PATENT SPECIFICATION

(11) 1 561 767

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(21) Application No. 37626/76 (22) Filed 10 Sept. 1976

(31) Convention Application No. 2 540 681 (32) Filed 12 Sept. 1975 in

(33) Fed. Rep. of Germany (DE)

(44) Complete Specification published 5 March 1980

(51) INT. CL.[3] H01T 19/00

(52) Index at acceptance

H1X 5G

(19)

(54) CORONA DISCHARGE APPARATUS

(71) We, HOECHST AKTIENGESELLSCHAFT, a Body Corporate organised according to the laws of the Federal Republic of Germany, of 6230 Frankfurt/Main 80, Federal Republic of Germany,

do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to corona discharge apparatus suitable for the application of film webs to moving support surfaces, especially to rolls and/or for the surface treatment of film webs, for example to improve their wettability.

It is known from practical experience, especially in the plastics film-processing and paper-processing fields, that the application of moving webs of material onto a moving support surface, for example of a rotating drum or roller, presents difficulties. The main problem is that pockets of air tend to get trapped between the moving support surface and the web of material. The extent to which this occurs depends on the machine speed, the size of the moving support surface, the width of the web of material and the tension in the web. Particularly at the high machine speeds which nowadays are sought, the amount of air trapped can assume such a magnitude that firm, smooth contact of the web with the support surface cannot be ensured. Non-uniform adhesion of the material web results in phenomena, for example creasing and skew running of the web, which may interfere with subsequent processing of the web. These phenomena can, of course, have a particularly disadvantageous effect in machine installations in which the moving support surfaces are intended to supply or remove heat to or from the web, as is the case in, for example, drying devices of coating apparatus. The air trapped between the moving support surface and the web prevents uniform heat transfer, which otherwise is of course an advantageous characteristic of contact systems, so that local overheating can occur in the suspended zones of the web. This can in turn result in irregular shrinkage and drying phenomena on the coated materials. In most cases, the difficulties mentioned can be circumvented by adapting the heat transfer conditions, but this is necessarily almost always associated with a reduction in the machine performance, such as, for example, the drying capacity or rate of production.

It has, therefore, always been endeavoured in industrial practice to be able to utilise the advantages of passing webs over and in close uniform contact with moving support surfaces, even at high machine speeds.

The universally used applicator techniques employable with uncoated web materials, such as, for example, pressure rolls, air jets and the like, are usually unsuitable for use with coated webs since they frequently affect the coating to an undesirable degree.

Methods of preventing or reducing the undesirable air intake, or the provision of means for air already taken in to flow away by specially adapting the surface of the moving surface, have been proposed for the case of coated webs. Such means include, for example, coverings of porous materials, for example paper, textiles or metal fabrics, as well as the provision of grooves, fluting, knurling, embossed patterns and the like in the surface which in most cases is metallic.

In the case of coverings of porous materials the heat transfer between the support surface and the web is reduced and in the case of grooves etc., the web tends to become embossed which can render the web unusable.

A further proposal to reduce the air inclusion between the moving support surface and the web is to provide vacuum chambers, for example as described in French Patent Specification 1 296 772. Apart from the technical complexity of the provision of such chambers, they do not completely remove the air trapped.

The electrostatic applicator method should also be mentioned. Such methods described in, for example, German Offenlegungsschrift 1 504 661 and utilise direct current in the range from 15 to 30 KV. They can, however, only be carried out on uncoated materials which are electrically non-conductive or have only a very poor electrical conductivity, and require very low take-off speeds which, for example in the case of a coating machine, would not be commercially viable.

In addition, such processes are — as emerges from German Auslegeschrift 1778 228 — very sensitive to the environmental conditions prevailing in the vicinity of the apparatus, for example the temperature and, very particularly, the relative humidity. Fluctuations in these two parameters, which can never be prevented in a cating installation, result in changes in the breakdown voltage of the air dielectric present between the electrode and the counter-electrode, and this, when the permissible value is exceeded, inevitably can lead to spontaneous discharges in the form of local electrical breakdown. In most cases, this results in damage to the web.

It is known that, because of their chemical structure, some plastics materials, for example polyethylene and polypropylene, present difficulties during printing, coating, inscription or similar finishing processes because of poor wettability and/or inadequate surface adhesion.

To overcome this problem, great endeavours have been made which have resulted in the development of new treatments, for example mechanical or chemical roughening, treatment by means of gases, flames or electrical discharges, or combinations of two or more thereof. Of these methods, the pretreatment process by means of an electrical corona discharge has found greatest response in industry because of several advantages, for example the achievement of high working speeds, low technical effort required, cleanliness and non-pollution of the environment.

A comparison of two possible modes of treatment in this case, that is to say the simultaneous surface treatment of both sides and surface treatment on one side only, in respect of their utilisation, comes out, by a large margin, in favour of the latter variant of the process. The mode of operation of this technique comprises guiding the film to be treated over an electrically earthed support surface, for example a roller, a drum or an endless belt, and subjecting the surface of the film that faces away from the support surface to an electrical corona discharge which is generated by feeding an electrode, spaced from the support surface, with a high voltage, high frequency alternating current (see for example U.S. Patent Specification 2 802 085).

Essentially, the proposed processes and apparatuses which operate on this basic principle differ more or less only in the nature of the support surface which serves as a counter-electrode for example it may be a central roller with several electrodes, several support rollers with several electrodes or the like, in the dielectric materials used for the counter-electrode, for example they may be glass, ceramic, plastics films (for example of polyester) or special grades of rubber, in the constructional design of the electrode used, for example it may be a plate, wire, comb, knife, half-shell, spring or spindle electrode, and in the construction of the particular generator which may be of the low frequency, medium frequency or high frequency type. The most serious disadvantage of the conventional corona apparatus designed for one-sided material pre-treatment is the so-called "rear face effect". This undesirable side effect results from inadequate contact of the film to be treated with the counter-electrode roller, caused by air inclusion between the film and the roller surface. Particularly in the case of especially large machine widths, for example of five or more metres, this problem occurs to an even greater degree, since the factors which determine the air inclusion — assuming the decisive parameter, namely the machine speed, to be constant — such as, for example, the diameter and working width of the roll, are disadvantageous in the case of such machine widths.

Apart from the fact that a film pretreated on both sides presents difficulties during the subsequent process steps, for example, winding, making-up, metallising, printing and the like, the treatment of the rear face also results in a significant reduction in the surface voltage on the front face of the film.

A further disadvantage of the proposed corona discharge devices is the use of the generally very thin corona wires. On the one hand, endeavours are made to employ extremely thin wires, the diameters of which usually lie in the range of from 70 to 300 μ, since the high charge densities required for good contact between the web and the support can only be achieved with such thin wires. On the other hand, the mechanical strength of the wires is too low to be able to subject them to tensile stresses which ensure that they remain, along their lengths, at a uniform distance from the counter-electrode, i.e. in practice they tend to sag.

This results in a varying degree of charge exposure across the web which becomes noticeable in an adverse manner during subsequent treatments, for example coating or vapour-deposition operations.

So-called roller electrodes have been proposed for the surface treatment of thermoplastic materials (see for example U.S. Patent Specification 2 864 755 and Canadian Patent Specification 553 045). The roller electrodes are coated with a dielectric, whilst the roller used as the counter-electrode is uncoated, in contrast to the corona discharge devices described above. The considerable disadvantage of these corona apparatus is that, firstly, roller-shaped electrodes are difficult to manufacture, since they require particularly refined winding techniques for applying the dielectric, in order to produce a completely air-free winding, and furthermore difficulties arise in the making of the electrical connections. Further shortcomings are the low discharge density and the limitation of their use to narrow film webs, since in the case of broad film webs the roller electrodes would sag. Further, since the roller electrodes move over the film webs to be treated, they cannot be used for coated webs and can cause abrasion tracks on uncoated webs.

German Offenlegungsschrift 2 418 664 discloses an apparatus for the treatment of the surfaces of plastics films which employs an electrode which is surrounded by an insulator. This insulator consists of a hollow glass body which is filled with a conductive medium and in which the electrode wire is positioned.

The disadvantage of such an electrode is, firstly, that the glass body can easily be destroyed, in which case the conducting medium runs out and, secondly, the sealing problems which necessarily arise with such an electrode.

The present invention provides a corona discharge apparatus having a relatively simple electrode arrangement which can be used both for the application of an uncoated or, especially, a coated film web to a moving support surface and for the surface treatment of a plastics web, and which overcomes at least to a large extent the disadvantages and shortcomings of the hitherto proposed apparatus.

The present invention provides a corona discharge apparatus comprising: a first, movable electrode for receiving and supporting a web of material to be subjected to corona discharge, the web-supporting surface of the first electrode being electrically conductive, means to transport the web of material onto said surface and at least one second electrode comprising a plurality of wires, preferably in the form of a stranded wire, in the same dielectric sheath, wherein the second electrode faces said supporting surface, extends transversely to the direction of transport of the web onto said surface in use of the apparatus, is spaced from said surface at a substantially uniform distance therefrom and is located at or ahead of the region where, in use of the apparatus, the web comes into contact with the surface, the arrangement being such that at least that part of the second electrode that is in juxtaposition to the first electrode is completely enclosed within the sheath. The first electrode advantageously comprises a solid or hollow right-circular cylinder rotatable about its axis.

In developing the apparatus according to the invention, an attempt has been made to meet the requirements for an optimum apparatus. The or each second electrode comprises stranded wires of metallic materials of good electrical conductivity, for example copper, brass or nickel-iron alloys, but preferably steel.

The diameter of the plurality of wires is preferably between 0.5 and 5 mm, depending on the nature of the metal used and is preferably from 1 to 2 mm in the case of steel.

The wires are closely surrounded by a dielectric which may comprise, for example, an epoxide resin, a polyester, polytetrafluoroethylene or a crosslinked polymer, but preferably a silicone rubber, such as is employed, for example, for high voltage cables in the electrical industry. The dielectric is preferably applied to the wires by an extrusion coating process, whereby optimum contact with the wire core is achieved so that, a priori, points at which internal corona discharges can develop are reduced to a minimum. The thickness of the dielectric coating is preferably between 0.5 and 1.0 mm and is advantageously from 0.6 to 0.8 mm. The extrusion coating process is also advantageous in respect of the maintainance of the thickness tolerances, which in some cases are narrow.

Since the corona discharge process can, after only a short time, lead to a pronounced rise in the temperature of the electrode(s) and hence, at the same time, to an increase in length of the wire electrode(s), a tensioning device for the or each wire electrode with a length compensator, for example in the form of springs, adjustment cylinders or the like, is preferably provided. In this way, sag and resulting changes in the spacing of the wire electrode(s) from the first electrode can be prevented.

The or each wire electrode is connected to an alternating current generator which provides a high frequency alternating current preferably of 0.2 to 2.0 A at a voltage of 10 to 100 KV, preferably 10 to 30 KV, and a frequency of 3 to 100 KHz, preferably 10 to 20 KHz.

The or each wire electrode of the apparatus according to the invention, if appropriately constructed, for example in the form of wound coils, permits variable adaptation to the working width of the material webs to be treated.

It is known that the corona treatment of a preheated film leads to improved results because of the generation of higher surface voltages. This process can of course be carried out substantially more advantageously with the apparatus according to the invention, which preferably utilises a metallic, non-insulated counter-electrode in the form of a roller which may be provided with heating means, than with the conventional systems in which the roller is insulated with a dielectric layer and therefore permits relatively little heat transfer.

A further unexpected effect makes the apparatus according to the invention exceptionally valuable for use in coating machines or printing machines. Whilst with the conventional corona discharge devices moisture entrained into the pre-treatment station leads, for example if the web should break, to immediate arcing and hence to perforation of the dielectric, the apparatus according to the invention reacts in no such way. Even liquid puddles produced deliberately on the film to be treated led to no perforation of the dielectric or breakdown of the discharge.

A further advantage of the apparatus according to the invention may be seen, above all, in its universal applicability for the pre-treatment of both plastics films and metal foils. This can very particularly come fully into play in the case of laminating and extrusion coating installations, in which a very great variety of materials are processed to form laminates. By using only one pre-treatment system for all materials which may be employed, the investment costs can of course be lowered.

The universal applicability and technical advantages of apparatus according to the invention are once again summarised briefly below.

a. As a result of the air-free application of the web to the first electrode, treatment of the rear face of the film is prevented, as are the difficulties associated therewith. Additional equipment, such as vacuum applicator boxes or separate direct current corona apparatus are not needed.

b. High surface voltages may be achieved by the use of electrode wires of small dimensions, which almost achieve the effect of point discharges.

c. Using the corona system according to the invention, plastics films and metal foils can be treated. This results in a reduction in the investment costs for laminating installations and extrusion coating installations, in which both types of materials are frequently processed. It becomes possible to keep a single stock of spare parts in the form of electrode wires.

d. A reduction in the operating costs of the corona device results from the following—

Cheap electrode wires can be employed instead of expensive counter-electrode rollers.

First electrodes, which may be in the form of metallic rollers, no longer have to be kept as spare parts, since such electrodes will last indefinitely.

The repair times are reduced, since defective electrode wires can be replaced very rapidly.

e. There is no limitation on the working widths, since the electrode wires can, using an appropriate tensioning device, be tensioned over virtually any desired machine width.

f. The working width of the electrode wires can be varied, by an appropriate wind-up device, and matched to the film width to be treated.

g. By appropriate construction of the parts of the apparatus other than the first electrode, the said parts can be made transportable, so that they can be mounted on practically any metallic roller in a machine installation.

h. The electrode wires are insensitive to moisture and therefore very well suited to coating machines and printing machines.

An apparatus according to the invention will now be described in more detail by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows in cross-section, a stranded wire electrode of an apparatus of the invention, and

Figure 2 is a schematic side elevation of an apparatus of the invention in use.

Referring to Figure 1, the stranded wire electrode comprises stranded wire L insulated with a layer of dielectric D.

Referring to Figure 2, a film web 7 to be treated is drawn off a storage roll (not shown), and is passed, *via* a guide roll 6 to the corona apparatus comprising groups of stranded wire electrodes 2 and 3 and a counter electrode 1 in the form of a rotatable roller. A guide roll 6′ serves to lead the film web 7 away.

The electrodes 2 and 3 are connected, *via* a high tension cable 8, to a transformer 4 whch is fed by a generator (not shown).

The counter-electrode is connected to earth potential by cable 5.

A group of electrodes 3 is provided at the point of contact of the film web 7 with the counter-electrode 1. The electrodes 3 of this group are spaced closer together (e.g. 1 to 3 mm) than the subsequent group of electrodes 2 (which are spaced apart by, e.g. 5 to 15 mm and preferably 3 to 10 mm). In this way, mutual influence, and impairment of the point discharges which are a decisive factor in good surface treatment, are avoided. In addition, the danger, which can never be excluded if the electrodes are closely spaced, that a breakdown at one electrode only can additionally result in damage to the adjacent electrodes, is reduced to a minimum. It is furthermore advisable to fit a safety circuit which, in the event of a breakdown, immediately cuts off the current supply.

The distance of the electrode from the counter-electrode is in principle not critical but in practice it has proved advantageous for this distance to be from 1 to 10 mm, preferably from 2 to 3 mm.

WHAT WE CLAIM IS:

1. Corona discharge apparatus comprising: a first, movable electrode for receiving and supporting a web of material to be subjected to corona discharge, the web supporting surface of the first electrode being electrically conductive, means to transport the web of material onto said surface, and at least one second electrode comprising a plurality of wires in the same dielectric sheath, wherein the second electrode faces said supporting surface, extends transversely to the direction of transport of the web onto said surface in use of the apparatus, is spaced from said surface at a substantially uniform distance therefrom and is located at or ahead of the region where, in use of the apparatus, the web comes into contact with the surface, the arrangement being such that at least that part of the second electrode that is in juxtaposition to the first electrode is completely enclosed within the sheath.

2. Apparatus as claimed in claim 1, wherein the first electrode comprises a solid or hollow right-circular cylinder rotatable about its axis.

3. Apparatus as claimed in claim 1 or claim 2, wherein there is a plurality of second electrodes arranged parallel to one another in spaced relationship, each electrode being spaced at substantially the same, substantially uniform distance from the first electrode.

4. Apparatus as claimed in claim 3, wherein the spacing between adjacent second electrodes positioned at or near the region where the web, in use of the apparatus, comes into contact with the first electrode is less than the spacing between other adjacent second electrodes.

5. Apparatus as claimed in claim 4, wherein the spacing between adjacent second electrodes positioned at or near the region where the web, in use of the apparatus, comes into contact with the first electrode is from 1 to 3 mm.

6. Apparatus as claimed in claim 4 or claim 5, wherein the spacing between said other adjacent second electrodes is from 5 to 15 mm.

7. Apparatus as claimed in claim 4 or claim 5, wherein the spacing between said other adjacent second electrodes is from 3 to 10 mm.

8. Apparatus as claimed in any one of claims 1 to 7, wherein the diameter of the plurality of wires is from 0.5 to 5 mm.

9. Apparatus as claimed in claim 8, wherein the diameter of the plurality of wires is from 1 to 2 mm.

10. Apparatus as claimed in any one of claims 1 to 9, wherein the thickness of the dielectric is from 0.5 to 1 mm.

11. Apparatus as claimed in any one of claims 1 to 10, wherein the dielectric has been extruded onto the wires.

12. Apparatus as claimed in any one of claims 1 to 11, wherein the dielectric comprises an epoxide resin, a polyester, polytetrafluoroethylene or a cross-linked polymer.

13. Apparatus as claimed in any one of claims 1 to 11, wherein the dielectric comprises a silicone rubber.

14. Apparatus as claimed in any one of claims 1 to 13, wherein the or each second electrode is spaced at a distance of from 1 to 10 mm from the first electrode.

15. Apparatus as claimed in claim 14, wherein the or each second electrode is spaced at a distance of from 2 to 3 mm from the first electrode.

16. Apparatus as claimed in any one of claims 1 to 15, wherein the or each second electrode is provided with a tensioning device.

17. Apparatus as claimed in any one of claims 1 to 16, wherein the stranded wires comprise steel.

18. Apparatus as claimed in any one of claims 1 to 17, comprising means to feed to the or each second electrode alternating current of from 0.2 to 2.0 A at a potential of from 10 to 100 kV and a frequency of from 3 to 100 KHz.

19. Apparatus as claimed in claim 18, comprising means to feed the or each second electrode with an alternating current of 0.2 to 2.0 A at a potential of from 10 to 30 kV and a frequency of 10 to 20 KHz.

20. Apparatus as claimed in any one of claims 1 to 19, wherein the plurality of wires is in the form of a stranded wire.

21. Apparatus as claimed in claim 1, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

22. A method of subjecting a web of material to a corona discharge wherein there is used an apparatus as claimed in any one of claims 1 to 21.

23. A web of material which has been treated by the method of claim 22.

24. A plastics or metal film or sheet which has been treated by the method of claim 22.

ABEL & IMRAY
Chartered Patent Agents,
Northumberland House,
303-306 High Holborn,
London, WC1V 7LH.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1980. Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

FIG.1

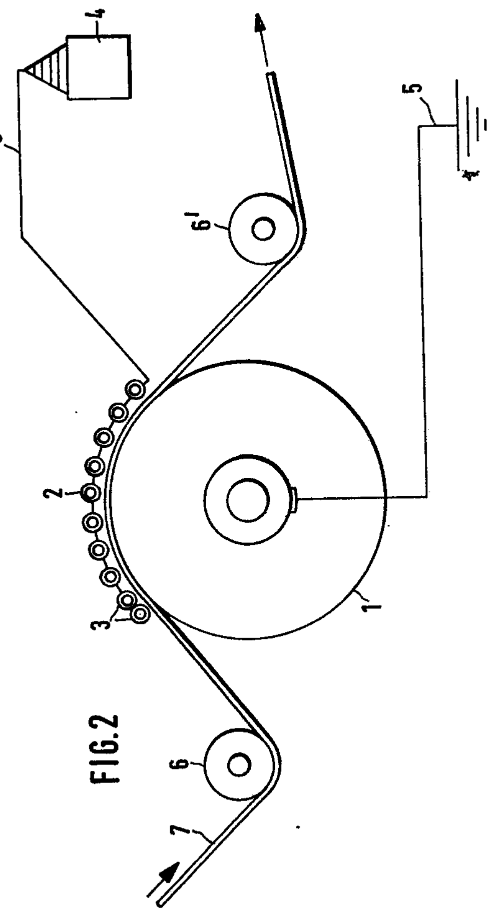

FIG.2