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DESCRIPTION

[0001] This invention is concerned with methods for inspecting pallets of a kind that uses an automated inspection station which includes a frame that carries a transport system for transporting the pallet to be inspected, and one or more pallet feature sensing heads for inspecting the transported pallet.

[0002] A method of this above-specified kind is known from EP-A-0 823 629 in which the pallet is transported by conveyor from one to another of a series of video cameras that during a first stage scan the transported pallet element by element to pinpoint defects in these elements. In a second stage the defects are compared for compliance with a catalogue of recognised defects to identify whether the elements of the pallet are, or are not, in a satisfactory condition.

[0003] According to the present invention a method of said above-specified kind is characterised in that the one or more pallet feature sensing heads comprise a laser and camera system, that the one or more pallet feature sensing heads create a three-dimensional data map of the pallet for detecting gaps and protrusions in the pallet, that the three-dimensional data map is filtered into a two-dimensional image of on/off values by using a dynamically created height value which corresponds to a reference plane or set threshold offset above a board surface of the pallet, and that data about the pallet is compiled into a database.

[0004] According to another aspect of the present invention there is provided an automated pallet inspection station for receiving a pallet, which includes a frame that carries a transport system for transporting a pallet to be inspected, and one or more pallet feature sensing heads for inspecting the transported pallet, characterised in that the one or more pallet feature sensing heads comprise a laser and camera system, that the one or more pallet feature heads create a three-dimensional data map of the pallet for detecting gaps and protrusions in the pallet, that an image analysis algorithm filters the three-dimensional data map into a two-dimensional image of on/off values by using a dynamically created height value which corresponds to a reference plane or set threshold offset above a board surface of the pallet, and that data about the pallet is compiled into a database.

[0005] The filtering of the three-dimensional data map in the method and inspection station of the present invention provides locations of the gaps and protrusions in the pallet, and may be carried out by a Sobel or Gaussian filter.

[0006] Automated pallet-inspection stations or cells, and methods of using them for pallet inspection and for pallet-repair will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of an automated pallet-inspection and repair cell;

Figure 2 is a perspective view of a different pallet-inspection and repair cell from that of Figure

1;

Figure 3 is a perspective view of a pallet-gripping device used in the stations;

Figure 4 is a perspective view of an alternative pallet-gripping device to that of Figure 3;

Figure 5 is a perspective view of another, alternative pallet-gripping device;

Figures 6 (a) and 6 (b) are perspective views of a pallet-gripping device of the same type as that of Figure 5 for gripping pallets internally;

Figure 7 is a perspective view of a further pallet-gripping device for gripping pallets externally;

Figure 8 is a perspective view of an inspection table used with the stations and methods of the invention;

Figure 9 is a perspective view of a portion of the station or cell shown in Figure 1;

Figures 10 to 11 are perspective views of a board-removal saw;

Figure 13 is a perspective view of blade-position sensors of the board-removal saw;

Figures 14 (a)-(c) are elevations of the board-removal saw showing pallet positioning prior to a cutting operation;

Figure 15 is a perspective view of another portion of the station or cell shown in Figure 1;
Figures 16 and 17 are, respectively, a side elevation and a perspective view of a board-replacement machine.

[0007] As shown in Figure 1, an example of a robotic work cell for inspecting and repairing pallets 10 comprises an input conveyor 11 which delivers pallets 12 to an unloading area 13. The optional conveyor 11 is capable of assuming a number of different forms and styles. In this example, the inspection and repair cell 10 includes a first robot 14 and a second robot 15. The two robots 14,15 work together to transport a pallet through a number of stations. Each station performs one or more operations which are required during the inspection and repair process. In some examples, a single robot placed centrally within a cell, or circuit of stations (see Figure 2) is capable of transporting a pallet through the entire inspection and repair cycle. In the example of Figure 1, the first robot 14 transports a pallet through an automated inspection device 16 and a damaged board removal saw 17 before handing the pallet over to the second robot 15. The second robot 15 inserts the same pallet into a lead board adjustment station 18 and a board replacement station 19 before loading the pallet onto a second conveyor or etc. (not shown) for removal of the inspected and repaired from the cell.

[0008] As shown in Figure 2, a pallet may arrive at a basic or single robot inspection and repair cell 20, by any means (eg forklift, conveyor, pallet dispenser). This repair cell may take a number of configurations but in this particular embodiment the cell is essentially a continuous

circuit which begins on the input conveyor 21 and ends on the output conveyor 22. When the pallet has arrived at the cell it must be gripped before further operations to take place. Gripping is accomplished with a robotic style arm 23 which may be equipped with a machine detectable reference point (or datum) 24. This machine detectable reference point may be replaced by a datum generated by the software. The arm 23 terminates in wrist joint and a gripping device or appliance 25. The gripping appliance 25 may have its own datum 26, which may be the only datum. This single robot cell includes a lead board adjustment station 28, a board removal station 29 and a board replacement station 29a.

Gripping a Pallet

[0009] Gripping the pallet continuously throughout the automated inspection and repair process has several advantages. By "continuously" we include a hand-off between two or more robots where the orientation datum is preserved. First, gripping the pallet such that all elements of the pallet are, from that point onward, in a fixed location relative to at least one datum provides a convenient way of locating the pallet and its features, in space, throughout the entire inspection and repair process or circuit. This allows the pallet to be mapped and the pallet's features to be recorded to, for example, a database. Control over the inspection and repair process is possible because each recordable feature has a reference to a datum which can be read, whenever required, to locate the pallet relative to a particular workstation, inspection station, or repair station. Second, gripping provides a secure way of handling the pallet, making both sides of the pallet potentially accessible in a way which does not interfere with either inspection or repair.

[0010] In one preferred embodiment, the gripper is attached to a manipulating device such as a robotic arm that can move the gripped pallet through space in any direction and at any angle. This may be a multi-axis robotic arm (Figures 1 and 2), or any device for translating and rotating the gripped pallet. The robot arm or manipulating device may be fixed or on rails or tracks. It may be vertical or horizontal or at any angle, and may be attached to the walls, a pedestal, the floor, ceiling, overhead or suspended structures or a combination of these. The gripper may be permanently attached to the manipulating device, or it may be able to detach and reattach at various points in the repair cell if needed, to allow the manipulating device to work with multiple pallets. In all cases, the gripper must be small and thin enough to not impede access to the deck boards on the pallet, however it must be strong enough to hold the pallet against high inertial forces when moved between sections of the repair cell. The gripper may have sensing devices installed to check that a pallet has been successfully gripped. The gripping device, if detachable, must have a locking mechanism so that it stays closed and grips even when disconnected from the arm or device which manipulates it.

[0011] As shown for example in Figures 3-7, pallet gripping may take place in a number of ways. As shown in Figure 3, a gripper 30 having generally full length parallel compressing grips may be inserted between the bearers 32 for the purpose of clamping the central bearer 33 or central blocks.

[0012] As shown in Figure 4, the gripper may take the form of a large rectangular hoop or frame 40, which may be placed around the entire pallet. Such a hoop or frame would then be reduced in size to clamp the pallet securely around its periphery. Size reduction of the hoop or frame is achieved with pneumatic or hydraulic cylinders 41 attached together by an end piece 42. The terminal ends 43 of the arms 41 need not be attached to one another. The gripper or gripping device may include an integral wrist joint or coupling 45, for example as shown in Figure 4. In other examples the gripping device does not include a wrist joint or coupling.

[0013] Alternatively and as shown in Figure 5 a tensile gripper 50 may be inserted between the bearers 51 and use outward facing actuators 55 to force friction pads to expand outward so as to clamp against the inside edges of the outermost bearers or blocks 51. For example, Figure 5 shows sensors 55a which sense the presence or proximity of the inside surface of the adjacent bearer, thus confirming proper contact has been made. The sensors may be provided on all required pallet contacting surfaces. In the example of Figure 5, the contact sensors 55 may be built into the actuators that extend along the exterior lateral contacting surfaces 56. One or more sensors 55a are located in a position corresponding to the closest portion, front opening or mouth of the pallet 57. When this sensor 55a is activated, it confirms that the gripper is fully inserted in the pallet. This concept is extendible to other gripper styles.

[0014] The gripper may also expand against the inner faces 53 of the top and bottom deck boards. As shown in Figures 6 (a) and (b), a tensile gripping device of the type depicted in Figure 5 may include a rigid body 60 on to which are mounted the lateral actuators 55, sensors 55a etc. The rigid body 61 further comprises a pair of substantially full length tines 62. Each tine has a pair of longitudinal actuators 63. Each longitudinal actuator 63 runs approximately the full length of each tine. When the gripping device 60 is inserted into the pallet, the longitudinal braces or actuators 63 are retracted as shown in Figure 6 (a). When the actuators or braces 63 are extended (e.g. vertically with regard to a flat pallet), they exert themselves against the interior faces of the top and bottom sides of the pallet. This has a stabilising effect and complements the action of the lateral actuators 55.

[0015] As shown in Figure 7, another form of exterior gripping device comprises a discontinuous external gripping frame 70. The frame 70 is coupled to the robotic arm at an optional rotatable wrist joint 72. The frame 70 further comprises parallel external arms 73. The pallet fits between the arms 73. Each arm 73 terminates with a compressing device 74. Each compressing device 74 is adapted to compress the pallet against the transverse base 75 of the frame. The compressors 74 are driven toward and away from the pallet by actuators located within or on the arms 73. The compressor 74 may also rotate if required, to allow the pallet to be withdrawn from the frame 70 more conveniently.

Inspection

[0016] As shown in Figure 8, an automated inspection table 80 may be used in a stand-alone

capacity without the associated repair system, in a quality control system or sorting system. As a quality control system it could be used to determine whether pallets are fit for use (i.e. meet the quality standard for that style of pallet). As a sorting system it could be used to gather data for sorting pallets by type, size, or quality level. Various repair devices and methods are disclosed below. These may be used alone or in combination after either a manual or automatic inspection. The inspection table or station includes a transport system 82 and one or more sensing heads 83.

[0017] A pallet feature sensing head may be constructed in different styles. Firstly it may be constructed with a series of sensors in a line (linear array) to detect the presence or absence of timber (or other pallet material). This type of sensing head would be positioned adjacent to the moving pallet so that it scans the pallet surface passing near it. Such a sensing head would give a two dimensional image or map of pallet characteristic values. The values may be analogue or digital. This image can then be analysed against a set criteria with the identified differences used as a of pallet quality.

[0018] However, according to the invention the one or more pallet feature sensing heads comprise a laser and camera system to capture individual profiles (cross sections) of the pallet (i.e. the camera records the location of a projected laser line and triangulates its position to give height and coordinate data). The laser beam which is projected onto the pallet may be fan shaped or it may be scanned across the pallet surface using, for example, moving mirrors. Such a system will provide three-dimensional data map on the pallet and can be used for detecting gaps or protrusions such as nails, hanging plastic etc. The three dimensional data is filtered into a two dimensional image of on/off values by using a dynamically created height value, corresponding to a reference plane or set threshold offset above the bearer or connector board surface. The three dimensional data can also be filtered using image analysis algorithms (such as the Sobel or Gaussian filters) to provide locations of protrusions, cracks and other deviations in the pallet element surfaces.

[0019] As shown in Figure 8, a robotic arm is capable of placing a pallet requiring inspection into an inspection table 80. Of course, a pallet may be loaded manually or using other means where any robot is not available. The sensing table 80 includes a rigid frame 81 and a pallet transport mechanism 82. The transport mechanism serves as a motorised conveyor which is capable of propelling a pallet and a sensing head 83, preferably at a fixed velocity so that data about the physical dimensions and topography of the pallet may be obtained.

[0020] This system will then compile the data about the pallet into a database for use by the other equipment in the cell. This is a form of mapping of features relative to a datum. Data acquired in this way may include the location of protruding nails or other objects, the location of cracks, the location of cracked boards, or misaligned boards or missing boards.

[0021] Another form of automated inspection device is shown in Figure 9. As shown there, a conveyorless inspection device 90 comprises a rigid frame 91 which defines a central gap area 92. A lower rigidised support 93 retains a lower upward looking sensing head 94 and an upper

horizontal support 95 and an upper downward looking sensing head 96. In this embodiment, each support 93, 95 is reinforced by a pair of braces 97. The braces rigidise the support and also serve to mechanically protect the sensing heads 94, 96. In this form, the automated inspection device does not require a conveying surface. Instead, the pallet is gripped with an appliance or device and then pulled or pushed by the robot through the frame and between the sensing heads 94, 96 along a linear path.

[0022] Data in the two dimensional form noted above is sorted into arrays of related points representing each pallet element such as a board, broken board segment, bearer etc. Each element array is then tested against a range of criteria to determine the quality of that element, and whether a pallet component is missing or should be removed or adjusted. In addition, gaps between components or elements are also tested against a range of criteria to determine whether neighbouring pallet elements should be marked for inspection or repair. Decisions made for each element or gap are made in a hierarchical manner- e.g. element removal decisions override element position adjust decisions and so on. When all checks on a particular element have been made, the highest-ranking decision for that element is recorded to a database. Overall pallet analysis is carried out once all elements have been checked and decisions stored to the database. This overall analysis can be used to sort pallets into various styles (eg by number of boards or by a multiple of criteria set points) or into good and bad (eg by number of operations required on pallet), alternatively it can be used to determine whether the pallet is able to be repaired by an automated system or must be sent to a human operator for inspection. If the pallet can be repaired by an automated repair cell, the system generates a recipe of repair tasks for machine control within the repair cell. This recipe is handled by a combination of the Human Machine Interface (HMI) system, the analysis system, the programmable logic controller (PLC) and the robot controller.

[0023] As further shown in Figure 9, a robotic arm 14 is used to transport a pallet through the gap area 92 in a linear fashion and at a relatively constant velocity. After the pallet has been scanned and analysed, it is ready for introduction into a board removal machine 97. Because the robotic arm 14 is located between the inspection station 90 and the board removal machine 97 it is able to transport the pallet without letting go of it.

Board Removal

[0024] The board removal machine 97 may comprise a form of stationary horizontal band saw. As will be explained, the robotic arm 14 is capable of positioning the pallet in such a way that the blade of the band saw is located between adjacent boards of the pallet. By linearly advancing a pallet toward the blade, the nails or other fasteners which are used to hold a board to its bearers can be cut so that the board can be completely removed. The robot positions the pallet so that the saw cuts from a lower surface. The lower surface during cutting can be the top surface of the pallet if the pallet is inverted by the robot. Where the gap between adjacent boards is too narrow to admit the blade of the band saw, the pallet may be advanced past the band saw 98 to a pry station 98. The robotic arm 14 is used to advance the

pallet onto the pry station to the correct depths. As a result of the analysis inspection process, the pallet is inserted so that the pry tables rotating pry lever 99 enter the interior space of the pallet. Rotating the pry arms or levers 99 forces a board to be ejected from a pallet. Subsequently, a milling head of the pry station removes protruding nails.

[0025] As shown in Figure 10, the board removal saw 97 comprises a rigid frame 101 which supports a pair of rotating spools 102. The spools 102 support and transport a moving blade 103 having teeth which face the direction from which the pallet arrives by virtue of the robot arm. The saw blade 104 is narrow enough to fit between most adjacent top boards or bottom boards. The robot may be used to invert the pallet so that top boards are removed with the pallet in the inverted position.

[0026] The saw 97 may include a pair of blade lifters 105. The lifters are located in positions that correspond to the center of the gaps between adjacent bearers of an inserted pallet. Each blade lifter 105 includes a steel roller 106 which is carried by a pivoting head 107. The pivoting head 107 is carried by a hinge 108 which is attached to a vertical struck 109. An actuator 110 extends between the struck 109 and the pivoting head 107.

[0027] As shown in Figure 11, the rollers 106 can be extended so as to lift the central portion of the blade, as required. In some cutting situations, the central bearer of a pallet, when the pallet is inverted, is higher than the exterior bearers. In this case, the blade lifters are deployed to raise the central part of the blade so that it more closely contacts the central bearer.

[0028] As shown in Figure 12, the lifters 105 can pivot out of the way of an advancing pallet. If an unremoved board of an advancing pallet contacts the rollers 106 the heads 107 can pivot out of the way. They may be returned to their initial position by the actuators 110 so as to return to the position depicted in Figure 10.

[0029] As shown in Figure 13, the saw 97 includes both vertical and horizontal blade location or proximity sensors. The upper portion of the blade 104 is associated with a vertical deflection measurement device 130 at each end of the cutting portion of the blade. In one embodiment, a laser proximity sensor is used as the vertical deflection measurement device 130. The device 130 projects a beam 131 onto the moving blade 134 and drives a measurement which will be used for the purpose of accurately positioning the pallet with respect to the blade, as will be explained. The blade 104 is also associated with a rotating but resiliently suspended blade follower 132 which is associated with a horizontal deflection measurement device 133. A laser proximity sensor may also be used to project a beam 134 onto the blade follower 132. The horizontal deflection measurement device 133 generates a signal from which excessive force on the blade can be determined. When the force on the blade reaches a pre-established threshold, as determined by the deflection measurement device 133, the board removal operation can be stopped or reversed. A vertical deflection measurement device 130 may be located at each end at the top portion of the blade 104.

[0030] As shown in Figure 14, a vertical deflection measurement device 130 is located at each

end of the working portion of the blade 104. Because of variations in the construction of pallets, bearer thicknesses, warping and etc., it is possible that a pallet will require a level adjustment prior to cutting. Failure to adjust the pallet entry roll angle can cause uneven stress on the blade or a cutting path which removes material unevenly from the pallet. Hence, the robotic arm positions the pallet so that it is inclined with respect to the blade 104. This is shown in Figure 14 (a). The robot causes the pallet to roll in one direction with respect to the blade. As shown in Figure 14 (a), when rolled, one corner of the pallet will contact one end of the blade. When the pallet contacts the blade as shown in Figure 14 (a), the appropriate vertical deflection device will generate a signal from which the inclination of the pallet can be measured as an angle with respect to the blade 104. This same process is repeated by rolling in the other direction as depicted in Figure 14 (b) again, a deflection angle is measured by one of the sensors 130. The correct orientation angle for the pallet is determined by adding the 2 angles measured in Figures 14 (a) (b) and then determining the average. The pallet is rolled to a position in Figure 14 (c) which represents the subtraction of this average from the angular displacement depicted in Figure 14 (b).

Lead Board Adjustment

[0031] As shown in Figure 15 and with reference to Figure 1, the second robot 15 with the internal gripper 60 is associated with a lead board adjustment station 150 and a board replacement station 151. In this example, the lead board adjustment station 150 comprises two modules 152, 153. Each module further comprises a rigid frame 154 that defines a central loading opening 155. The robot 15 inserts the pallet into the opening 155 and lowers the pallet until it makes contact with the lower supporting surfaces 156. Hydraulic actuators 157 associated with each module are capable of adjusting the location of the front and rear lead boards with respect to the bearers. One side of the pallet is adjusted, and then pressed into position using the existing nails. If required and then the robot can be used to withdraw the pallet and reinsert it so that the opposite face of the pallet can have its front and rear lead boards adjusted. In the alternative the device can reposition and press all four lead boards at once. After the lead boards are adjusted, the robot 15 is used to transport the pallet to the board replacement station 151.

Board Replacement

[0032] As shown in Figures 16 and 17, the board replacement station 151 comprises a hopper 160 which contains a supply of lead boards 161 as well as intermediate boards 162. A board slide 163 is used to transport the appropriate and selected board to a location beneath an array of board clamps 165 and nail guns 164. A pusher such as a pneumatic or hydraulic actuator 166 is used to advance the selected board along and down the board slide 63 in the repair position.

[0033] As shown in Figure 17, a back stop 170 may be lowered into position to define a margin beyond which a board advanced by the actuator 166 cannot proceed. When the board advances down the slide 163 and contacts the back stop 170 it is considered in position. Once in position, the clamps 165 are actuated. This holds the board in position over the bearers. At this point, the nail guns 164 can be actuated to insert a first set of nails. The robotic arm is then used to reposition the board so that additional nails can be used to attach the replacement board to the 3 bearers.

[0034] After going through these machines, the pallet has been inspected and repaired, but may need cleaning to be fit for use. The manipulator will then guide the gripped pallet through a decontamination unit (not shown) that would consist of rotating (or fixed) brushes with dust extraction and a washing system.

[0035] When the pallet has been through each of these machines, it will be fit for use. When it is fit for use, the manipulator will move the pallet to an outfeed conveyor section of the cell, the gripper will disengage from the pallet and the pallet will be conveyed (by chain or roller or belt conveyor) away from the repair cell. Pallets may then proceed to a painting machine, if required. The gripper and manipulator will then return to the infeed section of the cell to start the process again on the next pallet.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- EP0823629A **[0002]**

Patentkrav

1. Fremgangsmåde til inspektion af en palle ved anvendelse af en automatiseret palleinspektionsstation (80), der omfatter
5 en ramme (81), som bærer et transportsystem (82) til transport af den palle, som skal kontrolleres, og ét eller flere pallefunktionsfølehoveder (83) til inspektion af den transporterede palle (12), kendetegnet ved, at det ene eller flere pallefunktionsfølehoveder (83) omfatter et laser- og
10 kamerasystem, at det ene eller flere pallefunktionsfølehoveder (83) danner et tredimensionalt datakort for pallen (12) til detektering af huller og fremspring i pallen, at det tredimensionale datakort filtreres til et todimensionalt billede af on/off-værdier ved anvendelse af en dynamisk skabt
15 højdeværdi, som svarer til et referenceplan eller et fastsat tærskelforskydning over en brætoverflade af pallen (12), og at data om pallen samles i en database.

2. Fremgangsmåde ifølge krav 1, hvori de tredimensionale
20 data også filtreres ved anvendelse af billedanalysealgoritmer.

3. Fremgangsmåde ifølge krav 2, hvori billedanalysealgoritmerne omfatter Sobel-filtre eller gaussianfiltre.
25

4. Fremgangsmåde ifølge krav 2 eller krav 3, hvori filtreringen ved anvendelse af billedanalysealgoritmer tilvejebringer placeringer af fremspring, brud og andre afvigelser i pallens overflade.
30

5. Automatiseret palleinspektionsstation (80) til modtagelse af en palle (12), hvilken station omfatter en ramme (81), som bærer et transportsystem (82) til transport af en palle, som skal kontrolleres, og ét eller flere pallefunktionsfølehoveder
35 (83) til inspektion af den transporterede palle (12), kendetegnet ved, at det ene eller flere pallefunktionsfølehoveder (83) omfatter et laser- og kamerasystem, at det ene eller flere pallefunktionsfølehoveder

- (83) udarbejder et tredimensionalt datakort for pallen (12) til detektering af huller og fremspring i pallen, at en billedanalysealgoritme filtrerer det tredimensionale datakort til et todimensionalt billede af on/off-værdier ved anvendelse af en dynamisk skabt højdeværdi, som svarer til et referenceplan eller et fastsat tærskelforskydning over en brætoverflade af pallen (12), og at data om pallen samles i en database.
- 10 6. Automatiseret palleinspektionsstation ifølge krav 5, hvori billedanalysealgoritmerne omfatter et Sobel-filter eller et gaussianfilter.

DRAWINGS

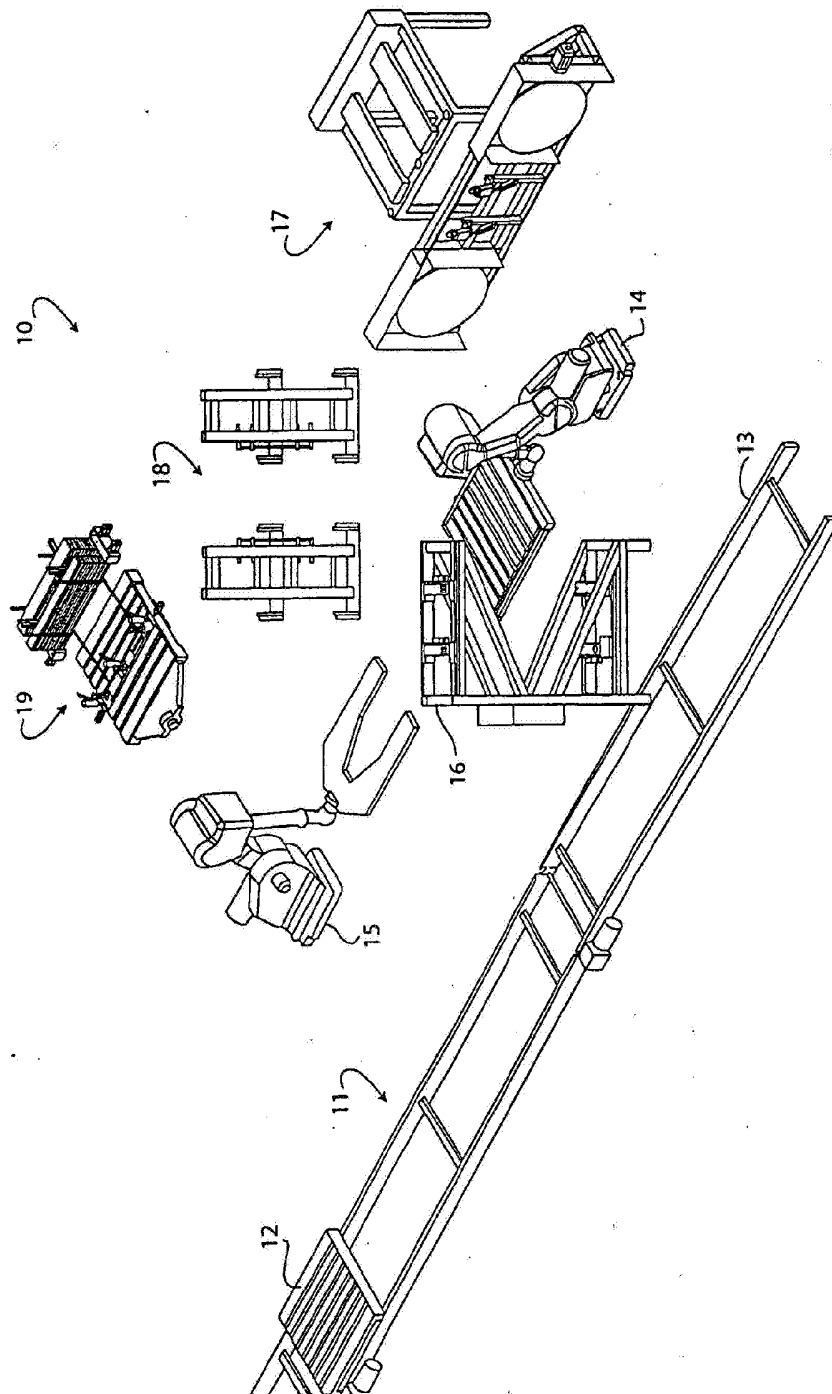


Fig.1

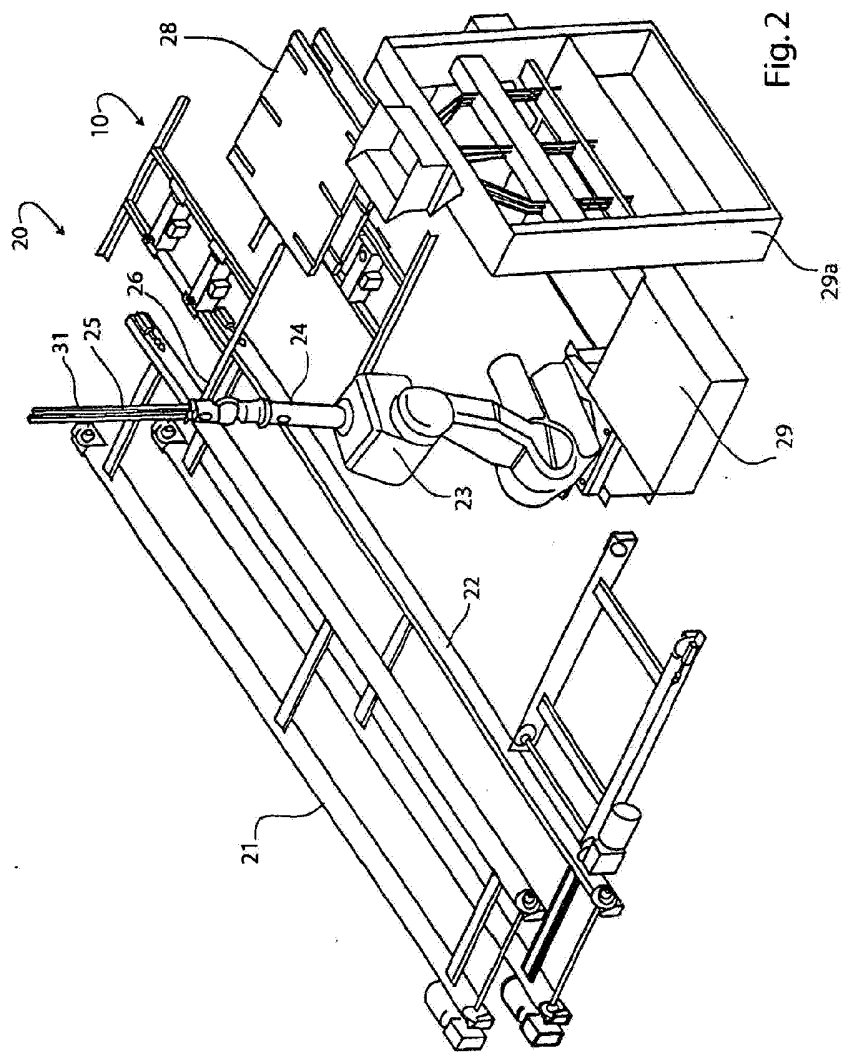
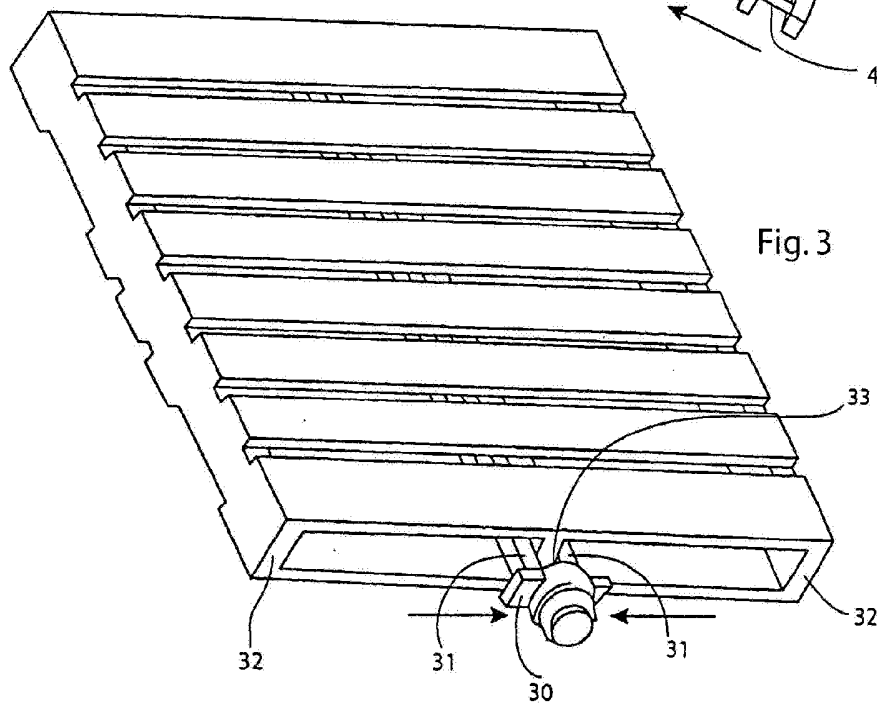
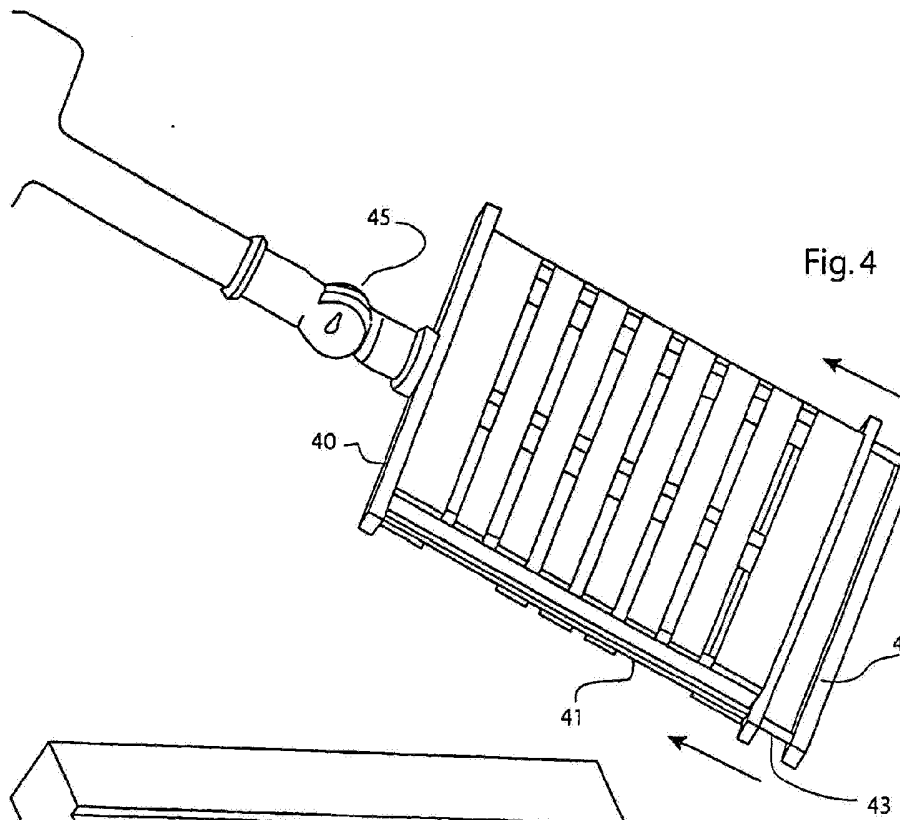


Fig. 2



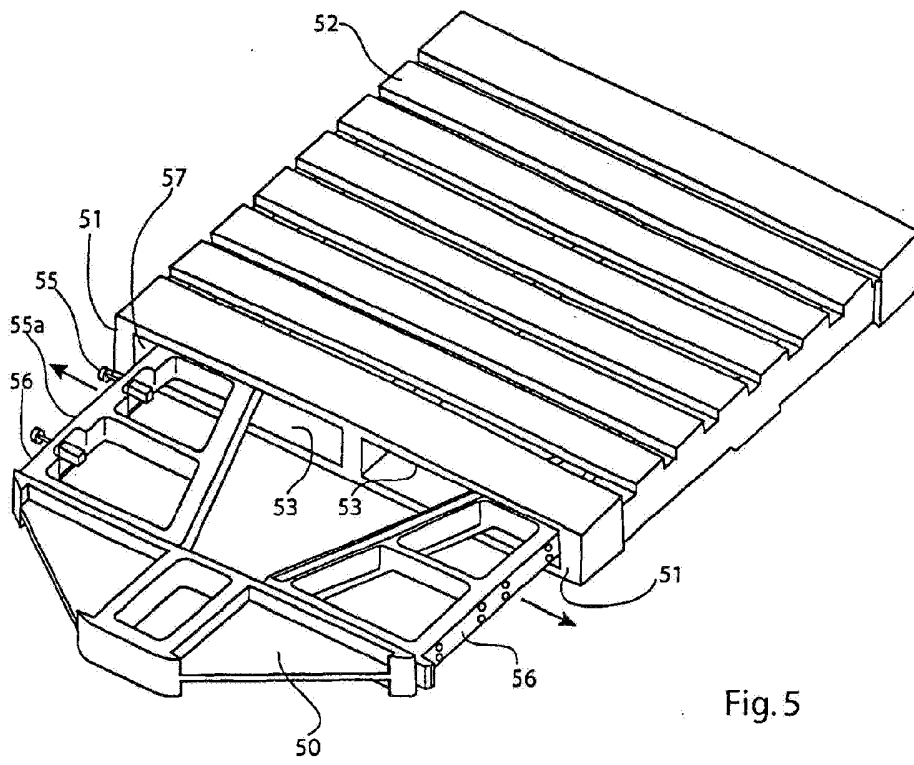


Fig. 5

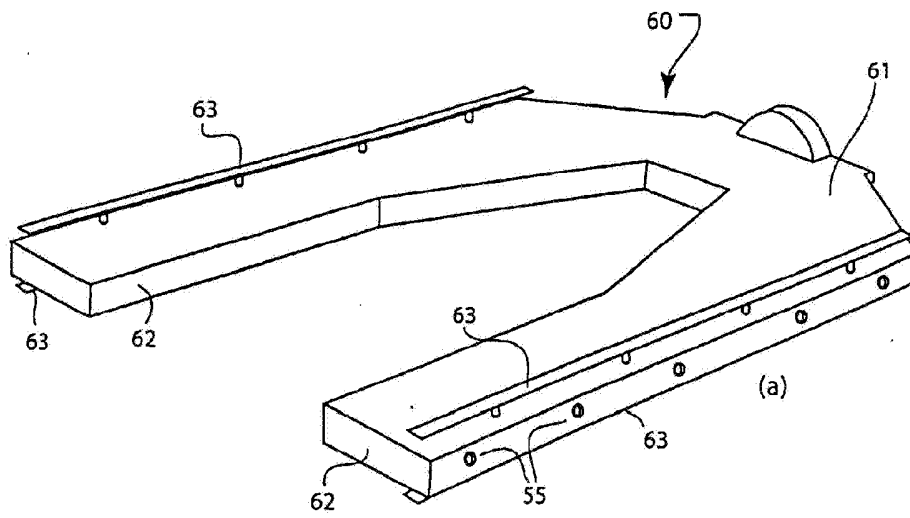
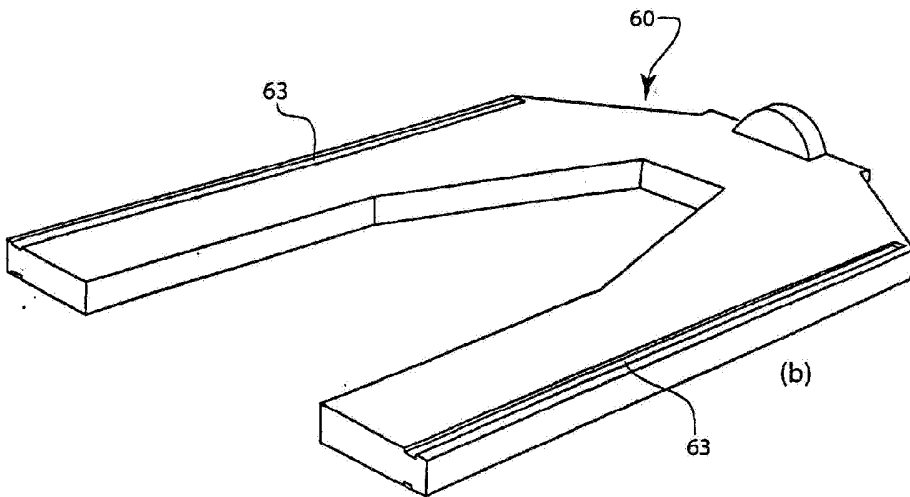


Fig. 6



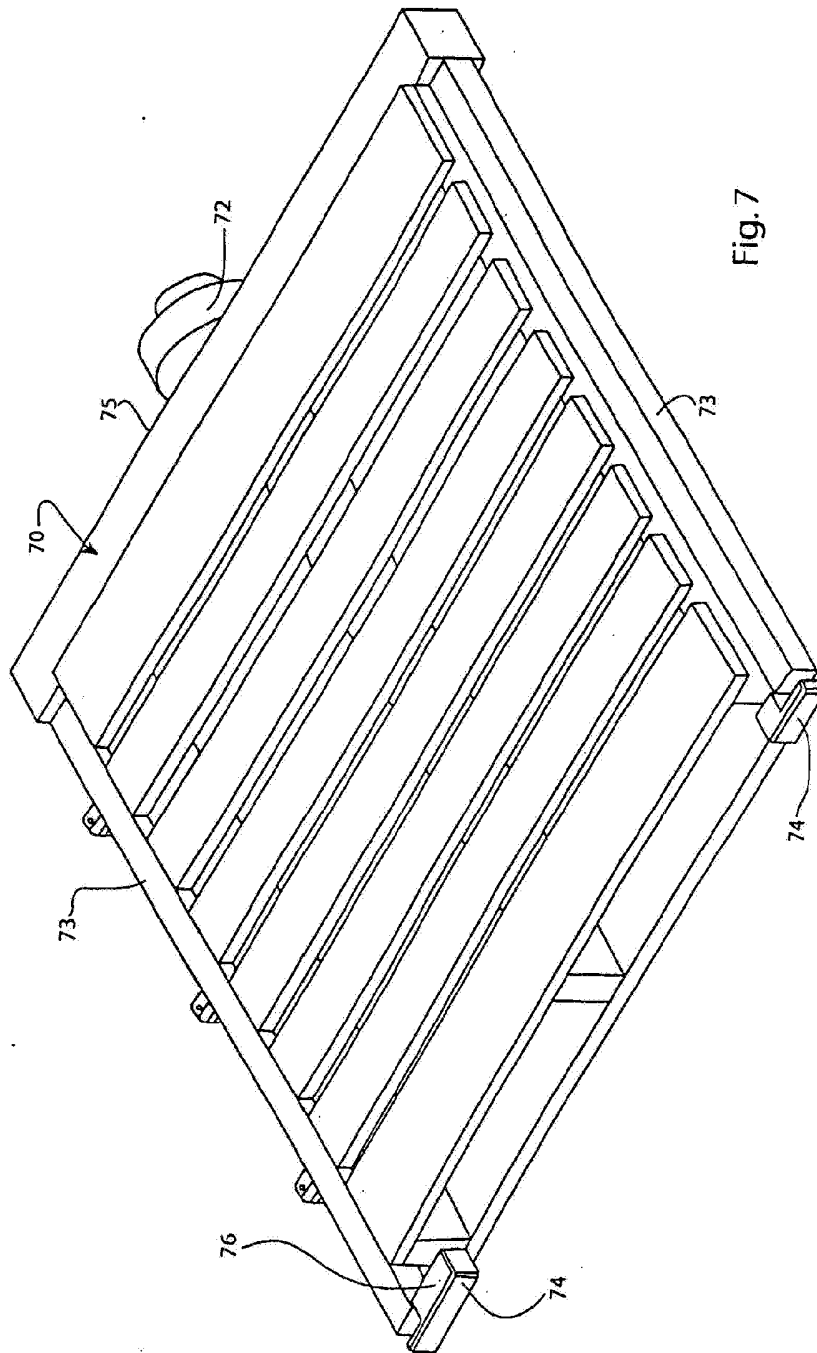


Fig. 7

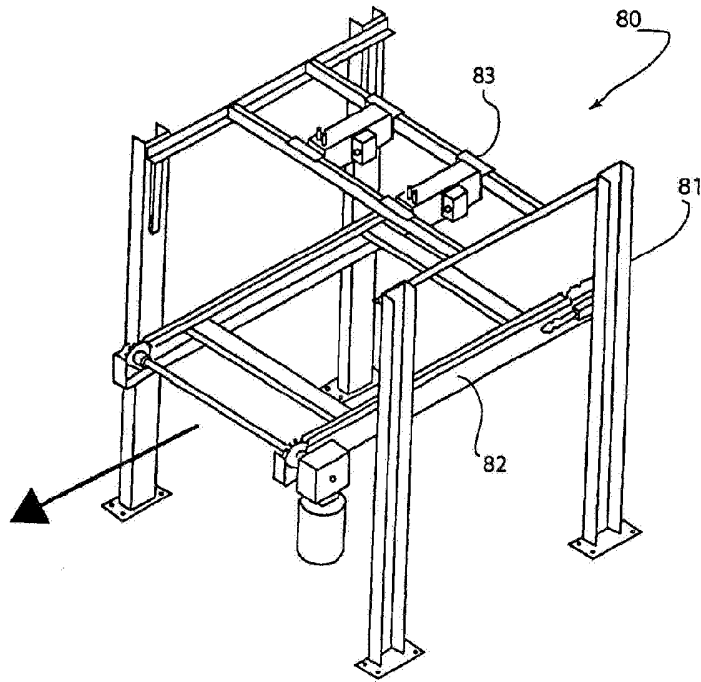


Fig.8

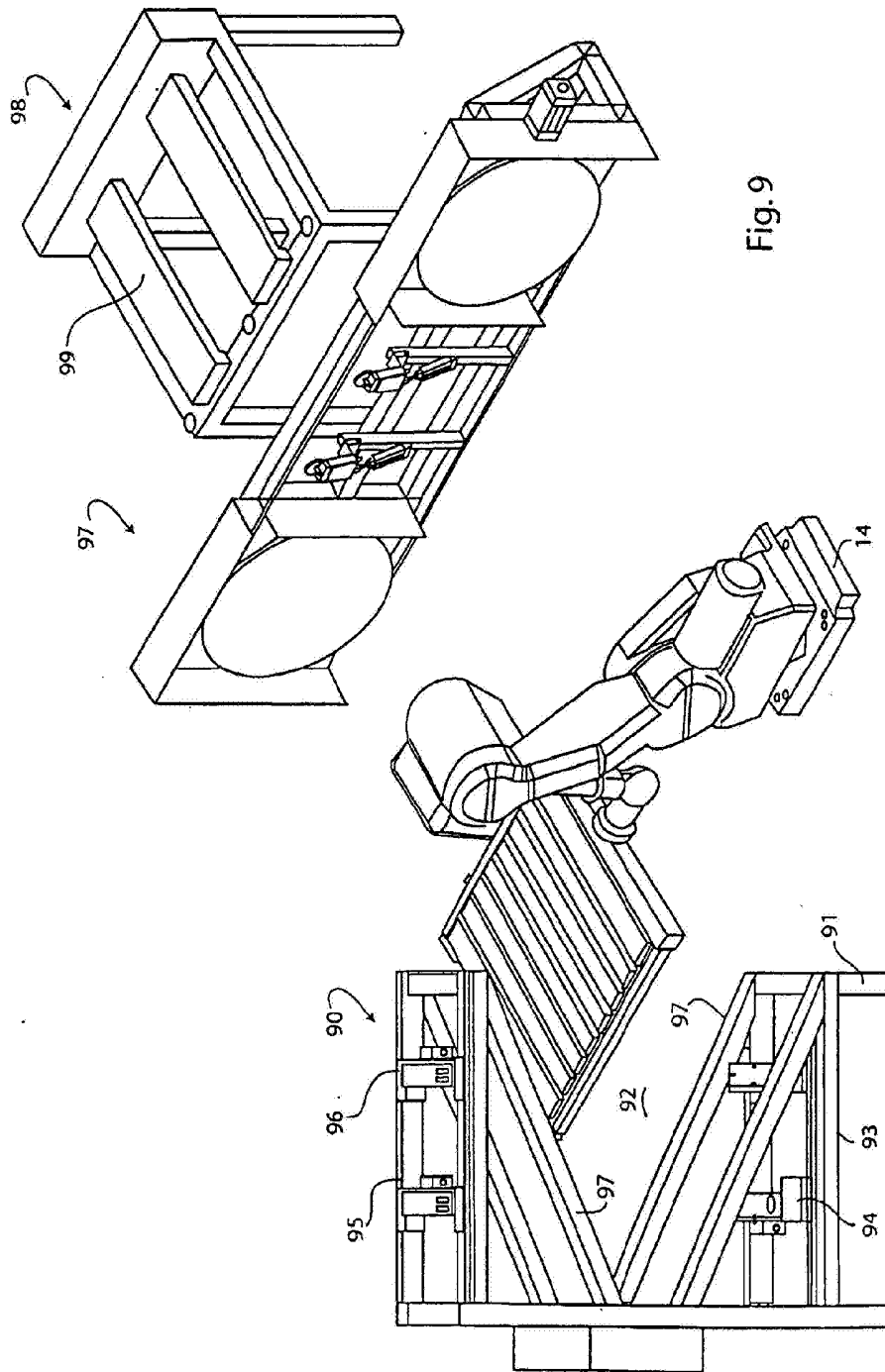
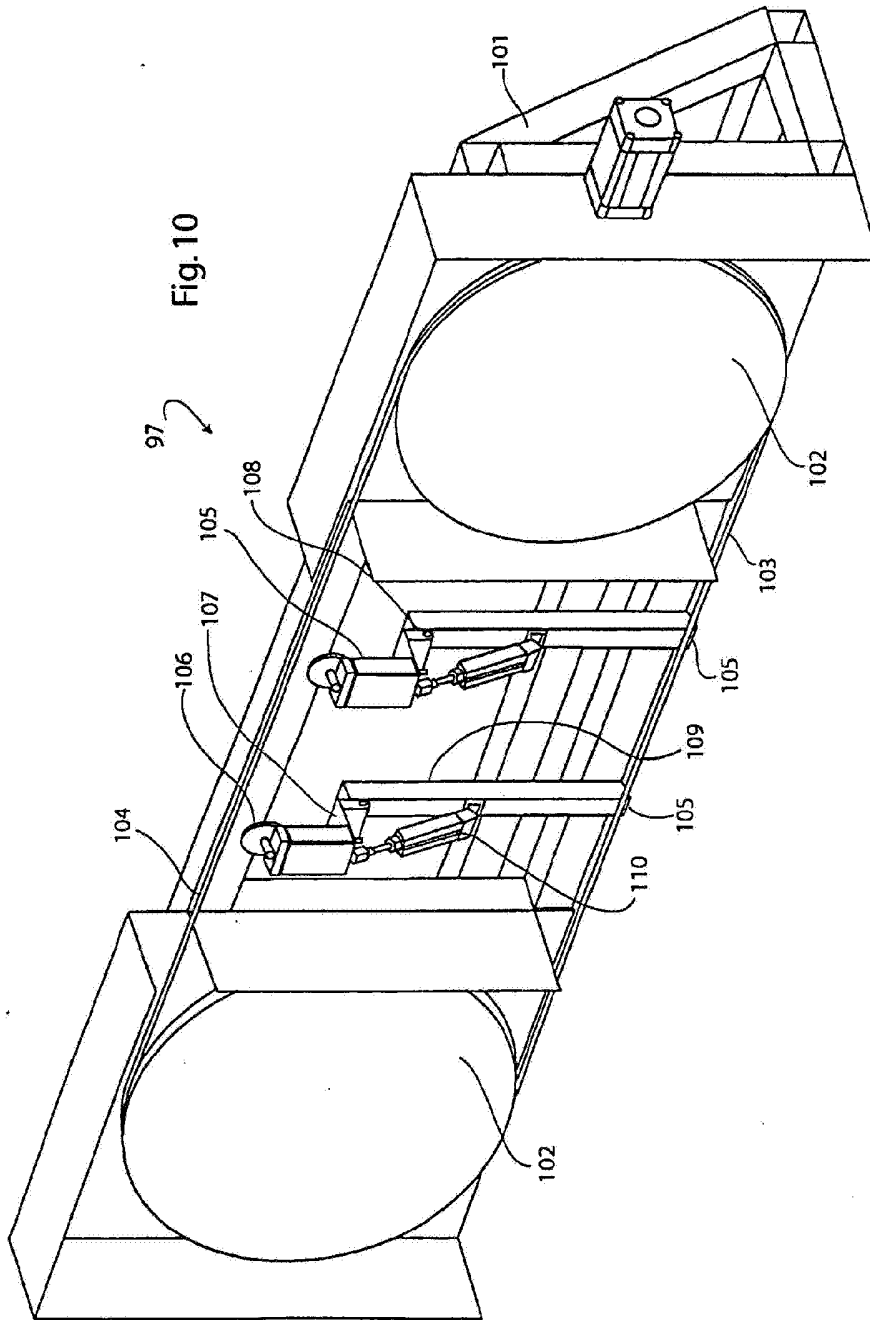
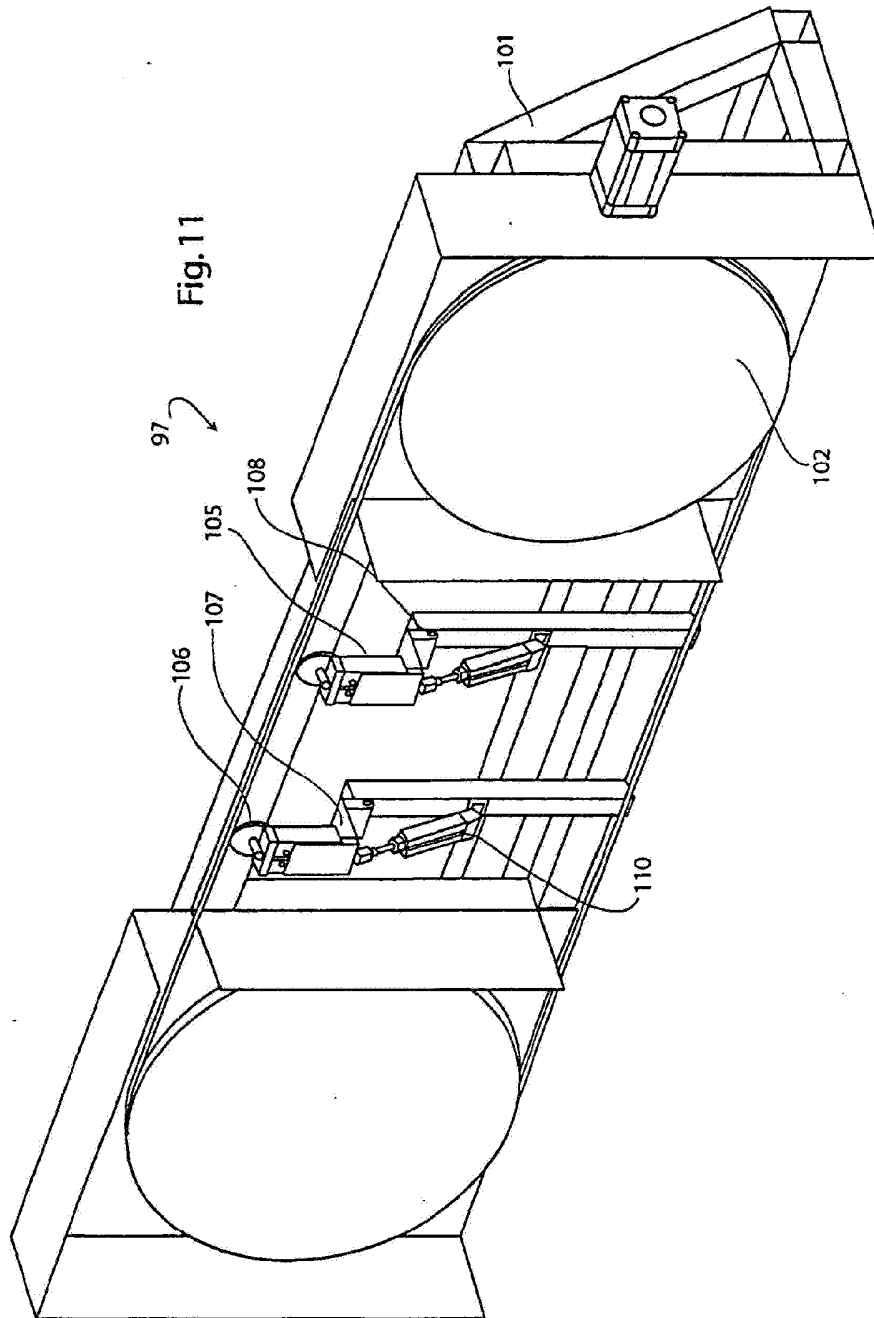
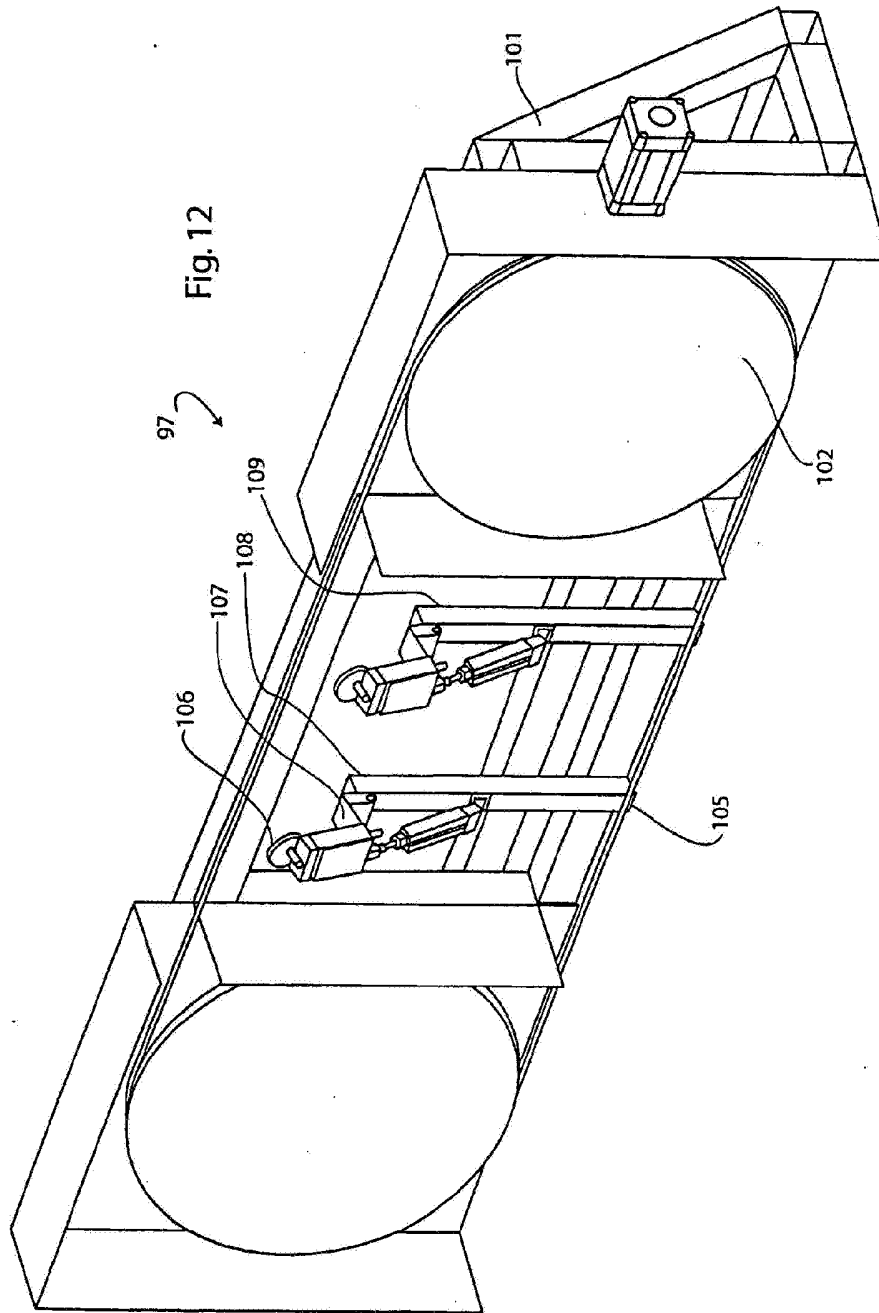


Fig. 9







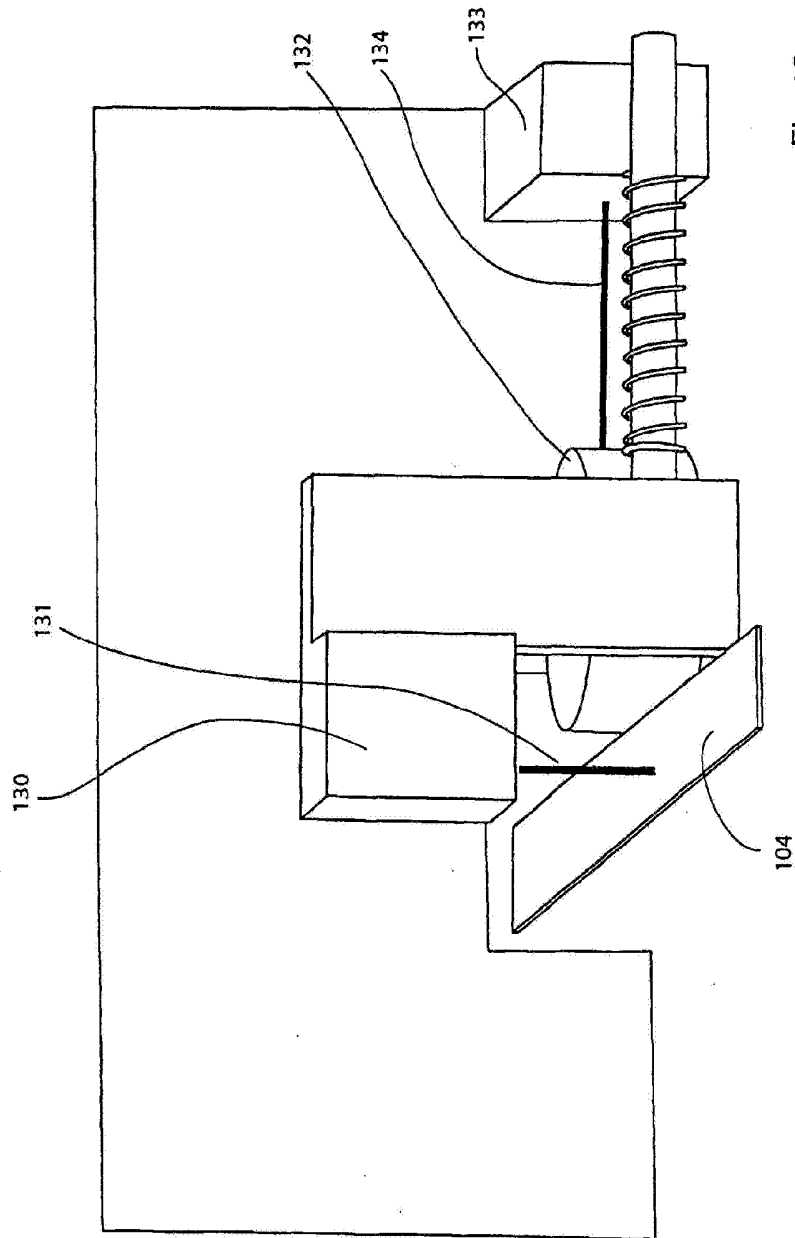


Fig. 13

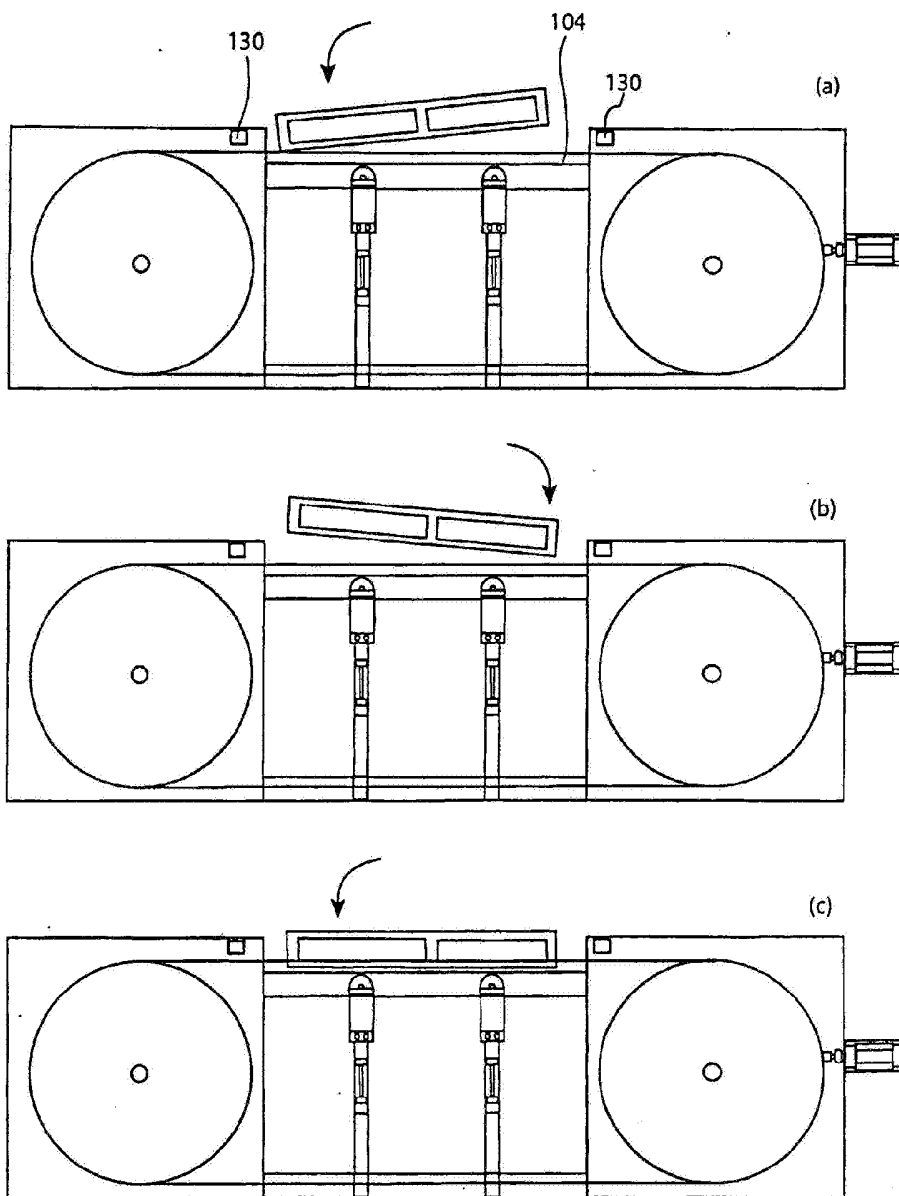


Fig.14

