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Microperforation to Control Gas Exchange

Microperforation to Control Gas Exchange. *Micropores make plastics films permeable to gases without affecting their impermeability to liquids. Such films are of interest for many purposes in packaging, in the non-wovens industry, and for technical applications. The micropores can be generated by electrostatic means, as described in the article.*

Perforation of papers, non-wovens, and special plastics films for use in a variety of applications has been practised for more than 15 years. In microperforation the hole diameters range from 2 to 70 µm, and in macroperforation from 50 to 500 µm. The holes can be distributed uniformly in area lines or defined zone performances (Fig. 1); their pore density can be up to 1.6 million pores/m^2, and in zoned performances up to 300 pores/cm^2.

If a material with simultaneous gas permeability and imperviousness to liquids is required, this can be achieved by perforation methods, since the surface tension of the liquid prevents droplets passing through the micropores. Such a material thus stops the passage of liquids while allowing gas exchange, and so prevents the condensation of water vapour.

Changes in the packaging industry are opening up new opportunities for microperforation: recyclable web materials can be microperforated very easily by electrostatical means. This opens up new applications for the product, which cannot (even prospectively) be made by other processes. Furthermore, other product opportunities are arising through the use of new materials like hydrophilic polysulphides, microporous polypropylene and biocoats.

Survey of perforation methods

Material webs can be microperforated by the hot-needle process, by liquid or gas jets, by high-frequency or ultrasound, by laser beams, and by electrostatical discharges.

Hot needle equipment is used to line perforate and area perforate films made from PP, PE-LD and PE-HD. The largest pore sizes are between 200 and 500 µm, the web speeds between 10 and 30 m/min, and the web widths up to 1500 mm.

The gas and liquid-jet techniques are complicated and are used only for cutting soft web materials. A cyclic or pulsed unit for area perforation is subject to rapid nozzle wear and is associated with high investment costs and large variations in pore size.

Ultrasonic processes for line perforation of PVC, PE, and PP films are also known, but these have not been generally accepted as production methods. In addition it is possible to perforate films 5 to 30 µm thick with high frequency. CO_2 laser-beam technology involves high investment and operating costs, and can be used in special applications, but only for small perforation lines up to 100 mm wide.

Electrostatical methods of microperforation can only be used with electrically insulated, discharge-puncturable web materials. Webs can be 50 to 2000 mm wide, with speeds up to 300 m/min; web material weights of ranges up to 5 to 160 g/m^2 are possible.

These materials include, among others, PET-coated papers, spun-bonded webs 100 to 200 µm thick, hydrophilic films 10 to 30 µm thick, 10 to 30 µm microporous polypropylene films, and 100 to 150 µm mineral-coated biocoats, as well as PE-LD, PET, BOPP and PTFE films up to 5 µm thick. Polyurethane coated materials, PSU, acrylates and films of special PVC mixtures up to 20 µm thick may also be processed.

The specific perforability, the size and quality of pores, and the perforation efficiency are dependent on dielectric strength, dielectric constant, material thickness, and the molecular structure, as well as on pigments, fillers, and surface quality. Therefore, the only way of determining the microperforability of materials is by advance trials.

Electrostatical microperforation lines

The essential components of a microperforation system, shown in Fig. 2, are the following:

- film unwind unit,
- perforation station,
- electrodes with holders,
- electrode cooling system,
- perforation controller with power electronics and main supply,
- high-voltage pulse transformers.

In addition, there is an in-line optical unit immediately at the end of the web, for porosity measurement.

The rewind and unwind stands of the machine and the web edge guidance system are designed to provide sensitive dynamic mechanical guidance of fine papers and thin films.

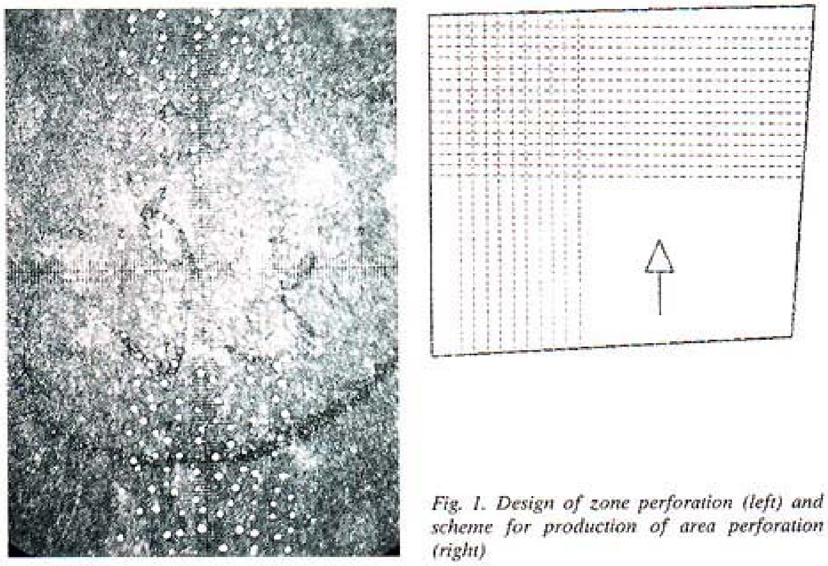

Fig. 1. Design of zone perforation (left) and scheme for production of area perforation (right)

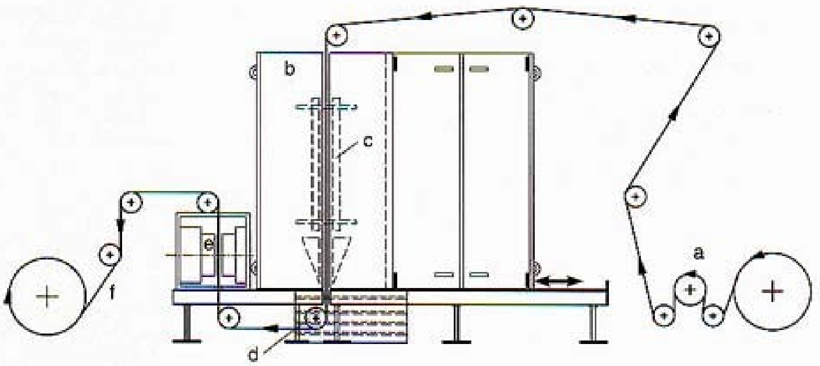

Fig. 2. Schematic diagram of an electrostatical microperforation system
a: film rewind and guide rolls, b: perforation unit, c: electrode carrier, d: deflecting shaft, e: optical porosity measuring device, f: film unwind

The significant part of the perforation system consists of many groups of opposed pairs of air-cooled unit electrodes (Fig. 3), carried by purpose-designed mountings. The film web passes through the gap of electrodes.

To allow the electrodes to be positioned, and for introducing the film web and facilitating cleaning and adjustment, the electrodes can be inserted from one side. Manual setting of the electrode pairs can be carried out with the use of leading bars and clamps passing through the unit, to obtain the desired pore rasters, and zone widths and their positions on the web width.

A solenoid generator system produces sequences of high-voltage pulses at frequencies between 500 and 10000 Hz; these are fed to the pairs of electrodes in predetermined sequences. For optimum perforation the breakdown strength of the web material should be smaller by a factor of about 1.5 than the high voltage applied between the electrodes.

Accurate positioning of breakdown sites is not possible because of the physical conditions between the electrodes and inhomogeneities in the material. In production it is possible to maintain zone boundaries to 0.15 mm and pore separation to 1 mm.

The spark produced during the discharge process creates a temperature high enough to vaporize the film material. Part of this material is precipitated on the electrodes as a sediment or an edge, with the result that the distance between them is gradually reduced. A special electrical controller compensates for this effect and reduces the sediment without burning and detrimental effects on production. A special electrode design and air cooling of the material passing between them ensures that thermal loading on the film web is small.

Complete metal covering of the perforation section by metal screening plus an protection system, ensures that requirements for EMI to the limits, noise reduction, and dust removal are met. The increase in electrode gap brought about by self-combustion is corrected at 12-hour intervals by a pneumatic adjusting device.

Electrodes are cooled by conventional side channel compressors circulating air at 400 to 1600 m^3/h, depending on the number and design of the electrode pairs.

The 19" racks next to the control panel contain all the components required for power supply and control, including the interface with computers located above (Fig. 4). The unit meets the requirements for EMI compatibility. These provisions ensure long-term disturbance-free operation.

The size, density and quality of pores are influenced by:

- the web speed,
- the number of groups of electrode pins,
- the repeat frequency, usually synchronized with the web speed,
- discharge energy,
- the diameter and shape of electrode-pins,
- cooling conditions,
- the web-guidance conditions within the discharge section.

The various perforation patterns, whether area, linear, or zonal, are achieved by suitable electrode arrangements. These determine the distribution and density of the pores over the width of the web. The pairs of electrodes arranged above and below the web can be mechanically interlaced to obtain the desired lateral pore separations and zone positions and widths. To increase pore density, pairs of electrodes can be arranged in cascade along the length of the web. If the electrode pairs are interlaced or the web displaced laterally, thus providing symmetrical arrangements of pores with given separations in lateral and lengthwise directions, area perforation results.

Measuring porosity on-line

The requirements of the line operator for targeted placement of porosity in predetermined zones or areas can be met with the help of a direct-positioning dimension mesh. And it is possible to measure the porosity attained by using a specially developed measuring procedure called ASPM, and a traversing device. This also enables the operator to hold the required porosity to tight limits under conditions of high web speed, different web widths, and different kinds of material. With the support of the computer it is then possible to process the measured values further and analyse them statistically.

With the new system of in-line measurement the operator can, in addition, meet requirements for quality improvements at lower variation coefficients in production. It even permits product certification with regard to Quality Assurance according to DIN/ISO 9000 ff, since it records porosity along the web and transverse to it. It is possible, furthermore, to set up a central data gathering system or a decentralized one. The ranges of porosity currently attainable and the relevant production parameters are listed in Table 1.

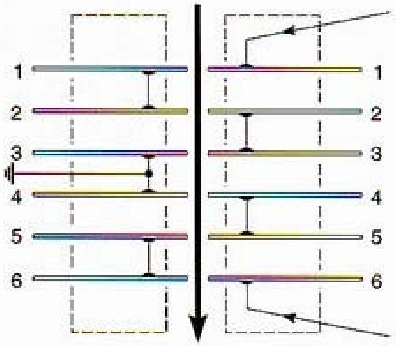

Fig. 3. Arrangement of opposed electrode pairs

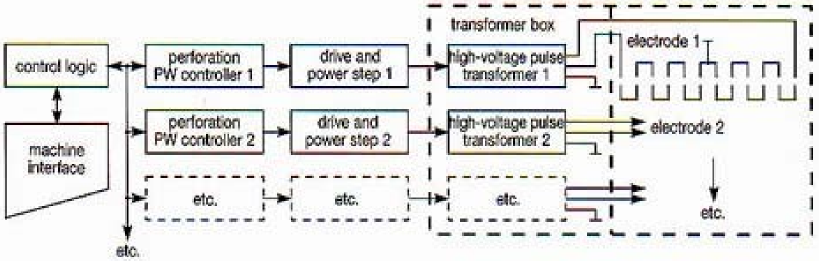

Fig. 4. Block diagram of electrical systems

Table 1. Summary of perforation production parameters and achievable densities

Parameter		Zone perforation	Area perforation
Porosity range	Coresta	60 to 800	20 to 300
Machine speed	m/min	30 to 300	30 to 300
Web width	mm	500 to 2000	500 to 2000
Pulse frequency	Hz	100 to 10000	100 to 10000
Pairs of electrodes		2	10 to 80
Zone width/pore raster	mm	2 to 10	1 to 20
Zones per pore raster	mm	11 to 40	1 to 20
Hole size	µm	10 to 80	2 to 150
Hole density (for z = 4)		25 to 200	1,6 mio/m^2
Variation coefficient (without control)	%	≤ 6	≤ 6
Variation coefficient (with control)	%	≤ 3.5	≤ 3.5

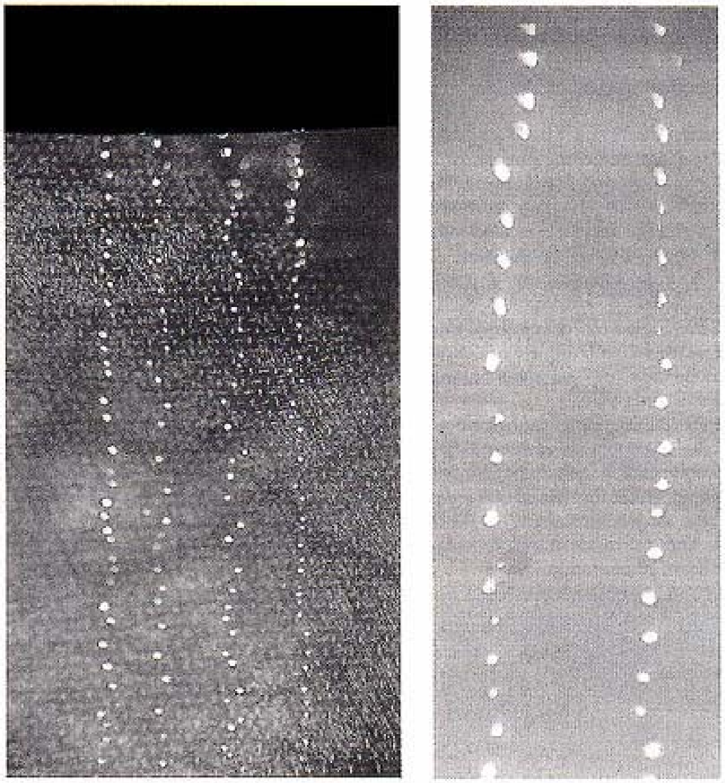

Fig. 5. Examples of different types of perforation in plastics films

The use of a digital controller and of modular power electronics, allows the ratio of discharge frequency to web speed to be accurately maintained. This ensures a high level of operating stability in relation to porosity (mean value and VC) and zone widths and zone rasters.

One important quality criterion is that the microperforations and pores on a film should not be visible. This can be achieved by overlapping the electrode interlacing, by web displacement, and by optimizing energy conditions in the spark discharge section.

Similar points have to be taken into consideration in order to achieve burr- and residue-free pore formation, so as to ensure that the pores have no detrimental effect on film conversion processes and that unwind pressure does not alter porosity.

Typical products

Electrostatical wide-web perforations offer hitherto unavailable product manufacturing facilities. The availability of on-line control of discharge energy allows requirements for particular types and arrangements of pores on specific materials to be met. With this type of area line and zone technology it is possible to produce microperforated special plastics films for a wide variety of applications (Fig. 5). Examples of these are films for the food and non-food fields, thin covering films for wares that cannot tolerate local condensation, films for filtration processes – for example for oxygen enrichment of biologically dead waters, films for rainwear and for waterproof finishing of clothing and one-piece throw-away overalls.

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