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Masters

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[54] **SYSTEM AND METHOD FOR COMPUTER AUTOMATED MANUFACTURING USING FLUENT MATERIAL**

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[51] **Int. Cl.**[5] **G06F 15/46;** B28B 17/00; B28B 1/14; B27G 11/02

[52] **U.S. Cl.** **364/474.24;** 156/379.6; 156/59; 156/272.8; 264/308; 425/162; 425/174

[58] **Field of Search** 364/474.24, 469, 473, 364/477; 156/379.6, 59, 272.8, 244.11; 264/22, 308, 309, 211.13, 211.12, 219; 219/121.73; 425/162, 174, 174.4; 365/119, 111

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,078,229	3/1978	Swanson et al.	365/111
4,238,840	12/1980	Swainson	365/119
4,247,508	1/1981	Housholder	264/308
4,333,165	6/1982	Swainson et al.	365/119
4,575,330	3/1986	Hull	364/473
4,665,492	5/1987	Masters	364/474.24
4,710,253	12/1987	Soszek	156/272.8
4,749,347	6/1988	Valavaara	264/219
4,752,352	6/1988	Feygin	219/121.73
4,915,757	4/1990	Rando	156/59
4,943,928	7/1990	Campbell et al.	364/477
4,961,154	10/1990	Pomerantz et al.	425/174.4
4,961,886	10/1990	Eckstein et al.	425/174.4

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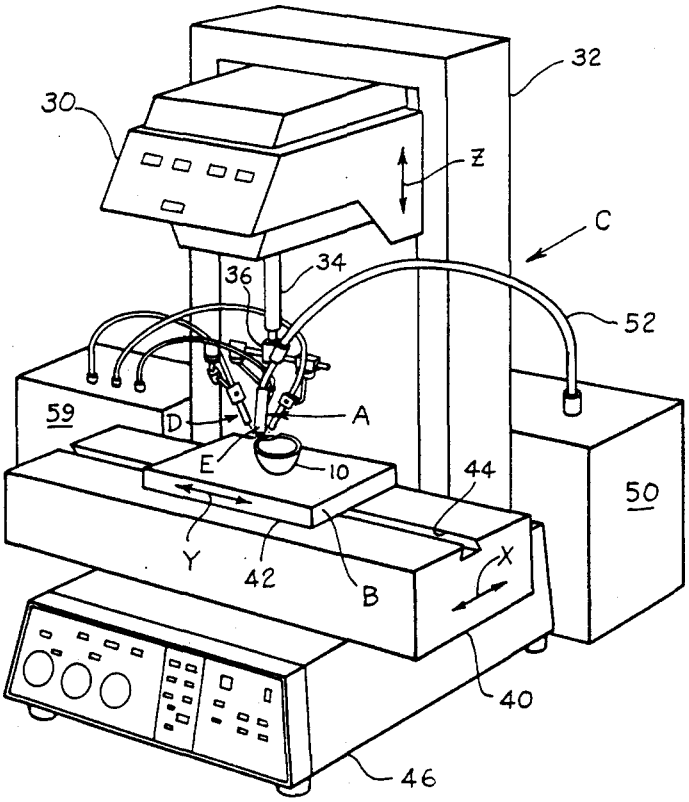
[57] **ABSTRACT**

A system and method for constructing a three-dimensional object (**10**) from a design created on a CAD machine (**14**) is disclosed which includes a support (B) which may be indexed along two coordinate axes (X, Y) and a movable dispensing head (A) which indexes along a Z-axis. A fluent material (**54**) is dispensed or extruded from head (A) and as it is dispensed, the fluent material is subjected to a treatment by treatment sources (D) which cause the fluent material to transform into a fixed solidified state in the form of a three-dimensional object. Fluent material (**54**) may be a polymeric material which is solidified by an energy beam of ultraviolet light (**56**) upon dispensing. A shield (E) is provided to shield the dispensing head (A) and strand of material (**54**) so that the material is treated at the proper time and location to cause it to solidify properly to form the three-dimensional object. In accordance with the method, indexing takes place in desired steps so a dimensionally accurate object is formed.

47 Claims, 3 Drawing Sheets



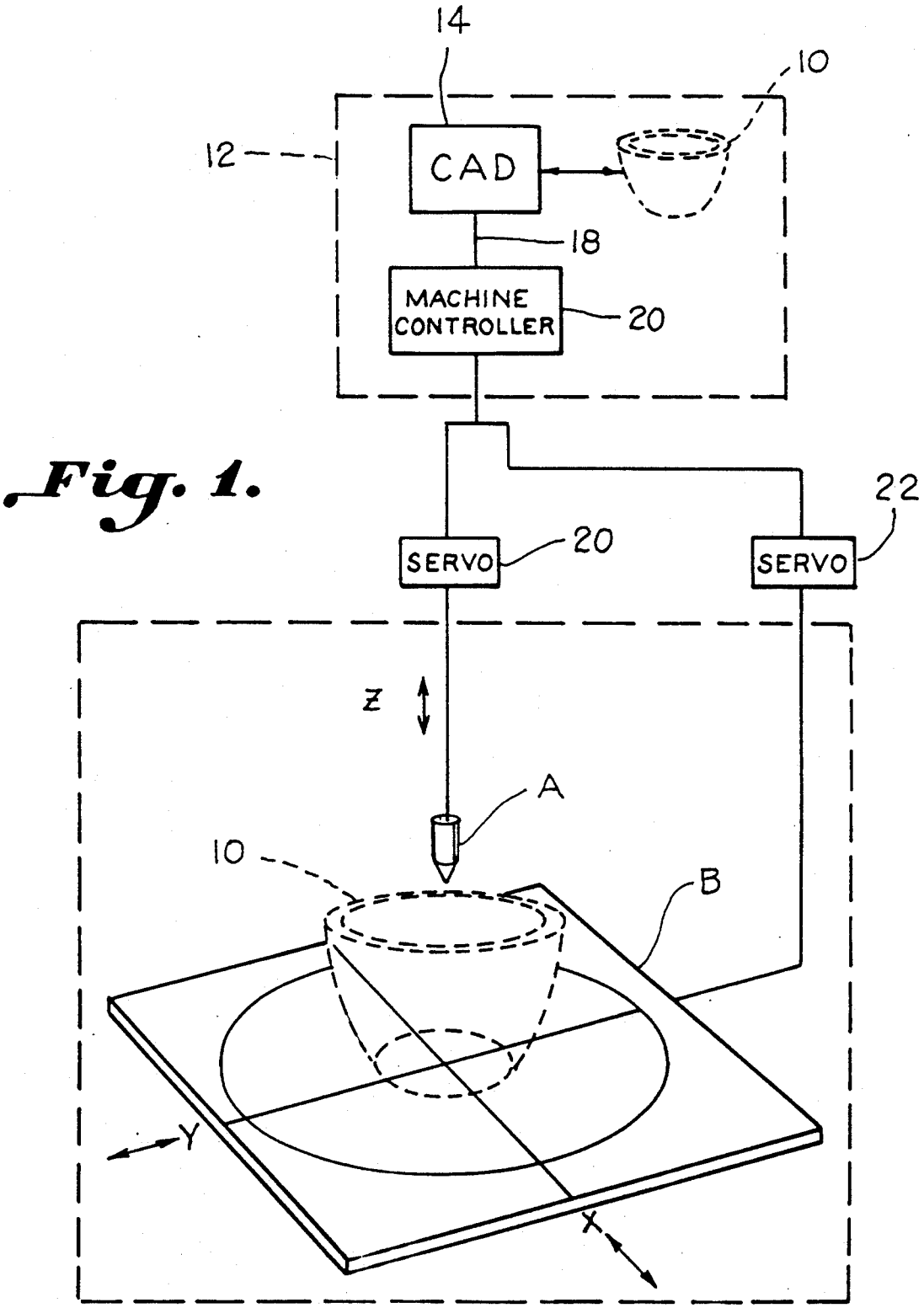


Fig. 1.

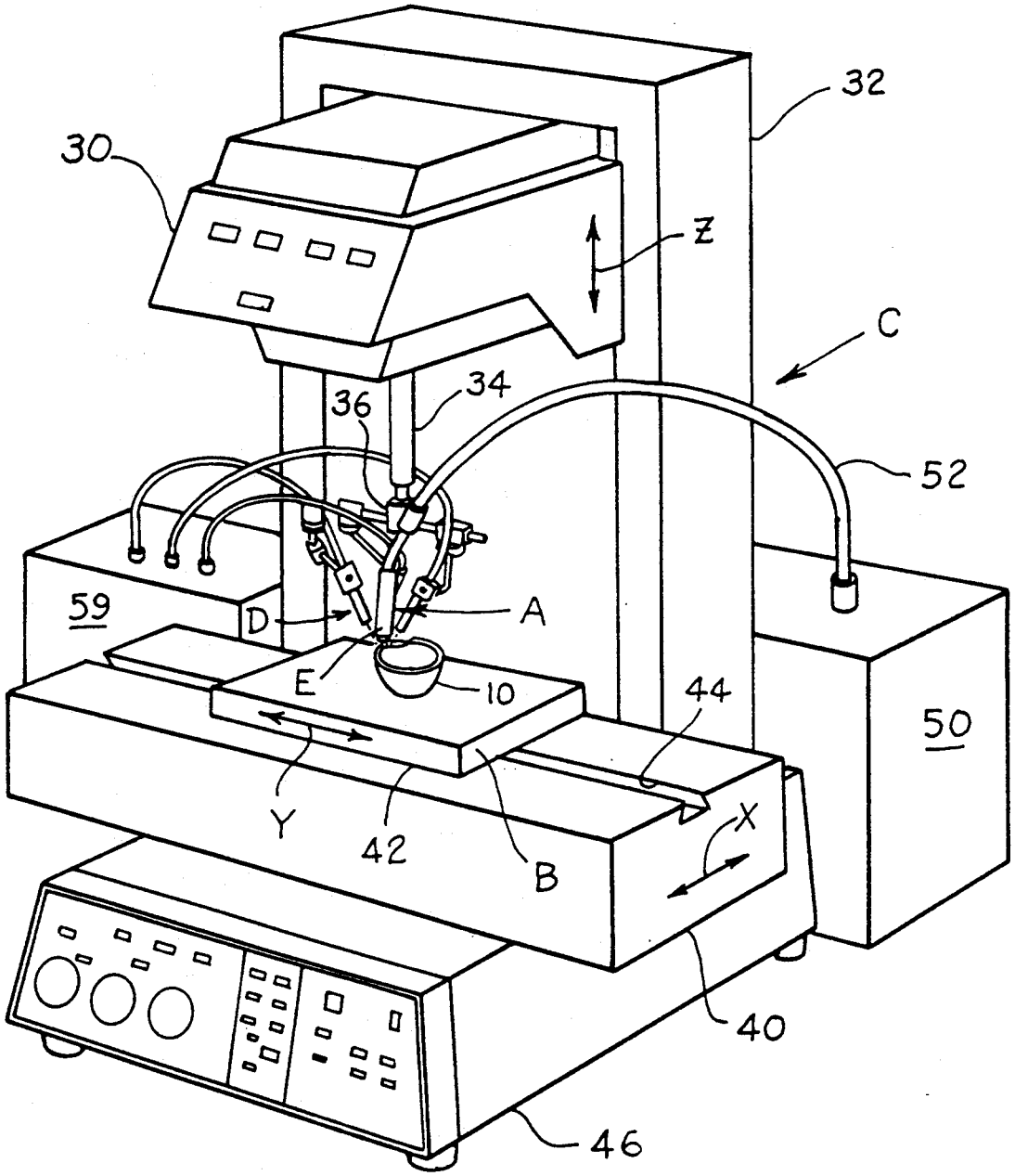


Fig. 2.

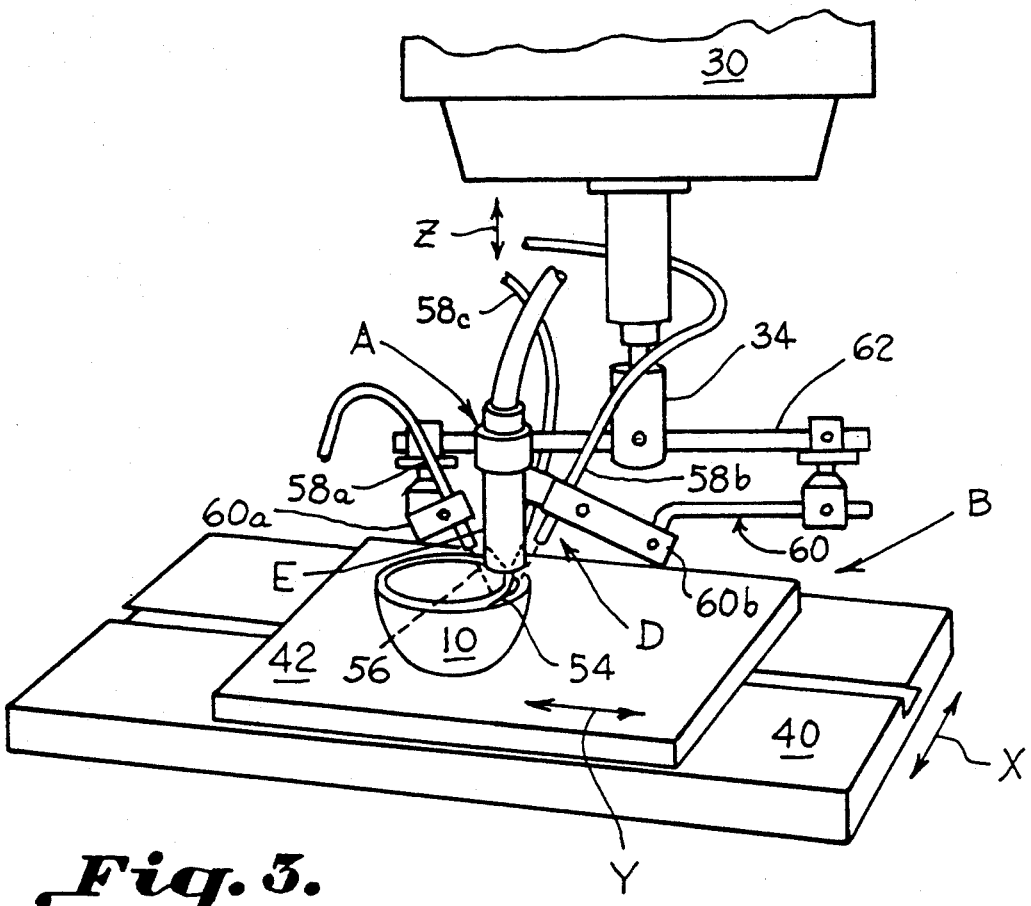


Fig. 3.

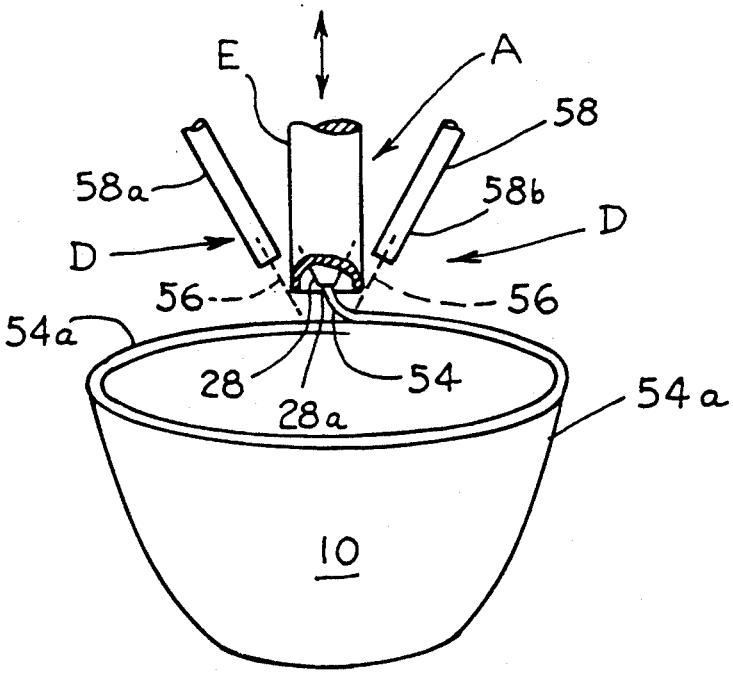


Fig. 4.

SYSTEM AND METHOD FOR COMPUTER AUTOMATED MANUFACTURING USING FLUENT MATERIAL

BACKGROUND OF THE INVENTION

The invention relates to the automated manufacturing of a three-dimensional object whose design has been created with a computer aided design (CAD) machine.

Modern day manufacturing technology continues to grow in complexity and sophistication. The result is a great need for flexibility in the manufacturing process. Several systems and methods for manufacturing three-dimensional objects which have been designed on a computer have been proposed. However, turning a computer aided design into a solid three-dimensional object quickly and inexpensively remains a problem to which considerable attention need be given.

Technology, commonly referred to as direct cad manufacturing (DCM), has been rapidly developing. In desk top manufacturing, a three-dimensional object is created on a computer screen using a CAD program. Any physical product that is designed, shaped, or prototyped prior to production could benefit from DCM. Industries that may use DCM include automotive, aerospace, appliance, toy manufacturers, and any process that involves the design, redesign, prototyping, and production of three-dimensional models, molds, patterns, or short production runs. Designs that once required weeks or months to be turned into actual models or prototypes can become objects in a matter of hours or days using DCM. Using DCM, a design can be recalled from a library and the object manufactured in just a short period of time, thus eliminating the need for large inventories. Basically, there are five identifiable desk top manufacturing systems and methods.

First is ballistics particle manufacturing as disclosed in U.S. Pat. No. 4,665,492. In this system, the coordinates of a three-dimensional design are stored in a computer data base. Particles are directed to specific locations and built up and deposited to construct the desired object. Second, in photochemical machining, shapes are formed by the polymerization of a monomer, or by sculpting a solid block of plastic, for example, see U.S. Pat. Nos. 4,078,229; 4,238,840; and 4,571,377. In polymerization, one laser may pump a photo initiator or photosynthesizer, while a second laser pumps energy. Polymerization takes place where the two beams intersect. When using the other sculpting technique, a block of rigid plastic is carved by degrading material at the intersection of the two beams. Third is laminated object manufacturing where objects are constructed by the successive definition of thin layers of powdered plastics or metals, thin layers of powder are deposited, then compressed with a heated press platform or by roller compression. Pulses from a single laser then sinter or melt the powder in the desired cross-sectional shape and to the required depth. An example of this type system can be seen in U.S. Pat. No. 4,752,352. Fourth is selective laser sintering where objects may be fabricated by the successive deposition and sintering of thin layers of powdered material, either plastic or metal. The powder layers are spread by a feeding mechanism, but are not compressed. Sintering energy can come from a laser or other suitable direct beam of energy. Fifth, stereolithography is a form of stereolithographic printing wherein a single laser beam cures successive thin layers of liquid monomer by a series of controlled photopolymerization reactions such as shown in U.S. Pat. No. 4,575,330.

Further, U.S. Pat. No. 4,749,347 discloses a topology fabrication apparatus in which a three-dimension solid body having a predetermined topography is automatically manufactured using an extrusion process. Thin sections of the solid body are extruded and successively built up next to each other to form the topographical form such as a topology model made from topographical map information. This system requires a fairly sophisticated apparatus and control for forming what is a relatively simple form. The types of objects which can be made with such an apparatus and control are relatively limited.

Accordingly, it can be seen that the field of desk top manufacturing or computer aided manufacturing is one in which considerable activity and attention need to be given. While the above systems and methods are all candidates for a practical system, a need for the development of more reliable and practical systems and methods still exists.

Accordingly, an important object of the present invention is to provide a method and system for the computer aided manufacture of three-dimensional objects which is reliable and practical.

Another object of the present invention is to provide a system and method for automatically manufacturing three-dimensional objects whose design has been created on a CAD machine using practical hardware and methods.

Another object of the present invention is to provide a system and method for automatically manufacturing a three-dimensional object whose design has been created on a CAD machine wherein the object may be accurately formed in a simple and reliable manner under ordinary manufacturing.

SUMMARY OF THE INVENTION

The above objectives are accomplished in accordance with the present invention by providing a computer machine which creates a design for a three-dimensional object and a data file of the corresponding three-dimensional coordinates. The data file is used to control servos which index and position a dispensing head which extrudes a generally continuous strand of fluent material on a base which is indexed in the remaining coordinate directions. As the dispensing head and support are indexed, material is extruded through an orifice having a desired cross-sectional profile and is treated upon being dispensed to solidify to construct the three-dimensional object. In a preferred embodiment, a polymeric material is extruded in a fluent state and is subjected to a radiation beam for transition into the solid three-dimensional object. A shield is provided about the dispensing head so that the dispensed material is contacted by the radiation beam at the proper time of location for transition. The sources of radiation are disposed relative to the dispensing head so that a prescribed time period is established between the time the material leaves the tip of the dispensing head and the time at which the radiation beam contacts it. By making this time constant, a dimensionally accurate object is produced. Controlling the indexing steps of the movement of the servo and control of the cross-sectional profile of the strand dispensed, the result is increased dimensional accuracy of the object.

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