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(54) **Title:** A METHOD FOR UTILISING THERMAL SPRAYING IN THE PRODUCTION OF STRUCTURES CONTAINING ELECTRICAL COMPONENTS

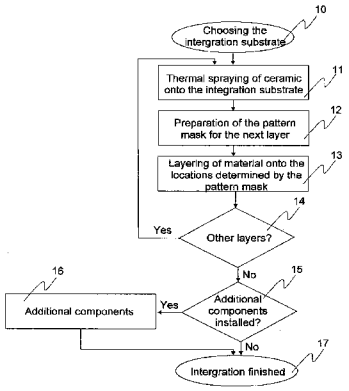


Fig. 1

(57) **Abstract:** According to the invention, thermal spraying can be used to integrate electric, pneumatic or hydraulic structures into existing mechanical structures. The producing of the structure being integrated begins by thermally spraying either conductive or dielectric material onto the surface of the structure which is the object of the integration process. If the base material is dielectric, conductor structures can be thermally sprayed on top of the base material. If the base material is at least partly conductive, a layer of an insulating ceramic substance is first thermally sprayed on top of it. A metallic, conductive substance is sprayed through a mask on top of the insulating ceramic layer. This results in a conductor pattern according to the aperture of the mask being duplicated onto the base material. The conductor pattern thus formed can be covered with a mechanically, chemically, and/or electrically protective substance. If needed, the surface of the protective layer can be further processed to the desired surface coarseness.

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A method for utilising thermal spraying in the production of structures containing electrical components

The object of the invention is a method for utilising thermal spraying in integrating an electric, pneumatic or hydraulic element, circuit or actuator as a part of a mechanical structure or set-up. The invention relates also to an electric, pneumatic or hydraulic component produced using the method in question.

The invention is based on thermal spraying. Thermal spraying is a method in which suitable plastic, metal or ceramic powder or liquid or wire containing said substances, is blown by compressed air or other gas onto a gas flame, for example. For example, an electric arc or laser for heating the material to be sprayed may also be utilised instead of a gas flame. The powder, liquid or wire heats up and sinters onto the surface of the object being sprayed. The adhering of the material onto the object being sprayed may also be due to extremely high kinetic energy, which causes the particles in the material to sinter or otherwise adhere onto the object. The object of the spraying may be ceramic, metal, plastic, wood or paper, for example. Thermal spraying does not actually heat the target onto which the material is sintered or its heating effect in the target is relatively small.

Currently, thermal spraying is typically used for repairing worn axles or other mechanically worn metallic components. For example, when the bearing on the axle of a paper machine is broken, the bearing's fitting on the axle is also often worn. The axle's fitting is then fixed by thermally spraying the bearing with steel or other metal or ceramic (for instance aluminium oxide Al_2O_3), with which the worn out part is filled. Subsequently, the bearing's fitting is typically lathed to the desired dimensions.

Another typical application for thermal spraying is to coat mechanical parts in the event they must be durable enough to withstand wear and tear and different conditions, such as corrosion. In such cases, ceramic materials are typically used for coating.

Prior art methods for producing electronic circuits have involved circuit boards or similar connection substrates onto which the electronic circuits have been produced. The circuit boards or similar substrates are typically produced in a separate production process. Additional known prior art methods also involve the production of switch box conductive patterns by growing, using deposition or by using another corresponding method onto the base structures of a switch box.

The object of the invention is to present a method by which electric, pneumatic, hydraulic or mechanical structures or components can be integrated as parts of at least a partly finished mechanical structure using thermal spraying in a cost efficient way.

The objects of the invention are achieved with a method by which suitable materials are thermally sprayed on top of an existing mechanical structure freely, layer by layer, or by using some type of pattern stencil. The layers sprayed can be either electrically and/or thermally insulating or conductive material. The choice of material for the layers and the location of the spraying on the surface of the structure have an impact on the functional properties of the integrated component.

Applying thermal spraying according to the invention to the manufacturing of electric circuits, the following advantages compared to prior art manufacturing methods can be achieved:

- integration of conductive and/or isolating structures into wood, metal, concrete, paper, films, fabrics
- advantageous on-site production
- advantageous mass production
- advantageous retrofitting
- cost-efficient, energy-saving solutions such as LED lighting

A further advantage of the invention is that a functional structure can be integrated as a part of an existing mechanical structure. The integration of the functional structure can also be done at the installation location of the existing mechanical structure. The functional structure can be an electric element, an element for cooling the temperature caused by electrical activity and/or a heating element, an electric protection structure, or other corresponding characteristic typical to an electronic and device.

Another advantage of the invention is that the functional structure being integrated does not necessarily need a separate support element between the mechanical structure and the component being integrated.

A further advantage of the invention is that the functional structure being integrated can also be produced on a three-dimensional surface.

Compared to conventional manufacturing methods, thermal spraying provides products with excellent durability against environmental conditions, and the electronic devices produced are reliable. Using the method according to the

invention allows on-site production and manufacturing of the device, building, structure, machine or machine part.

For instance, compared to traditional FR4 circuit board technology, thermally sprayed structures are durable against wear and tear, shock-absorbent, inert and stabile.

Compared to conventional LTCC technology, thermal spraying offers a more flexible method of production, which is not dependent on clean space and where, for example, sintering shrinking, which is a problem with LTCC, is non-existent. The range of materials to use for thermal spraying is extremely wide, and materials can be rather freely mixed with each other. This has an impact on the electrical, mechanical, physical and chemical properties of the materials. For instance, heat expansion coefficients can be adjusted to achieve optimal functioning with the base material or integrated silicon chip. This makes the customising of products flexible.

Thermal spraying can also be performed selectively, in which case a robot or other device, machine or other manipulator guides the spraying. This makes it possible to tailor products in such a way that the properties of a single product depend on the control file. Furthermore, the properties of separate components and modules being integrated can be customised and altered in which case the thermally sprayed or otherwise formed (e.g. paste printed, inkjet, decal, etc.) common structure of separate components and/or modules has customised properties and functions.

An example of selective spraying is the so-called Direct Write technology, by which an electronic file determines the shape and quality of a conductor and/or insulator.

The advantage of thermal spraying as compared to prior art Direct Write technology is that on-site production is easier and it is more cost-effective. Typically, in conventional thermal spraying, an entire layer of material is sprayed during one phase in which case selectivity is achieved using a mask, for example. Because of this, conventional thermal spraying is a more cost-efficient method in mass production. The choice of the spraying method has an impact on how the object heats up and on the achieved quality of the insulation and conductor layer. This is a significant advantage when the conductors and dielectrics call for customised physical, chemical, and mechanical properties of materials, such as

conductivity, capacity to isolate, tightness, durability against wear and tear and environmental conditions, etc.

Thermally sprayed structures can also be refined through secondary sintering in an oven, laser treatment, forging, by pressure or by some other physical or chemical treatment. For instance, a laser can be used to seal a thermally sprayed dielectric or conductor.

A substance such as glue, epoxy, paint, varnish or other protective or decorative substance may also be impregnated into a thermally sprayed surface, conductor and/or dielectric in which case the electrical, physical or chemical properties of thermally sprayed product, component or structure change.

The properties of a thermally sprayed surface, conductor or dielectric can also be varied by altering, for instance, the particle size of the sprayed material. For instance, nano-particles can be used to achieve tight and thin structures. Thin structures are required in capacitors, for instance, the isolating layer of which directly affects the charging capacity or capacitance of the capacitor.

Insulating materials, such as ceramics, plastics or other materials, can also be mixed with a conductive material, such as metal, plastic or other material, the result being a resistive material, which can be used to produce and integrate resistors that are partially ceramic, metal, and plastic and/or other materials. Alternatively, an existing resistive material can be used. Ceramic resistors can be tuned using a laser or other mechanical, chemical or physical method in which case a relatively exact resistance value can be achieved. Thermal spraying can also advantageously be used to bury tuned ceramic resistors. In this way, making extremely exact, stabile resistors is possible, the resistance value of which does not change during a period of time or use, or changes to a relatively small extent.

The method according to the invention for integrating an electric, pneumatic or hydraulic component as a part of a mechanical structure is characterized in that
- thermally insulating layer of material is blown onto at least one surface of a mechanical structure or onto a part of the surface,
- a mask utilised in the production of an electric, pneumatic or hydraulic component, circuit or part of a actuator, is made, or the spraying is done in another selective way, and
- a layer of material required by the electric, pneumatic or hydraulic component, circuit or actuator, is thermally sprayed onto the layer of insulating material.

The electric, pneumatic or hydraulic component according to the invention is characterized in that it is produced on site onto the surface of a mechanical component, structure, building, construction, vehicle, or machine part, and that it is at least partially sintered.

The basic idea of the invention is as follows: Thermal spraying is advantageously used in the production of the component integrated into the mechanical structure according to the invention. Thermal spraying is a method by which material that is entirely or partly melted into a liquid is blown or sprayed as a fine spray together with for instance a flow of gas onto the surface to be treated. The substance being sprayed melts and/or is sintered and adheres to the target due to its great kinetic energy. Various methods used for thermal spraying include, for instance, flame spraying, electric arc spraying, laser spraying, arc spraying, plasma spraying, vacuum plasma spraying, high-velocity flame spraying and detonation spraying.

In the first phase of the production method according to the invention, an insulating layer of ceramic material is advantageously thermally sprayed onto the surface or part of the surface of the mechanical structure onto which the component being integrated is connected, or initially an electrically conductive material is thermally sprayed onto the mechanical structure. The surface being the object of thermal spraying can be either planar or non-planar (3D objects). The second phase advantageously involves the formation of electric circuit conductors on top of the insulating ceramic layer. The conductors formed in this way can then be covered by another thermally sprayed layer of material.

The thermally sprayed protection provides the structure with protection against environmental conditions, such as humidity, heat, and electric or magnetic fields, or with a mechanical shield against wear and tear or corrosion, or an electric device can be hidden in this way.

The number of thermally sprayed layers and the material used in each layer depends on the type of component being integrated into the mechanical structure. The integrated component may comprise, for instance, conductors, passive electric elements and discrete components for installation, which may be a part of the component entity being integrated.

The invention is described in detail below. The description makes reference to the enclosed figures, in which

Fig. 1 shows, by way of example, the main phases of the production method according to the invention.

Fig. 2 shows, by way of example, a principal structure of a finger capacitor produced according to the method in the invention.

Fig. 3 shows, by way of example, an arrangement of power feed for electronics integrated in the axle of a rotating device utilising a thermally sprayed antenna.

In the following description, the embodiments are only examples and a person skilled in the art may implement the basic idea of the invention in another way than that described herein. Although the description may refer to another embodiment or embodiments in several places, it does not mean that the reference is meant for only one of the described embodiments, or that the characteristic described would only be useful in one of the described embodiments. The single features of two or several embodiments may be combined and thus create new embodiments of the invention.

The thermal spraying method according to the invention can be used to integrate various circuits, components, actuators and structures, which operate electrically, pneumatically or hydraulically, directly onto existing mechanical structures. The mechanical structures may be of ceramic, metal, plastic, concrete or wood, for example. The method according to the invention can be applied to, for instance, various beams, rails, wires, crane rails, rotating devices, vehicles, bridges, buildings, walls, various casings, pipes, tanks, valves, or other engine parts, etc.

Figure 1 shows, by way of example, a flow chart describing the main phases of the production process according to the invention. In phase 10, a structure into which the electric, pneumatic or hydraulic component is to be integrated as a fixed operational part, is chosen as an integration substrate.

The manufacturing of the electrically operating structure advantageously begins with dielectric material, if the integration substrate is at least partly of an electrically conductive material. If the surface material of the mechanical structure is an electrically insulating material as such, structural parts made up of a conductive material can be made directly onto its surface.

In the example in Fig. 1, the integration substrate is not of an insulating material. Due to this, a layer of insulating material, for example ceramic or plastic, is

thermally sprayed on top of the integration substrate chosen in phase 11. The thickness of the thermally sprayed layer depends on how it will be used.

Typically in thermal spraying the insulating material used may advantageously be functional or traditional plastics or ceramics, such as aluminium oxide Al_2O_3. Other advantageous materials to be used as an insulating ceramic are, for instance, $MgTiO_3$, $CaTiO_3$, ZnO, SiO_2, B_2O_3, Al_2O_3 alloys, $BaTiO_3$, $Ba_{1-x}Sr_xTiO_3$, PbO, BeO, SiC, AlN, Si, Si_3N_4, diamonds, quartz, steatite, titanate, mullite, alumina or glass and mixtures of the aforementioned.

During phase 12 a pattern mask is made, which is used to produce electrically conductive structures such as conductors or resistors on top of the ceramic layer, for example. The Direct Write method or another prior art method can be used to produce conductors. In this case a mask can refer to, for instance, a separate patterned object containing apertures placed on top of the integration substrate or close to it. A mask can also be a control file in the memory of a machining tool, robot, or selective thermal sprayer, by which the machining tool, robot or sprayer is made to layer material onto a part of the integration substrate specified by the control file. Additionally, a layer of material on top of the integration substrate can be used as a mask in which case certain parts of the layer of material have been removed using for instance a laser or other focused machining, such as machine tooling, and onto which places a material that adheres to the ceramic layer is layered.

During phase 13 the chosen material is layered onto the parts of the integration substrate determined by the mask or control file. The layering of the material can be done using, for instance, thermal spraying, paste printing, photolithography, growing, etching, transfer printing technique, decal technique, photo-gravure, inkjet or other prior art method. Advantageously, the material layered possesses the electric properties needed for the operational properties of the component being integrated.

In the event the material is layered by thermal spraying, suitable materials that also conduct electricity to produce conductors are, for example gold, silver, copper, aluminium, palladium, molybdenum, wolfram, TiO_2, $BaCO_3$, CoO, NiO, CuO, Mn_3O_4, RuO_x, tantalum-aluminium alloys, kovar, kanthal, nichrome, manganese, iron-based materials and other such materials, such as conductive plastics and alloys of the aforementioned substances.

Thermal spraying can be used to form layers on top of the ceramic layer using materials that have the desired electrical or electro-mechanical effects. Such materials are, for example, various piezoelectric materials, i.e. zirconium oxide, titanium oxide, and PZT. Additionally, ferroelectric or ferromagnetic materials, such as Fe_3O_4, AlB_2, ZnO, can be utilised.

Thermal spraying may also be used to make layers of other materials on top of the ceramic surface. Some examples of possible materials include various rubbers, polyimides, polyamides, polyesters, epoxies, resins, waxes, and bismanol-triazine alloys, kaptones, aramides and functional or traditional plastics.

At the end of phase 13, the parts of the pattern mask that may have been left onto the integration substrate can be removed if necessary.

In stage 14, it should be decided whether or not another layer of any substance is to be layered on top of the existing structure. If the answer is "YES", the process returns to phase 11 during which a layer of ceramic is thermally sprayed on top of the existing structure.

During stage 12 of the renewed processing round, the pattern mask can be left out if necessary and subsequently, during stage 13, either no material is layered or the material is layered onto the entire area of the integration substrate.

When all the layers of material for the integrated component are ready, the process proceeds from phase 14 to phase 15. At stage 15 an inspection is made to determine whether or not the component being integrated includes discrete components. If necessary, discrete components are installed at stage 16. After the discrete components have been installed, the integration process ends at stage 17.

Traditional electronics can also be installed into the structure, such as circuit boards and modules produced using LTCC- (Low Temperature Co-fired Ceramic), HTCC- (High Temperature Co-fired Ceramic), MCM (Multi Chip Module), TAB (Tape Automated Bonding), FC (Flip Chip), BGA (Ball Grid Array) techniques, or other prior art techniques, as well as separate components and strain gauges, sensors and actuators.

Examples of applying the production method according to the invention:

1. Antenna

One method of producing simple conductor structures, for instance RFID antennae (Radio Frequency Identification), is to blow a metallic substance onto the dielectric base material through a mask forming the conductor pattern in which case a pattern according to the aperture in the mask is repeated directly onto the base material. In the event the base material is not already dielectric, a dielectric substrate can advantageously first be thermally sprayed. The method makes it possible to spray, for instance, large antenna or other wire surfaces on large surface areas. Some examples of such structures are a wall, a container carried by a lorry, or a goods pallet or trolley. The active part of an RFID antenna is advantageously connected to the antenna structure using conductive glue, by soldering, using a wire connection, or other corresponding prior art connection method, which creates a conductive contact between the active component and the antenna structure. The application advantageously makes it possible, for instance, to track cargo containers equipped with an RFID antenna using satellite or other tracking methods to detect a need for servicing after break down (for instance the break down of a pump in a large sewer system), the tracking of devices or consumer goods being sold, or other types of tracking of valuables.

2. A 3D circuit structure

The construction of an electrically functioning 3D structure advantageously begins by spraying, for instance, a ceramic material onto a metal or ceramic substrate, or onto a freely chosen surface or part of a surface of a finished 3D object. Subsequently, wire patterns are formed by, for instance, thick film printing, photolithography, and laser sintering, thermal spraying, or using any other method. If for instance thick film printing is used, the conductive paste can advantageously be "sintered" using, for instance, the same gas flame used for the thermal spraying. Alternatively, the sintering can be performed traditionally in a sintering oven. The finished conductor pattern can advantageously be covered at least partly by thermally spraying an insulating material on top of the wires.

Subsequently, a new conductor pattern can advantageously be thermally blown on top of the conductor pattern using a separate mask or a sprayer guided by a selective control file in such a way that the conductor pattern created during the previous phase is left uncovered at the vias or connection points. By repeating the process phases described above, a true 3D structure can be produced inside, for

instance, aluminium oxide, or an electric, physical or chemical function can be prepared inside a finished 3D object.

Additionally, a silicon chip can be integrated into the structure. To connect a silicon chip, conductor patterns are printed or otherwise formed on top of the insulating material (for instance a ceramic produced with thermal spraying), and the silicon chip is attached using a wire connection or Flip Chip technique. Subsequently, the silicon chip is advantageously protected using prior art glob top material or other material with an epoxy base, for example. After the silicon chip has been connected, the entire structure can advantageously be embedded into the ceramic using thermal spraying. This results in a hermetically sealed ceramic structure, which is extremely reliable and durable. If, for instance, aluminium oxide is used as the substrate, its heat expansion coefficient is in the same range as that of silicon.

In the same way embedded passive components can also be produced, e.g. resistors, capacitors, and coils. In an advantageous embodiment of the invention, component connections can be made on top of the ceramic using traditional SMD technology, and these components are protected by thermal spraying.

Thermal spraying can also be applied to protect structures made using LTCC technology. An LTCC module, onto the surface of which glob top protected silicon chips or SMD components (Surface-Mount Device) have been connected, can be buried in the ceramic structure using thermal spraying. The silicon chip or other discrete component, which is glob top protected, is not damaged, if for instance alumina is layered on top of it using thermal spraying, since alumina and LTCC ceramics have heat expansion coefficients very close to each other and thermal spraying does not markedly heat the LTCC base.

Using the same principal method, efficient EMC (Electro-magnetic Compatibility) and EMP (Electro-magnetic Pulse) or ESD (Electro-static Discharge) shields can be produced for circuit solutions produced using the method under survey, or for known electric circuit solutions. An example of this is the metal coating of the inner surface of an electronic and device box, advantageously using thermal spraying, or manufacturing of electronics integrated into a switch box. The manufacturing of electronics integrated into a switch box makes a circuit board unnecessary for instance in light dimmers. The method can also be used to integrate electronic control functions into the switch boxes of motors and pumps or into other mechanical structures.

3. Cooling and/or heating using thermal spraying

Thermal spraying can also be used to create, for example, cooling and/or heating channels into the most advantageous place in a mechanical structure from the point of view of heat transfer. Using the production method according to the invention, cooling and/or heating elements can be produced close to heat generating structures and components.

For example, the production process of a cooling or heating channel is as follows: A groove where the cooling or heating liquid or gas is to flow is made into the base material. The completed groove is filled with a substance, which may evaporate or dissolve from the groove, or it can be removed mechanically. The filler substance can be e.g. wax or other so-called sacrificial material. The filler substance is used to prevent the cooling channel from filling up during the next stage of the production process.

Subsequently, the area of the cooling channel, at least, is covered with material using thermal spraying, covering up the cooling channel. Advantageously the material sprayed can be the same material as the base material. At the same time, a part of the channel that does not contain filler substance can be filled up with the same substance, for instance.

After making the thermally sprayed layer, the filler substance, for instance wax, is removed from under the thermally sprayed layer through e.g. heating, pressure, ultra sound, dissolving, or another chemical, physical or mechanical method.

Subsequently, the object into which the cooling or heating channel has been made can be refined to make the quality of the surface suitable for its desired use.

The cooling channels can also be made without mechanized tooling by forming the desired channel structure onto the surface or part of the surface of the structure with a sacrificial material that dissolves, melts or burns such as wax, carbon pasta, or another type of material that can be removed from the channel. Advantageously, a layer of the same material or other material unlike the base material is then thermally sprayed onto the pattern. The result is a sacrificial material structure sealed in between the base and the thermally sprayed coating which forms the desired cooling channel. When the sacrificial material is removed using e.g. heat, pressure, ultra-sound, dissolving, or other physical, chemical or mechanical method, a structure that has complex cooling and/or heating or other energy transfer structures is easily and cost-effectively made. A hole, to which

coolant liquid is connected with a hose or other corresponding connection, can advantageously be drilled into the channel, or circulating air may be used to do the cooling.

Components and other electronics can be connected to the surface using prior art methods, for example.

Similar structures can also be made for transferring liquid or gas to a hydraulic or pneumatic actuator, for example.

4. Induction loop or antenna

An induction loop or antenna can be made on the surface of any object. First, a ceramic insulation substance is sprayed onto the surface of the object. The desired induction loop or antenna is thermally sprayed on top of the insulation substance or insulation base material using a suitable mask. If the base material is dielectric, i.e. insulation, the conductor acting as the antenna or induction loop can be sprayed directly onto the base material. The finished induction loop or antenna is advantageously protected with an electrically and mechanically protective substance or it can be left unprotected if it is not needed.

Using the described method an inductive power feed can also be advantageously constructed. The power feed can be used for feeding power into small electronic devices using a magnetic field in public premises e.g. card readers or in other battery operated devices, such as pulse meters, devices and sensors monitoring vital functions, toys, or similar low-power devices. For example, ageing tends to cause problems with the use of different elderly health care devices; the power feed of a safety bracelet, for example, can advantageously and in a user-friendly way be executed by placing the bracelet onto a base plate into which electronics have been integrated using thermal spraying or other corresponding prior art method. Such devices can be charged using inductive power feeding.

Another example of use advantageously makes the surveillance of public places possible as regards metal objects such as weapons. Inductive loops can advantageously be installed into the passages, corridor walls and other critical sites of e.g. schools, offices or other public buildings.

A third example of the cost-effective application of an induction loop thermally sprayed on paper or film is the surveillance against theft of consumer goods in shops.

5. Monitoring the condition of a rotating object

A place for measurement and transmitter electronics to be used in an axle, paper machine roll, train wheel, or other revolving object is made. The place is coated with insulating material by way of thermal spraying. The necessary measurement and transmitter electronics are mounted into the insulated place using a prior art method. If the equipment to which the measurement and transmitter electronics are to be mounted permits, the said electronics may be directly mounted onto it without making a separate place for them.

An induction loop and/or antenna is created next to the prepared place and/or measurement and transmitter electronics using thermal spraying or conventional methods, e.g. prefabricated coil, via which the necessary power can be fed to the measurement electronics.

Next, the operating voltage feed for the measurement and transmitter electronics is connected to the induction loop and the antenna output is connected to the antenna by way of soldering, for example. After the electric connections have been made, the electronics are protected with resin, glue or other suitable protective substance. Additionally, the strain gauges can be connected to the measurement and transmitter electronics to allow the measurement of power or momentum and the temperature calibration of the strain gauges. Additionally, the strain gauges and sensors are advantageously protected with prior art methods, such as glob-top- or epoxy-based materials.

After the electric connections have been completed, the measurement electronics and the entire structure are advantageously concealed using thermal spraying. After the thermal spraying, the surface of the axle or corresponding object is advantageously lathed, milled or abraded to achieve the desired surface quality and/or shape. If the area of use of the axle so permits, the surface may be left unmachined.

The operating voltage for the measurement electronics is advantageously fed while the axle or roller is rotating from the voltage induced into the induction loop by a permanent magnet installed adjacently.

The measurement electronics can e.g. "listen" to the sounds of the bearings from the axle, which are sent via the produced antenna by radio signal to a suitable receiver. A variable to be measured from a rotating object can also be e.g. the force, momentum, temperature, sound of a bearing, acceleration, or acoustic

impedance applied to the rotating object, e.g. an axle, or other corresponding physical or chemical quantity measuring the state or condition of a corresponding system.

Fig 3 shows, by way of example, a method for creating induction-based voltage. A permanent magnet element 37 has been fastened to the frame of the measured or monitored object 36 using a fastening element not shown in the figure. A conductor loop 32 has been thermally sprayed to the rotating axle 38 inside the frame 36. Additionally, sensor unit 31, the electronics 33 needed to create operating electricity, and a radio unit 35 have been integrated into the axle 38 of the equipment being measured or monitored. After the equipment or machine has started up, the induction loop 32 fastened onto the rotating axle passes the permanent magnetic element 37 fastened to the frame of the object being measured and the magnetic field it has created whereby voltage is induced into the loop 32 according to the induction principle which creates the operating electricity necessary for the measurement or control system.

In another advantageous embodiment the rotation described above has been replaced with a linear to-and-fro movement between two objects. A permanent magnet has been integrated into one of the objects, while the other object has a thermally sprayed induction loop. The to-and-fro movement of the permanent magnet passed the induction loop induces voltage into the induction loop which can be utilised as the operating voltage of an electronic device.

The inventiveness in the production of the said method for monitoring condition lies in the use of thermal spraying as an advantageous production method, retrofitting, durability to withstand various conditions, the reliable operation of the equipment in demanding environments, the integration of the antenna and power feed using thermal spraying, and the possibility to conceal the equipment.

6. Active, piezo-ceramic structure

PZT (Lead Zirconate Titanate) or other piezoceramic is thermally sprayed onto a chosen surface. The proposed use of the piezoceramic structure determines the shape of the thermally sprayed element. The surface created can be made to vibrate. Examples of possible areas where a piezo-ceramic structure can be utilised include various antennae, self-cleaning walls of a combustion space, automobile valves, valve housings and piston surfaces.

The operating voltage for the piezo-ceramic structure can be produced by inductive power transfer (which can be executed with thermal spraying, for example).

The retro-sintering of the structure can also be done in a sintering oven. Retro-sintering may also be necessary to make the crystal structure of the PZT material function in the desired way through retro-sintering.

7. Coating of paper or film

A metal coating is thermally sprayed onto paper or other film-like surface. The end-product may be e.g. a RFID antenna produced on paper or other advantageous antenna, moisture sensor, ESD, EMC or EMP protective structure, or other circuit with an electronic function, such as a transmitter/receiver pair. Paper ESD, EMC, or EMP protection can advantageously be made by forming a casing-like structure to be folded or otherwise around the electronics to be protected or to cover a passage for protection. A paper, textile or other film-like protection is coated advantageously by thermal spraying making it possible to produce an ESD, EMC, or EMP protection.

A paper- or textile-based moisture sensor can be made by spraying a finger capacitor structure 20 as seen in Fig. 2 onto the surface of paper or textile with the help of a mask, for example. The capacitor 20 comprises overlapping capacitor plates 21 and 22. When the paper or textile becomes wet or moist, the capacitance of the capacitor changes indicating e.g. moisture damage in a building. An inexpensive moisture sensor such as this can be installed behind wallpaper, under a rug, or a domestic equipment or other machine that uses water, e.g. a dishwasher, washing machine or other such machine. An alarm, or electronics used to cut off water, is connected to the paper-based or other film-like moisture sensor. This way, damage caused by water can be reduced significantly or prevent water damage completely. A second possible application of a sensor made according to the said method is to place it in crucial intersections of sewage and water distribution networks to prevent the water distribution network from pollution.

Using a corresponding solution with a film- or textile-type material, a moisture sensor can advantageously be made and integrated into the material of a bed for use in hospitals for long-term patients, children, and the elderly aged.

Using a corresponding method, access control sensors can be constructed or retrofitted into a floor, for example.

8. Monitoring the condition of buildings and structures

Thermal spraying can be used to construct a sensor that extends more or less from one end of a structure to the other, over a place essentially important as regards measuring, or into a structure or a part of it. Thus, a measurement sensor can be integrated into e.g. a bridge beam, a roof truss or a railway track.

Advantageously the measurement sensor is constructed as follows: A relatively narrow, ca. 15 mm wide, isolating layer is thermally sprayed into a roof truss, bridge beam, or other support structure, from one end of the grating to the other. If the structure is isolating as such, as in the case of wood or concrete, spraying the isolating layer is not necessary.

Subsequently, a narrower conductor 5 mm in width made of conductive thread-, ribbon or adhesive-type material is sprayed or otherwise formed or mounted on top of the isolating layer. The conductor is advantageously protected with an isolating layer which is thermally sprayed.

During use resistance or other suitable electric variable is measured from the ends of the conductor or from elsewhere e.g. a space in between or from another advantageous location as regards measuring. When the shape of the structure changes, also the resistance of the conductor or other measured electric variable changes, the conductor breaks or stretches. This is indication that a wall, foundation of a building, bridge beam, roof truss, etc. is experiencing strain, a change in condition or breaking.

Thermal spraying can advantageously be used to measure the moisture or curve of a laminated wooden beam or single piece of wood. A conductor pattern, which forms a strain gauge structure or finger capacitor structure, is sprayed onto a wooden beam advantageously using a mask. The measurement conductor structure can advantageously be protected by placing it in between the glue seam of a laminated wooden beam. A finger capacitor structure or similar electric structure formed by thermal spraying advantageously indicates the changes in moisture or curve in a wooden beam when the capacitance, resistance, or other measurable electric variable of the capacitor or other measurement device changes as a function of the moisture of a wooden beam, or as a function of a curve, strain, pressure or other measurable phenomenon. When the resistance,

capacitance, or other measurable electric magnitude of a structure formed by thermal spraying in between a wooden beam changes due to a curve, strain, or pressure in the wooden beam, the curve or other change in the wooden beam can be measured.

Applications constructed according to the method can be used to indicate earthquakes or to monitor the burden caused by snow or wind, moisture, curvature, pressure, strain, or other measurable phenomenon.

9. A sensor to indicate the wear and tear of a coating or a surface

A ceramic or corresponding electrically insulating layer of material is thermally sprayed onto the surface of the object being monitored. A conductor pattern is formed on top of the isolating layer by thermal spraying or prior art method of constructing conductors, or it is a wire mounted on the surface. The conductor pattern is protected with a thermally sprayed layer of ceramic material.

When the coating wears out, either mechanically or chemically, the constructed conductors break or their resistance or other electrically measured variable changes. These changes indicate a need for re-coating. Examples of surfaces that may require monitoring for wear and tear include various turbines, pumps, sliding surfaces or coated surfaces in general, and structures subject to wear and tear e.g. due to corrosion.

10. Construction of a large capacitor

A capacitor with a relatively large capacity can advantageously be constructed onto an existing surface. The surface in question may be the wall of a building, for example. The capacitor according to the invention is advantageously constructed by thermally spraying an isolating ceramic and a conductive material one after the other. Nano-particles can be added to the ceramic forming the isolating layers of the capacitor, which make the needed isolating layer less thick. The area of the capacitor according to the invention can be large, for example 100 m^2. Numerous layers can be thermally sprayed into the capacitor, for example a thousand layers. The large area and number of layers make the construction of a capacitor with a relatively large charging capacity possible.

11. Passage control sensor

Thermal spraying can be used to advantageously construct a passage control sensor for monitoring movements in selected targets such as rooms, business

premises, public buildings, or other similar space. A sensor structure is formed by thermal spraying a mask onto a floor or wall of a room or onto some other suitable surface. The sensor structure can advantageously be a finger capacitor structure or other capacitive or inductive structure. When a person, animal, machine or other material comes within the identifying range of the sensor, the electric or magnetic field created by the sensor is disturbed and this disturbance can be amplified at the signal level and be used for identification purposes. This measurable change in capacitance, inductance or other electric magnitude indicates that something is moving in a room or other space being monitored. A sensor constructed according to the method can be used to identify metal objects in public places, for example.

The method can be used to make a passage sensor advantageously onto paper, textile, wallpaper, laminate, wood, parquet, concrete, and other floor structures.

12. General lighting and/or guide lights and emergency exit lights

Thermal spraying can be used to construct advantageously exit routes with LED guide lights in buildings, on banisters, airplanes, ships, trains or other similar places. The exit routes of theatres or other similar public places can be cost-effectively created using thermal injection moulding. A conductive pattern with points for connections is placed on the premises structure, such as a concrete, brick or wooden wall, using thermal spraying. The LED components are soldered, glued, or otherwise reliably adhered to the connection points. Correspondingly, the same structure can advantageously be placed on a metal of wooden banister. With metal banisters, thermal spraying is used to make an isolating base layer first and then the conductive pattern layer with connection points is placed on top of it. Finally, the electric circuit can be protected by thermally spraying plastic on top of the structure. Another possible way of construction is to glue or fasten the LED lights reliably onto their bases, and in the next stage the conductor pattern is made using thermal spraying to connect the conductors to the connection points on the LED lights. In this case thermal spraying acts as an independent connection method. Typically, batteries or accumulators actuate and/or secure the electricity feed for emergency exits. Low-voltage LED applications save energy, increase safety, reduce the risk of accident, and are economical to utilise in different places.

Guide lights can be made using the same construction technique. Typically, the electricity feed comes from a network via a transformer.

Using the above described methods, thermal spraying can also be utilised to create general lighting elements for buildings and various premises using LED lights. A lighting element with a conductive pattern may be of wood or similar interior decorating material onto which conductor patterns have been made using thermal spraying. The LED lights connected to the conductor patterns form a matrix which lights up a premises in general nearly resembling natural light. The electricity feed comes from a network via a transformer. The intensity of the lighting can be regulated by changing the number of LED lights per square area. The size of the elements may be one square meter or other production size and they can be connected together mechanically and electrically either in a parallel connection or as a series. Such lighting elements can be used to decorate the ceilings, walls and other suitable of various premises. General lighting created using the said method emits very little heat, consumes little energy, is environment friendly, and has a low emissions rate.

13. Construction of a heating resistor

With thermal spraying heating elements can advantageously be constructed on the surface of buildings, vehicles, pipe systems, and water and sewage pipes that require transfer heating. Advantageously the use of thermally sprayed heating resistor material is suitable for small and large surfaces such as walls, floor and ceiling structures, outdoor structures that must be thawed or kept thawed such as drainpipes, steps, passageways, and heated streets. Retrofitting in the construction of isolating and resistor elements on location using thermal spraying makes the method cost-effective. The heating elements can be mass-produced as piece goods using thermal spraying and mounted where they will be used when needed.

Some advantageous embodiments of the method and device according to the invention have been described above. The invention is not restricted to the said solutions but instead the idea according to the invention can be applied in numerous ways within the limits of the claims.

Claims

1. A method for integrating an electric, pneumatic, or hydraulic component as a part of a mechanical structure, **characterized** in that
- an insulating layer of material is thermally sprayed (11) onto at least one surface of a mechanical structure or onto a part of the surface,
- a mask utilised in the production of an electric, pneumatic or hydraulic component, circuit or part of a actuator, is made or the spraying is done in another selective way, and
- a layer of material required by the electric, pneumatic, or hydraulic component, circuit or actuator is thermally sprayed onto the layer of the insulating material using a mask.

2. The method according to claim 1, **characterized** in that the electric, pneumatic, or hydraulic component is protected with a layer of material, which is thermally sprayed.

3. The method according to claim 2, **characterized** in that the sprayed protective layer is used to protect the component against at least one of the following factors: moisture, heat, electric field, magnetic field, mechanical wear or corrosion.

4. The method according to claim 2, **characterized** in that the surface of the layer of material sprayed for protection is processed to appropriate the surface quality necessary for a given area of utilisation.

5. The method according to claim 1, **characterized** in that the component is integrated as a part of a finished mechanical structure.

6. An electric (20, 32), pneumatic, or hydraulic component, **characterized** in that it is a sintered element (20, 32) made onto a surface of a mechanical component (38) on a use location.

7. The component according to claim 6, **characterized** in that the sintered element comprises insulating elements, conductive elements, or open channels running under the insulating element.

8. The component according to claim 7, **characterized** in that the surface of the mechanical component differs from a planar surface.

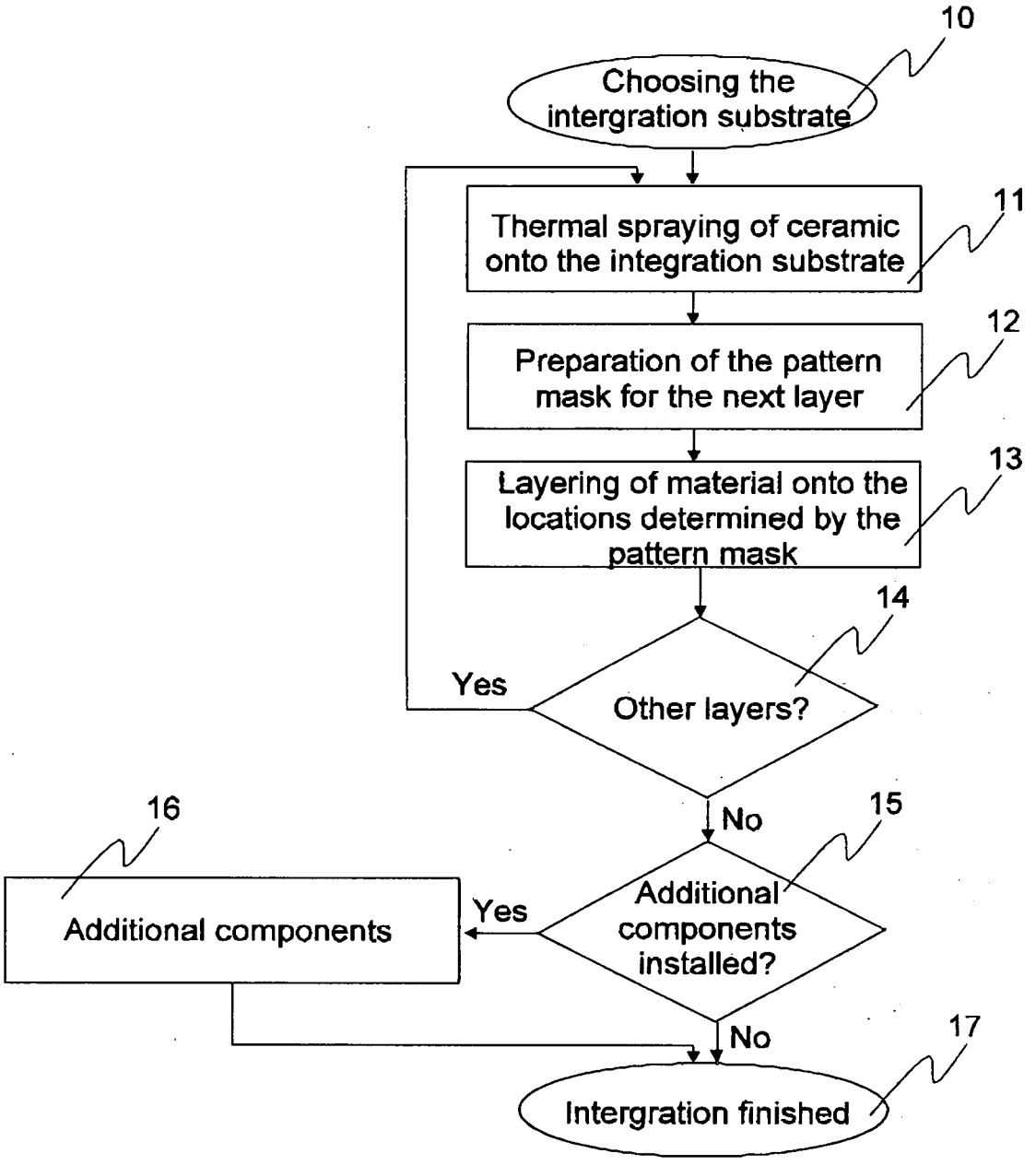

10
Choosing the intergration substrate
11
Thermal spraying of ceramic onto the integration substrate
12
Preparation of the pattern mask for the next layer
13
Layering of material onto the locations determined by the pattern mask
14
Other layers?
Yes
No
15
Additional components installed?
16
Additional components
Yes
No
17
Intergration finished

Fig. 1

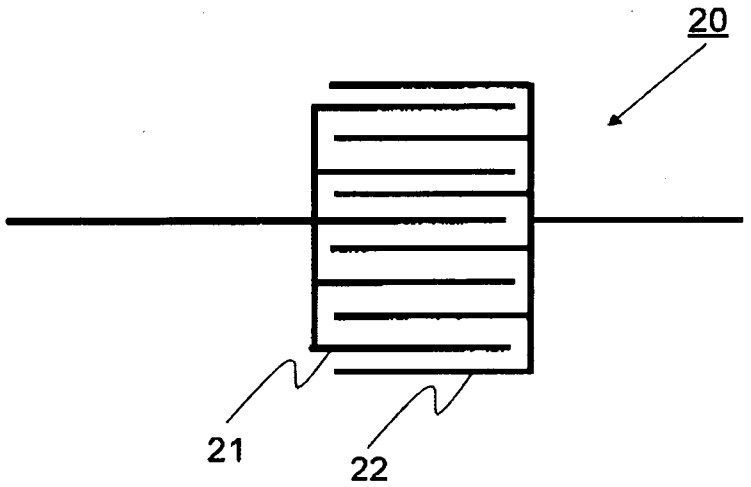


Fig. 2

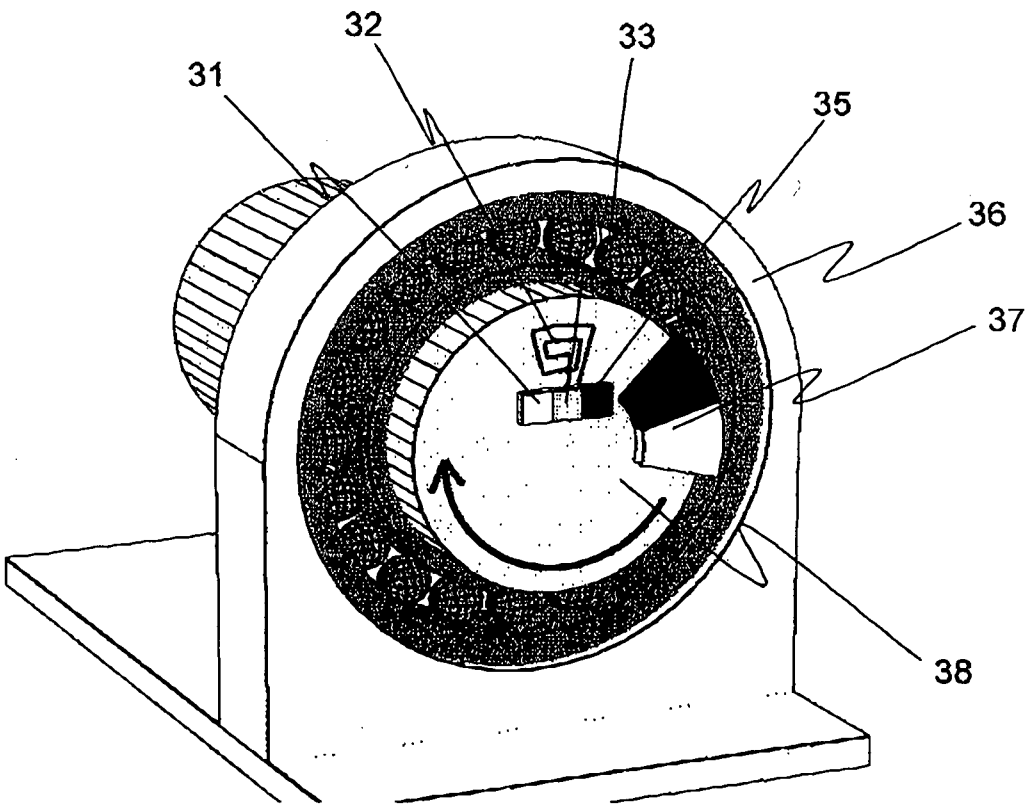


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2009/050057

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: C23C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal,WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2002012743 A1 (SAMPATH SANJAY et al.) 31 January 2002 (31.01.2002), paragraphs [0006]-[0008],[0036],[0040],[0044], claim 37	1-4
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A	US 2004047992 A1 (DONELON MATTHEW J) 11 March 2004 (11.03.2004)	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/FI2009/050057

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C23C 4/10 (2006.01)
C23C 4/00 (2006.01)