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Europäisches Patentamt
European Patent Office
Office européen des brevets

[bar code]

(11) Publication number: 0 470 901 A1

(12)

EUROPEAN PATENT APPLICATION

(21) Filing number: 91402187.8

(51) Int. ci.⁵: B29C 67/14

(22) Date of filing: 08/05/91

(30) Priority: 08/08/90 FR 9010120

(43) Publication date of the application:
02/12/92 Bulletin 92/07

(84) Designated Contracting States:
BE DE ES GB IT

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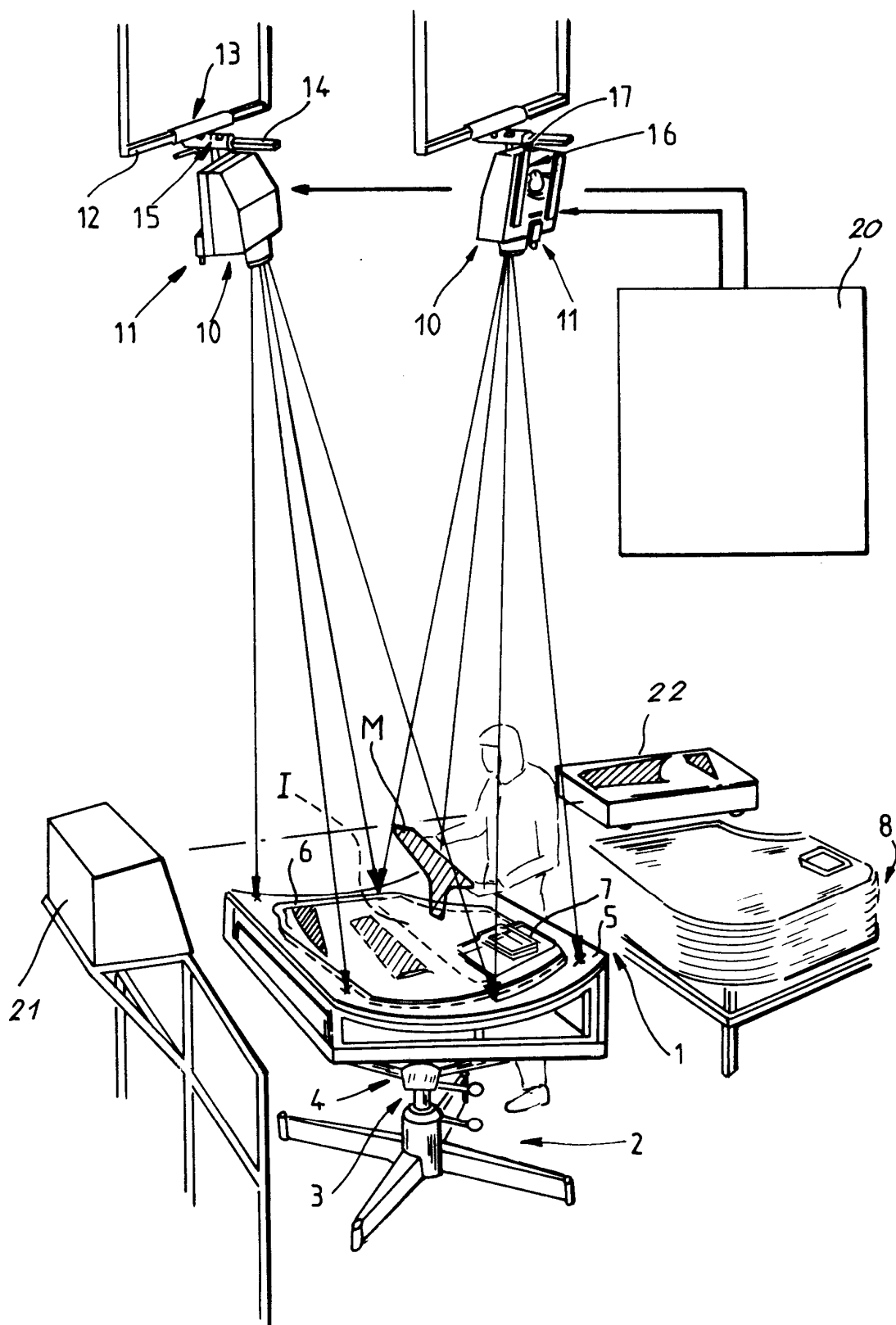
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(54) Support apparatus for hand lay-up of composite material parts.

(57) Apparatus for laying up a part through the assembling of cut fabric or strips of fibers pre-impregnated with resin onto a molding tooling (1), wherein the written list of instructions describing the manufacturing steps are replaced by projections of images on the tooling that indicate to the operator the nature and location of the cutouts to be successively placed. An optional camera (11) is used to check whether the placement is correct.
Application to the manufacture of composite material parts and panels.

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FIG. 1



The invention relates to a support and control apparatus in the hand lay-up of composite material parts.

The lay-up technique involves building the structure of parts such as hull or panel elements, by assembling fabric cutouts or high strength fiber strips pre-impregnated with curable synthetic resin, on the surface of a molding tooling so that they partially overlap. These assemblies are compacted and then the impregnation resin of the fibers is cured, so as to bind the component layers.

It is thus possible to make large parts with complicated shapes, where the fibers of each of the layers have a particular orientation, chosen to optimize the resistance of the part.

Each layer should be placed on the tooling in its intended position with good precision and in a determined order. Manufacturing ranges and templates are currently used, i.e. lists of written instructions that list the manufacturing steps and drawings that represent the position of each part on the tooling. However, the consultation of these sheets is not practical and extends the manufacturing time, especially for medium or large series, and it is not possible to easily check the proper execution of each layer.

It is already known that the implementation of a laser beam controlled by a computer and scanning over the tooling to deposit the contour of each element to be deposited facilitates the manual placement of fabric layers and strips on the molding tooling in such a way that the operator can distinguish the image of the external shape of the location to be occupied by the deposited layer using the afterimage of the spot.

However, this process presents practical application difficulties in particular to obtain good projection stability both statically and dynamically due to the drift over time of the mechanisms controlling the angular movements of the laser beam.

In addition, laser projection can cause operator eye fatigue due to the flickering of the beam and the dotted appearance of the light outline.

Finally, accidental projection of the laser beam into the operator's eyes can be dangerous and special precautions must be taken to avoid direct projection.

The purpose of the present invention is a partially automated apparatus for assisting lay-up personnel to speed up manufacturing and significantly reduce the risk of error, and which does not present the disadvantages of using a laser beam.

The apparatus according to the invention comprises, in addition to the molding tooling, a video image projection system directed towards this tooling and a control system capable of having the image projection system project the images that indicate the exact locations where the layers must be successively deposited with, if necessary, additional schematic indications to facilitate their placement by the operator.

The apparatus is supplemented with a lay-up control device that verifies that the successive layers are correctly deposited on the tooling. Specifically, this device ensures:

- that the texture or color of the layer matches that of the required material;
- that the shape of the layer is right;
- that the layer is placed in the correct location;
- that no foreign elements (e.g. an insulating piece of plastic) are included on the laid up surface.

This device consists on the one hand of a camera directed towards the tooling, connected to the projection control system and able to discern the texture, the shape and position of the layers actually placed on the tooling, and on the other hand a computer such as a microcomputer to which the camera is connected and which is able to compare the images from the camera with the reference images of the layers it has in memory, which were constituted either from shots made during a manufacturing-test operation, or from computerized drawings of the layers. The device is accompanied by screens displaying the images projected by the projection system or collected by the camera.

The invention will now be described in more detail using the attached figures for illustrative and not limiting purposes, including:

- Figure 1 shows an overview of the apparatus;
- Figure 2 is a diagram of the control system;
- Figure 3 represents a setup configuration of the projection system.

Figure 1 shows a molding tooling 1 placed on a height and position-adjustable bench 2 thanks to an adjustable leg 3 and a ball joint 4. The tooling 1 is formed of a plate 5 equipped with a flange 6 that delineates the shape and contour of the part to be made and which may comprise within this flange reliefs 7 such as protrusions or other flanges to delineate different layers or zones of curvature on the part to be manufactured.

Other similar or dissimilar molding tools are installed on a spare jig station 8, ready to be installed on bench 2 as soon as the lay-up of the current part is completed.

The apparatus includes a projector 10 of video images and a camera 11 attached to the projector 10. It is suspended above the tooling 1 via a structure that comprises a horizontal fixed bar 12 on which a cursor 13 slides. The cursor 13 is equipped with a horizontal movable bar 14 perpendicular to the previous one, on which slides a second cursor 15 bearing a fork 16 through a ball joint 17. The ball joint 17 allows the projector 10 and the camera 11 to turn in all directions. Furthermore, the projector 10 is screwed onto the fork 16 in a height-adjustable manner. It is therefore possible to adjust the position of the projector 10 and the camera 11 in all directions.

In fact, two projectors 10 and two cameras 11 hang from two separate structures. Such an arrangement may be considered in the case of large-area tooling 1: each projector 10 and each camera 11 are then associated with half of the surface of the tooling 1. For even larger tooling, more projectors 10 can be used.

Now we move on to Figure 2 in connection with Figure 1. The apparatus control system consists essentially of a computer 20 connected by power lines to the projectors 10 and cameras 11 as well as graphic consoles 21. The computer 20 was programmed to teach it the shape of each tooling 1 as well as the location and shape of the various layers that must be placed on this tooling 1. Before placing a layer, the operator signals it by typing an instruction on a graphic console 21. The computer 20 then controls the projectors 10 so that an image (I in Figure 1) of the layer to be placed at that time is projected on the correct location on the tooling 1. In the case of several projectors 10, those whose projection field on tooling 1 does not contain any portion of the image are obviously not put into service. The appropriate layer (M) is then placed by the operator so that it overlaps with the projected image. The cameras 11 verify the proper execution of this operation. To do this, when the computer 20 is told that we will move on to the next step, the image collected by the cameras 11 is examined by the computer 20 and compared to the image that should be found.

In the embodiment currently provided by the applicant, monochrome cameras are used that collect square images of 512 pixels per side and are capable of discerning 250 gray levels or, more generally, different shades of color. For each image point, we compare the reference gray level, obtained during a learning step, to the gray level obtained during the actual lay-up of the part on tooling 1. For example, the comparison can have four steps that are performed successively.

In the first step, the shape of the layer that has just been placed is recognized and compared to the shape of the layer to be deposited.

If the comparison is positive, the computer 20 compares, by their coordinates on the image, the location where the layer is placed in the intended location.

A comparison is then made of the overall gray level of the layer. For example, if the layer is too clear, it can

be detected that the protective polyethylene sheet that normally covers the layer has not been removed.

Finally, the gray level comparison is performed locally, for each pixel, in order to detect any residual polyethylene patches or other local irregularities on the layer.

If no errors are found, the computer 20 projects the image of the next layer when the operator requests it. Otherwise, an error message is displayed on the graphic consoles 21 based on the results of the various comparisons, and the operation of the projectors 10 is blocked until the error is corrected.

Other indications may also appear on the graphic consoles 21 if the programming of the computer 20 allows it. In particular, it is possible to view the image on the screen of the tooling and the theoretical locations of the layers of the part. The image collected by the cameras 11 of the lay-up actually carried out can also be viewed, superimposed on the previous one or on another screen. It is also possible to use video image reception stations directly connected to the cameras 11.

To complete the apparatus, it is planned to use a robotic cart 22 that provides the operator with all the pieces necessary to lay up the part. However, this robotic cart is not part of the invention.

Now we move on to the comment on Figure 3. In this embodiment, the projectors 10 are not suspended from the ceiling of the room where the lay-up is carried out using an adjustment installation, but are hooked to a frame 25 placed on the ground and formed of intersecting metal beams. The frame 25 comprises in particular two parallel upper spans 26 and each bearing two rails 27 on which a projector 10 is screwed so that it is adjustable in height, horizontally and in position.

The spans 26 can also be screwed in different locations on a top frame 28 which is part of the frame 25 to provide additional freedom to adjust the position and orientation of the projectors 10.

A middle frame 29 bears a rolling walkway 30 that allows easy access to the projectors 10 and the spans 26, and a lower frame 30 bears a removable grid test pattern 32. The test pattern 32 is used to properly focus the projected images. In the event that the projectors 10 have an electronic adjustment capability, this adjustment is used to refine the projected images. However, in the case of fixed focal length projectors, it is only possible to fine-tune the projection setting by moving them.

The adjustment method consists of projecting an image on the grid, known as "source pattern" and created by the computer 20, onto the pattern 32, and moving the projectors 10 or adjusting them if they are equipped with an electronic adjustment so that the image on the grid lines up with the pattern 32 itself. The pattern 32 is then removed, the tooling 1 is installed substantially at its location and the image of the reference tooling is matched with the actual tooling. The lay-up can then begin.

Many detailed changes can be made to the apparatus described according to the concrete conditions of how the workstations and available devices are installed. It should also be noted that cameras 11 may be omitted if individual control of each layer is not required.

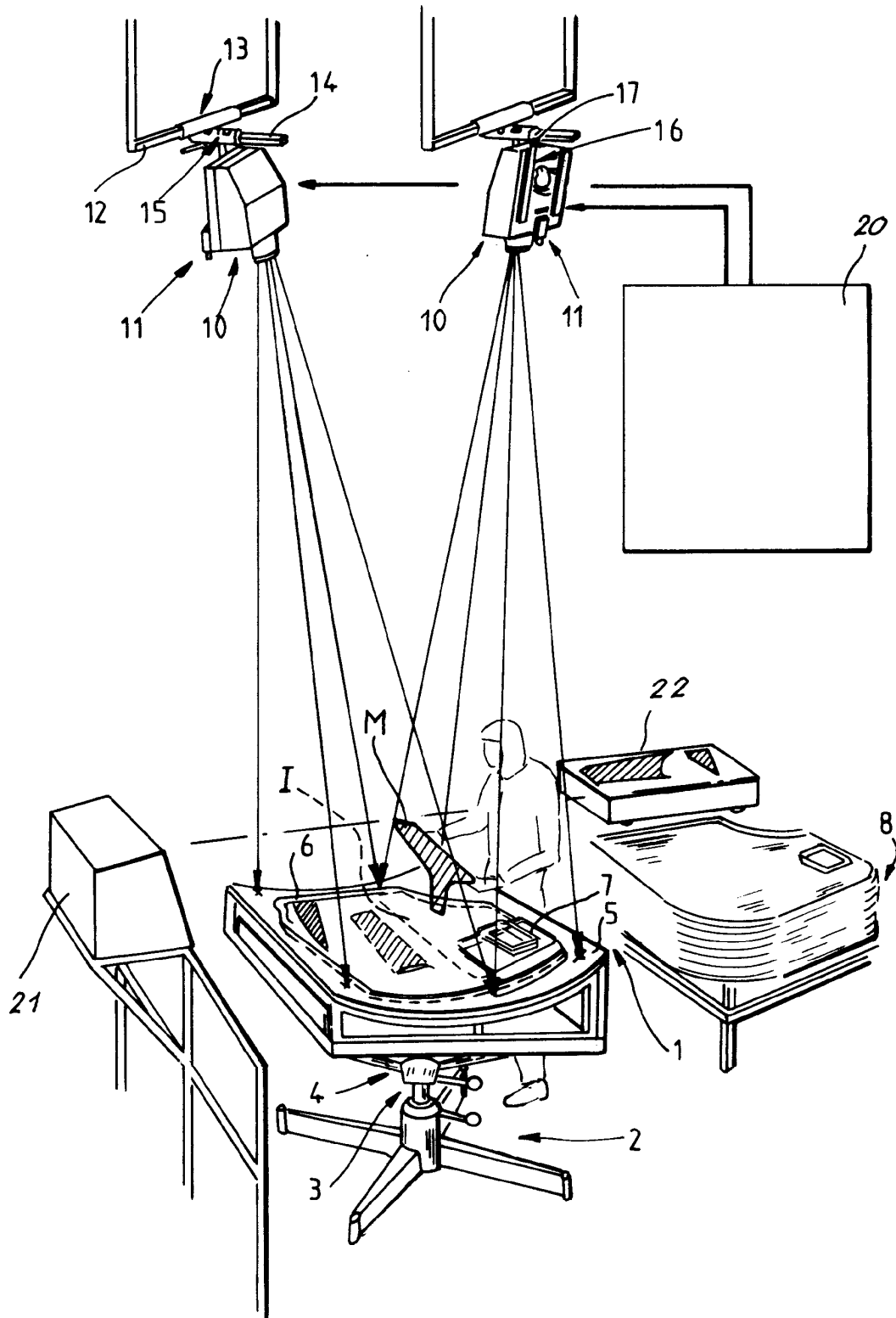
Claims

1. Apparatus for assisting in the hand lay-up of parts by assembling multiple layers (M) of fabrics or high strength fiber strips pre-impregnated with curable resin comprising an application apparatus (1) and controlling the proper execution of the lay-up, characterized in that it comprises:
 - at least one video projector (10) directed towards the tooling (1) and a control system (20) capable of having the projectors (10) project images indicating the shape, location and texture of the layers to be deposited successively by the operator;
 - a viewing screen (21) connected to the control system and on which said images appear;
 - a camera (11) directed towards the tooling (1), connected to the control system (20) and capable of discerning the shape, position and texture of the layers deposited on the tooling;
 - and a computer integrated into the control system (20), capable of comparing the images from the camera with reference images of the layers deposited on the tooling and stopping the manufacturing process if a
 - difference is detected between a reference image and an image of a layer in place.
2. The lay-up support apparatus according to claim 1, characterized in that it comprises a moveable adjustment test pattern (32), arranged at the

location of the tooling (1) and in that the control system (20) is capable of projecting a calibration image onto the pattern (32).

3. Device for controlling the proper execution of the lay-up performed according to claim 1 or 2, characterized in that the camera (11) is a monochrome camera.
4. Device for controlling the proper execution of the lay-up according to claim 3, characterized in that it further comprises a viewing screen (21) of the images collected by the camera (11).

FIG. 1



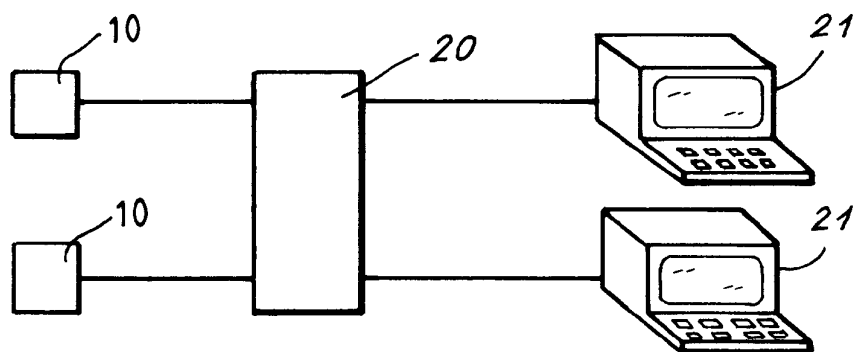


FIG. 2

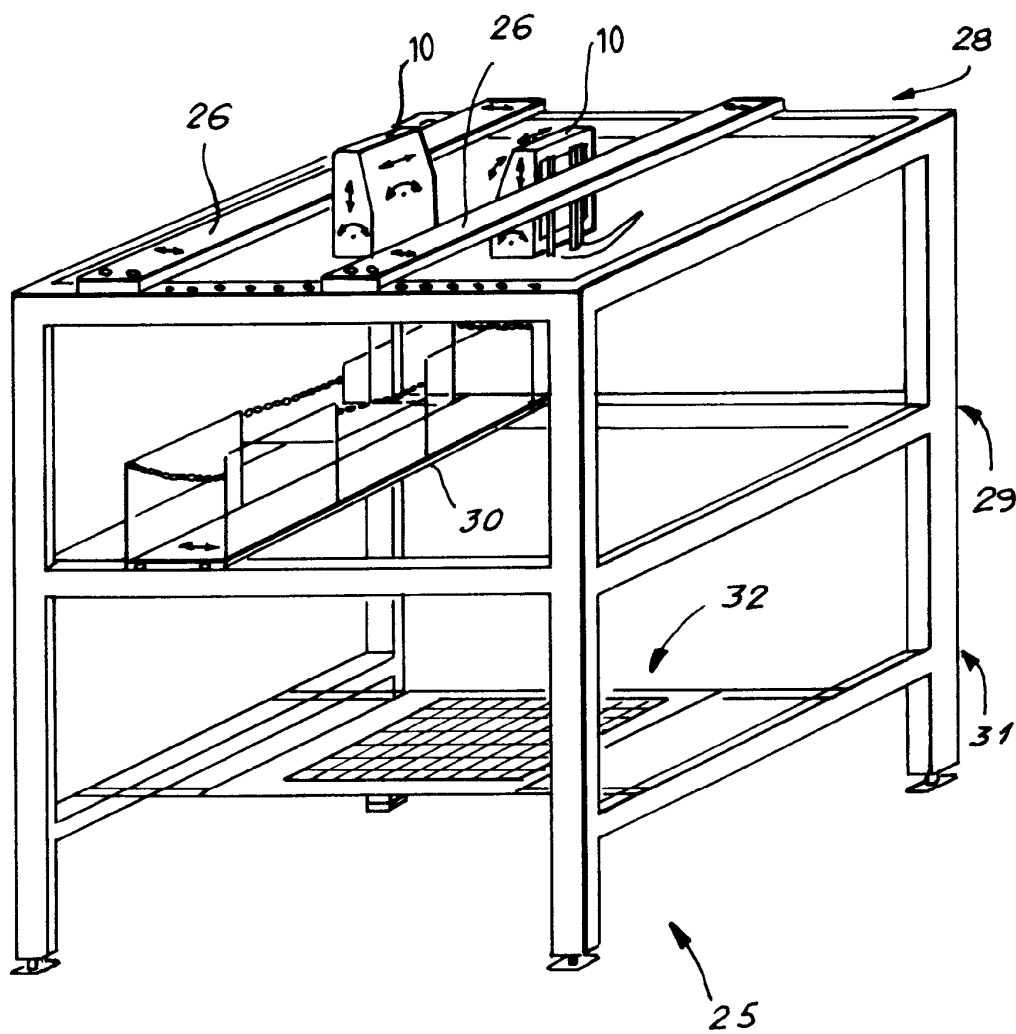


FIG. 3

DOCUMENTS CONSIDERED RELEVANT			
Category	Citation of the document with indication, if necessary, of the relevant parts	Claim concerned	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	DE-A-3 242 949 (MESSERSCHMITT BOTKOW BLOHM) * the entire document *	1.2	B29C67/14
Y	EP-A-0 165 890 (G. IMBERT) * page 4, line 24 - line 29 * * page 6, line 2 - line 25; claims; figures *	1.2	
A	EP-A-0 128 826 (AEROSPATIAL) * the entire document *	2.4-6	
A	IEEE 1986 NATIONAL AEROSPACE AND ELECTRONICS CONFERENCE, NAECON 1986 vol. 2, Mal 1986, DAYTON pages 508 - 511; T. HALL: ⁵¹ CAD/AI applications for automated manufacturing of composite structures ¹ * page 508, column 2, line 22 - line 47 *	4-6	
			TECHNICAL DOMAINS RESEARCHED (Int. Cl.5)
			B29C
This report has been prepared for all claims			
Search location THE HAGUE		Search Completion Date NOVEMBER 14, 1991	Reviewer VAN WALLENE A.M.
CATEGORIES OF DOCUMENTS CITED			
X: particularly relevant in itself Y: particularly relevant in combination with another document in the same category A: technological background O: unwritten disclosure P: insert document		T: theory or principle at the basis of the invention E: prior patent document, but published on or after the filing date D: cited in the application L: cited for other reasons ----- &: member of the same family, corresponding document	