, the smallest hole was obtained with a discharge of 20 ms between two electrodes spaced by 4 mm. For a 0.04 mm thick film, perforation size decreases as the spark time increases. Holes drilled with an electric arc do not let rims around the holes and the eroded plastic is removed by vaporization.

KEYWORDS : modified atmosphere packing, drilling, needles, machine control

INTRODUCTION

Modified atmospheres inside containers are determined by the total area of holes on the film surface and micro drilling use orifices from 50-200 µm in diameter [1]. Modified atmosphere packing (MAP) of fresh fruits and vegetables is based in modifying O2 and CO2 levels in the atmosphere within the sealed package. MAP reduce the respiration rate, ethylene production and physiological changes, inhibiting enzymatic chemistry and microbiological mechanisms that decompose fresh products; freezing, dehydration and sterilization are avoided [2, 3]. Perforations vary in size from micro-perforations (50–200µm diameter holes) to macro-perforations with holes or tubes greater than 200µm in diameter [4]. A number of techniques produce such perforations in polymeric films, including mechanical/semi-automated cold or hot needle puncturing and most recently, laser technology [5]. The success of mechanical needle perforation is due to its flexibility, cost effectiveness, but it is time consuming. It is difficult with needles to achieve consistent perforation shapes [6].

The objective of this work was to design an electrical system that could generate an arc to punch the film surface and produce holes within a controllable area.

MACHINE DESIGN

Some modifications were carried out to the previous needle machine [7] as the holes are produced by an electric arc, which does not require contact with the film. The transmission clover-shaped cam maintains the plastic film motionless [7] after generating the spark, Fig. 1. All the rollers (A to H) provide traction and tension to the plastic film.

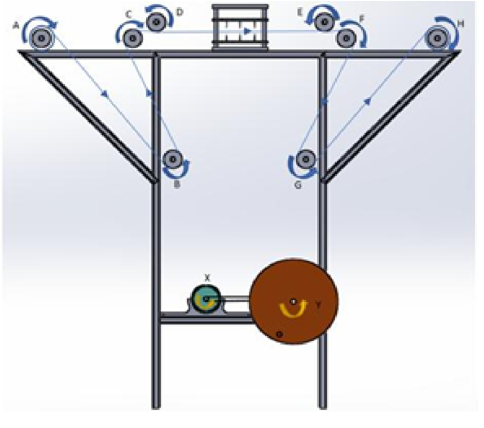

Figure 1: machine design.

Table 1: Average hole diameter for different spark duration, film thickness and distance between needles.

Variables		Hole diameter according to spark timing, mm							
Needle	Thickness,	Pulse 20 ms		Pulse 40 ms		Pulse 80 ms		Pulse 100 ms	
Distance, mm	Film, mm	Ds/ std	Di/ std	Ds/ std	Di/ std	Ds/ std	Di/ std	Ds/ std	Di/ std
4	0.02	0.14/1.07	0.14/0.87	0.25/ 1.08	0.20/1.08	0.40/0.83	0.25/ 0.49	0.25/ 0.89	0.15/0.52
4	0.03	0.70/ 0.93	0.35/ 0.71	0.20/ 0.90	0.19/ 0.53	0.18/ 0.83	0.11/ 0.49	0.22/ 0.89	0.19/ 0.52
4	0.04	0.64/ 0.97	0.62/ 0.63	0.59/ 0.92	0.56/ 0.58	0.46/ 0.9	0.39/ 0.56	0/26 0.27	0/25 0.25
6	0.02	0.90/ 0.97	0.60/ 0.6	1.00/ 0.96	0.70/ 0.64	1.0/ 0.94	0.66/ 0.61	0.92/ 0.89	0.61/ 0.53
6	0.03	1.00/ 0.92	0.70/ 0.70	0.70/ 0.9	0.50/ 0.53	0.56/ 0.81	0.33/ 0.49	0.50/ 0.29	0.46/0.25
6	0.04	1.60/ 0.98	1.10/ 0.65	0.90/ 0.91	0.80/ 0.56	0.90/ 0.92	0.90/ 0.56	0/ 0	0/ 0

In this machine rollers D and E increased the tension and high voltage isolated electrodes micro-eroded the plastic film.

ELECTRIC CIRCUIT FOR ARC GENERATION

A spark between two needles is needed to micro perforate the plastic film, so a high voltage creates such a discharge. The ignition coil (Spectra C-502. AC Delco, USA) is a step-up transformer consisting of two coils of wire wrapped around an iron core. The secondary coil has several thousand turns of thin wire producing and not allowing some 40,000 volts. A capacitor of 10 µf at 370V connected in series with the primary of the ignition coil absorbs the back emf, Fig. 2. The spark (Fig. 2b) appears between two acupuncture needles having a diameter of 0.19 mm and the distance between them represents one of the main parameters of the system. An Arduino UNO board activates the solid-state relay every time that the spark comes through which is generally two seconds; however this period can be programmed. In addition, this program depends according to the number of holes required per bag. As several holes are done in parallel as the film advances, a stand-alone circuit is required for each pair of needles.

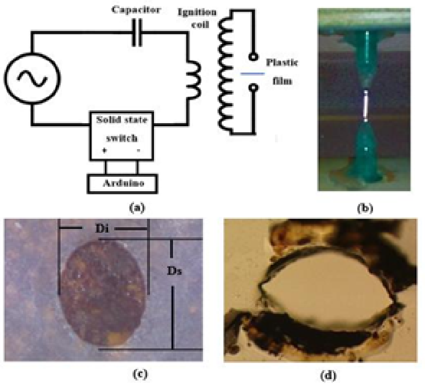

Figure 2: Micro-perforation (a) circuit, (b) spark, (c) orifice with variables, and (d) with rim.

FILM HOLE EVALUATION

After applying a signal to the electric power circuit an arc was generated (Fig. 2b), producing an ellipse-hole in the plastic film (Fig. 2c). Holes produced by electric arcs gave better circularities than those punched by tailor's needles [4]. Holes are observed with a X100 digital microscope and the circularity studied using mainly the following parameters: larger diameter Ds and smaller diameter Di, Fig. 2c. All the perforations presented an ellipsoidal form and the area can be obtained from both diameters.

EXPERIMENTAL SETUP

Micro-perforation tests on polyethylene film having different widths was carried out using different spark duration, and distance between needles; diameters of the resultant holes were analyzed using Gyddion software. One hundred perforations were done and the average and standard deviation of them obtained. Minimum size was obtained for a plastic =0.02 mm thick, high voltage timing of 20 ms an distance between needles of 4 cm.

HOLE SIZE FOR DIFFERENT FILMS AND DISTANCE BETWEEN ELECTRODES

For a polyethylene film having a width of 0.02 mm, hole size increases as spark time rises and when the distance between electrodes becomes larger. The lower diameter Di decreases when the electric spark time increases over 100 ms. Table 1 shows that the diameter of the drilling hole varies from 0.14 mm to 0.40 mm when the distance between electrodes is of 4 mm for all the different spark timing intervals; optimum size was achieved for an arc of 20 ms.

Minimum hole-size for 0.03 mm thick polyethylene film is achieved with a 80 ms spark being the electrodes separated 4 mm, Table 1. Hole size decreases in 0.04 mm thick plastic film as the spark time increases. Sparks longer than 80 ms and distance between electrodes shorter than 8 mm will not cross the film. The hole upper diameter Ds performed on a 0.4 mm film increases four times after receiving a discharge of 20 ms as the needles are separated from 4 to 8 mm. Although not presented on Table 1, a 0.07 mm thick polyethylene film was perforated with 20 or 40 ms short pulses and at distances between electrodes of 6 and 8 mm.

COMPARISON BETWEEN ELECTRIC-ARC AND HOT NEEDLE HOLES

Hot needles melt the plastic to form the hole and redeposit the melt plastic as a large rim around the edges; meanwhile cold needles punch rough holes in the plastic film, leaving the plastic material from the holes attached as flaps that can cover the holes [8,9].

This electric-arc technique referred as sparks eroding machining is a new technique used for micro-perforation of plastic films. Plastic material is removed by melting and vaporization caused by electrical discharges provided by a generator to produce micro-perforations on film [8].

CONCLUSIONS

A machine was built to drill small orifices in a plastic film continuously. The motor never stopped and a spark crossed through the film perforating it. Holes without rim resulted being more properly suited for MAP applications. Another advantage of the high voltage discharge system is that it is a non-contact method, which avoids that the melted plastic covers the needles and the heat transfer gets lost with time.

This system uses an ignition coil, a capacitor and a solid-state relay, which is turned-on using an Arduino microcontroller board to program the number of holes and the spark time. Spark pulses of 20, 40, 80 and 100 ms, were programmed, and distance between acupuncture needles (electrodes) was varied between 4 and 10 mm. As plastic thickness changed, optimum parameters for spark pulse and electrode distance obtained.

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