
EUROPEAN QUALIFYING EXAMINATION 2002

PAPER B ELECTRICITY / MECHANICS

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APPLICATION

Description

Simple and robust pressure sensors in which two electrodes are kept apart by a compressible medium such as a spring or a block of foam are known. On compression
5 of the medium, when a specific pressure has been reached or exceeded, the electrodes make contact, which is detected by an electrical circuit. Such a sensor, by itself, cannot be used to measure a plurality of pressures. State of the art sensors for measuring a plurality of pressures or forces, such as those based on piezo-resistance or silicium membranes, are susceptible to damage. They thus require complicated protective
10 means, and are expensive to manufacture.

There is therefore a need for an improved pressure sensor capable of measuring a plurality of pressures. The present invention, according to the independent claims, results in a cheap, simple and robust solution to this problem.
15

Fig. 1 shows the sensor of the invention in its most simple form, with two electrodes.

Fig. 2 shows an embodiment of the invention, using an array of electrodes.

20 Fig. 3 shows one arrangement for producing conductive polymeric foam according to the invention.

Fig. 4 shows a cross-section through a layer of foam according to the invention.

25 In its most simple form as shown in Fig. 1, the sensor of the invention comprises an electrically non-conducting substrate 2 on which are provided, at a distance from each other, two electrodes 1. The substrate may be rigid or flexible. Above and in contact with the electrodes is a layer of polymeric foam 6. The foam contains graphite particles which, upon compression of the foam, are brought into contact with each other, and

thus form an electrically conducting path through the foam. As the foam is subjected to increasing pressure, it is further compressed and more graphite particles contact each other. The electrical resistance of the foam is thus reduced. The electrical signal measured across the electrodes may be fed to a processor or computer and converted by means of a suitable algorithm into a signal for giving a corresponding pressure reading.

The electrodes may be discrete elements, or may be etched on a printed circuit board. In the latter case, the printed circuit board also fulfils the function of the substrate. Fig. 2 shows a sensor arrangement using a plurality of circular electrodes 1' provided on substrate 2' and in contact with foam layer 6'. The electrodes may be placed anywhere on the various surfaces of the foam, eg on a two dimensional surface or a three dimensional object, which allows precise measurement of the pressures in different areas of the foam.

The sensor can be used as an electrical switch. With a suitable mass provided on the foam layer, it can be used as a vibration detector. It could also be used as part of a robot hand.

The foam may be made from any suitable polymer such as polyurethane, and is produced as a continuous web. Fig. 3 shows an apparatus capable of producing the foam of the invention, in which the details of the right side of the drawing are shown in magnified view. Polymeric material is firstly extruded through an extruder 30 and then shaped by a die 31. Shortly after the material 5 leaves the die 31, it enters expansion and curing chamber 32, where it transforms into foam. At this stage the foam thus obtained is supported by conveyor belt 34. Inside chamber 32 heaters 35 circulate hot air to accelerate the foaming and curing process. Graphite particles are applied to the curing foam by spraying through spray heads 36 onto its upper surface.

The particles sink under gravity into the foam, until they are trapped in a certain position as the foam is sufficiently cured. The penetration depth of the graphite particles into the foam is regulated principally by control of the curing temperature inside the chamber 32. As the fully expanded web of foam 6" exits the chamber 32 it undergoes a final shaping step by rollers 33 for ensuring accurate dimensions. The apparatus of Fig. 3 is well known, apart from the presence of the plurality of spray heads 36. A spray head may be any device suitably adapted for the even distribution of particles across the width of the foam. Such spray heads are commercially available and normally take the form of slits or nozzles. The apparatus also comprises a computerised control system, enabling the automatic regulation of all process parameters.

Fig. 4 shows a cross-section through a layer of foam 6" thus produced. The cross-section shows visible bands 61, 62, 63 and 64 of graphite particles, each band being laid down by a different spray head. In each band, the concentration of graphite particles is slightly more dense towards the centre of the band (i.e. it appears darker), and slightly less dense at the edges of the band (i.e. it appears lighter). This is a result of the movement of the particles during the foaming process. The particles at the edges of adjacent bands are intermingled. The particle distribution within each band, and the thickness of the band itself, may be very finely regulated by careful control of process parameters such as the curing-rate of the foam, the speed of the foam passing through the apparatus, the weight and size of the particles, and the spraying velocity and density. These process parameters are regulated so that each band has a substantially identical thickness and a substantially identical particle distribution.

The electrical resistance characteristics of the foam layer are a function of the particle size and particle distribution within the bands, the thickness of the bands, and the total number of bands in the foam layer. These can be regulated by adjustment of appropriate process parameters and by the number, position and design of the spray heads so as to produce a foam layer having an even, predetermined electrical change in resistance per unit change of pressure. It has been found that particle distribution in a band is difficult to regulate if the band is too thick. It is therefore desirable that the

thickness of each band is limited, in order to ensure a predictable particle distribution. For instance, for a layer of polyurethane foam having a thickness of 15 mm, 12 bands or more are necessary to ensure predictable particle distribution. The process of the invention allows greater reproducibility of identical foam layers, and hence identical sensors. Using such sensors, highly accurate measurements may be achieved, whilst at the same time guaranteeing consistent and reproducible performance.

To produce the sensor, firstly the substrate is provided with electrodes. This may be by etching electrodes on a printed circuit board. Alternatively, electrodes may be attached at specific intervals to a suitable substrate by means of e.g. adhesive. The substrate with electrodes is then joined to the foam layer by any suitable means (such as application of adhesive near the edges of the substrate), such that electrical contact between the electrodes and foam is not impeded.

Claims

1. Polymeric foam (6, 6', 6'') comprising graphite particles.
- 5 2. A sensor for the measurement of pressure comprising:

an electrically non-conducting substrate (2, 2'), and

a plurality of electrodes (1, 1') provided at a distance from each other on a first side
10 of the substrate, and

a layer of foam (6, 6', 6'') according to claim 1 provided on the first side of the
substrate and in electrical contact with the electrodes.
- 15 3. The sensor of claim 2, comprising more than two electrodes (1, 1') provided on the
substrate (2, 2').
4. A device for measuring pressure comprising the sensor of claim 2 or 3 and a
processor or electrical circuit capable of converting the electrical resistance
20 between the electrodes into a signal for giving a corresponding pressure reading.
5. A switch comprising a sensor according to claim 2 or 3.
6. A method for making polymeric foam comprising graphite particles, whereby the
25 foam is produced continuously, and the graphite particles are sprayed onto the
foam before the foam has fully cured.

DRAWINGS OF THE APPLICATION

1/2

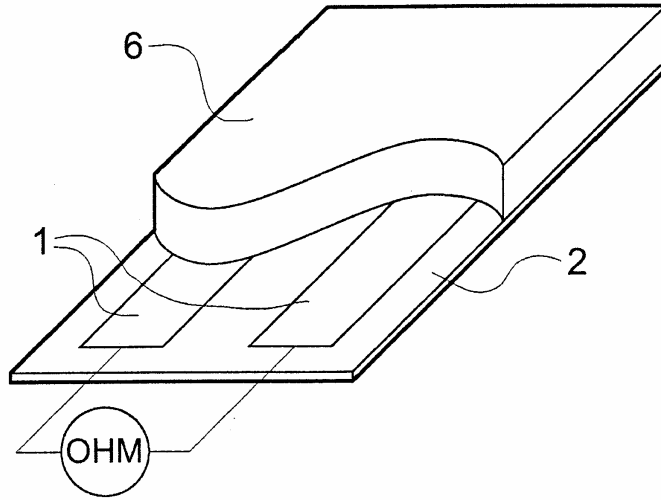


Fig. 1

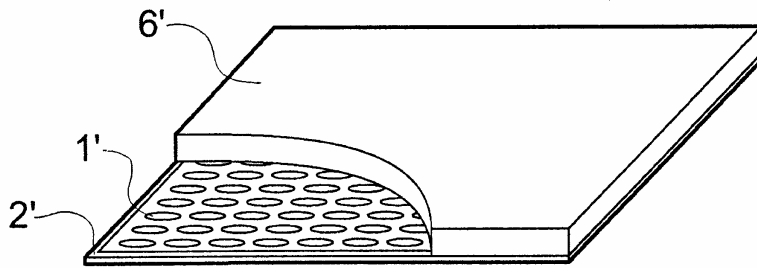


Fig. 2

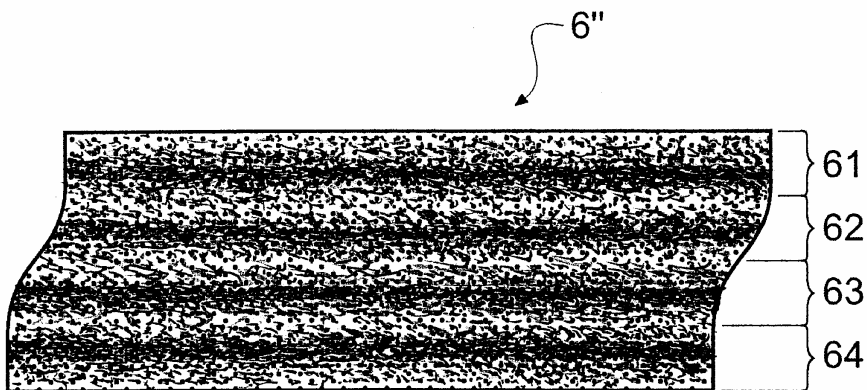


Fig. 4

DRAWINGS OF THE APPLICATION

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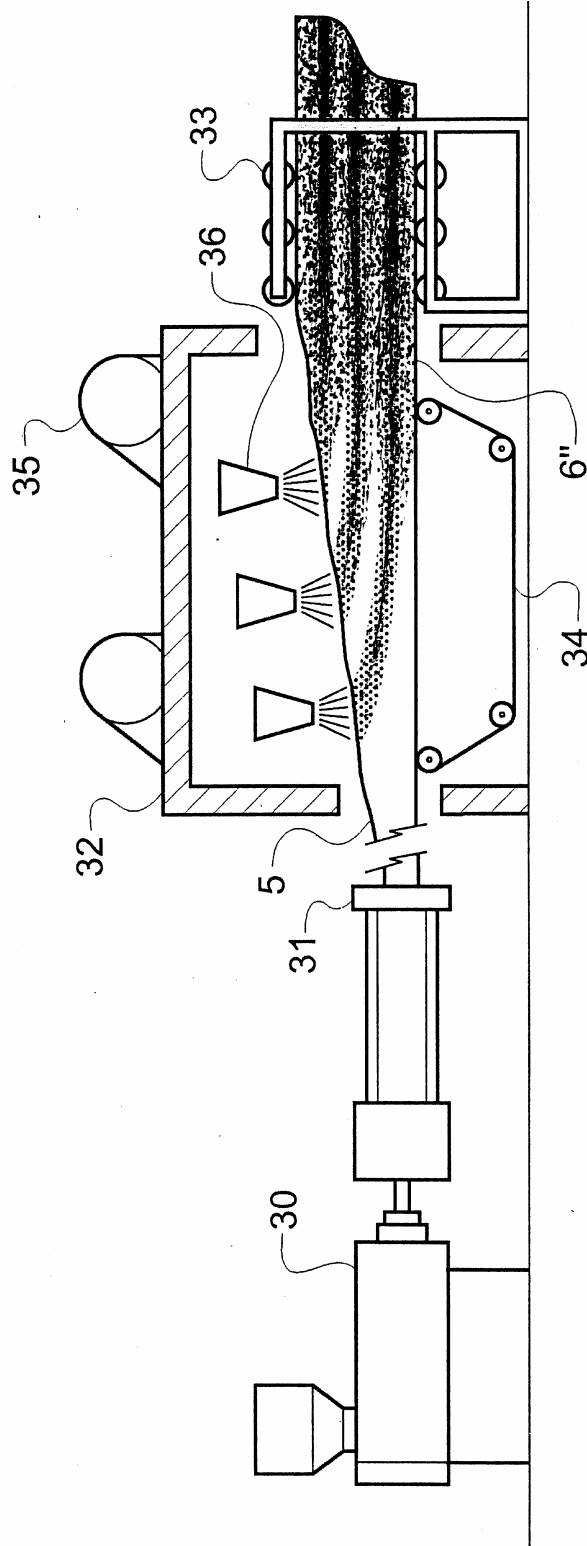


Fig. 3

Communication under Article 96(2) and Rule 51(2) EPC

The examination is being carried out on the application documents as originally filed.

1. The following pre-published documents are mentioned in the communication:

Document D1 and Document D2

2. The present application does not meet the requirements of Articles 52(1) and 54(1)(2) EPC, because the subject-matter of claims 1 - 6 is not new.
3. A polymeric foam comprising graphite particles is known from both D1 (reference 5 of Fig. 1) and D2 (reference 1 of Fig. 1). The subject-matter of claim 1 therefore lacks novelty with respect to these documents.
4. D1 furthermore teaches a sensor for the measurement of pressure comprising an electrically non-conducting substrate 3, and more than two electrodes 4 provided at a distance from each other on a first side of the substrate, and a polymeric foam layer 5 comprising graphite particles provided on the first side of the substrate and in electrical contact with the electrodes. Moreover it discloses a cavity 7 with an electrical circuit capable of converting the electrical resistance between the electrodes 4 into a signal for the activation of the warning lamp 8, this signal being also suitable for giving a corresponding pressure reading. The sensor arrangement of D1, Fig. 1 is also a switch, which activates a light.

The subject-matter of claims 2 - 5 therefore also lacks novelty with respect to D1.

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5. D2 teaches a method for making polymeric foam comprising graphite particles, whereby the foam is produced by spraying it on the surface of a roller. The roller is rotated and the uncured foam is further sprayed with graphite particles from a stationary nozzle before the foam has fully cured. D2 states that this outer layer of foam may, alternatively, be produced separately as a continuous polymeric foam web which is later cut to length and fixed around the roller. Clearly, producing this web in a continuous process leads to the subject-matter of claim 6, which is therefore not new.
 6. It is not at present apparent which part of the application could serve as a basis for a new, allowable claim. Should the applicant nevertheless regard some particular matter as patentable, an independent claim including such matter should be filed. The applicant should indicate and justify in the letter of reply, on the one hand, the difference of the subject-matter of the new claim vis-à-vis the state of the art and, on the other hand, the inventive significance thereof.
 7. Should the applicant submit an amended set of claims with a plurality of independent claims, convincing arguments justifying the unity of invention are expected.

DOCUMENT D1 (State of the Art)

Milking cups for milking machines comprise a rubber sleeve that surrounds and squeezes the teat to produce milk flow. It is vital that this sleeve exerts the correct pressure, as excessive pressure can lead to inefficient milking and even infection of the teat. This invention provides a test apparatus that can be inserted into the milking cup
5 in place of a teat, in order to verify that the rubber sleeve is not exerting excessive pressure and therefore not defective.

Fig. 1 shows a cross-section through the test apparatus.

10 Fig. 2 shows a perspective view of the test apparatus.

The apparatus comprises a probe 1 and a head portion 2. The probe 1 has a solid central core 3 on which are provided a series of gold-plated electrical contacts 4. Around and in contact with these contacts is a sleeve of electrically conductive foam 5.
15 The foam is protected by an elastomeric outer layer 6. The head portion 2 contains a cavity 7 with an electrical circuit (not shown) and an aperture for a warning lamp 8 comprising a red lens 9. As the conductive foam is compressed by the rubber sleeve of the milking cup, the electrical resistance of the foam decreases. This resistance is detected by a resistance measuring circuit connected to the contacts. Once the
20 resistance drops below a preset level, this is detected by the circuit which illuminates the warning lamp, indicating that the milking cup is defective.

To produce the probe, an electrically non-conducting solid core 3 is injection moulded from polypropylene. A series of gold-plated metallic strips 4 are glued along the core to
25 provide the electrical contacts. Wires (not shown) are connected to each contact for connection to the measuring circuitry. The core and contacts are placed into a mould and a polymeric resin pre-mixed with graphite particles is then introduced into the mould. The resin expands and cures to form electrically conductive foam layer 5, and

the thus formed probe is then extracted from the mould. A thin elastomeric tube is placed over the foam to protect it. The probe and connecting wires are connected to the head portion, which carries the resistance measuring circuit and warning lamp. The simple and robust apparatus is subsequently calibrated and sold as a sealed i.e. tamper-proof unit.

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DRAWINGS OF DOCUMENT D1

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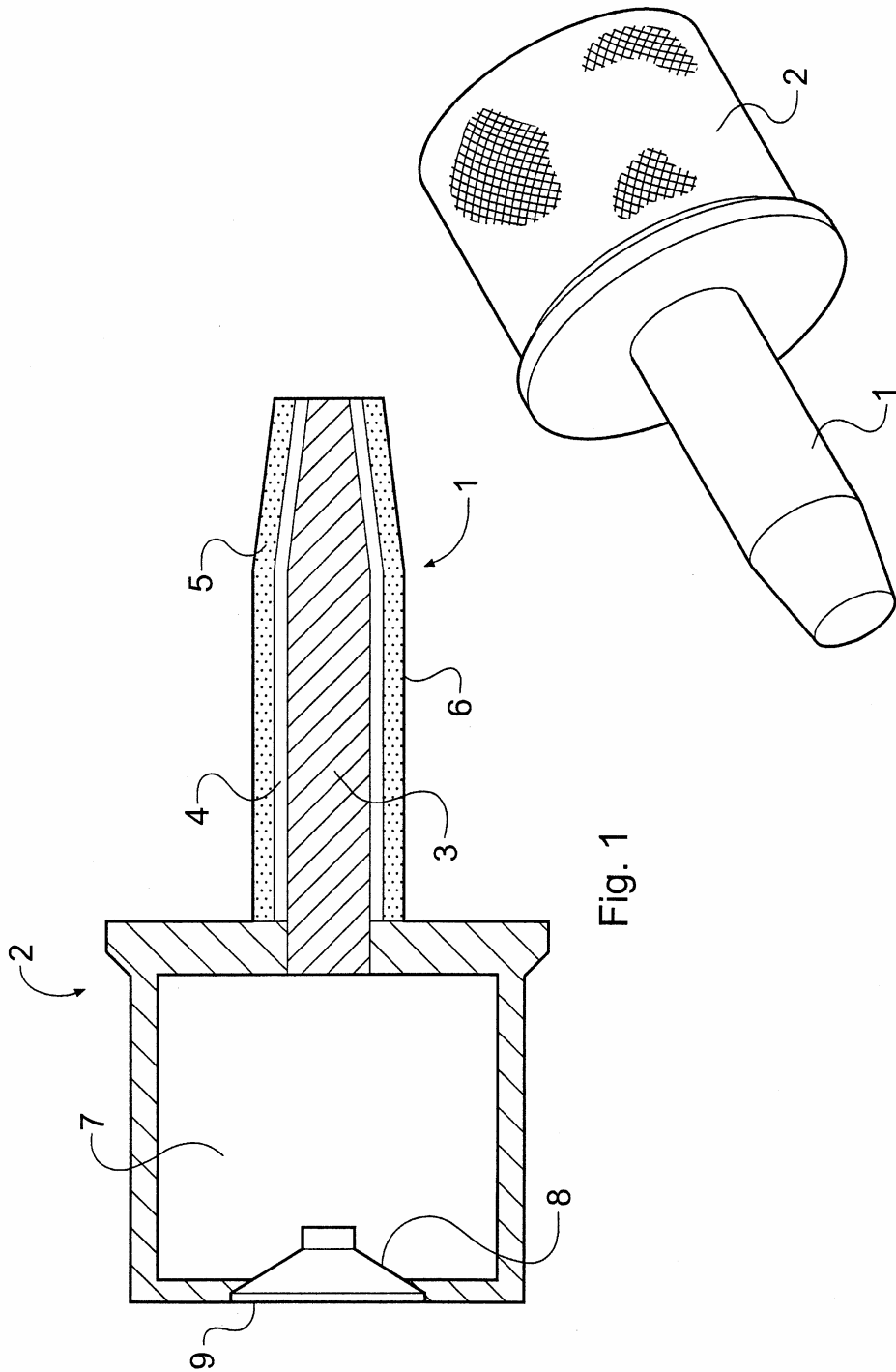


Fig. 2

Fig. 1

DOCUMENT D2 (State of the Art)

Conveyor belt systems are prone to generate static electricity, the discharge of which poses a potential fire risk. In the prior art this problem is overcome by supporting the conveyor belt on rollers which have an electrically conducting surface. When the roller is installed, this surface is electrically earthed via contact brushes. The build up of a static charge is thereby avoided.

Prior art rollers are manufactured by attaching a layer of electrically conductive foam to the periphery of the roller. This conductive layer is made in a continuous process from foam which has been pre-mixed with graphite particles. However, poor mixing leads to particle agglomeration and voids, and a generally non-homogenous particle distribution. This results in unpredictable effects and an irregular conductivity of the coating, with potentially serious consequences for the earthing of the conveyor belt.

Fig. 1 shows a cross-section of the roller of the invention.

Fig. 2 shows a perspective view of the roller of the invention.

Fig. 3a shows an open mould and the central axle.

Fig. 3b shows the second foam layer being sprayed on the insulating layer.

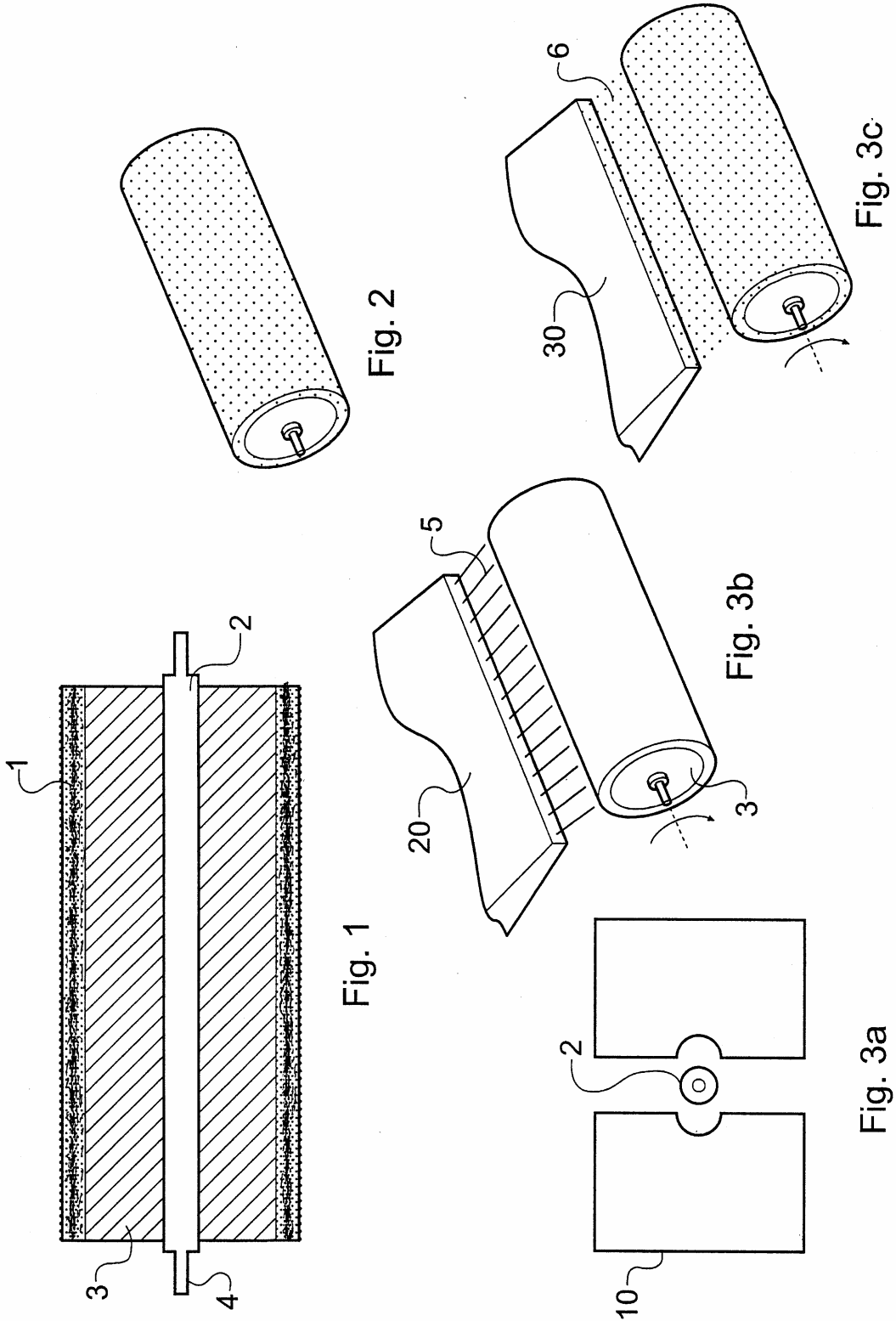
Fig. 3c shows the second foam layer being sprayed with graphite particles.

The rollers used in the present invention comprise a central axle 2, an electrically non-conducting layer 3, and a peripheral electrically conductive covering 1. The central axle 2 has end pieces 4 which are insulated from the electrically conductive covering 1 by the non-conducting layer 3. The roller comprises two different layers of foam. The foam is preferably polyurethane.

To manufacture the conducting roller, the central axle 2 is first placed in a mould 10. An insulating layer 3 of polymeric foam is then moulded directly onto the central axle 2. Once this foam is fully cured, the axle 2 with its electrically non-conducting first foam layer 3, is removed from the mould 10. The axle 2 and first foam layer 3 are then rotated and sprayed from a first spray nozzle 20 with a thin layer of a second foam 5. Before the second foam layer cures, it is sprayed with graphite particles 6 whilst rotating in front of a second spray nozzle 30. Particles 6 build up and contact each other both within and on the surface of the foam 5, so as to form, together with the foam 5, the conductive covering 1. Alternatively, the conductive foam layer can be manufactured separately in a continuous process similar to that used for the prior art, but applying the graphite particles by spraying rather than by pre-mixing. The resultant foam web is then cut to length and attached around the roller.

DRAWINGS OF DOCUMENT D2

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CLIENT'S LETTER

Wim Sickle Engineering Solutions

Sir Lee Gyt, Frank Lee Te Deus and Partners
Patent Agents
Normandy House
Teddington
Bertshire

Dear Mr. Te Deus,

Thank you for the copy of the examiner's communication. Since filing the application I have had more time to compare the pressure-sensor of my invention to similar products on the market, and that of D1 in particular. Whilst pressure-sensors based on conductive foam are known, mine appears to give more accurate and consistent results.

I ask you to obtain the broadest possible protection for my invention.

Yours sincerely,

Wim Sickle