US 20050103147A1

(19) United States
(12) Patent Application Publication
Lee et al.

(10) Pub. No.: US 2005/0103147 A1
(43) Pub. Date: May 19, 2005

(54) ROBOT ARM WITH IMPACT ABSORPTION STRUCTURE

(76) Inventors: **Dai Gil Lee**, Daejeon (KR); **Jung Do Suh**, Daejeon (KR); **Chang Sup Lee**, Daejeon (KR); **Tae Seong Lim**, Daejeon (KR); **Woo Seok Chin**, Daejeon (KR); **Hak Gu Lee**, Daejeon (KR); **Hui Yun Hwang**, Daejeon (KR); **Seung Min Lee**, Daejeon (KR); **Byung Chul Kim**, Daejeon (KR)

Correspondence Address:
BRINKS HOFER GILSON & LIONE
P.O. BOX 10395
CHICAGO, IL 60610 (US)

(21) Appl. No.: **10/954,569**

(22) Filed: **Sep. 30, 2004**

(30) **Foreign Application Priority Data**

Oct. 1, 2003 (KR) 2003-68433

Publication Classification

(51) **Int. Cl.**[7] **E02F 3/00**
(52) **U.S. Cl.** **74/490.01**

(57) **ABSTRACT**

A robot arm has an impact absorption structure for absorbing impact energy caused by a collision to protect a person from injury and the robot arm from being damaged. The robot arm includes a plurality of rigid beams provided at both end portions thereof to define a frame of the robot arm, and side members made of an elastic material and provided between the plurality of rigid beams to define an appearance of the robot arm and absorb the impact energy. Each side member includes a sheet made of a plastic material, a foam or honeycomb structure, and a fiber reinforced composite material attached to the sheet.

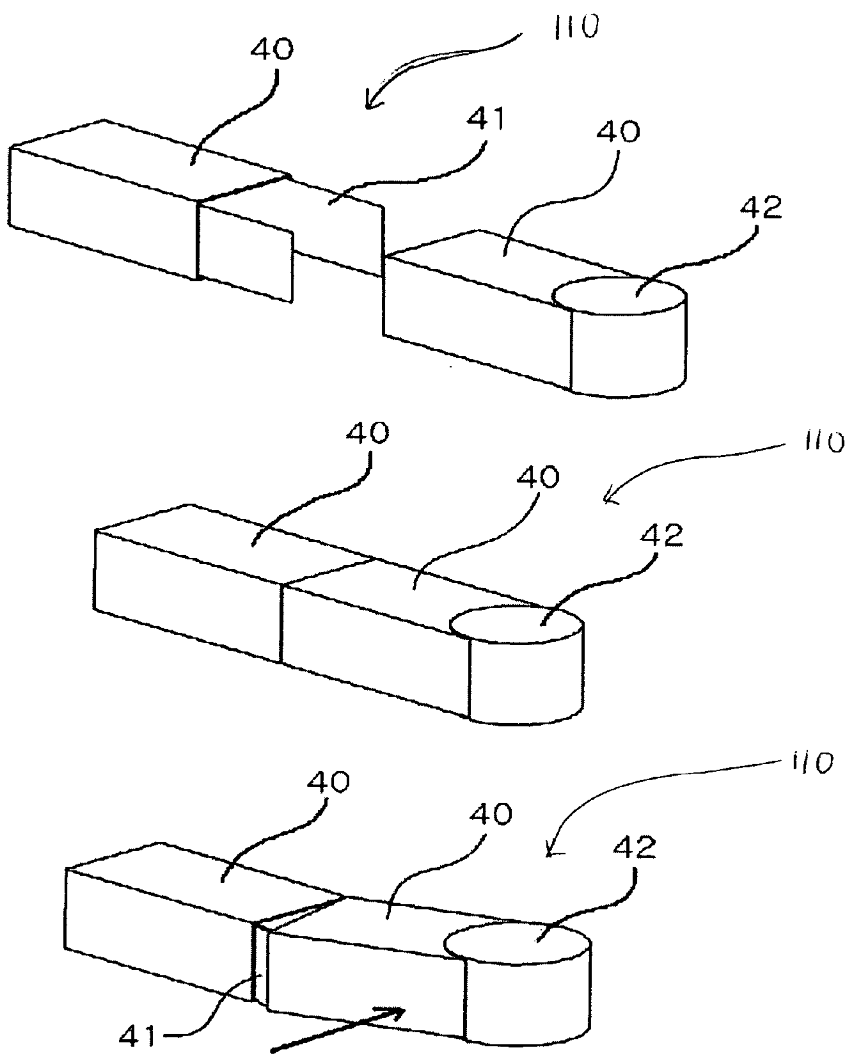


FIG. 1

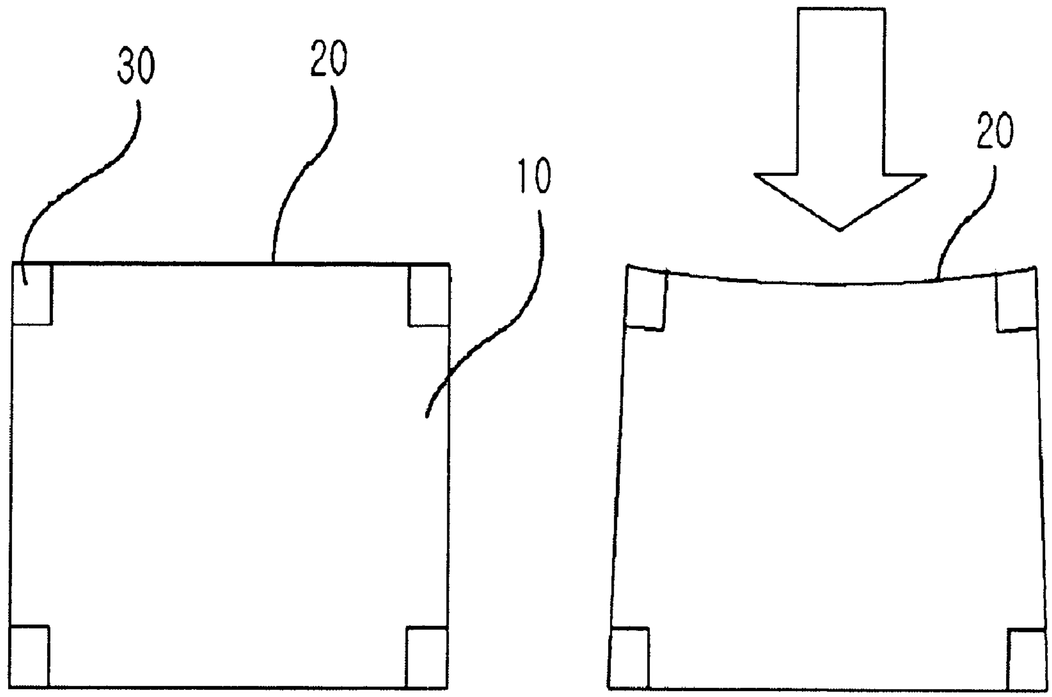


FIG. 2

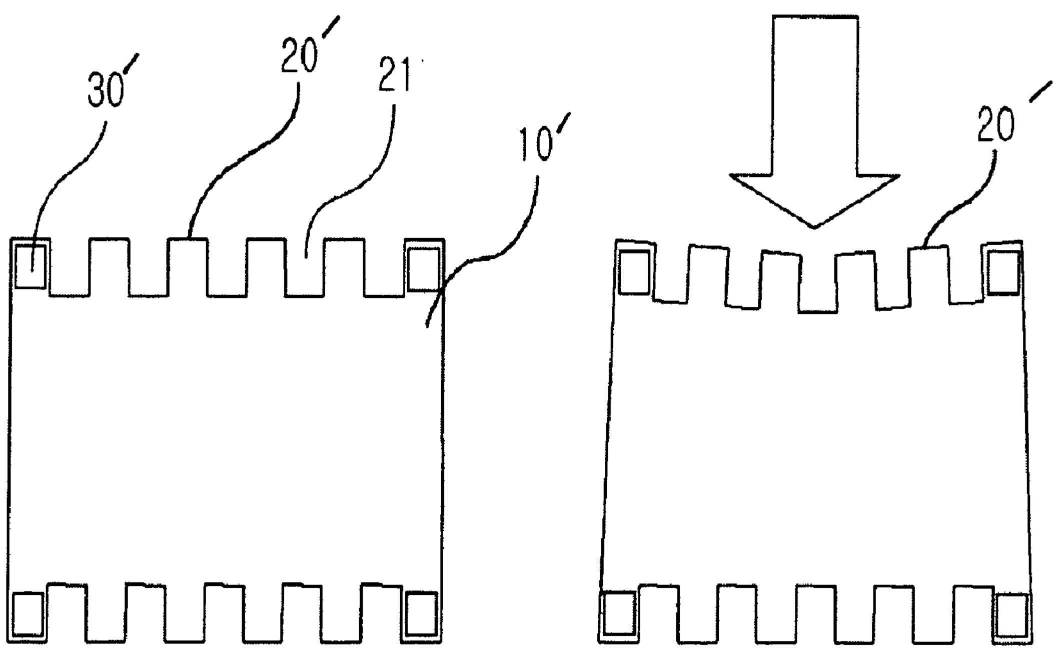


FIG. 3

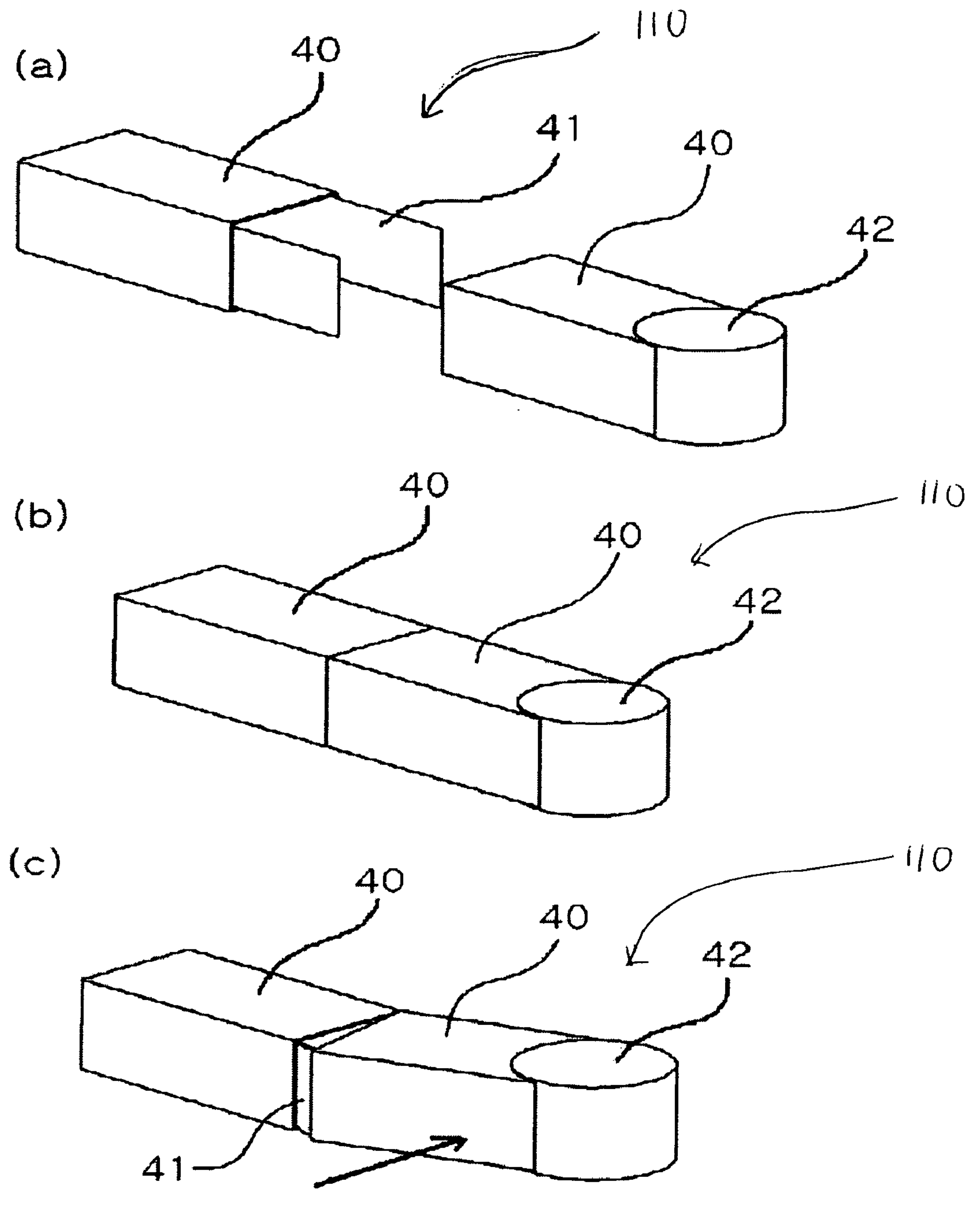


FIG. 4

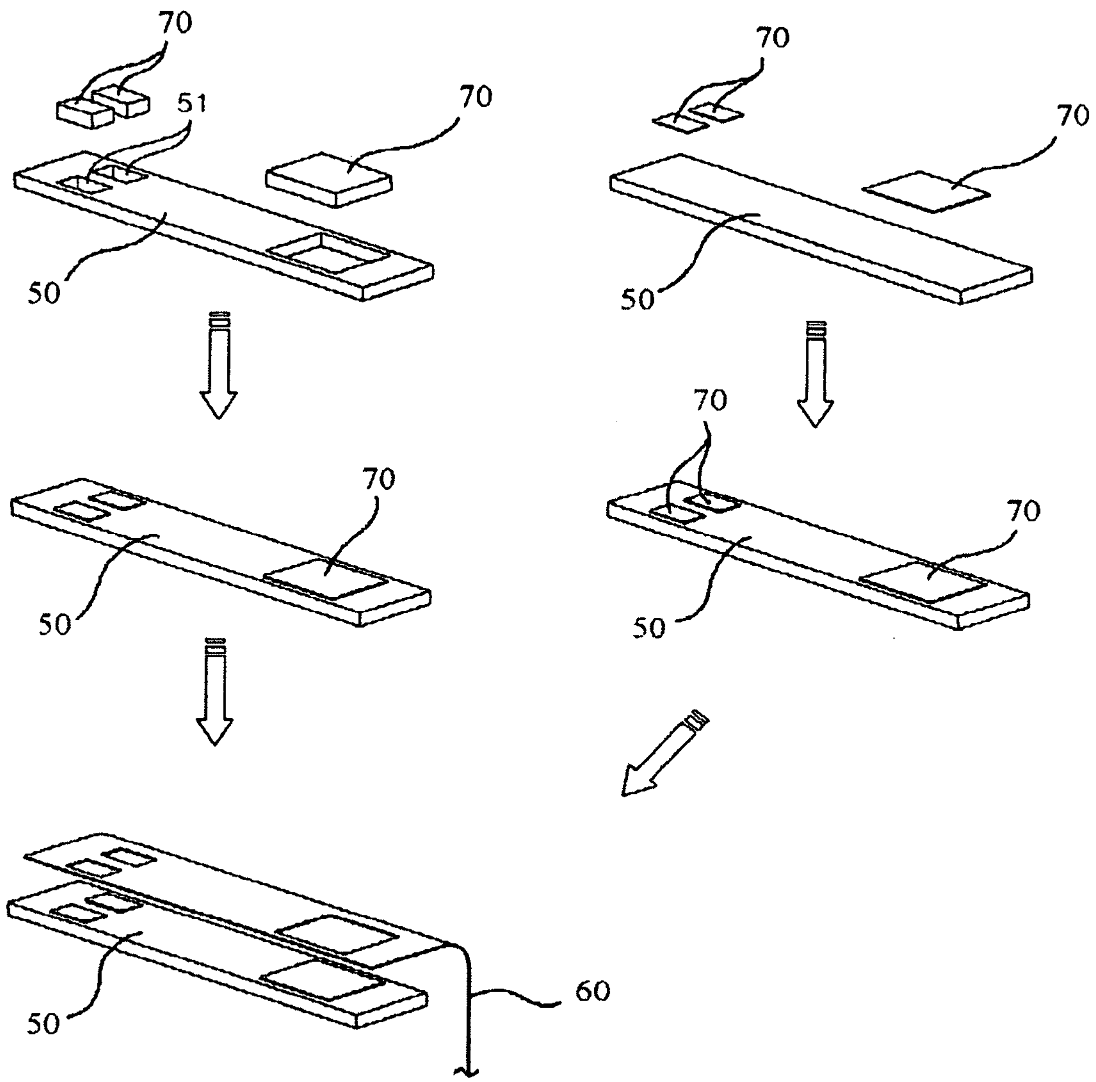


FIG. 5

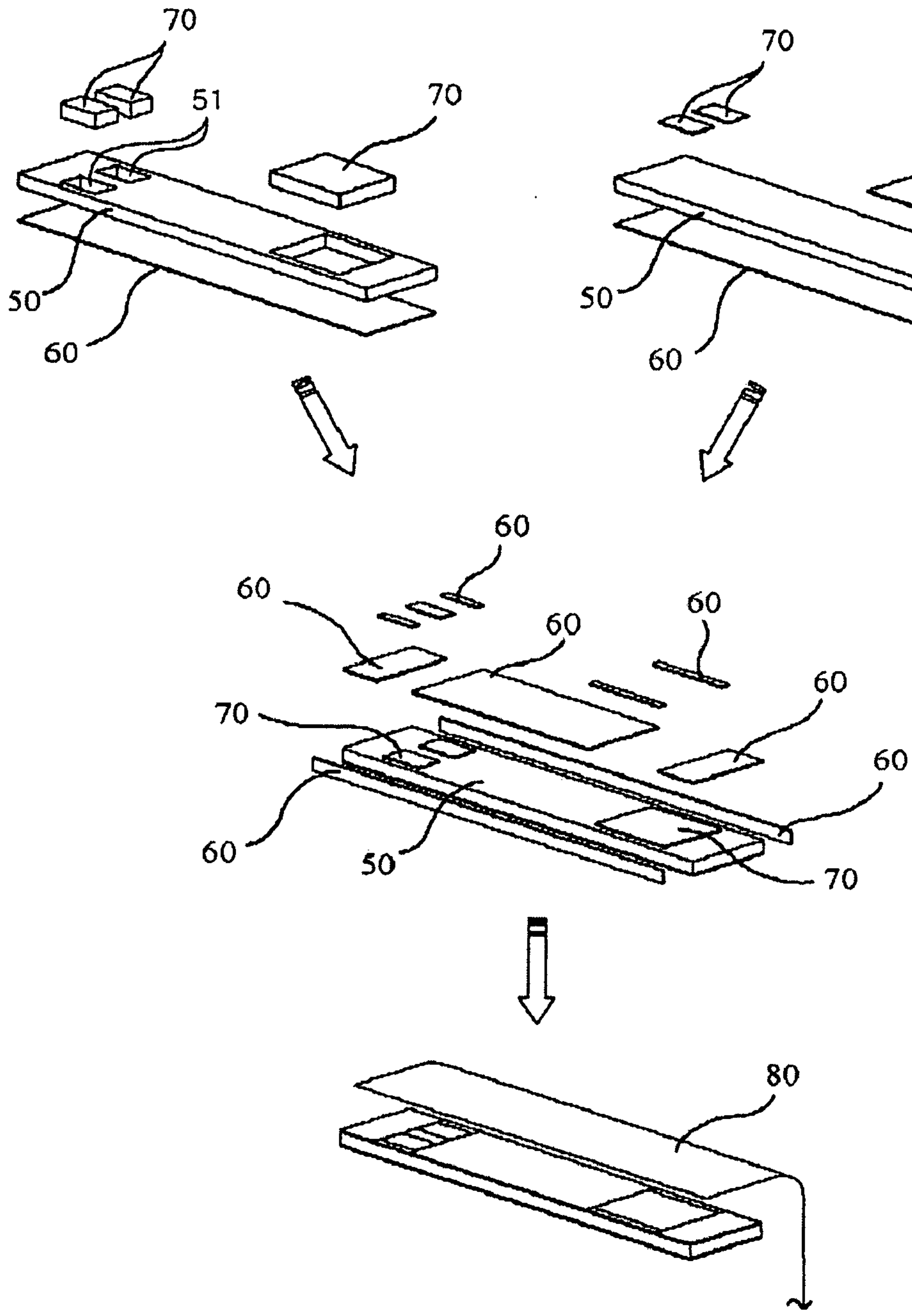


FIG. 6

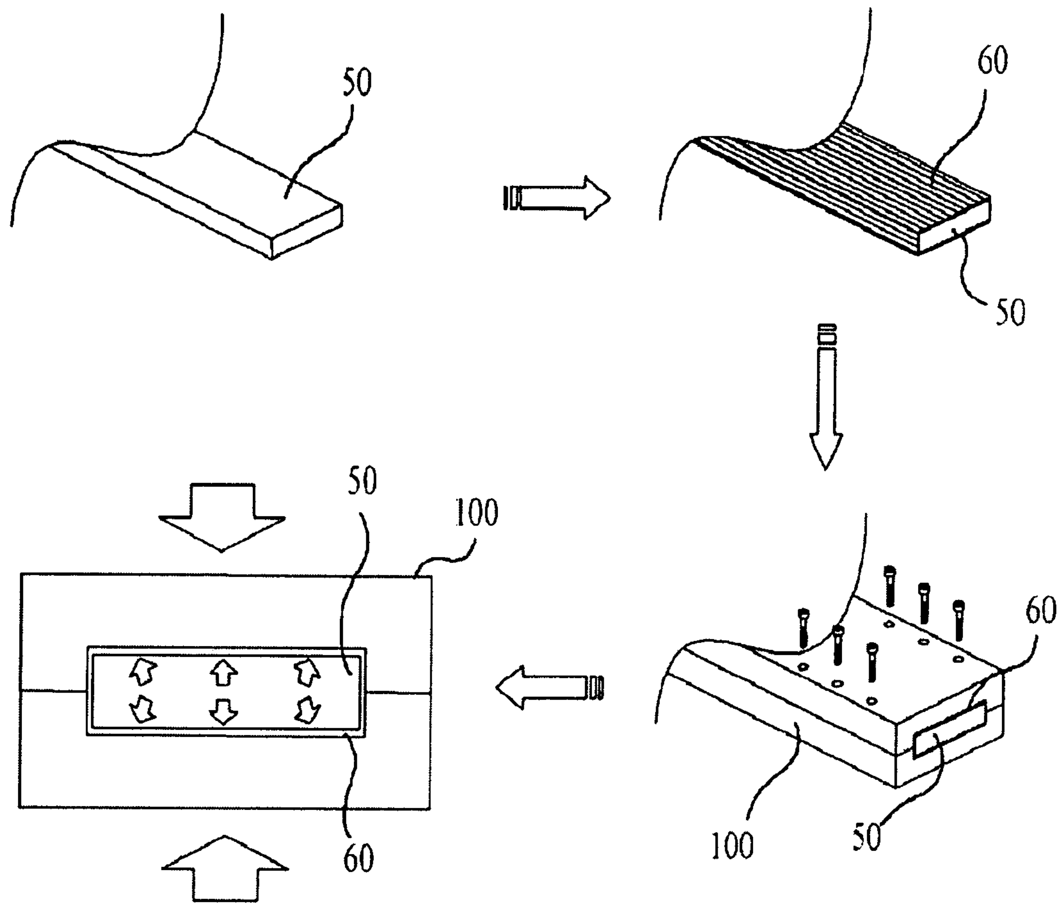
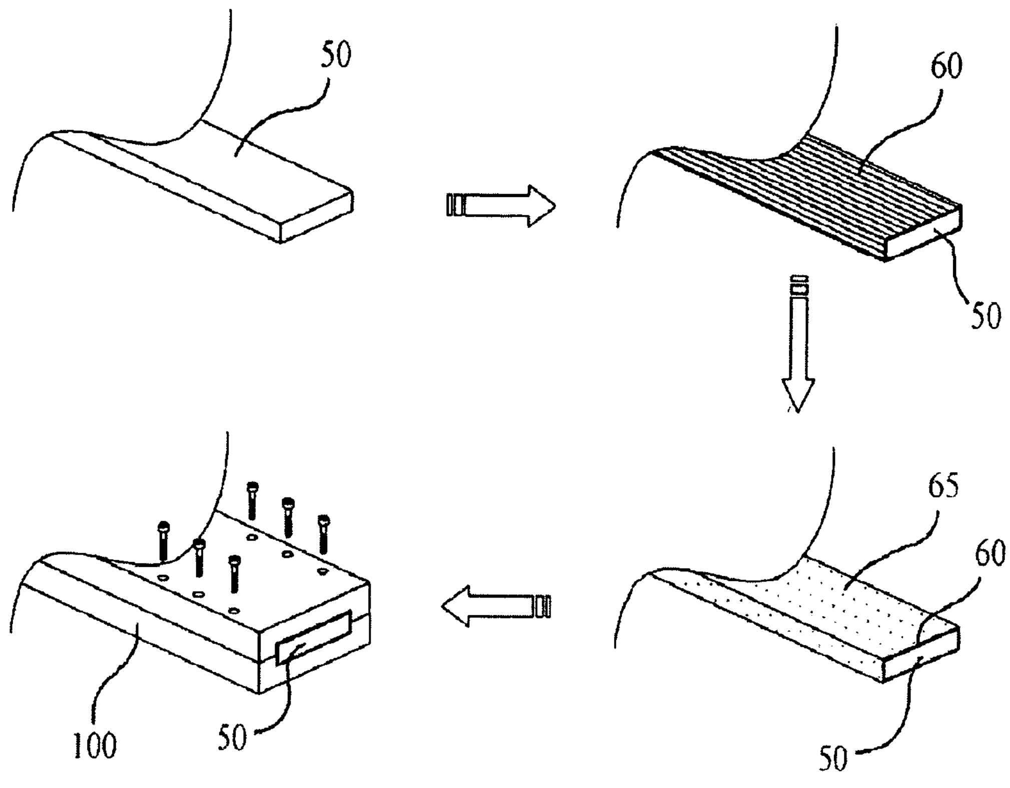


FIG. 7



ROBOT ARM WITH IMPACT ABSORPTION STRUCTURE

PRIORITY CLAIM

[0001] This application claims under 35 U.S.C. § 119 the benefit of the filing date of Oct. 1, 2003 of Korean Application No. 2003-68433, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] 1. Technical Field

[0003] The invention relates generally to a robot arm which absorb impact energy caused by a collision, thereby protecting a person from injury and specific parts of the robot arm from being damaged or broken. More particularly, the invention relates to a robot arm with an impact absorption structure in which a replaceable part is deformed by impact energy rather than other parts of the robot arm.

[0004] 2. Background Information

[0005] Generally, robots have been used in a variety of industrial fields. Industrial robots have been used in various places where it may be dangerous to humans or it is impossible for humans to work, for example, clean rooms, a universal space and atomic furnaces, etc. Furthermore, there are robots which have been used in rehabilitation for patients and for the betterment of living or for leisure to improve and enjoy the life. The conventional robots have been gradually more intimate in their association with people.

[0006] The conventional robots are generally produced to have a strong structure to enhance their weight-support abilities. Particularly, robot arms are made of thick and massive metals to enhance the weight-support abilities. When the conventional robot arm is involved in a collision, a person may be injured, or a surrounding structure may be damaged. Further, the robot arm may be badly damaged at the joint parts or drive parts. Because the conventional robot arm is made of the metal, it requires a variety of processes, thereby complicating its manufacturing process. The conventional robot arm is problematic in that processing costs and production costs increase.

[0007] To solve the foregoing drawbacks, it is required that a robot arm has an impact absorption structure as well as the strong structure for the desired weight-support ability. This allows a robot arm to effectively respond undesirable motions and prevent safety hazards from being caused by the robot arm. Specifically, when a robot arm collides with a person or a surrounding structure, a certain part of a robot arm rather than a person or a surrounding structure should be easily deformed or broken. Therefore, a person is protected from injury and specific parts of the robot arm can be protected from being damaged.

SUMMARY

[0008] An object of the invention is to provide a robot arm with an impact absorption structure which has a sufficient strength to support its structure, and in which a predetermined part of the robot arm is easily deformed or broken by impact energy higher than a predetermined level, thereby preventing safety hazards.

[0009] In one embodiment, a robot arm with an impact absorption structure is provided that absorbs impact energy caused by a collision, thus protecting a person from injury and protecting specific parts of the robot arm from being damaged or broken. The robot arm includes a plurality of rigid beams provided along longitudinal edges of the robot arm to define a frame of the robot arm, and a side unit made of an elastic material and provided between the plurality of rigid beams to define an appearance of the robot arm and to absorb the impact energy. The side unit includes a sheet made of a plastic material, a foam or honeycomb structure, and a fiber reinforced composite material attached to the sheet.

[0010] In another embodiment, a robot arm includes a plurality of blocks made of a rigid material, and a connecting unit to connect one block to another block, thereby defining an appearance of the robot arm with the plurality of blocks connected to each other. The connecting unit is deformed by a force higher than a predetermined level, and includes a sheet made of a plastic material, a foam or honeycomb structure, and a fiber reinforced composite material attached to the sheet.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention can be better understood with reference to the following drawings and description. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like referenced numerals designate corresponding parts throughout the different views.

[0012] **FIG. 1** is a latitudinal sectional view showing a construction and operation of a robot arm, according to a first embodiment;

[0013] **FIG. 2** is a latitudinal sectional view showing a construction and operation of a robot arm, according to a modification of the first embodiment of **FIG. 1**;

[0014] **FIGS. 3*a*** through **3*c*** are perspective views showing a construction and operation of a robot arm, according to a second embodiment, wherein:

[0015] **FIG. 3*a*** is a perspective view of the robot arm, in which a plurality of blocks are separated from each other;

[0016] **FIG. 3*b*** is a perspective view of the robot arm, in which a connecting unit connects one block to another block; and

[0017] **FIG. 3*c*** is a perspective view of the robot arm, in which the connecting unit is deformed by impact energy applied to the block;

[0018] **FIG. 4** shows a process of manufacturing a side unit of the robot arm of **FIG. 1** or a connecting unit of the robot arm of **FIG. 3**;

[0019] **FIG. 5** shows another process of manufacturing the side unit of the robot arm of **FIG. 1** or the connecting unit of the robot arm of **FIG. 3**;

[0020] **FIG. 6** shows a molding process of the side unit or the connecting unit of the **FIG. 4** or **5**; and

[0021] **FIG. 7** shows another molding process of the side unit or the connecting unit of the **FIG. 4** or **5**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] Hereinafter, embodiments of a robot arm will be described in detail with reference to the attached drawings.

[0023] **FIG. 1** is a latitudinal sectional view showing a construction and operation of a robot arm **10**, according to a first embodiment. **FIG. 2** is a latitudinal sectional view showing a construction and operation of a robot arm **10**, according to a modification of the first embodiment of **FIG. 1**. **FIGS. 3A through 3C** are perspective views showing a construction and operation of a robot arm **10**, according to a second embodiment.

[0024] As shown in **FIG. 1**, the robot arm **10** according to the first embodiment includes a plurality of rigid beams **30** which are provided along longitudinal edges of the robot arm **10**. The robot arm **10** further includes a plurality of side units **20** which are respectively provided between the pluralities of rigid beams **30**. The plurality of rigid beams **30** defines a frame of the robot arm **10**, and the plurality of side units **20** defines an appearance of the robot arm **10**. Outer surfaces of the robot arm **10** except for the longitudinal edges are surrounded by the plurality of side units **20** which are exposed to an outside of the robot arm **10**. Each of the side units **20** comprises a foam structure and a fiber reinforced composite material. Generally, the fiber reinforced composite material has a different strength according to directions. In the robot arm **10**, the robot arm **10** with the plurality of side units **20** has a higher strength in a longitudinal direction and has a lower strength in a latitudinal direction. Due to the above-mentioned construction of the robot arm **10**, when external impact is applied to the robot arm **10** in the latitudinal direction, the side unit **20** of the robot arm **10** is deformed inwardly to absorb impact energy, as shown in **FIG. 1**. Therefore, when the robot arm **10** collides with a person or a surrounding structure, the plurality of side units **20** absorb the impact energy caused by the collision. Thus, the robot arm **10** protects the person from injury and protects the surrounding structures and specific parts of the robot arm **10** from being damaged or broken.

[0025] As shown in **FIG. 2**, a robot arm **10'** is modified to include a plurality of side units **20'** which have corrugated surfaces **21** to enhance the impact-absorbing ability of the robot arm **10'**. Each of the side units **20'** with the corrugated surface **21** has a surface area larger than the side unit **20'** of **FIG. 1**, which does not have any corrugated surface. Therefore, the side unit **20'** with the corrugated surface **21** is easily deformed in response to external impact, thus enhancing its impact-absorbing ability.

[0026] The robot arm **10'** may have a rigid body to absorb the impact energy, different from the robot arm **10** shown in **FIG. 1**. **FIGS. 3*a*** through **3*c*** are perspective views showing construction and operation of a robot arm **110**, according to a second embodiment. **FIG. 3*a*** is a perspective view of the robot arm **110**, in which a plurality of blocks **40** are separated from each other. **FIG. 3*b*** shows the robot arm **110**, in which a connecting unit **41** connects one block **40** to another block **40**. **FIG. 3*c*** is a perspective view of the robot arm **110**, in which the connecting unit **41** is deformed by impact energy applied to the block **40**.

[0027] The robot arm **110** according to the second embodiment includes the plurality of blocks **40**, and the connecting unit **41** to connect the plurality of blocks **40** to each other. Each of blocks **40** may have the same sectional structure as the robot arm **10**, **10'** of the first embodiment shown in **FIG. 1** or **2**. The plurality of blocks **40** are connected to each other by the connecting unit **41**. The connecting unit **41** comprises a foam structure and a fiber reinforced composite material in the same manner that is described for the side unit **20** of the robot arm **10** according to the first embodiment.

[0028] Each of the blocks **40** of the second embodiment is made of a metal, so that a shape of the blocks **40** of the robot arm **110** is not easily deformed or broken regardless of external impact applied to the blocks **40**. On the other hand, the connecting unit **41**, which connects the plurality of blocks **40** to each other, has a high elasticity and strength lower than the blocks **40**. When external impact lower than a predetermined level is applied to one of the plurality of blocks **40**, the connecting unit **41**, which has the strength higher than the block **40**, is deformed or broken as shown in **FIG. 3*c***. The connecting unit **41** absorbs impact energy applied to the block **40**, thereby protecting the blocks **40** or a joint part **42** which is difficult to replace and is expensive to manufacture. In the meantime, the fiber reinforced composite material of the connecting unit **41** has a different strength according to the directions in the same manner as that described for the side unit **20** of the first embodiment. Thus, a manufacturer must consider the above-mentioned specific characteristics of the fiber reinforced composite material while attaching the fiber reinforced composite material on the connecting unit **41**.

[0029] **FIG. 4** shows a process of manufacturing the side unit **20** of the robot arm **10** of **FIG. 1** or the connecting unit **41** of the robot arm **110** of **FIG. 3**. **FIG. 5** shows another process of manufacturing the side unit **20** of the robot arm **10** of **FIG. 1** or the connecting unit **41** of the robot arm **110** of **FIG. 3**. **FIG. 6** shows a molding process of the side unit **20** or the connecting unit **41** of the **FIG. 1** or **3**. **FIG. 7** shows another molding process of the side unit **20** or the connecting unit **41** of the **FIG. 1** or **3**.

[0030] As shown in **FIGS. 4 through 7**, the side unit **20** of the first embodiment or the connecting unit **41** of the second embodiment comprises a sheet **50** to define shape of the side unit **20** or the connecting unit **41**. The sheet **50** is made of a foam or honeycomb structure. The foam structure is a porous structure which is made by foaming a plastic material, such as urethane, polymethacrylimide(PMI), polyvinylchloride(PVC), acrylonitrile-butadiene-styrene(ABS), phenol and etc. The honeycomb structure is that a material, such as paper, aramid, aluminum and etc., is formed to have a honeycomb pattern before being coated with a resin material. The molding process of the sheet **50** of the robot arm **10** will be described below, in particular, where the sheet **50** comprises the foam structure.

[0031] As shown in **FIG. 4**, the robot arm **10** includes a plurality of mounting pieces **70** that are mounted on the sheet **50**. To mount the plurality of mounting pieces **70** on the sheet **50**, two methods may be used. First, a plurality of grooves **51** may be provided on the sheet **50**, so that the plurality of mounting pieces **70** is respectively inserted into the grooves **51**. Alternatively or additionally, the plurality of mounting pieces **70** may be attached on an outer surface of the sheet **50**. After the plurality of mounting pieces **70** are mounted on the sheet **50**, a plurality of fiber reinforced composite materials **60** may be attached on the sheet **50**. The plurality of fiber reinforced composite materials **60** are cut to expose the plurality of mounting pieces **70** to an outside of the sheet **50**. Preferably, the fiber reinforced composite materials **60** remains a soft state prior to the attachment on the sheet **50**, because it is very difficult to process the fiber reinforced composite material **60** once it is hardened. However, as shown in **FIG. 5**, if the soft fiber reinforced composite material **60** is not prepared, the manufacturer cuts the hardened fiber reinforced composite material **60** to provide a plurality of pieces, prior to attaching the fiber reinforced composite materials **60** on the sheet **50**. Thereafter, the manufacturer attaches a laminated sheet **80** on the fiber reinforced composite materials **60**. The above-mentioned method has advantages that production costs are substantially reduced by using the fiber reinforced composite material **60**, available in open market, without any additional process.

[**0032**] As shown in **FIG. 6**, the sheet **50**, on which the fiber reinforced composite materials **60** are attached, is inserted into a mold **100**, prior to tightening the mold **100** with bolts or clamps to compress the sheet **50** under a sufficient pressure. The mold **100** is thereafter heated, taking into consideration thermal capacities of both the robot structure and the mold **100**. The sheet **50** and the fiber reinforced composite materials **60** have thermal expansive coefficients higher than that of the mold **100**, so that pressure in the mold **100** is increased in response to an increase in the temperature of the mold **100**. Thus, the fiber reinforced composite materials **60** are hardened and attached to the sheet **50** in a compression state. The above-mentioned process of hardening and attaching the fiber reinforced materials **60** to the sheet **50** is so-called a simultaneous hardening process. As shown in **FIG. 7**, the robot arm **10** may further include a porous thin sheet **65**, which is provided on the fiber reinforced composite material **60** to enhance an impact-absorbing ability of the sheet **50**. As described above, the sheet **50** of the robot arm **10**, produced by the simultaneous hardening process, does not require an additional post-process, thus reducing its processing costs. Furthermore, because the fiber reinforced composite materials **60** having a higher strength is hardened, and, simultaneously, attached to the sheet **50**, an additional attaching process is not required.

[**0033**] Since the sheet **50** is made of the soft material, such as the foam or honeycomb structure, and the fiber reinforced composite material **60**, surrounding the sheet **50** is not easily processed, it is very difficult to mount separate components on the sheet **50**. Therefore, the mounting pieces **70**, made of a metal or an industrial plastic material which has a predetermined strength and is possible for machine work, are mounted on the sheet **50**, so that the desired additional components, such as a sensor, a hydraulic apparatus, etc., are mounted on the mounting pieces **70**. Alternatively, the sheet **50** of the robot arm **10** is easily coupled to a robot.

[**0034**] As described above, a robot arm with an impact absorption structure is provided that absorbs impact energy caused when the robot arm collides with a person or a surrounding structure, thereby protecting a person from injury and preventing a surrounding structure from being damaged. In addition, specific parts of the robot arm are protected from damages.

[**0035**] It is therefore intended that the foregoing detailed description be regarded as illustrative rather than limiting, and that it be understood that it is the following claims, including all equivalents, that are intended to define the spirit and scope of this invention.

We claim:

1. A robot arm having an impact absorption structure for absorbing impact energy caused by a collision, comprising:

a plurality of rigid beams provided at both end portions of the robot arm to define a frame of the robot arm; and

side members made of an elastic material and provided between the plurality of rigid beams to define an appearance of the robot arm and to absorb the impact energy, each side member including:

a sheet made of a plastic material and having a foam or honeycomb structure; and

a fiber reinforced composite material attached to the sheet.

2. The robot arm according to claim 1, wherein each side member has a corrugated surface.

3. The robot arm according to claim 1, wherein each side member is made by a simultaneous hardening process and includes:

a hollow core member being made of the sheet , and having a plurality of grooves provided thereon.

4. The robot arm according to claim 3, wherein each side member further includes:

a mounting piece inserted into each of the grooves of the hollow core member and made of a material suitable for machining work; and

a rigid structural member including the fiber reinforced composite material and attached to each of upper, lower, left and right side surfaces of the hollow core member, the rigid structural member having an opening provided thereon to expose the mounting piece to an outside of the rigid structural member.

5. A robot arm having an impact absorption structure for absorbing impact energy caused by a collision, the robot arm comprising:

a plurality of block members made of a rigid material and connected with each other; and

connecting members for connecting one block member to another block member to define an appearance of the robot arm, each connecting member being deformed by a force stronger than a predetermined level, each connecting member including:

a sheet made of a plastic material and having a foam or honeycomb structure; and

a fiber reinforced composite material attached to the sheet.

6. The robot arm according to claim 5, wherein each connecting unit is made by a simultaneous hardening process and includes:

a hollow core member being made of the sheet and having a plurality of grooves provided thereon.

7. The robot arm according to claim 6, wherein each connecting unit further includes:

a mounting piece inserted into each of the grooves of the hollow core member and made of a material suitable for machining work; and

a rigid structural member including a fiber reinforced composite material and attached to each of upper, lower, left and right side surfaces of the hollow core member, wherein the rigid structural member has an opening provided thereon to expose the mounting piece to an outside of the rigid structural member.

8. The robot arm according to claim 7, further comprising:

a porous sheet provided between the hollow core member and the rigid structural member.

* * * * *