

THREE-DIMENSIONAL STRUCTURE FORMING APPARATUS

The invention relates to a three-dimensional structure forming apparatus.

5 Such apparatus may be used to form a three-dimensional structure on the basis of an optional stereographic image by irradiating a liquid photosetting resin with a light beam.

10 A method of forming a structure having a desired morphology by irradiating a liquid photosetting resin with a light beam is proposed, for example, in Japanese Patent Application No Sho 63-267945. Figure 5 of the accompanying drawings shows the main components of three-dimensional structure forming apparatus 51 for carrying out such a method.

15 The three-dimensional structure forming apparatus 51 has a main resin tank 52 to contain a liquid photosetting resin A which sets when exposed to ultraviolet rays, a horizontal stage 53 which has the shape of a plate and which can be placed in the main resin tank 52, an elevating mechanism 54 vertically to move the stage 53, a scanning unit 55 to irradiate the surface of the liquid photosetting resin A with a light beam, and a moulding controller 56 to control the exposure and scanning operation of the scanning unit 55 and the operation of the elevating mechanism 54 to move the stage 53.

25 In forming a three-dimensional structure of a desired morphology by the three-dimensional structure forming apparatus 51, the elevating mechanism 54 locates the stage 53 at an initial position indicated by continuous lines where the liquid photosetting resin A spreads in a predetermined thickness over the stage 53, and the surface of the liquid photosetting resin A is then scanned with a light beam B for raster scanning in a pattern corresponding to the pattern of one of a plurality of parallel planes obtained by slicing an optional stereographic image, which will be referred to as "parallel decomposed planes".

30 Portions of the liquid photosetting resin A irradiated with the light beam B set in a hard resin layer of a shape corresponding to the pattern of the decomposed plane. Every time one hard resin layer is formed, the elevating mechanism 54 lowers the stage 53 by a predetermined distance corresponding to the pitch of the decomposed

planes of the stereographic image to spread the liquid photosetting resin A over the hard resin layer in a thickness corresponding to the pitch of the decomposed planes. Then, the liquid photosetting resin A spread over the hard resin layer is scanned with the light beam B in a pattern corresponding to the pattern of the next decomposed plane to form a hard resin layer of a shape corresponding to the pattern of the corresponding decomposed plane on the previously formed hard resin layer. These successive hard resin layers join together.

Thus, hard resin layers of shapes respectively corresponding to the patterns of the decomposed planes are formed successively in adjoining layers to form a desired three-dimensional structure.

A three-dimensional structure can thus be formed on the basis of an optional stereographic image by this method.

In irradiating the surface of the liquid photosetting resin A contained in the main resin tank 52 with the light beam B by the three-dimensional structure forming apparatus to harden portions of the liquid photosetting resin A in a pattern, the diameter of the spot of the light beam B is dependent on the distance between the objective lens of the three-dimensional structure forming apparatus and the surface of the liquid photosetting resin A. Accordingly, if the liquid level of the liquid photosetting resin A contained in the main resin tank 52 is variable, the diameter of the spot of the light beam B is variable and hence it is impossible to form a three-dimensional structure with accurate dimensions.

The liquid level of the liquid photosetting resin A in the main resin tank 52 is liable to vary with the variation of the temperature of the liquid photosetting resin A or with the reduction of the amount of the liquid photosetting resin A contained in the main resin tank 52.

When a very large main resin tank is used or when the light beam is focused in a very small spot to reduce the terminal depth, in particular, the liquid level of the liquid photosetting resin must precisely be controlled. However, no effective liquid level control system for such a purpose has been developed so far.

According to the invention there is provided a three-dimensional structure forming apparatus, to form a desired three-dimensional structure by sequentially laminating hard resin layers by repeating a hard resin layer forming cycle, which cycle comprises the steps of

irradiating the surface of a liquid photosetting resin with a light beam in a pattern corresponding to a desired stereographic image and spreading the liquid photosetting resin over the hard resin layer, wherein the three-dimensional structure forming apparatus comprises a
5 main resin tank to contain the liquid photosetting resin and the main resin tank is provided with a liquid level control system comprising:
a replenishing tank;

resin supply means continuously to supply the liquid photosetting resin from the replenishing tank to the main resin tank at a
10 predetermined rate so that the liquid photosetting resin overflows the main resin tank continuously; and

liquid photosetting resin return means to return the liquid photosetting resin that overflows the main resin tank.

The liquid photosetting resin returning means thus forms a liquid
15 level control system and can return the liquid photosetting resin that overflows the main resin tank through a suction opening or an overflow weir formed in one side surface of the main resin tank.

Thus, the quantity of the liquid photosetting resin contained in the main resin tank can be maintained constant so that the liquid level
20 of the liquid photosetting resin contained in the main resin tank can be maintained constant. Accordingly, a light beam can precisely be focused in a spot of a constant diameter to form a three-dimensional structure in accurate dimensions.

The invention is diagrammatically illustrated by way of example
25 in the accompanying drawings, in which;

Figure 1 is a schematic sectional view of a three-dimensional structure forming apparatus provided with a liquid level control system, in a first embodiment according to the invention;

Figure 2A is an enlarged fragmentary sectional view of an edge
30 portion of an overflow weir of the apparatus of Figure 1;

Figure 2B is an enlarged fragmentary sectional view of the edge portion of an overflow weir for comparison with the edge portion shown in Figure 2A;

Figure 3 is a schematic sectional view of a modification of the
35 three-dimensional structure forming apparatus shown in Figure 1,

additionally provided with a filter mechanism and a laser liquid level detector;

Figure 4 is a schematic sectional view of a three-dimensional structure forming apparatus in a second embodiment according to the invention; and

Figure 5 is a schematic sectional view of a conventional three-dimensional structure forming apparatus.

Referring to the drawings, Figure 1 shows a main resin tank 2 and associated equipment included in a three-dimensional structure forming apparatus 1. The main resin tank 2 contains a liquid photosetting resin A which sets when exposed to ultraviolet rays and is mounted on a base 3 provided with a levelling mechanism 3a. A heater 4 is wound around the main resin tank 2 to heat the liquid photosetting resin contained in the main resin tank 2 to a predetermined temperature. The heater 4 is controlled by a temperature controller 6 on the basis of the temperature of the liquid photosetting resin A detected by a temperature detector 5 so as to maintain the temperature of the liquid photosetting resin A contained in the main resin tank 2 at the predetermined temperature.

A stage, not shown, is placed in a horizontal position in the main resin tank 2 and is moved vertically by an elevating mechanism, not shown. A scanning unit, not shown, is disposed above the main resin tank 2 to irradiate the surface of the liquid photosetting resin A for scanning with a light beam. A moulding controller, not shown, controls the scanning unit for exposure and scanning operation and controls the elevating mechanism for vertically moving the stage. The liquid photosetting resin A is irradiated with a light beam to form a hard resin layer of a shape corresponding to the pattern of a decomposed plate.

The main resin tank 2 is provided with at least one overflow weir 7 in one side wall thereof. Surplus liquid photosetting resin A overflows the overflow weir 7 and is returned to a replenishing tank 8, so that the liquid level of the liquid photosetting resin A is maintained constant. The overflow weir 7 comprises an edge member 9 having a sharp edge 9a and disposed slightly below the upper edge 2a of the main resin tank 2, and a resin receiver 10 provided on the outer surface of the side wall of the main resin tank 2 to receive the liquid

photosetting resin which has overflowed the overflow weir 7. The position of the sharp edge 9a of the edge member 9 corresponds to a predetermined liquid level of the liquid photosetting resin A in the main resin tank 2.

5 Although the liquid photosetting resin A is heated by the heater 4 to reduce its viscosity, the liquid photosetting resin A has a very high viscosity and a high surface tension. Accordingly, the liquid photosetting resin A forms a meniscus and the liquid level of the liquid photosetting resin A varies as shown in Figure 2B before the
10 liquid photosetting resin A overflows the main resin tank 2. This variation of the liquid level of the liquid photosetting resin A is a significant problem in precisely controlling the liquid level of the liquid photosetting resin A.

 To solve such a problem, the edge member 9 is used to make the
15 liquid photosetting resin A overflow the sharp edge 9a of the edge member 9 continuously so that the liquid level of the liquid photosetting resin A is constant.

 The liquid photosetting resin A which has overflowed the overflow weir 7 into the resin receiver 10 is returned through a return pipe 11
20 to the replenishing tank 8 to store the surplus liquid photosetting resin A therein.

 The liquid photosetting resin A is supplied continuously at a predetermined rate through a supply pipe 13 to the main resin tank 2 by a supply pump 12 to replenish the main resin tank 2 with the liquid
25 photosetting resin A so that the surplus liquid photosetting resin A overflows the overflow weir 7 continuously and the liquid level of the liquid photosetting resin A in the main resin tank 2 remains constant.

 As shown in Figure 3, a filter 14 may be inserted in the supply pipe 13 to remove set photosetting resin particles, dust and impurities
30 from the liquid photosetting resin A before supplying the same to the main resin tank 2.

 The main resin tank 2 may be provided with a laser liquid level detector 15 to detect the liquid level of the liquid photosetting resin A in the main resin tank 2 for monitoring and controlling the liquid
35 level. The laser liquid level detector 15 comprises a laser 16 and a line sensor 17. The liquid level of the liquid photosetting resin A is detected from the position of incidence on the line sensor 17 of the

laser beam projected by the laser 16 and reflected by the surface of the liquid photosetting resin A. A liquid level control bar 18 partly immersed in the liquid photosetting resin A is raised or lowered according to a liquid level detection signal provided by the laser liquid level detector 15 to regulate the liquid level of the liquid photosetting resin A precisely by varying the volume of the immersed portion of the liquid level control bar 18.

Referring to Figure 4, in a three-dimensional structure forming apparatus of a second embodiment components corresponding to those shown in Figures 1 to 3 are given the same reference numerals. The main resin tank 2 is provided with one or a plurality of suction openings 21 instead of the overflow weir 7. The suction opening 21 is formed in the side wall of the main resin tank 2 at a position corresponding to a predetermined liquid level, and a return pipe 11 is connected to the suction opening 21. Surplus liquid photosetting resin A overflowing the suction opening or suction openings 21 is sucked directly by a suction pump 20. Liquid photosetting resin A sucked through the suction opening or suction openings 21 is returned to a replenishing tank 8.

Where the main resin tank 2 is provided with a laser liquid level detector 15, the liquid level may be controlled positively by controlling the suction pump 20 and the supply pump 12 according to a liquid level detection signal provided by the laser liquid level detector 15 so that the liquid level of the liquid photosetting resin A is maintained constant.

CLAIMS

1. A three-dimensional structure forming apparatus, to form a desired three-dimensional structure by sequentially laminating hard resin layers by repeating a hard resin layer forming cycle, which cycle comprises the steps of irradiating the surface of a liquid photosetting resin with a light beam in a pattern corresponding to a desired stereographic image and spreading the liquid photosetting resin over the hard resin layer, wherein the three-dimensional structure forming apparatus comprises a main resin tank to contain the liquid photosetting resin and the main resin tank is provided with a liquid level control system comprising:

a replenishing tank;

resin supply means continuously to supply the liquid photosetting resin from the replenishing tank to the main resin tank at a predetermined rate so that the liquid photosetting resin overflows the main resin tank continuously; and

liquid photosetting resin return means to return the liquid photosetting resin that overflows the main resin tank.

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2. A three-dimensional structure forming apparatus according to claim 1, wherein the liquid photosetting resin return means comprises an overflow weir formed in one side wall of the main resin tank and provided with an edge member having a sharp edge located at a position on the side wall corresponding to a desired liquid level of the liquid photosetting resin contained in the main resin tank.

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3. A three-dimensional structure forming apparatus according to claim 1, wherein the liquid photosetting resin return means comprises a suction mouth provided at one side wall of the main resin tank with its lower side located at a position on the side wall corresponding to a desired liquid level of the liquid photosetting resin contained in the main resin tank, and a suction pump connected to the suction mouth to suck the liquid photosetting resin that overflows the main resin tank through the suction mouth.

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4. A three-dimensional structure forming apparatus according to any one of claims 1 to 3, wherein filter means is inserted in a resin supply line interconnecting the main resin tank and the replenishing tank.

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5. A three-dimensional structure forming apparatus substantially as hereinbefore described and illustrated with reference to any of Figures 1 to 4 of the accompanying drawings.
