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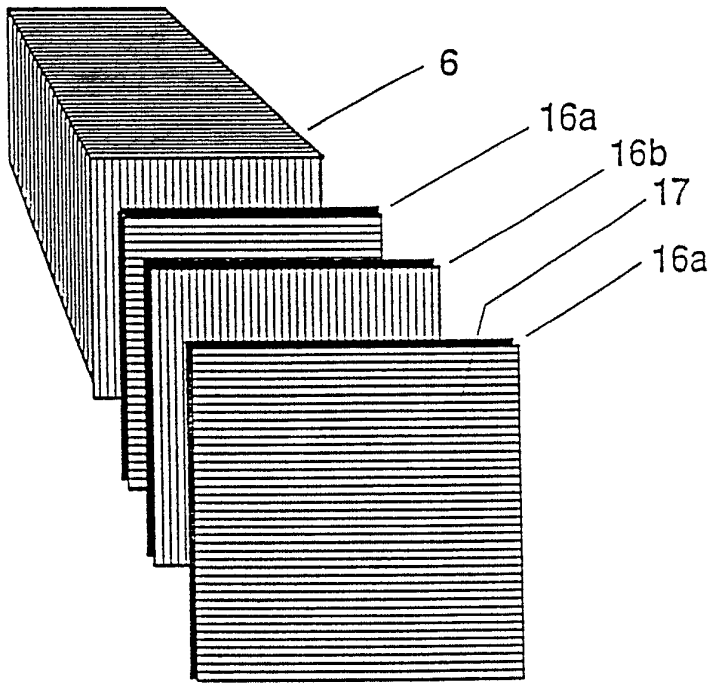

(57) Abstract

The invention refers to a method and an apparatus for producing three-dimensional objects by using a converting machine, which is controlled by computer instructions. The material consists of a number of sheet- or disc-shaped sections (16). On the flat side of each section (16) at least one electrode (17a, 17b; 42, 43) is placed, and an electric voltage is impressed thereon sufficient to cause a breakover between the electrodes. Parts or particles of material located opposed to the electrodes are thus removed from or connected with the respective section (16). The treated sections are integrated layer by layer in a programmed sequence forming said three-dimensional object.

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APPARATUS AND METHOD FOR PRODUCING THREE-DIMENSIONAL OBJECTS

The invention refers to a method for producing three-dimensional objects by using a converting machine controlled by computer instructions, at which the material comprises a number of sheet- or disc - shaped sections defind in size, which are treated in accordance with given computer instructions, so that parts of material are permanently removed, and the sections treated in this way are connected to each other layer by layer in a programmed sequence forming said three-dimensional object.

Background of the invention

In construction work it is desired to visualize and sometimes also physically present the three-dimensional geometry of the constructive element. This applies especially to work with computer aided design (CAD) where the data bases often directly without human intervention are used for manufacturing purposes (CAM). The costs for errors in connection with treatment in numerically controlled converting machines and other automatic manufacturing machines due to misconstructions, are high.

In complex three-dimensional geometries, e.g. cylinder heads of internal combustion engines, and mounting of several cooperating components which are difficult to survey, e.g. in lay-out works in engine houses for private cars, the access of physical models early in the construction process is often a condition for the performance of the actual construction work.

Big companies, e.g. car industries, which are often confronted with this need, generally have pattern shops of their own where details are produced at the demand of the constructor in materials that are relatively simple to work or shape. Certain industries also use CAD-data bases for model production in e.g. NC-cutters. Small companies engage external pattern shops or in certain cases completely eliminate this step in the product development work, resulting in high cassation costs at the finish manufacture.

It however applies to all pattern manufacturing methods used at present that the recording - and manufacturing work is time-consuming and causes discontinuity in the actual working task of the constructor, i.e. to finish and approve the manufacturing basis for the final product or component.

Thus it is desired that if possible offer the constructor a more direct apprehension of his or her object, so that an interactive process can be provided between the creativity of the constructor and his or her result without time - consuming delivery periods.

One way of providing a certain sense of the three-dimensional geometry of the object is used by some CAD-suppliers, at which the system allows the constructor to look at the object from an optional visual angle on the viewing screen and by that experience a photo-like perspective picture of the object. Great efforts have been made by the supplier aiming at increasing the realism in this type of presentation, e.g. by means of choice of colour scheme and shading. In practice it has however proved that this type of appliance are of greater use at sales and aesthetical presentations than actively contributing to a decreased need of real physical models in the construction work.

A method of making physical models by means of CAD-data bases in direct connection of the work place of the constructor is described in US-A-4,575,330 (C.W. Hull). This so called stereolithographic method is based on the principle that a UV-radiating focused light beam cross links and by that cures the point of impact on the surface layer of a liquid photo polymer. The light source, which is controllable in two dimensions above the bath with the UV-curing plastic liquid, can then cure a cross-section from the desired model. The section made in this way is deposited on a table which is movable in the vertical direction of the bath. By gradually lower the table after each finished cross section each layer can be bound to each other and a completed model of the object be produced.

This method, which by time reasons only should produce scale models, has up to now been tested successfully only in small machines having a capacity of some cubic decimeters. The dimensional accuracy has been said to be a problem due to shrinking and interior tension which cause deformity in the finished model. The high cost price of the equipment and the relatively time-consuming process for model manufacturing of a number of hours per model, are factors which limit the utility of the method.

The US-A-4,752,352 discloses an apparatus and a method for forming an integral three-dimensional object from laminations. A sheet - shaped material is cut into the required shapes in a work station and the individually shaped laminations are assembled in a pre-selected sequence in an assembly station into the form of the three-dimensional object. This apparatus leaves quantities of waste material from the cutting operation, which is a drawback.

As a summary it can be stated that effective and practical appliances in the product development work for interactive model manufacture in immediate connection to the work place of the constructor are still missing.

The purpose and most important features of the invention

The object of the present invention is to provide a method which enables an interactive manufacture of three-dimensional models, which in all essentials are in agreement with the CAD-data base which the operator intends to reproduce. The method shall in this way provide a quick manufacture of the object in question without human intervention after the operator, via his or her working terminal, has ordered manufacture of one or more models, and an apparatus for performing the method.

By that is meant a method which provides an apparatus which can be placed in offices and which apparatus can produce complex three-dimensional models, which digitally can reproduce the object defined in the data base.

Thus the method should admit manufacture models with hollow spaces, which not necessarily need to have a draught for imaginary cores or other tool parts at shaping, e.g. injection moulding. The method should further allow manufacture in different materials such as stiff homogeneous or foaming plastic materials, elastic rubber - like materials and certain metals and other materials with low melting temperature. The method should further not leave quantities of waste material after the manufacture of the object.

These object have been solved by the fact that on each fat side of the respective section there is placed at least one electrode, and that an electric voltage, sufficient for causing spark - over between the electrodes is impressed upon these, so that parts or praticles of material located substantially opposed to the electrodes are removed from or connected to the respective section.

An apparatus for performing this method solves the problem by the fact that on each flat side of the respective section there is placeable or placed at least one electrode and that the electrodes in accordance with given computer instructions are connectable to an electric voltage source, which is sufficient for providing a spark - over between the electrodes, so that prats or particles of material are removed from or connected with the respective section.

Description of the drawings

Figure 1 shows a typical user situation where an apparatus according to the invention enables interactive manufacture of models at terminal work.

Figure 2 shows the device according to fig. 1 in perspective and partial in cross - section, so that the interior of the invention is shown.

Figure 3 shows a contact frame in perspective view having internal contact teeth and on a larger scale a portion of the frame where the contact teeth are shown.

Figure 4 shows a work piece in perspective view where three of

the outermost material discs have been separated from the work piece and from each other, in order to show the direction of the grid threads.

Figure 5 shows a portion of a material disc with surrounding electrode layers in perspective. A voltage source is symbolically connected between a grid thread on the upper side od the disc and a grid thread adjacent to the underside of the disc, at which a spark discharge through the crossing area of the grid threads has also been illustrated.

Figure 6 shows a spark discharge between two grid threads in the outermost disc of a piece of material. The crossing area is also shown on an enlarged scale in order to illustrate how the spark can cut undesired rests of grid threads.

Figure 7 a shows an alternative apparatus according to the invention in which the grid threads continuously can be removed from the piece of material through extraction after completed material treatment in every cross - section. The figure also shows both end portions of the grid threads on an enlarged scale.

Figure 7b shows a section through the enlarged, right end portion of fig. 7a, as seen in the direction of the arrow in fig. 7a.

Figure 8 shows how a cross - section S - S in an object is shaped in a material disc with its surrounding electrodes.

Figure 9 shows in perspective an apparatus with moveable treatment tool according to the invention.

Figure 10 is a side view of the device in fig. 9. The working station of the treatment tool is enlarged in order to show the details more clearly.

Figure 11 is a side view of a further apparatus with fixed electrode disc. The working station of the treatment tool is enlarged in order to show the details more clearly.

Figure 12 shows how a flatbed plotter can be provided with accessories which can treat discs according to the method of the invention.

Figure 13 is a side view of an apparatus according to the invention where a single - row spark electrode cam can be brought close to an untreated material disc with very high speed.

Figure 14 shows the apparatus according to fig. 13 from above.

Description of embodiments

On the drawings, which show embodiments of apparatuses for performing the method, the numerals denote:

1. A complete apparatus for manufacturing models according to the invention.
2. A terminal or working station connected to a CAD-computer or the like.
3. A model manufactured according to the invention.
4. A feed screw for propulsing the work piece through a contact frame.
5. A drive means for the feed screw.
6. A work piece material.
7. A control unit connected to a CAD-computer or the like.
8. A connection member, e.g. a cable, between control unit and contact teeth.
9. A frame with internal contact means for electric connection to grid threads, called contact frame.
11. A table for finished models.
13. A contact member called contact tooth.
16. A sheet -, path- or disc shaped section of material called material disc.
17. A grid thread.
18. A spark or arc.
19. A voltage- / current source.
20. An imaginary geometry in a material disc which is intended to be left after completed spark treatment .
21. A symbolically illustrated circuit breaker or other member which can form the intended circuit and which can be controlled by the control unit.
22. A thermal barrier layer.
23. A contact block for grid threads.
24. An insulating layer, e.g. a lacquer layer, surrounding a grid thread.
25. A hollow space caused by treatment where material has been removed, e.g. melted or evaporated from the material disc.
26. A connection means, e.g. a conical hole, for grid threads to the connection means of the control unit.

27. A segment of a material disc corresponding to the cross section in question of the object of which a model is intended to be manufactured.

28. A store of untreated disc - shaped material, e.g. a roll.

29. A servo- steered movable device for displacing the treatment tool in two independant directions parallel with the material disc and called X - Y servo.

30. A guide, e.g. a gear rack, for guiding and driving the X - Y servo.

31. A model, manufactured according to the invention, during manufacture.

32. An assembly plate for fixing, e.g. through vacuum, the first finished disc section of a model.

33. A drive - and guide means for translating movement of the uncompleted model, called stamp.

34. A base plate which is fixed with respect to the holding - on plate.

35. A cable for energy supply.

36. A treatment tool, e.g. a spark electrode or laser gun, called tool.

37. A plate called holding - on plate which does not actuate the treatment process.

38. A hollow space made in the material disc by the treatment-process.

39. A store for collecting material disc rests after finished treatment , e.g. a roll.

40. A cable for connecting the sliding contact and the current supply of the apparatus.

41. A sliding contact for galvanic contact to the foil layer of the material disc.

42. A spark electrode.

43. An electrical conductive layer, e.g. graphite or metal foil, called foil layer substantially covering one side of the whole material disc.

44. A logic and/or power supply unit, called drive circuit, which distributes the necessary voltages to the spark electrode in question, according to control data from the control unit.

45. A cable for serial communication and energy supply between

drive circuits and control unit and/or current supply unit.

46. A flatbed plotter.

47. A unit which supplies the treatment tool with the required energy.

48. A spring device which prestresses the store of unconnected material discs against gussets.

49. A store guiding untreated material discs.

50. A staple of untreated and unconnected material discs.

51. A servo- steered moveable device for displacing a single row spark electrode cam and e.g. a infra - red tube in i direction parallel with the material disc.

52. A gusset which positions an untreated material disc.

53. A heat radiating element, e.g. an infrared tube.

54. A wastage material surrounding a finished material disc.

55. A layer of thermally effectable joining agent, e.g. a melting glue.

56. A single - row spark electrode cam.

57. A means for treatment material.

58. A unit for joining treated material discs.

The method according to which the invention is applied enables different principles for the design and the function of the work piece material and the apparatus. According to one principle a good three-dimensional steerability of the treatment is enabled with a considerably smaller number of grid threads per material disc than the case would be if every single spark discharge spot was connected to separate conductors. Figs. 2,3,4,5, and 6 show apparatuses according to this principle.

The workpiece material, e.g. a block with bigger dimensions than the finished model 3, consists of a great number of sections 16 physically connected to the block or consisting of loose discs 16a and 16b, between which a great number of electrically conductive, thread - shaped and in their longitudinal direction parallel eletrodes 17, called grid threads, are electrically insulated from each other and applied in a grid - like pattern along the entire surface formed in the cross - section between each material disc 16. Each such electrode layer is besides

arranged transverse to adjacent electrode layers. The workpiece material 6 can thus in its longitudinal direction (according to fig. 4) be composed of electrode layers 17 with horizontal net threads 17, a material disc 16a, a electrode layer with vertical grid threads 17, a material disc 16b, a electrode layer with horizontal net threads 17, a material disc 16a etc. etc. A workpiece material 6 composed in this way shall be uniformly joined together and externally have flat limiting surfaces with dimensional accuracy. Each separate net thread 17 should at one end be terminated with, or in connection with, one of the outer limiting surfaces of the workpiece material.

Net threads 17, which encloses a separate material disc 16 in two crossing layers, form a bar pattern with a large number of crossing spots, defined by the crossing point of two transverse grid threads, as seen in the longitudinal direction of the workpiece material, and the material located therebetween, as seen in the cross direction of the workpiece material, see fig. 4.

By connecting a net thread 17 in each electrode layer on both sides of a material disc 16 in the workpiece material, to an appropriate voltage 19 short - circuits can cause a spark discharge with adherent arc 18 in the crossing area, between the connected electrodes. By adapting the current and the duration of this arc through the material disc 16, the material in the crossing area can be caused either to melt or evaporate. A hole through the material disc 16, in the crossing area, can in this way be provided, at which the supplied energy and its duration determines the size of the hole and its surface quality. More than one net thread 17 can simultaneously be connected, at which several spark discharges 18 can be provided at the same time.

By supplying electric energy sequentially in certain chosen net threads 17, desired patterns of holes can in this way be provided in the material discs 16. If the graduation of the net threads 17 are adapted to the size of the holes, the holes can overlap each other, at which spark discharges in adjacent crossing areas

form street - shaped hollow spaces. The conductivity of the material can also be adapted to cause the spark discharge to initially occur through an earlier created adjacent hole, at which the arc takes the shortest way through the material through the crossing area. The arc 18 can in this way "draw" a hole path between two adjacent crossing points.

Thus it is possible to melt or evaporate desired parts of the workpiece material 6 by supplying energy sequentially to appropriately chosen net threads 17. This is shown in fig. 8. By simultaneously connecting all net threads 17 which surrounds a separate material disc 16 and letting a control unit 7 connected to a CAD-system 2, sequentially convert all crossing areas representing hollow spaces or outer limiting surfaces, for a corresponding cross section S-S, in the detail constructed on the CAD system, to hollow spaces 25a in the material disc 16 in question, the invention can display the geometries of the physical detail in the cross section S-S in question. This method can be repeated sequentially by connecting all net threads, that surround the adjacent material disc, and via the control unit 7 make them to produce the next corresponding cross - section of the CAD-constructed detail. Undersired portions of the section can in this way be removed for each material disc, so that a complete three-dimensional model 3 of the detail can be manufactured. The control unit of the apparatus should also burn off material 25b in the workpiece material, so that the operator can separate rests of the workpiece material and expose the model.

The ability of the model 3 to reproduce the geometries of the CAD data base depends on the thickness of the material discs 16 and the relative graduation of the eletrodes 17. The workpiece material 6 can be compared with a three-dimensional grid die in which material can be evaporated or melted through a controlled spark discharge. The resolution of the net die thus gives the digital surface structure of the model.

An apparatus for performing this method could thus consist of a frame 9 in which thin pointed contact teeth 13 are internally arranged with the same graduation as the net threads. The frame

9 should with high accuracy surround the outer limiting surfaces of the workpiece material 6, at which the contact teeth 13 projecting from the frame are caused to penetrate into the workpiece material 6 to some degree. The contact teeth 13 are in this way brougth to galvanic contact with the grid threads 17 or sufficiently close, so that energy can be transferred with a controlled spark discharge. That means that the graduation of the net threads 17 at the outer limiting surfaces of the workpiece material 6 and the thickness of the contact teeth 13 must be adapted, so that all possible tolerance results of the position of the net threads 17 with respect to the contact teeth 13 guarantee an unambiguous coupling even if the teeth 13 are not in galvanic contact with the net threads 17.

The frame should further be provided with a feeding device 4 and 5 which with high accuracy can feed the workpiece materal 6 through the frame 9, so that the contact teeth are in unambiguous contact with the net threads 17 surrounding the material disc 16 in question. The feeding device 4 and 5 should, upon actuation by the control unit 7, press the workpiece material 6 through the frame 9 so that the connections of the contact teeth 13 shift to one electrode layer at a time. The workpiece material 6 can preferably be made with such a length in the longitudinal direction, so that several models can be manufactured from one and the same workpiece.

The apparatus 1 finally should include a way of removing or in some other way eliminate remaining net threads 17 from the model 3. This can be provided by evaporating or melting the net threads 17 concurrently with that they are consumed and no longer needed in the process. Fig. 3 illustrates a way of performing this. In this embodiment the net threads 17 should have essentially the same thermal properties as the rest of the workpiece material 6. The net threads 17 can in this case preferably consist of strings 17 with low resistivity in the material disc 16. This can be provided by injecting conductive particles, e.g. powdered carbon, in thin nozzles during the manufacture of the material disc, e.g. at extrusion. Another way is to join the material

discs 16 with a conductive glue with substantially the same thermal properties as the material discs.

It may be desired that the net threads 17 have a somewhat higher melting temperature than the surrounding workpiece material, in order to ensure that the conductivity of the net threads is maintained during the melting of the material disc 16 in the crossing area. Fig. 6 shows the sequence, according to the arrow P, at which suitable net threads 17b must be connected via the symbolically denoted circuit breakers 21a-21n in order to consume, i.e. burn away, the net threads 17 in a correct way.

If the temperature conducting properties of the untreated workpiece material 6 are not sufficient for cooling the grid threads 17a, so that these remain intact after completed burning of the net threads 17b, a thermal blocking layer 22, e.g. a crystalline glue with high melting point, can be applied in the dividing plane between each material disc 16. The blocking layer 22 ensures that the net threads only can be burnt from one side.

This connection direction P and this blocking layer 22 ensures that the net threads 17a remains uneffected until it is no longer needed in the process. Rests of the thermal blocking layer 22 will however remain, which preferably can have a very brittle mechanical strength. The layer 22 will therefore not alone be able to form a self-supporting structure in the areas of the workpiece material which have been evaporated or melted off, i.e. the layer 22 transforms to some kind of dust or powder, since this is not supported by material discs 16.

Another way of removing the grid threads is by burning off a certain amount of material at the outer limiting surfaces of the workpiece 6, so that the net threads 17 are exposed as projecting fringes, at which removal by means of rollers, arranged about the outlet opening of the workpiece are facilitated.

Another way is to make the net threads 17 of a thermally resistant but mechanically weak material, e.g. thin metal foil.

Thin single-fibre carbon threads have also shown appropriate properties, as they are easy to bend fatigue after completed model manufacture with e.g. ultrasonics or other excitating frequencies.

A further way of removing net threads 17 is thermal burning, at which every net thread 17 has to be in galvanic contact at both ends with a power supply circuit. The inner resistance of the threads will very rapidly cause a burning of the thread, which does not necessarily effect the surrounding material due to the big difference in mass and cooling effect.

Another way according to the invention is shown in fig. 7 where the longitudinal direction of the net threads parallel with the feeding direction of the workpiece material 6 out of the apparatus 1, and where end surfaces of the threads 17 located in the material block form electrode surfaces. This principle implies that the apparatus 1 can draw the net threads 17 out of the workpiece material in a controlled way. Each net thread 17 is electrically insulated from the environment with e.g. a lacquer layer. Both end surfaces of the threads 17 are however uninsulated. At one free end of the grid threads 17 there is by that created a point-shaped electrode surface within the workpiece material 6, which through relative movement between the thread 17 and the workpiece material 6 can be positioned anywhere in the workpiece material 6.

All grid threads 17 are at its other end attached to a contact block 23, which also allow galvanic connection of the grid threads via connection means 26 to a control unit 7. For each position of the free net thread ends within the workpiece material 6 it will thus be possible to provide a spark discharge 18 and by that generate hollow spaces 25. The device should thus step for step draw out the net threads through a relative movement between the contact block 23 and the workpiece material 6.

The advantage of the last mentioned apparatus is that the finished models directly are free from remaining net threads 17.

The disadvantage is that the number of net threads is considerably larger than required in the first mentioned principle.

According to another embodiment of the invention shown in fig. 9 the treatment tool 36 is movable in X - and Y - direction (arrows C and D) along a holding-on plate 37, which also is an electrode plate. Untreated material disc, e.g in the form of a continuous band 16 is fed stepwise from a roll 28 (arrow A) in a position behind the holding-on plate 37, as seen from the tool 36, and holds e.g by means of vacuum, the material disc 16 against the holding-on plate 37. The control unit, not shown, controls the tool 36 in the X- and Y - direction by means of a servo means 29 in a path 25 corresponding to e.g. the outlines of the cross section in question of the object, by means of data from the CAD-system. The tool 36 is then capable of either separating material e.g. through melting or evaporation, or joining material together, e.g. through thermal curing and/or sintering, to a disc section, not shown in fig. 9, which in all essential details reproduces the shape in question of the object.

After finished treatment , the stamp 32 with the unfinished model 31, is brought to contact with the finished disc section (arrow B). Thus this finished disc section will be pressed between the outermost and last mounted disc section of the model 31 and the holding-on plate 37. By e.g. supplying heat from the holding-on plate 37 with built-in resistance heating, a melting glue on the latest finished disc section can join said disc section with the earlier produced staple of disc sections 31.

Thus it is possible, according to this method, to treat and join together a model disc after disc, said model digitally reproduces the geometries of the CAD-data base. After completed joining the finished model can be released from the apparatus e.g. by interrupting a vacuum suction between the model and the assembly plate 32.

These different solutions of transporting the material discs 16, rest products 39 and model 31 allow different kinds of treatment.

Only a few embodiments are shown in the drawings

Fig. 10 shows treatment of the sections 16 by means of an arc 18 caused by a spark-over between a spark electrode 42 in the tool 36 and an electrically conductive foil layer 43 on the backside of the material disc 16. The holding-on plate 37 should then have an optimated electrical and thermal resistance, so that the arc 18 is not disturbed or in any other way is effected negatively. The supplied energy in the arc 18 and the movement speed of the servo means 29 will then effect the geometry of the treated hollow space 25.

A sliding contact 41 connected to e.g. electrical earth via the cable 40 enables the creation of an electrically closed system between the foil layer 43 and the spark electrode 42.

The tool 36 could also be an energy-radiating means, e.g. a laser gun which emits a well focused beam. The energy of the beam must then be adapted so that a suitable hollow space 25 can be provided through melting or evaporation. The holding-on plate 37 should then be made of a material which is permeable for the laser beam and which has a sufficient thermal resistance, e.g. quartz glass.

Another apparatus for thermal treatment of the material discs is shown in fig. 11. In this embodiment the servo means has been replaced with an electrode die which is fixed with respect to the material disc, or a grid of conductive rods 42, e.g. spark electrodes, which can be sequentially connected with control data from the control unit, not shown, in the cable 45 via series/-parallel converting drive circuits 44. In this embodiment a holder - on plate 37 or a foil layer 43 makes the counter electrode.

A further embodiment is shown in fig. 12 where a simple accessories makes it possible to use a common standard flatbed plotter 46 as converting machine according to the invention. In this embodiment the pen in the holder of the plotter 46 is

replaced by a treatment tool 36. This tool can e.g. be a spark electrode from which an arc passes to a counter electrode in the form of a fixed plate or an electrically conductive foil.

The embodiment of figs. 13 and 14 are based on a linearly displaceably cam of spark electrodes 56. This can with high speed be led by the servo device 51 immediately above the surface of an untreated material disc. 16. Every material disc 16, which is not joined with any other material disc before its treatment , is provided with a conductive layer 43 and a thermally effectable layer of e.g. a melting glue 55 on the side of the material disc which faces away from the spark elctrodes 42. These layers 43 and 55 can preferably be integrated in one and the same layer, e.g. a conductive layer of melting glue.

While the servo unit 51 leads the elctrode cam 56 forwards the control unit (not shown) connect the spark electrodes 42 in question, according to the geometry of the cross section in question, so that arcs 18 occur between the activated spark electrodes 42 and the conductive layer 42, which is connected by way of a suitable earth means (not shown). It is in this way possible at a very high speed to permanently remove the material sections 25 of the material disc 16 that is desired. The device can in this way treat one disc per sweep of the servo device 51.

Thes first disc treated in this way of each new model can after completed treatment and transport by the electrode cam 56 to a position aside, be gripped by an oscillating assembly plate 32 by e.g. vacuum forces. The finished material disc can then be pulled loose from the store 49 out of four gussets 52. When the assembly plate 32 and the material disc held thereon have returned to their initial position the servo 51 can be restarted and drive the electrode cam 56 over the next material disc, which by the spring device 48 has been pressed in position against the four gussets 52, when the previous disc was pulled loose. The treatment can then be repeated. A heat-radiating unit 53 mounted on the servo device 51 will simultaneously with the

treatment or separately heat a melting glue 55 applied on the backside of the previously treated disc.

When the treatment of the disc no. 2 is completed also the glue of disc no. 1 will be melted and ready for joining with disc no. 2. This is made through the fact that the assembly plate again performs an oscillating movement, so that disc no. 1 will be pressed long enough against the disc no. 2 for the melting glue to join the discs together. When the assembly plate returns to its initial position disc no. 2 will be pulled loose from the four gussets 52.

The device according to figs. 13 and 14 can after that at a very high speed repeat this sequence, at which a new material disc 16 is supplied to the model 31 for each sweep with the electrode cam 56 and the assembly plate 32. When the model is completed the vacuum force between the model and the assembly plate can be discontinued, at which the finished model and the surrounding waste material 54 can be released from the device.

When using this and other embodiments described herein, where the surrounding waste material 54 comes along with the finished model 31, the operator must manually remove the surrounding waste material 54, which preferably is lightly attached to the model in smaller material sections placed by the control unit of the apparatus.

The invention is not limited to the examples of treatment-processes and apparatuses described here, but a plurality of variants and combinations are possible within the scope of the invention.

Thus it is possible, within the scope of the invention, to make apparatuses with fixed needle-shaped electrodes, instead of grid thread provided workpiece material, said needle electrodes penetrate into the work piece materials and by that enable partial evaporation or melting. It is also possible to provide workpiece materials of easily fusible homogeneous or sintered metal alloys.

It is also possible to use ceramic materials in cases where the treatment can be provided through decomposition of the material through concentrated mechanical oscillation energy, e.g. focused ultrasonics.

This method can very rapidly and without human intervention manufacture three-dimensional models and objects with dimensional accuracy in an apparatus or machine, which can be placed in a common office environment. It should be possible to market the equipment and the material disc to a relatively low cost and the method should therefore give the opportunity to many constructors, designers and architects to have a direct access to the invention at their work place.

Claims

1. A method for producing three-dimensional objects by using a converting machine controlled by computer instructions, at which the material comprises a number of sheet - or disc - shaped sections (16) defined in size, which are treated in accordance with given computer instructions, so that parts of material are permanently removed, and the sections treated in this way are connected to each other layer by layer in a programmed sequence forming said three-dimensional object (3),
c h a r a c t e r i z e d i n,
that on each flat side of the respective section (16) there is placed at least one electrode (17a, 17b;42,43), and that an electric voltage, sufficient for causing spark - over between the electrodes is impressed upon these, so that parts or particles of material located substantially opposed to the electrodes are removed from or connected to the respective section (16).

2. A method as claimed in claim 1,
c h a r a c t e r i z e d i n,
that material particles in the respective section (16) chosen at their position by means of computer instructions are removed preferably by being annihilated or melted by influence of concentrated heat energy.

3. A method as claimed in claim 1,
c h a r a c t e r i z e d i n,
that material particles in the respective section (16) chosen at their position by means of computer instructions are connected to each other by influence of concentrated heat energy, and that the rest of the material particles are removed by dissolution of a binding agent which provisionally holds the particles together.

4. An apparatus for performing the method according to claim 1 for producing three-dimensional objects (3) by means of a converting machine (1), which is controllable by computer instructions at which the material which consists of a number of sheet - or disc - shaped sections (16) is arranged to be exerted

to a material cutting or material connecting treatment in said converting machine in accordance with given computer instructions, and said treated sections are arranged to be brought together and integrated with each other in a programmed sequence,
c h a r a c t e r i z e d i n,
that on each flat side of the respective section (16) there is placeable or placed at least one electrode (17a,17b;42,43) and that the electrodes in accordance with given computer instructions are connectable to an electric voltage source (19), which is sufficient for providing a spark - over between the electrodes, so that parts or particles of material are removed from or connected with the respective section (16).

5. An apparatus as claimed in claim 4,
c h a r a c t e r i z e d i n,
that the converting machine (1) comprises at least one means (57) in the form of at least of two electrodes (17a,17b;42,43) on each side of the section (16) for annihilation of material particles in the section (16), said means and/or said section is controllable in the X - and/or Y - direction of the section plane by means of computer instructions.

6. An apparatus as claimed in claim 5,
c h a r a c t e r i z e d i n,
that said means (57) comprises at least one electrode, e.g. a spark electrode (36), which is moveable over substantially the entire section surface, on one side of the section (16) and an electrode plate, - roll or - foil extending over substantially the entire section surface, on its opposite side.

7. An apparatus as claimed in claim 4,
c h a r a c t e r i z e d i n,
that said means (57) comprises two net - shaped electrode dies (17a, 17b), the net threads (17) of which in one die are arranged at an angle to the net threads of the other die, that the sections is arranged to be placed between two electrode dies, and that the net threads (17) are selecting, galvanically connectable to a voltage source via a control unit (7).

8. An apparatus as claimed in claim 4,
c h a r a c t e r i z e d i n,
that said means (57) comprises at least one bar (42) extending over substantially the entire section and provided with a number of electrode rods (42a) placed in at least one row along the bar, on one side of the section and at least one electrode plate (43), electrode roll, electrode foil or the like on the other side.

9. A device as claimed in claim 7,
c h a r a c t e r i z e d i n,
that the material consists of a block (6), which comprises a number of sections (16) separated from each other by means of net - shaped electrodes (17).

10. An apparatus as claimed in claim 9,
c h a r a c t e r i z e d i n,
that all net threads (17) that are electrically insulated with respect to the environment are connected to a contact block (23) designed as a pull - out means, that the end surfaces of the net threads are uninsulated and designed as electrode surfaces within the material block (6) and that the working through spark discharge between two adjacent electrode end surfaces is intended to take place while pulling out the net threads from the block.

11. An apparatus as claimed in claim 4, said apparatus comprising or being connected to resp. a unit (58) for mechanical or manual joining of the sections (16) in a programmed sequence, after treatment in the converting machine,
c h a r a c t e r i z e d i n,
that the sections (16) on one flat side are covered with an adhesive glue, said glue layer during the treatment being protected by an electrically conductive foil serving as electrode die.

12. A material for producing three-dimensional objects of an essentially homogeneous material by means of a converting machine (1), which is controllable by means of computer instructions, at which the material, which consists of a number of sheet - or disc

- shaped sections (16) is arranged to be exerted to a material cutting or material connecting treatment in said converting machine in accordance with given computer instructions, end said sections treated in this way are arranged to be connected to and integrated with each other in a programmed sequence, according to the method of claim 1 and the apparatus according to claim 4,
c h a r a c t e r i z e d i n,
that the material, which is divided in a number of sheet -, path - or disc - shaped sections (16) resp. are in the form of at least one block, which is divided into a number of sections (16), consists of a cellular -, particle - and/or fibre structure.

13. A material as claimed in claim 12,
c h a r a c t e r i z e d i n,
that the cellular structure of the material consists of a framed plastic material preferably polystyrene.

14. A material according to claim 12,
c h a r a c t e r i z e d i n,
that the plastic material contains electrically conductive addihives, which gives the material an eletric breakdown resistance, which is bigger than or approximately equal to the breakdown resistance of the ambient madium, which e.g. is air.

15. A material according to claim 14,
c h a r a c t e r i z e d i n,
that the filler material consists of or contains < 20 % powdered carbon.

16. A material as claimed in claim 12,
c h a r a c t e r i z e d i n,
that the particle structure of the material consists of loosely joined particles, which at the treatment in the converting machine are permanently connectable to each other, while untreated particles, preferably by means of a solvent or a solution procedure (e.g. ultrasonics), are disconnectable from the permanently connected particles.

17. A material as claimed in claim 12,
c h a r a c t e r i z e d i n,
that the fibre structure of the material consists of a paper-fibre mass.

18. A material as claimed in claim 12,
c h a r a c t e r i z e d i n,
that the material contains at least one substance which forms or sets free a gas for the treatment.

19. A material as claimed in claim 12,
c h a r a c t e r i z e d i n,
that the material at least on one flat side is covered with a reactivateable glue.

20. A material as claimed in claim 19,
c h a r a c t e r i z e d i n,
that the glue is provided with electrically conductive additives.

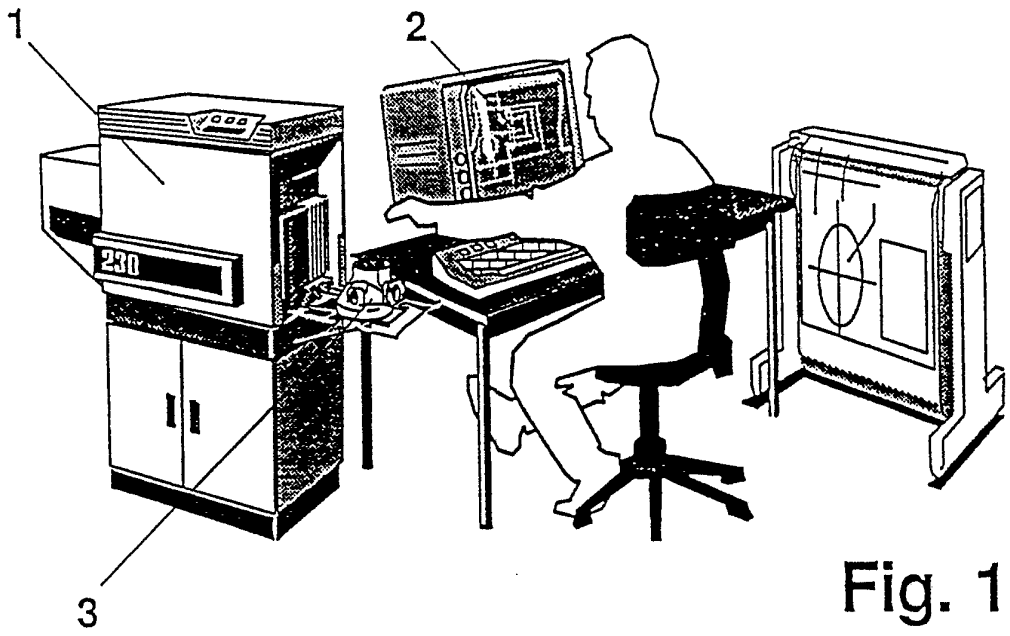

Fig. 1

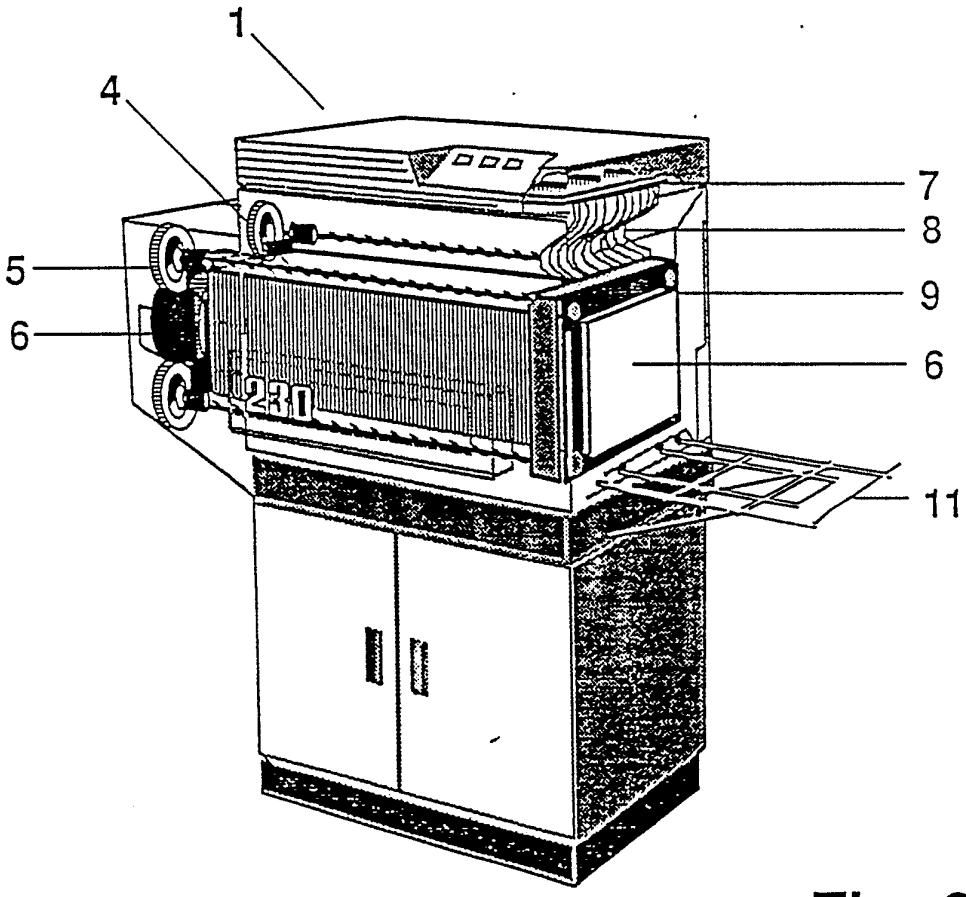

Fig. 2

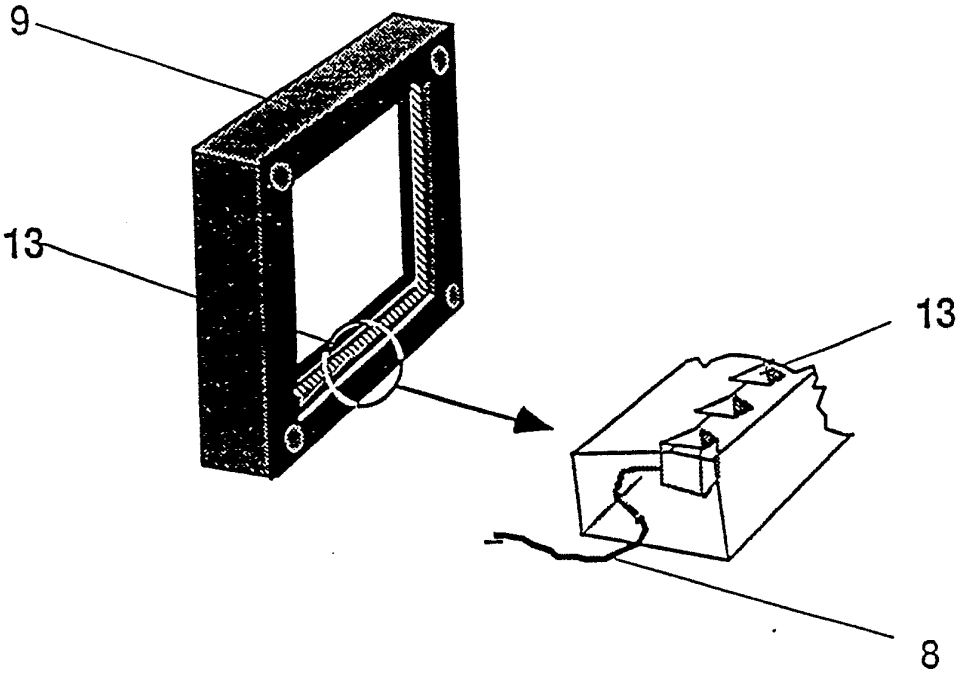

Fig. 3

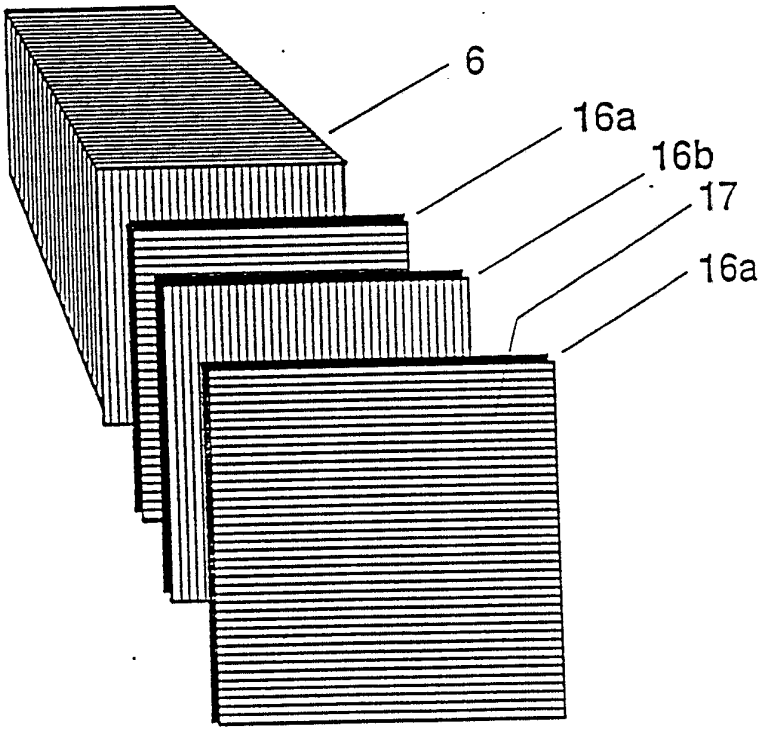

Fig. 4

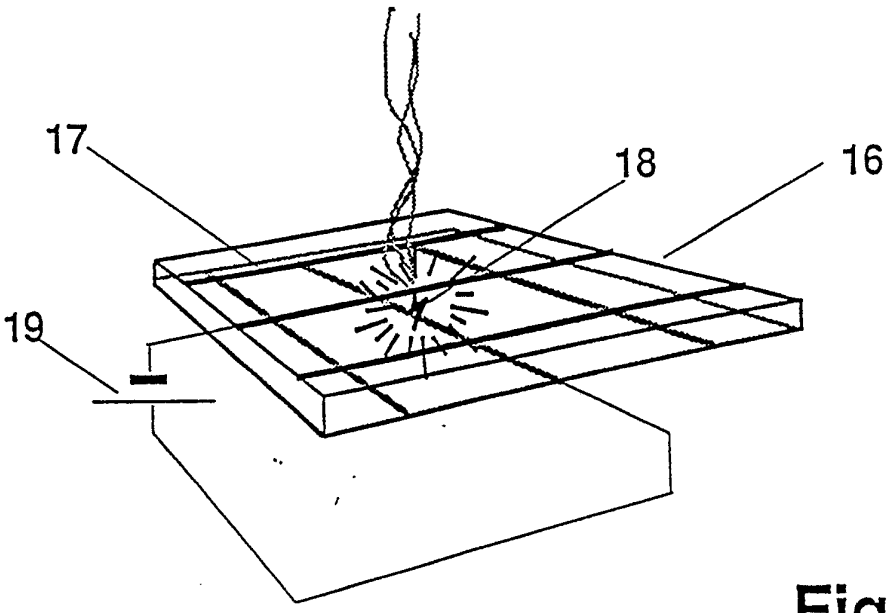
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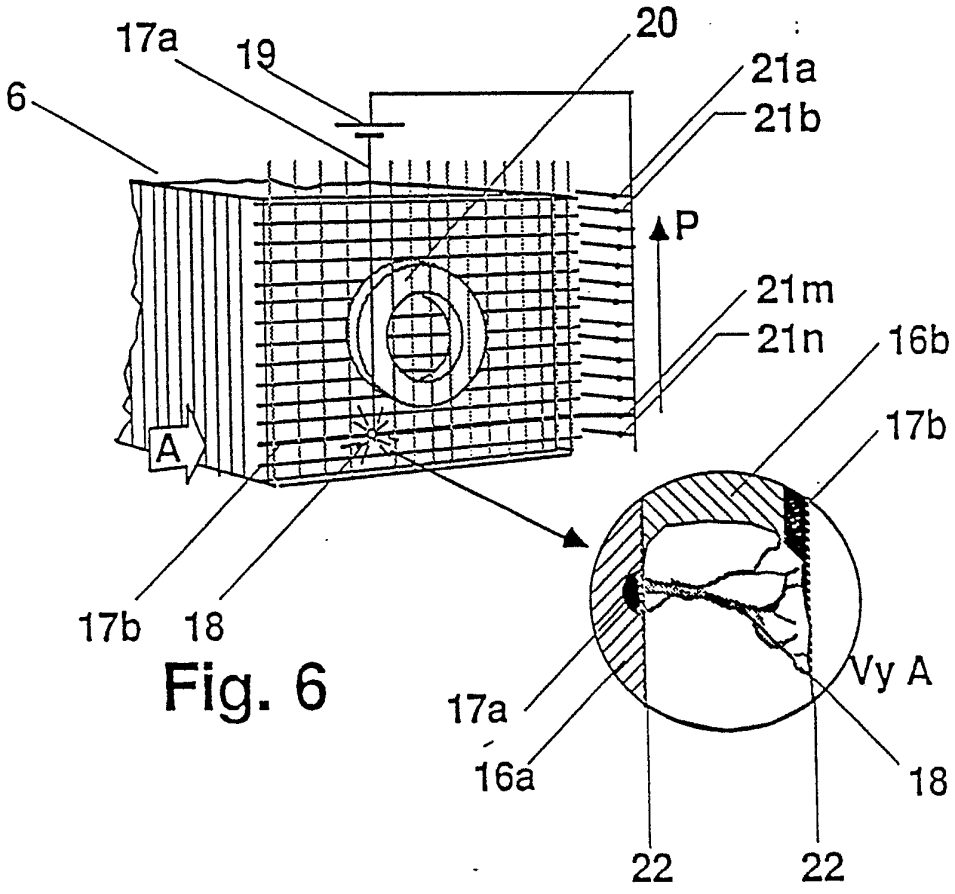
Fig. 5


17a
19
20
6
21a
21b
P
21m
21n
16b
17b
A
17b
18
17a
16a
Vy A
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22
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Fig. 6

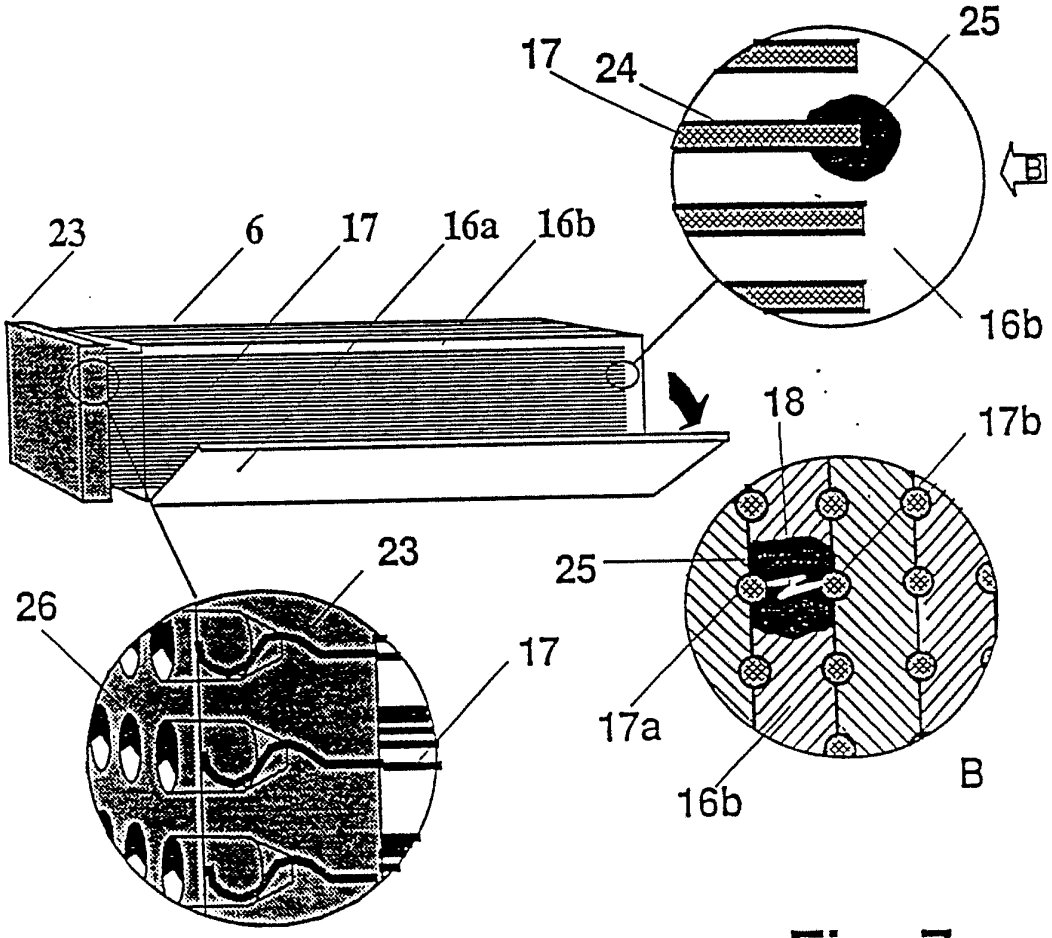


Fig. 7

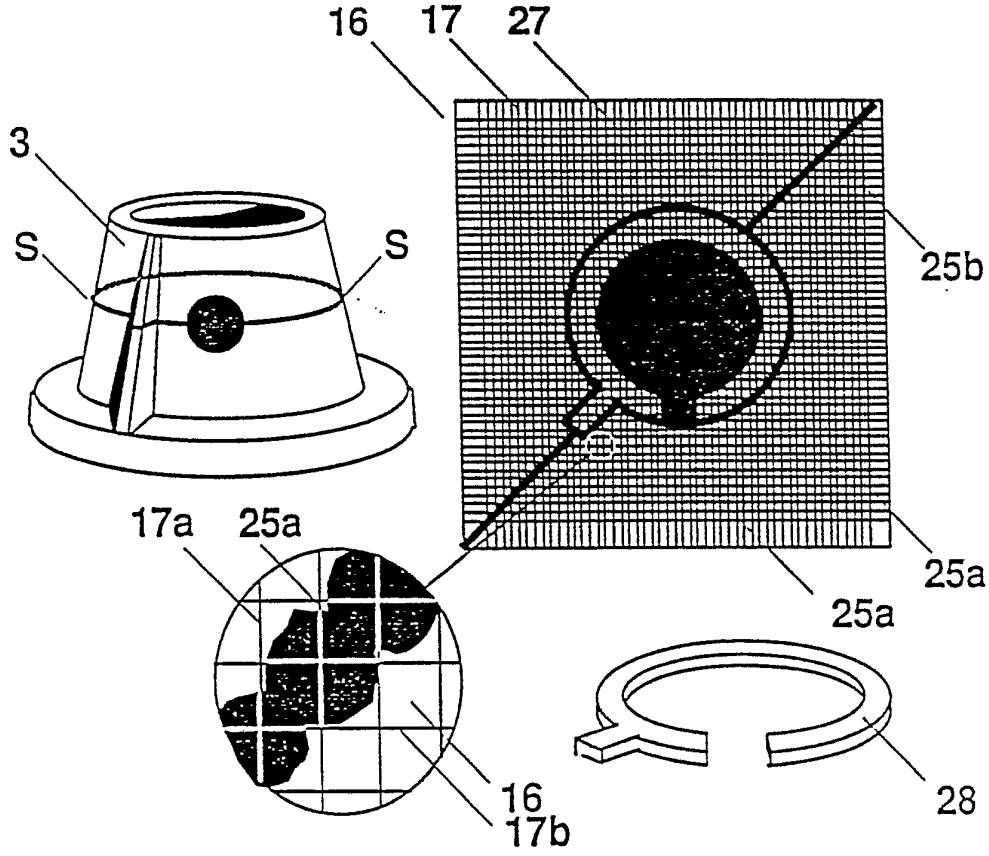
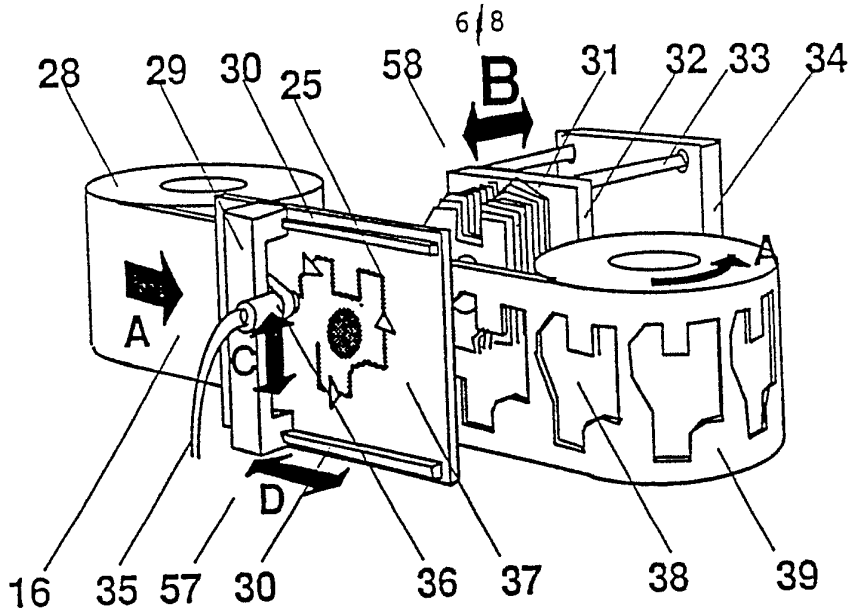


Fig. 8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C
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FIG. 9

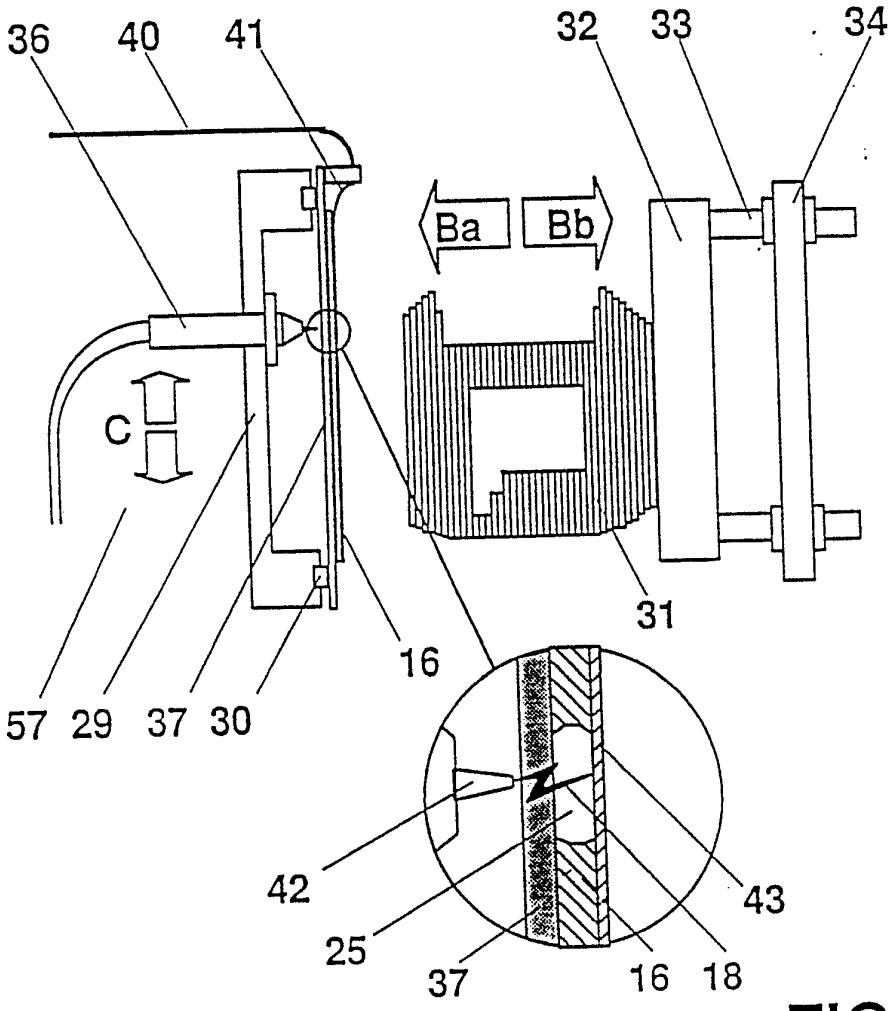
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FIG. 10

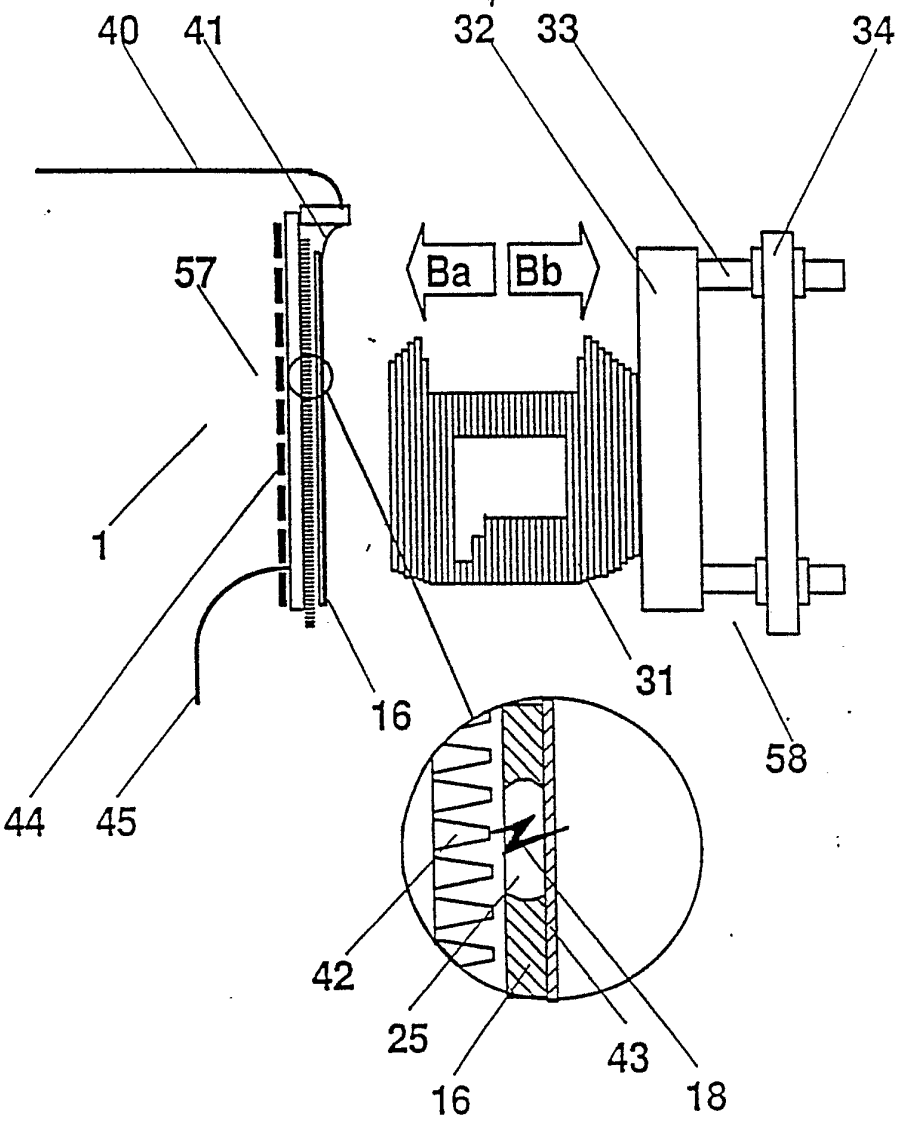

FIG. 11

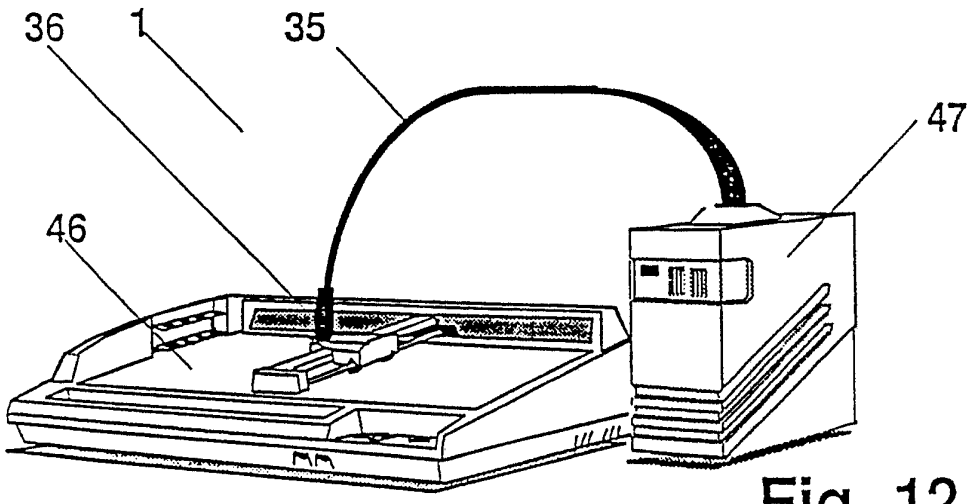

Fig. 12

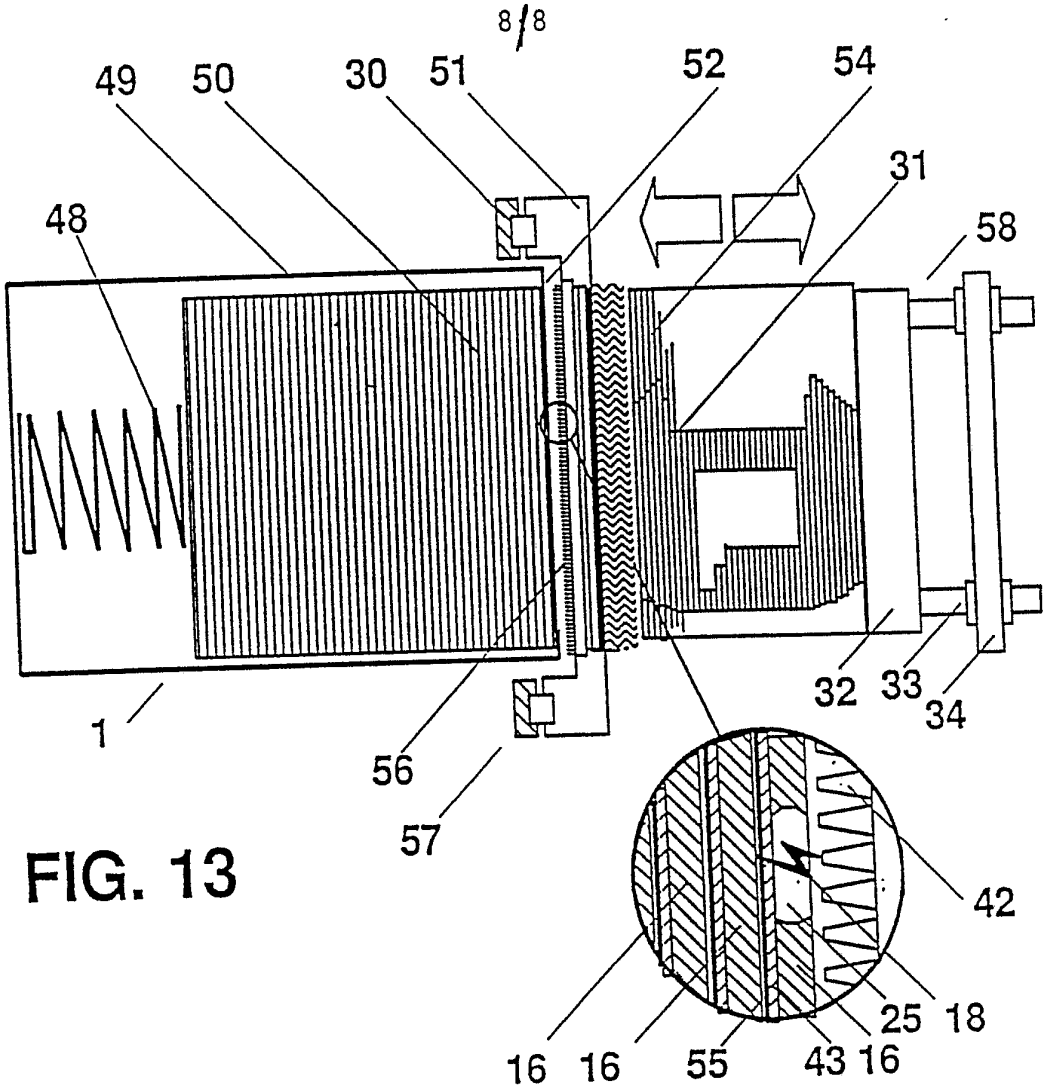
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FIG. 13

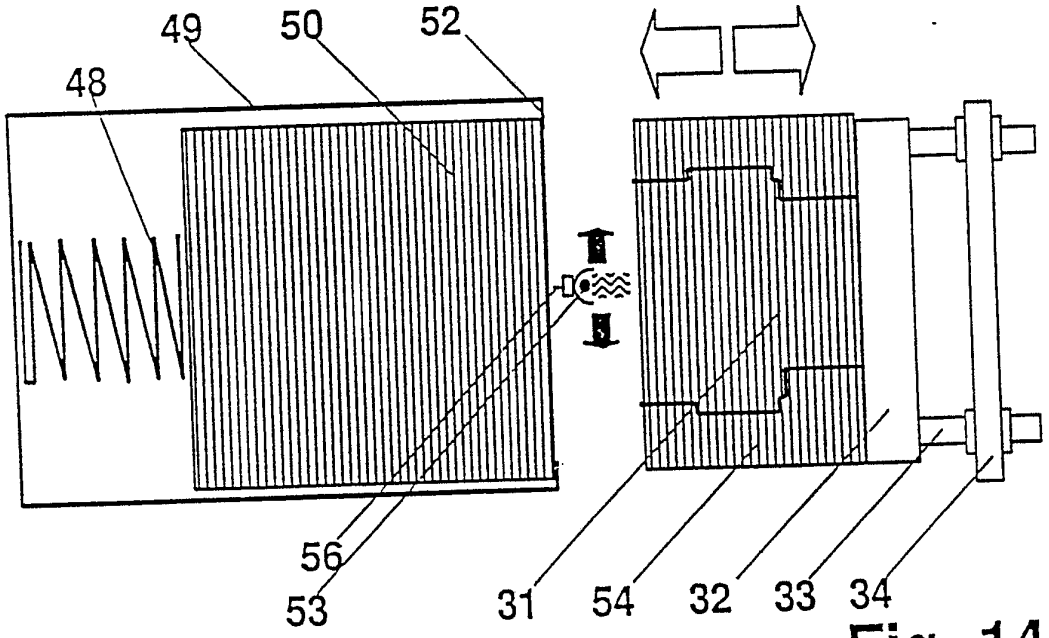
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Fig. 14

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE89/00437

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

G 03 C 9/08, B 23 Q 35/00 // B 44 B 1/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	G 03 C; G 09 B; B 44 B; B 23 Q; B 29 C; G 05 B; B 23 H; B 26 D; B 26 F; B 23 K
US Cl	29; 364

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	US, A, 4 041 476 (WYN KELLY SWAINSON) 9 August 1977 see column 2, lines 10-24	1-3
A,D	US, A, 4 752 352 (MICHAEL FEYGIN) 21 June 1988 see column 2, line 37 – column 5, line 9 column 6, lines 56-57, figure 7	1-6
A	EP, A2, 0 171 069 (UPV, INC.) 12 February 1986 see page 3, lines 12-30, page 4, lines 13-24, page 5, lines 6-30	1-3, 4, 11
A,P	EP, A2, 0 290 016 (HOECHST AKTIENGESELLSCHAFT) 9 November 1988 see column 2, line 16 – column 3, line 11	1-3
A	EP, A2, 0 250 121 (SCITEX CORPORATION LTD.) 23 December 1987 see column 21, line 51 – column 22, line 4	1-3, 4, 11

* Special categories of cited documents: [10]

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

"E" earlier document 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

"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

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1989-10-24	1989 -10- 31
International Searching Authority	Signature of Authorized Officer
Swedish Patent Office	Bengt Christensson

Form PCT/ISA/210 (second sheet) (January 1985)