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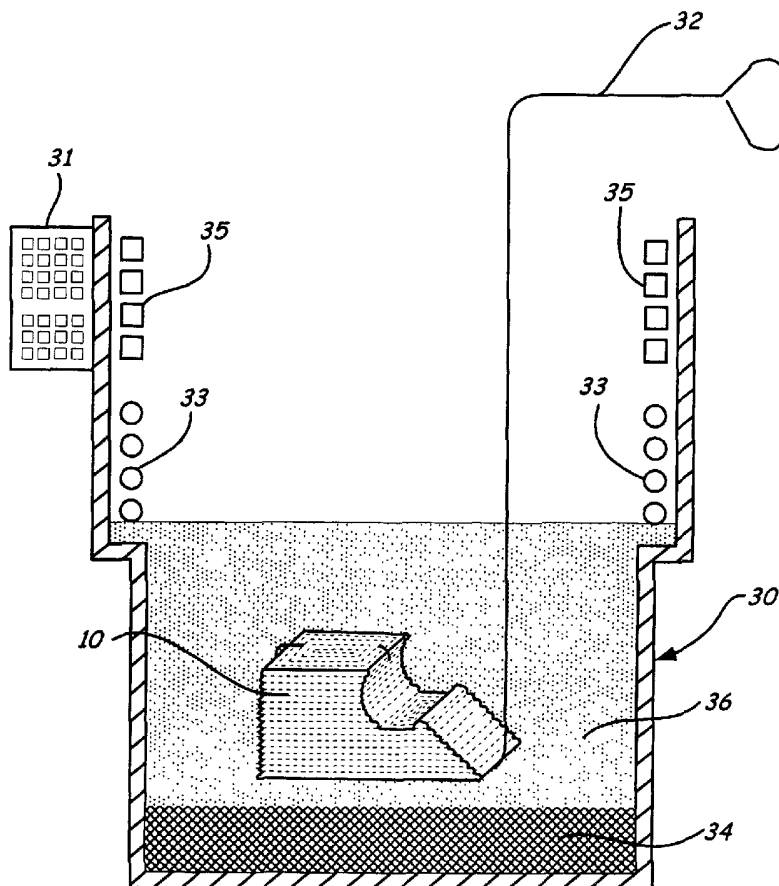
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[Continued on next page]

(54) Title: SMOOTHING METHOD FOR LAYERED DEPOSITION MODELING

(57) Abstract: Disclosed is a method for smoothing the surface of an object built from a polymeric or wax material using a layered manufacturing rapid prototyping technique. After the object is built it is exposed to a vaporized solvent such as in a vaporizer for an exposure time sufficient to reflow the object surface. A solvent is chosen based on its ability to transiently soften the material which forms the object, and thereafter evaporate off the object. The object is removed from the solvent and allowed to dry, producing a smooth finished part.

European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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SMOOTHING METHOD FOR LAYERED DEPOSITION MODELING

BACKGROUND OF THE INVENTION

The present invention relates to the field of rapid prototyping, and particularly to methods of achieving surface smoothness in prototype objects made by layered manufacturing.

Production and testing of prototype objects is a commonly used step in developing new products, machines and processes in a wide range of industries. A variety of layered manufacturing methods for forming three-dimensional prototypes are known, which develop prototype objects cheaply and quickly from a geometric computer model under computer control. These rapid prototyping methods generally slice or divide a digital representation of a desired object (computer aided design (CAD)) into horizontal layers, then build the object layer-by-layer by repetitive application of materials. Exemplary rapid prototyping techniques include layered deposition modeling, selective laser sintering and stereolithographic processes.

One example of layered deposition modeling is a fused deposition modeling technique performed by Stratasys® FDM® modeling machines. Fused deposition modeling builds up three-dimensional objects by extruding solidifiable modeling material from an extrusion head in a predetermined pattern, layer-by-layer, based upon design data corresponding to the particular shape of each object layer. Examples of extrusion-based apparatus and methods for making three-dimensional objects are described in Crump U.S. Patent No. 5,121,329, Crump U.S. Patent No. 5,340,433, Danforth et al. U.S. Patent No. 5,738,817, Batchelder et al. U.S. Patent No. 5,764,521 and Dahlin et al. U.S. Patent No. 6,022,207, all of which are assigned to Stratasys, Inc., the assignee of the present invention.

In the Stratasys® FDM® modeling machines of the current art, modeling material is typically loaded into the machine as a flexible filament wound on a supply reel, such as disclosed in U.S. Patent No. 5,121,329. A solidifiable material which adheres to the previous layer with an adequate

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bond upon solidification and which can be supplied as a flexible filament is used as the modeling material. Motor-driven feed rollers advance the strand of filament into a liquifier carried by an extrusion head. Inside the liquifier, the filament is heated to a flowable temperature. Flowable modeling

5   material is forced out of a nozzle on the far end of the liquifier, and deposited from the liquifier onto a base. The flow rate of the material extruded from the nozzle is a function of the rate at which the filament is advanced to the extrusion head. A controller controls movement of the extrusion head in a horizontal x, y plane, controls movement of the base in

10   a vertical z-direction, and controls the rate at which the feed rollers advance filament. By controlling these processing variables in synchrony, the modeling material is deposited in "beads" layer-by-layer along tool paths defined from the CAD model. The material being extruded fuses to previously deposited material and solidifies to form a three-dimensional

15   object resembling the CAD model.

The surfaces of objects developed from layered manufacturing techniques of the current art are textured or striated due to their layered formation. Curved and angled surfaces generally have a "stair step" appearance, caused by layering of cross-sectional shapes which have

20   square edge profiles. The stair-stepping effect is more pronounced as layer thickness increases. Although the stair-stepping does not effect the strength of the object, it does detract aesthetically.

Surface roughness of objects created by layered manufacturing techniques also arises from errors in the build process. For

25   example, in the fused deposition modeling systems of the current art, errors can arise due in part to inconsistent extrusion flow rates. Errors particularly occur at start points and end points of the tool path, for instance, at the location of a "seam" (i.e., the start and end point of a closed-loop tool path). These errors can cause undesired inconsistencies in the shape of the

30   resulting model.

Rapid prototyping of three-dimensional objects includes not only the production of prototype parts, but also may include the production

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of molds. Exemplary uses of molds created with rapid prototyping include forming molds used to create injection molding tool inserts such as described in U.S. Patent No. 5,189,781, and forming fugitive molds for green ceramic pieces prior to sintering such as described in U.S. Patent 5,824,250

5   and U.S. Patent 5,976,457.

The current art teaches manually trimming, machining or grinding objects formed by layered manufacturing to remove excess material. Buffing with cloths, sand paper or solution-born abrasives are current methods of smoothing or polishing the objects. For example, Hull et

10   al. U.S. Patent 5,059,359, Methods and Apparatus for Producing Three-dimensional Objects by Stereolithography, describes their prototypes as "perfect for smoothing by sanding to yield the right-sized part". The need for hand-finishing of models made from additive process techniques is also recognized in U.S. Patent No. 6,021,358, which utilizes subtractive modeling

15   techniques to attain smooth models. There is a need in rapid prototyping systems of an expedient and relatively inexpensive method of post-processing layered manufacturing prototype objects.

A previously developed technique used in manufacturing of plastics involves the use of chemical vapors or liquids to smooth by reflowing

20   the surface of the plastic, termed solvent polishing. Solvent polishing was developed in the plastics industry over twenty years ago for the purpose of developing a smooth level and/or high gloss coating or surface without needing to exercise extreme care in the application or manufacturing of the items. For example, U.S. Patent No. 3,437,727 discloses a method using

25   chemical vapors for refinishing telephones that were returned to the telephone company as a method of recycling them.

There are two standard methods for solvent polishing articles. The first is to immerse the entire plastic article in a bath of liquid plastic solvent for a period of time based on the solvent and type of plastic involved.

30   This allows the solvent to penetrate the outer layer of the plastic, thereby causing it to reflow. Reflowing causes the outer surfaces of the plastic article to become smooth and/or shiny.

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The second method of solvent polishing is the exposure of the plastic article to vaporized solvent. A handheld vaporizer as shown in U.S. Patent No. 4,260,873 may be used to expose the plastic object. Alternatively, the object can be placed into a chamber filled with a vaporized
5   solvent, generated from a heated bath below, as in U.S. Patent No. 3,737,499. An advantage of the vaporizing chamber is that the solvent is contained and can be recycled, thereby minimizing potential environmental pollution.

The use of hot solvent vapors to melt or plasticize the surface
10   of the substrate has been used in the circuit board manufacturing area to facilitate the transfer of printed circuits, as disclosed, for example, in U.S. Patent No. 4,976,813. Another example is disclosed in U.S. Patent No. 4,594,311, where solvent vapor is used to treat the non-imaged areas of the plastic base material which holds a printed circuit board in order to further
15   enhance the printed pattern and secure it more strongly to the surface. In U.S. Patent No. 5,045,141, a substrate, typically a circuit board, may be treated to facilitate transfer of the printed circuit to it.

Solvent polishing using liquid or vapors is also commonly used as a degreasing or cleaning step in manufacturing processes, especially
20   prior to painting.

Despite the need in rapid prototyping for an expedient and inexpensive surface finishing technique, Applicant is unaware of any teaching or suggestion in the prior art to use a vapor polishing technique for the smoothing of objects formed by layered manufacturing rapid prototyping
25   techniques.

BRIEF SUMMARY OF THE INVENTION

The present invention is a method for smoothing the surface of an object built from a polymeric or wax material using a layered manufacturing rapid prototyping technique. After the object is built, it is
30   exposed to a vaporized solvent for an exposure time sufficient to reflow the object surface. A solvent is chosen based on its ability to transiently soften the material which forms the object, and thereafter evaporate off the object.

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The object is removed from the solvent and allowed to dry, producing a smooth finished part. Optionally, portions of the object surface may be masked prior to exposing the object to solvent, so as to preserve fine details of the object. Alternatively, portions of the object surface may be pre-

5   distorted prior to exposing the object to solvent, so that said surface portions will attain a desired geometry following vapor smoothing.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective, magnified view illustrating a raw object formed by a layered manufacturing rapid prototyping technique.

10   Figure 2 is a perspective, magnified view of the object shown in FIG. 1, after undergoing vapor smoothing.

Figure 3 is a diagrammatic view illustrating the process of vapor smoothing an object in accordance with the present invention.

Figure 4a is a cross-sectional detailed view of a portion of a

15   raw object formed by fused deposition modeling.

Figure 4b shows the object cross-section of FIG. 4a after vapor smoothing.

Figure 5a is a cross-sectional detailed view of the object portion shown in FIG. 4a, wherein the object geometry has been pre-

20   distorted in anticipation of vapor smoothing.

Figure 5b shows the object cross-section of FIG. 5a after vapor smoothing.

DETAILED DESCRIPTION

The method of the present invention may be employed with

25   respect to objects formed from a polymeric or wax material using layered manufacturing rapid prototyping techniques.   An exemplary layered manufacturing technique is the type disclosed in U.S. Patent No. 5,121,329, wherein an extrusion head deposits "roads" of molten material in layers of predetermined shape, and which material solidifies upon a drop in

30   temperature to form a solid model.

Figure 1 shows an exemplary object 10, formed by a layered manufacturing rapid prototyping technique. The object 10 has an angled

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surface 12, a curved surface 14, two horizontal surfaces 16, and three vertical surfaces 18. In another embodiment, the object may be a mold tool for use in making prototype plastic injection molded parts, such as is disclosed in International Application No. PCT/US03/_____ entitled

5   "Layered Deposition Bridge Tooling", S. Crump and J. Hanson, filed on even date herewith and assigned to the same assignee as the present application. The object 10 is made of a polymeric or wax modeling material, which may also include fillers and other additives as well as dispersed particulate materials. Amorphous thermoplastics are particularly suited for

10   use in the present invention, for instance, ABS, polycarbonate, polyphenylsulfone, polysulfone, polystyrene, polyphenylene ether, amorphous polyamides, acrylics, poly(2-ethyl-2-oxazoline), and blends thereof. The present invention may also be used to advantage with other polymeric and wax materials, including glass-filled nylon, jetting wax,

15   sintered thermal plastic powders, and green metals or green ceramics dispersed in a polymeric binder.

As shown in FIG. 1, the object 10 is "raw", that is, it has not undergone post-process smoothing. Prior to vapor smoothing in accordance with the present invention, surfaces 12 and 14 exhibit a stair-stepping effect.

20   Surfaces 16 and 18 exhibit striation and roughness.

To smooth the surfaces of object 10, the object 10 is placed in a vaporizer 30, where it is exposed to vapors of a solvent 34. This is illustrated in FIG. 3. A suitable vaporizer is of the type available from Detrex Corp. of Southfield, Michigan, model VS-2000, although those skilled in the

25   art will recognize that many alternative vaporizers can be used in practicing the present invention. Vaporizer 30 is shown as having a control panel 31 for controlling operation of the vaporizer, and primary and secondary cooling coils, 33 and 35, respectively.

The solvent 34 is selected to be compatible with the modeling

30   material which forms the object 10. Suitable solvents will react with the modeling material so as to soften and flow the material at the object surfaces. The solvent should also be able to vaporize off the surface of the

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object, leaving the object intact and unscathed. A preferred solvent for use with a wide range of amorphous thermoplastics is methylene chloride. Other suitable solvents will be recognized by those skilled in the art, for instance, an n-Propyl bromide solution (e.g., Abzol®), perchloroethylene,

5   trichloroethylene, and a hydrofluorocarbon fluid sold under the name Vertrel®.

As illustrated in FIG. 3, the vaporizer 30 boils the solvent 34 into a vapor zone 36, which is maintained at or above the boiling point of the solvent and contained by the cooling coils 33 and 35. The object 10 is

10   suspended in the vapor zone 36, held by a wire skewer 32, which is bent to fit around the object. Alternative holding means may also be used, such as a basket, a net or a mesh platform. The object 10 is exposed to the vaporized solvent 34, allowing vapors of the solvent 34 to penetrate the surfaces 12, 14, 16 and 18 of object 10. Penetration of the solvent 34

15   softens the modeling material at the object surfaces, so that the surface material may reflow. Reflowing of the material smooths the object surfaces.

The object 10 remains exposed to the vapors of solvent 34 until a desired surface finish is obtained. An exposure time is selected based on the type of solvent and modeling material, the fineness of the

20   object features, and the concentration of the solvent vapors. The exposure time can be gauged by observing condensation of solvent vapors on the object, or can be pre-selected according to a formula. Condensation will stop when the temperature of the object surface reaches the temperature of the boiling solvent. This is an indication that solvent penetration has

25   occurred. Using methylene chloride as the solvent 34, an amorphous thermoplastic modeling material will soften and reflow in a short time, typically between about 0.1 seconds to 5 minutes exposure time. If smoothing of an object is expected to occur in a short exposure time, it may be desirable to reduce the concentration of solvent vapors so that the

30   exposure time can be increased. A longer exposure time allows an operator more time to observe the smoothing process and more room for error in removing the object from the solvent vapors.

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When the exposure time elapses, the object 10 is removed from the vapor zone 36 and allowed to dry. In a preferred embodiment, the object 10 dries within seconds to minutes after its removal from the vapor zone 36, as the solvent 34 evaporates off of the object 10. The object 10

5   may then be handled, as it is not sticky, soft or wet. In some cases, such as where solvent exposure time is great or the solvent is highly concentrated, it may be desirable to dry the object 10 in an oven to remove any residual solvent. Oven drying should be done at a temperature greater than the boiling point of the solvent.

10   Following the vapor smoothing process, the stair steps in surfaces 12, 14, 16 and 18 of object 10 are either significantly reduced or eliminated. The extent of the smoothing achieved for a given object using the method of the present invention will depending upon the exposure time, the solvent, the modeling material, and the initial surface condition of the

15   object. FIG. 2 illustrates a significant reduction in the stair steps and roughness of the object 10, achieved by vapor smoothing.

Optionally, selected features of an object (e.g., features smaller than 0.25 inches, thin walls, corners, convex edges and concave edges) can be masked with a substance that will inhibit smoothing of said

20   selected portions, or, exposure of said selected features to the solvent vapors can be otherwise avoided. For example, it may be desirable to mask the corners of object 10, to prevent the corners from rounding. Similarly, concave surfaces of an object can be masked to prevent in-flow of surrounding material. Suitable solvent masking substances include those

25   used in printed circuit board manufacturing, such as gums, waxes, pastes, adhesives or masking tape, which may be applied either manually or automatically. Masking may also be accomplished by surrounding a feature with a gas.

Automatic application of a masking substrate may be done, for

30   example, by jetting a masking material onto the surface of selected object features, in a layered deposition process such as is known in the art. A masking substance may also be applied by depositing roads of masking

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material, using a fused deposition modeling process such as performed by Stratasys® FDM® modeling machines. Those skilled in the art will recognize additional masking techniques know in the art, that may be applied in carrying out the present invention.

5   When an automatic masking technique is used, the features to be masked may be identified using a software algorithm that creates a digital representation of the surface area to be protected. The protected area may be identified in a digital representation of the object, such as in an .stl file geometry using a CAD system, a Graphic Pixel system or a Voxel

10   system. Alternatively, the surface areas to be masked may be identified by the user via a haptic input interface, such as a FreeForm™ system available from SensAble Technologies, Inc. The haptic input system creates a digital mask of the areas for which smoothing is not desired.

         As an alternative to masking techniques, the geometry of an

15   object surface may be pre-distorted in anticipation of the vapor smoothing. The pre-distortion is accomplished by using a software algorithm to modify a digital representation of the object (e.g., a CAD model of the object or a sliced representation of the object as in a .stl file). Using a pre-distortion software algorithm, feature details are distorted so as to overbuild corners

20   and edges, and underbuild pockets, such that following vapor smoothing such features will attain approximately the desired geometry. More specifically, an exemplary pre-distortion algorithm will: (1) identify geometric features with radii of curvature equal to or smaller than the slice height (i.e., the thickness of a layer); (2) for identified features having a positive radius

25   of curvature (e.g., a corner or edge), the algorithm will build up the initial object representation at such features; and (3) for identified geometric features having a negative radius of curvature (e.g., a pocket or a joint between planes), the algorithm will hollow out the object representation in the vicinity of such features. The pre-distortion software algorithm thus

30   creates a modified object representation, so that the identified geometric features will be distorted by either depositing additional material or

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depositing less material than is ultimately desired in the final smoothed
object. A similar algorithm can be used to identify features for masking.

According to the pre-distortion algorithm, features should be
built up by not more than the slice height, for instance, by half of a slice

5   height. The surface roughness of a typical part made by fused deposition
modeling is about 0.3 times the slice height. The additional material added
in pre-distortion of positive features may be roughly the thickness of this
surface roughness, so that when the re-flowed material is pulled away, the
solid material left takes on the desired final object geometry. For the

10   negative curvature regions, enough material needs to be removed by the
pre-distortion algorithm that the in-flow from the surrounding regions fills in
the removed material.

Pre-distortion of object geometry is illustrated in FIGS. 4a and
4b and FIGS. 5a and 5b. FIGS. 4a and 4b show a cross-sectional view of

15   a portion of an object 40 that has not been pre-distorted, superimposed onto
an outline 42 illustrating the desired final surface object geometry of object
40 (i.e., the unmodified object representation). As illustrated in FIG. 4b,
vapor smoothing results in rounding of convex corners 44 away from the
desired outline 42, and rounding of edges 46 beyond the desired outline 42.

20   FIGS. 5a and 5b illustrate a portion of an object 40' which has the same
desired final surface geometry as object 40. Unlike object 40, object 40' has
been pre-distorted according to the pre-distortion algorithm of the present
invention. As illustrated in FIG. 5a, the pre-distorted surface geometry of
object 40 extends beyond the desired outline 42 at corners 44 and concave

25   edges 46. Following vapor smoothing, as illustrated in FIG. 5b, the corners
44 and edges 46 of the pre-distorted object 40 more closely follow the
desired outline 42 than do the corners 44 and edges 46 of the object 40.

Although the present invention has been described with
reference to preferred embodiments, workers skilled in the art will recognize

30   that changes may be made in form and detail without departing from the
spirit and scope of the invention.

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CLAIMS:

1.   A method for making a three-dimensional object comprising
the steps of:

        building an object from a polymeric or wax modeling material
            using a layered manufacturing rapid prototyping
            technique; and

        smoothing an object surface by exposing the object to vapors
            of a solvent that transiently softens the modeling
            material.

2.   The method of claim 1, wherein the layered manufacturing
technique is fused deposition modeling.

3.   The method of claim 1, where the modeling material is a
thermoplastic resin.

4.   The method of claim 3, wherein the thermoplastic resin
comprises at least about 50 weight percent of an amorphous thermoplastic
selected from the group consisting of ABS, polycarbonate,
polyphenylsulfone, polysulfone, polystyrene, polyphenylene ether,
amorphous polyamides, acrylics, poly(2-ethyl-2-oxazoline), and blends
thereof.

5.   The method of claim 4, wherein the solvent is selected from
the group consisting of methylene chloride, an n-Propyl bromide solution,
perchloroethylene, trichloroethylene, and a hydrofluorocarbon fluid.

6.   The method of claim 1, wherein the modeling material is
selected from the group consisting of thermoplastics, green metals
dispersed in a polymeric binder, green ceramics dispersed in a polymeric
binder, and jetting wax.

7.   The method of claim 6, wherein the modeling material is glass-
filled nylon.

8.   The method of claim 1, and further comprising the step of:

        selecting a length of time during which the object is to be
            exposed to the solvent vapors as a function of

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concentration of the solvent vapors, prior to the smoothing step.

9.   The method of claim 8, and further comprising the step of:

reducing the concentration of solvent vapors so that the selected exposure time will increase.

10.   The method of claim 1, and further comprising the step of:

masking selected portions of the object surface with a substance that will inhibit smoothing of the selected portions, prior to the step of smoothing the object surface.

11.   The method of claim 10, wherein the masking substance is applied using an automatic process.

12.   The method of claim 11, wherein the automatic process is a jetting process.

13.   The method of claim 11, wherein the automatic process is a fused deposition modeling process.

14.   The method of claim 11, and further comprising the step of:

identifying the selected portions of the object surface for masking accordingly to their geometry.

15.   The method of claim 14, and further comprising the step of:

identifying the selected portions of the object surface for masking accordingly to their radii of curvature.

16.   The method of claim 11, and further comprising the step of:

identifying the selected portions of the object surface using a software algorithm that creates a digital representation of the surface area to be protected.

17.   The method of claim 16, wherein digital data identifying the surface area to be protected is stored in an .stl file.

18.   The method of claim 1, and further comprising the step of:

creating a digital mask of selected portions of the object surface for which smoothing is not desired, using a haptic input interface.

19.   The method of claim 1, wherein the building step comprises pre-distorting certain object features so that said features will obtain a desired geometry following the smoothing step.

20.   The method of claim 19, and further comprising the steps of:

providing an initial object representation in a digital format, the initial object representation having a surface geometry; and

modifying the initial object representation to pre-distort certain features of the surface geometry, producing a modified object representation;

wherein the object built in the building step has a geometry defined   according   to   the   modified   object representation; and

wherein the desired geometry attained following the smoothing step   approximately matches that of the initial object representation.

21.   A method for eliminating surface roughness of an object built from a modeling material using a layered manufacturing rapid prototyping technique, comprising the step of:

reflowing a surface of the object by exposing the object to vapors of a solvent that transiently softens the modeling material.

22.   The method of claim 21, where the modeling material is a thermoplastic resin.

23.   The method of claim 22, wherein the thermoplastic resin comprises at least about 50 weight percent of an amorphous thermoplastic selected   from   the   group   consisting   of   ABS,   polycarbonate, polyphenylsulfone,   polysulfone,   polystyrene,   polyphenylene   ether,

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amorphous polyamide, methyl methacrylate, poly(2-ethyl-2-oxazoline), and blends thereof.

24.   The method of claim 23, wherein the solvent is selected from the group consisting of methylene chloride, an n-Propyl bromide solution, perchloroethylene, trichloroethylene, and a hydrofluorocarbon fluid.

25.   The method of claim 21, wherein the modeling material is selected from the group consisting of thermoplastics, green metals dispersed in a polymeric binder, green ceramics dispersed in a polymeric binder, and jetting wax.

26.   The method of claim 25, wherein the modeling material is glass-filled nylon.

27.   The method of claim 21, and further comprising the step of:
            masking selected portions of the object surface with a
                substance that will inhibit smoothing of the selected
                portions, prior to the step of reflowing the surface.

28.   The method of claim 27, wherein the masking substance is applied using an automatic process.

29.   The method of claim 28, wherein the automatic process is a jetting process.

30.   The method of claim 28, wherein the automatic process is a fused deposition modeling process.

31.   The method of claim 28, and further comprising the step of:
            identifying the selected portions of the object surface for
                masking accordingly to their geometry.

32.   The method of claim 31, and further comprising the step of:
            identifying the selected portions of the object surface for
                masking accordingly to their radii of curvature.

33.   The method of claim 28, and further comprising the step of:
            identifying the selected portions of the object surface using a
                software algorithm that creates a digital representation
                of the surface area to be protected.

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34.   The method of claim 33, wherein digital data identifying the
surface area to be protected is stored in an .stl file.

35.   The method of claim 28, and further comprising the step of:

             identifying the selected portions of the object surface for
                    masking using a haptic input interface.

36.   A method for making a three-dimensional object comprising
the steps of:

             providing an initial object representation in a digital format, the
                    initial object representation having a surface geometry;

             modifying the initial object representation to pre-distort certain
                    features of the surface geometry, producing a modified
                    object representation;

             building an object as defined by the modified object
                    representation, from a modeling material using a
                    layered manufacturing technique; and

             vapor smoothing surfaces of the object to produce a finished
                    object, the finished object having a surface geometry
                    that approximately matches that of the initial object
                    representation.

37.   The method of claim 36, and further comprising the step of:

             identifying features of the surface geometry for pre-distortion
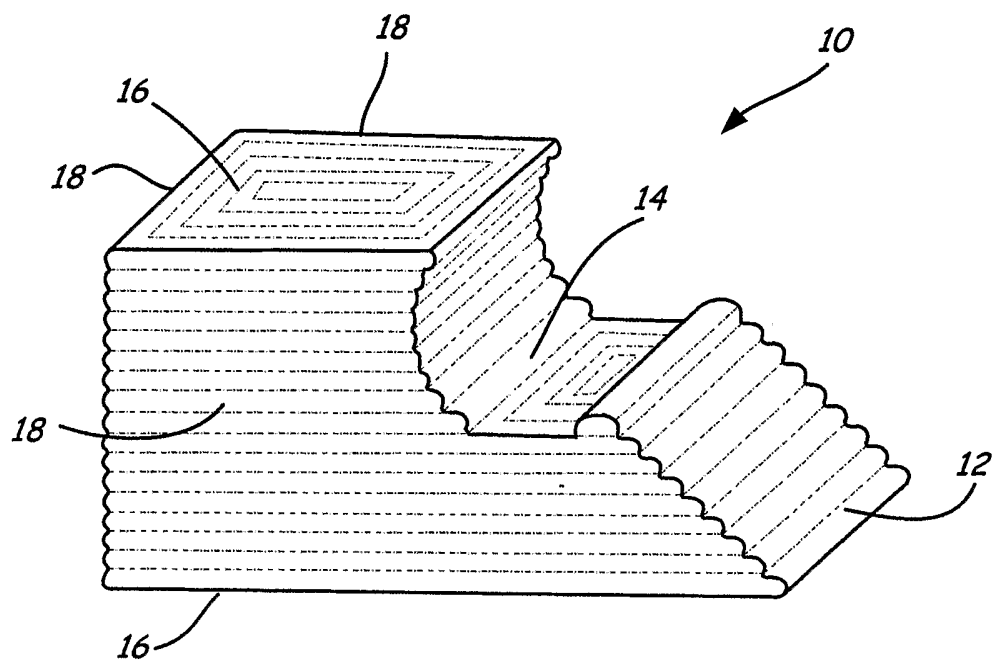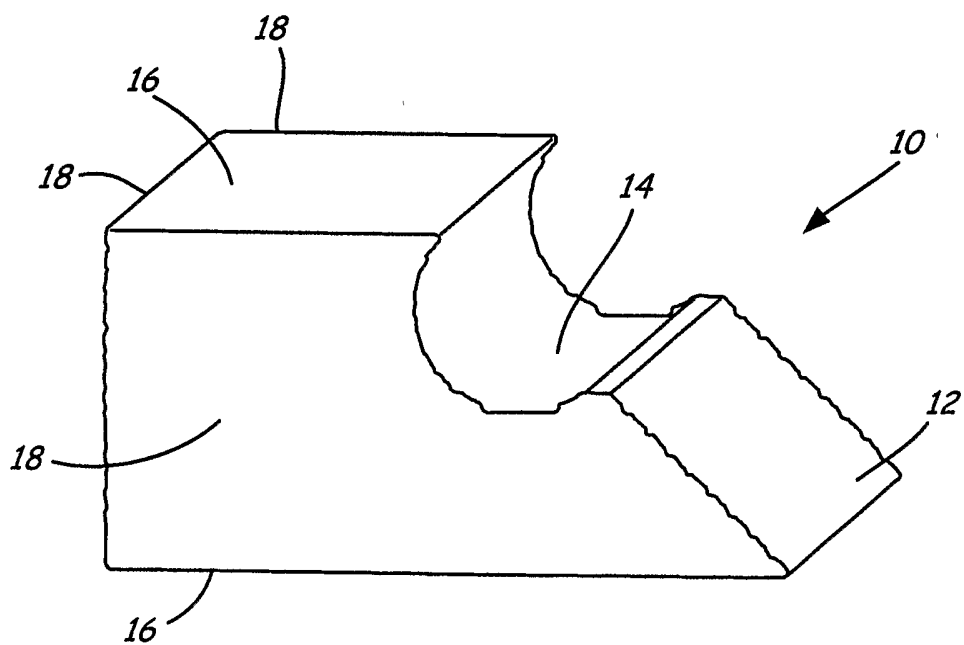   according to their radii of curvature.
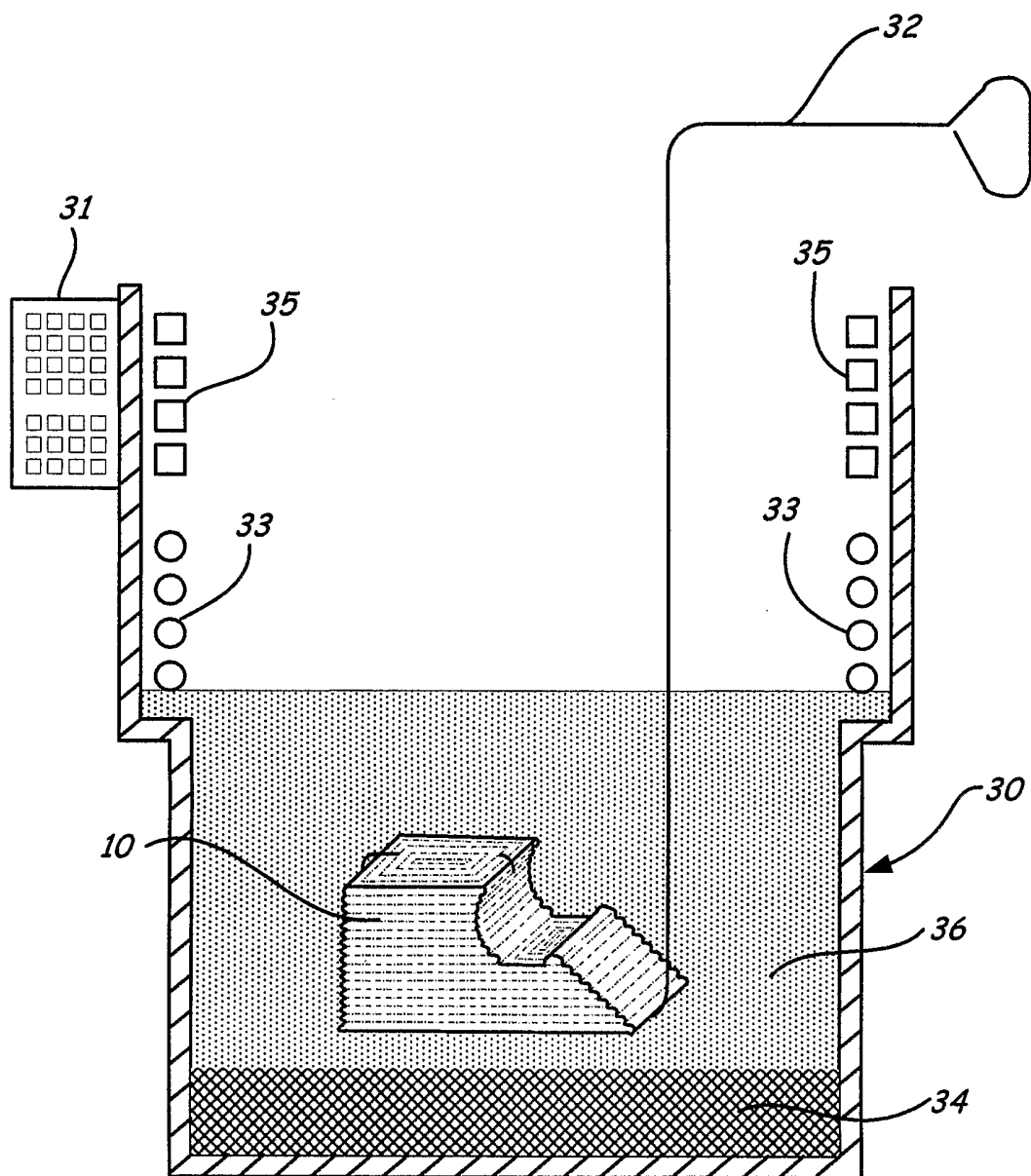
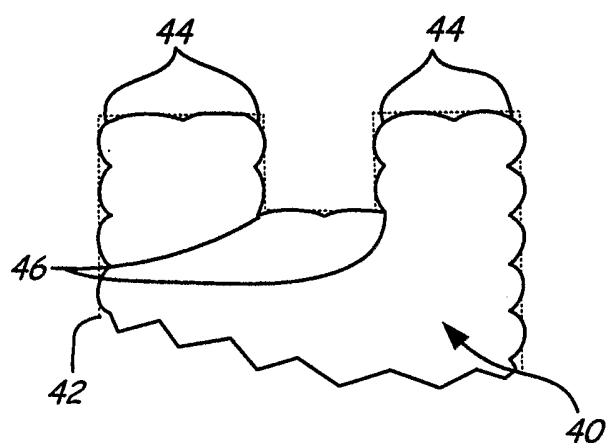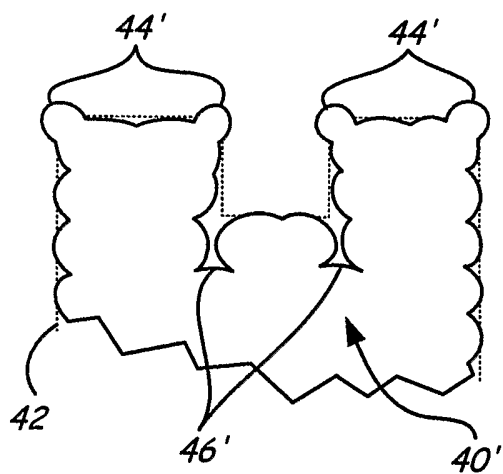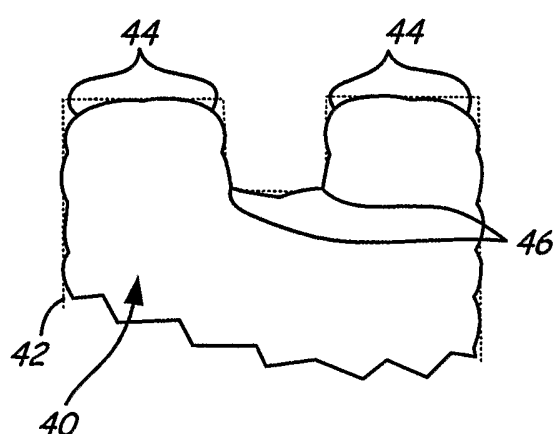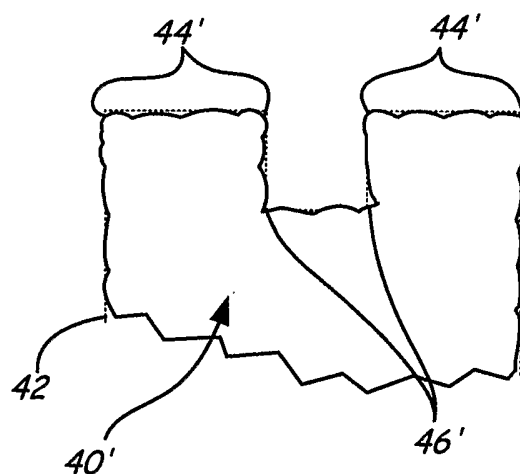1/3

FIG. 1

FIG. 2

FIG. 3

FIG. 4A

FIG. 4B

FIG. 5A

FIG. 5B

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/10220

A.   CLASSIFICATION OF SUBJECT MATTER
IPC(7)   :   B29C 41/02, 71/00, 71/02; G06F 17/50, 19/00
US CL   :   264/232, 234, 308; 700/119

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)
    U.S. : 264/232, 234, 308; 700/119

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

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

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,143,663 A(LEYDEN et al) 01 September 1992 (01.09.1992), column 10, line 40 to column 11, line 44.	1, 3-6, 21-25

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

* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent published on or after the international filing date	"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
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Date of the actual completion of the international search	Date of mailing of the international search report
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