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(54) Title: GRIPPER MODULE FOR AN IMPROVED GRASPING OF AN OBJECT

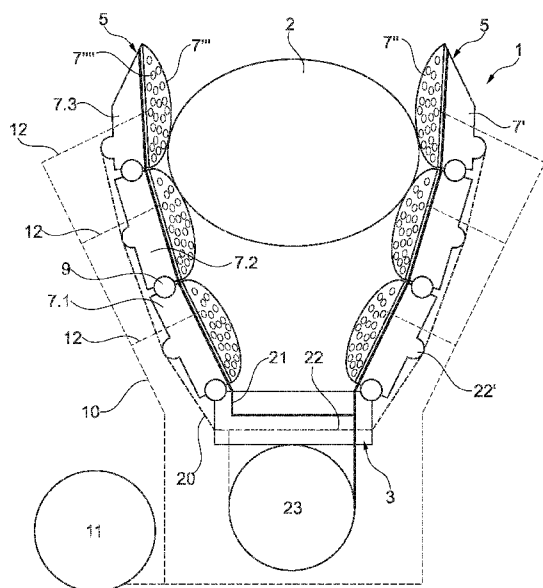


Fig. 1

(57) Abstract: The invention concerns a gripper module for an improved grasping of an object, wherein the gripper module comprises a base member and at least two fingers, wherein each finger comprises at least two phalanges, a first phalanx and a second phalanx, wherein two adjacent phalanges are rotatably connected to each other by a joint, wherein the phalanges each comprise a rigid phalanx base and a deformable gripping section that is mounted to the rigid phalanx base, wherein the deformable gripping sections each comprise a flexible outer layer and particles, wherein the particles are movably arranged within the gripping sections so as to allow for geometrical adjustment of the gripping sections for an enhanced grasping of the object. Furthermore, the invention concerns a robot comprising such a gripper module.

Gripper module for an improved grasping of an object

The invention concerns a gripper module for an improved grasping of an object, wherein the gripper module comprises a base member and at least two fingers. Additionally, the invention concerns a robot comprising such a gripper module.

The advancing automation degree of industrial processes necessitates the employment of an ever increasing number of robots, wherein the robots are utilised for a variety of purposes. In particular, grasping and transporting of objects, especially in production sites, require grippers or gripper modules with specific designs in order to meet technical requirements. For instance, under conditions of high velocity or vibrations, sufficiently large clamping forces between the gripper and the objects must be ensured. At the same time, the clamping forces must not exceed specific values in order not to deform, break or otherwise harm the object. Furthermore, the objects can have different geometries which can call for a gripper design that can adapt, at least to a certain degree, to the object geometry. Also, mechanical properties such as softness of the objects can vary and must therefore be considered in the design process of grippers. Moreover, physical properties of the objects can be diverse, e.g. wet or dry, heavy or light, conductive or dielectric et cetera.

Grippers according to the state of the art typically comprise fingers, hereby at least partially emulating a human hand. However, fingers according to the prior art are conventionally rigid one-piece fingers, leaving no or little space for geometrical adjustment to the object in particular and its mechanical, physical, chemical etc. properties in general. Also, grippers can be suitable for a specific requirement such as exerting high clamping forces in one direction in order to carry heavy objects, but deficient when it comes down to cover a wide range of requirements.

Against this background the problem to be solved is to provide a gripper with improved grasping capabilities that particularly meets a broad range of the abovementioned requirements.

For solving the problem, the invention proposes a gripper module for an improved grasping of an object, wherein the gripper module comprises a base member and at least two fingers, wherein each finger comprises at least two phalanges, a first phalanx and a second phalanx, wherein two adjacent phalanges are rotatably connected to each other by a joint, wherein the phalanges each comprise a rigid phalanx base and a deformable gripping

section that is mounted to the rigid phalanx base, wherein the deformable gripping sections each comprise a flexible outer layer and particles, wherein the particles are movably arranged within the gripping sections so as to allow for geometrical adjustment of the gripping sections for an enhanced grasping of the object.

The inventive gripper module comprises at least two fingers that perform the actual grasping or gripping or holding of the object. The two fingers can be pincer shaped and formed movably towards each other so as to enable clamping of the object in-between of them. The gripper module further comprises a base member, wherein the fingers can be, preferably rotatably, connected to. The base member can be plate-shaped or cuboidal.

Each finger comprises at least two phalanges. A first phalanx can be a proximal phalanx and a second phalanx can be a distal phalanx. Adjacent phalanges are connected to each other rotatably by a joint, so that a relative motion between the phalanges can be carried out and an angle differing from 180 degrees between two adjacent phalanges can be formed. In other words, the fingers can be formed linearly or curved. Fingers that have a bent or curved shape enable a better geometrical adjustment to the object and the exertion of forces in more than one direction, for instance, firstly clamping forces in one direction and, secondly, holding forces perpendicular to the clamping forces. In other words, lateral and vertical forces can be applied to the object. Consequently, the stability of the grasped object while transporting it can be increased. The joints can be formed to enable motion around one-axis.

Each phalanx comprises a rigid phalanx base. The rigid phalanx bases provide – analogously to a bone in a human finger – mechanical and thus also geometrical stability. Each phalanx further comprises a deformable gripping section that is mounted to the rigid phalanx base. The deformable gripping sections can be formed advantageously between the fingers and enhance the grip between the fingers and the object.

Each deformable gripping section comprises a flexible outer layer and particles. The particles are movably arranged within the gripping section. The particles of each phalanx can be advantageously arranged in a non-constant volume limited on one side by the flexible outer layer and on a second side by the rigid phalanx base. By means of the deformability, at least partially supported and maintained by the movability of the particles, the phalanges can adapt their shape and stiffness to a variety of objects. The deformable gripping section can act as a cushioning pad when clamping the object, thus avoiding or least reducing harm to the object to be grasped and transported.

The subject matter of the invention has the advantage of covering a wide spectrum of different purposes, especially sufficient stability for grasping heavy objects, enough grip for transporting wet objects, deformability for adjustment to diverse object geometries and avoiding harm etc. Therefore, it combines multiple advantageous properties, hereby providing an enhanced and universal gripper module.

According to one advantageous embodiment of the invention, the gripper module is detachably connectable to another apparatus, preferably to a robot or drone, by means of the base member. The connectivity to multiple apparatus renders the gripper module versatile and usable in multiple applications – not only manufacturing but also in medical, agricultural, aeronautical or military applications.

According to a preferred embodiment of the invention, the gripper module is provided with exactly three fingers that are rotatably connected to the base member. The base member can comprise a first lateral surface and a second lateral surface. The two lateral surfaces can be parallel to each other and formed at two opposing sides of the base member. Two of the three fingers can be arranged on the first lateral surface and the third finger can be arranged on the second lateral surface. The fingers can also be connected to the base member on a distal surface of the base member. Each finger can be rotatably connected to the base member by means of a joint connecting phalanges or another form of joints.

In a preferred embodiment of the invention, at least one of the fingers comprises at least one third phalanx that is rotatably connected to the second phalanx by a joint. Each finger can comprise four, five, six or more phalanges, wherein two adjacent phalanges are rotatably connected to each other by a joint. Increasing the number of phalanges per finger improves the adaptability of the fingers to the geometry of the object.

According to an advantageous embodiment of the invention, the flexible outer layer is a membrane, in particular made of silicon rubber. The membrane has the advantage of simple deformability and thus of better geometrical adaptability. A silicon rubber can increase the friction between the fingers and the object, hereby enhancing grip, stability and safety. All or some of the flexible outer layers of the gripper module can be a silicon rubber. Furthermore, a silicon rubber can reduce the risk of structural and superficial – internal and external – harm to the object, especially scratches and dents. Additionally, silicon rubber can insulate the object electrically from the gripper module.

In a preferred embodiment of the invention, a surface of the flexible outer layer comprises at least one of a texturization and suction cups protruding towards the object or away from the rigid phalanx base. A texturization, suction cups or a combination thereof can increase the adhesion and/or clamping between the object and the fingers which can enhance stability and safety. The texturization can comprise multiple linear, undulated or dot-shaped protrusions.

An advantageous embodiment of the invention is provided with a pneumatic system that comprises gas supply pipes, wherein each gas supply pipe is fluidically connected to a deformable gripping section for controlling at least one of volume and stiffness of the deformable gripping sections, wherein a gas can be pumped into or out of the deformable gripping sections. The volume and stiffness of the deformable gripping sections can be designed such that a soft contact between the finger and the grasped object can be realized. Control of the volume and stiffness can be carried out by vacuuming the gripping sections, especially by means of air, or pumping air into the gripping sections. Each gas supply pipe can pass through an opening formed in each rigid phalanx base or be connected directly, by circumventing the corresponding rigid phalanx base, to the gripping section.

According to a preferred embodiment of the invention, the gripper module is provided with a cable system, wherein each finger (5) of the at least two fingers comprise at least one of a first cable for contracting or closing the finger and a second cable for extending or opening the finger. The cables can be Kevlar cables and maintain tension of the fingers. The first cables can be arranged advantageously on an inner side of the fingers facing the flexible outer layer or between the rigid phalanx base and the gripping sections. The second cables can be arranged advantageously on an outer side of the fingers facing the rigid phalanx bases, away from the gripping sections. The cables can be lead through one or many tunnel elements or supported by one or many, particularly spherical, protrusions, or a combination thereof. The tunnel elements and spherical protrusions can be formed on one or many phalanges. They can be formed monolithically with their corresponding rigid phalanx bases. A distal end of the first cable and a distal end of the second cable of each finger can be attached to the most distal phalanx of the corresponding finger.

In a preferred embodiment of the invention, the first cables and the second cables are connected to and controllable by a servomotor, wherein the servomotor is attachable to the base member. A proximal end of the first cable and a proximal end of the second cable of each finger can be attached to the servomotor or an axis of the servomotor. The servomotor can control the opening/extending and/or closing/contracting of the fingers. The servomotor

can also control the velocity and acceleration of the fingers while opening and closing. Furthermore, by modifying the torque, the servomotor can control the clamping forces exerted by the fingers on the objects. The servomotor can be mounted to the base member which can bring about a compact gripper module.

Another subject of the invention is a robot comprising a gripper module according to one of the preceding embodiments of the invention. The same technical effects and advantages mentioned within the framework of the above embodiments also hold for the inventive robot.

These and other characteristics, features and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention. The description is given for the sake of example only, without limiting the scope of the invention. The reference figures quoted below refer to the attached drawings.

Fig. 1 shows a first embodiment of an inventive gripper module with two fingers in a sectional view;

Fig. 2 shows a second embodiment of an inventive gripper module with three fingers in a perspective view.

The present invention will be described with respect to particular embodiments and with reference to two drawing but the invention is not limited thereto but only by the claims. The drawing described is only schematic and is non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes.

Where an indefinite or definite article is used when referring to a singular noun, e.g. “a”, “an”, “the”, this includes a plural of that noun unless something else is specifically stated. Furthermore, the terms first, second, third and the like in the description and in the claims are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order. It is to be understood that the terms so used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein. Moreover, the terms top, bottom, over, under and the like in the description and the claims are used for descriptive purposes and not necessarily for describing relative positions. It is to be understood that the terms so used are interchangeable under appropriate

circumstances and that the embodiments of the invention described herein are capable of operation in other orientations than described or illustrated herein. It is to be noticed that the term “comprising”, used in the present description and claims, should not be interpreted as being restricted to the means listed thereafter; it does not exclude other elements or steps. Thus, the scope of the expression “a device comprising means A and B” should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Fig. 1 depicts schematically a first embodiment of an inventive gripper module 1 for an improved grasping of an object 2 in a sectional view. The gripper module 1 comprises a base member 3 and at least two fingers 5 for grasping the object 2. The object 2 is formed exemplarily as an ellipsoid so as to show that the gripper module 1 has the capacity for grasping and transporting objects 2 without edges or corners that are easier to get hold of.

Either finger 5 comprises a first phalanx 7.1, a second phalanx 7.2 and a third phalanx 7.3. The first phalanges 7.1 are arranged proximally, the second phalanges 7.2 intermediately and the third phalanges 7.3 distally with respect to the base member 3. The first phalanx 7.1 and the second phalanx 7.2 of each finger 5 are rotatably connected to each other by a joint 9. The second phalanx 7.2 and the third phalanx 7.3 of each finger 5 are also rotatably connected to each other by a further joint 9. Furthermore, each finger 5 is rotatably connected to the base member 3 by a joint 9 by means of the fingers 5 first phalanx 7.1. This configuration of fingers 5 enables the gripper module 1 to “bend” its fingers 5 in order to grasp the object 2 in a geometrically enhanced manner since the fingers 5 can adjust their shape to object 2.

Each phalanx 7.1, 7.2, 7.3 comprises a rigid phalanx base 7' and a deformable gripping section 7''. Each deformable gripping section 7'' is mounted to its corresponding rigid phalanx base 7' and comprises a flexible outer layer 7''' and particles 7'''. The particles 7''' are movably arranged within their gripping sections 7'' so as to allow for geometrical adjustment of the gripping sections 7'' for an enhanced grasping of the object 2. The flexible outer layer 7''' is formed as a membrane made of silicon rubber to optimize/increase friction between the fingers 5 and the object 2. The curvature of the fingers 5 can be interpreted as a geometrical adaptation of first degree, whereas the deformability of the gripping section 7'' can be deemed an adaptation of second degree, both enhancing the grasping and transportation of the object 2 due to increase of stability and safety.

The gripper module 1 as shown in **Fig. 1** further comprises a pneumatic system 10. The pneumatic system 10 comprises a vacuum pump 11 and six gas supply pipes 12. Each gas supply pipe 12 runs through a phalanx 7.1, 7.2, 7.3 and is arranged such that the vacuum pump 11 can pump air into the and out of the deformable gripping sections 7'' in order to control volume and stiffness of the gripping sections 7''.

Moreover, the gripper module 1 comprises a cable system 20 with a servomotor 23 that is mounted to the base member 3. The servomotor 2 controls, at each finger 5, a first cable 21 and a second cable 22. The first cables 21 are arranged between the gripping sections 7'' and the rigid phalanx bases 7'. The second cables 22 are formed outside the fingers 5, away from the gripping sections 7'' and the object 2. The second cables 22 are supported partially by spherical protrusions 22'. The first cables 21 and the second cables 22 are attached at one end to the third phalanges 7.3 for opening and closing the fingers 5. At an other, opposing, end, the first and second cables 21, 22 are connected to the servomotor 23.

A second embodiment of the invention is shown schematically in **Fig. 2** in a perspective view, wherein the gripper module 1 comprises three fingers 5. Two of the fingers 5 are arranged on one side of the base member 3, one finger 5 is arranged on a second, opposing, side of the base member 3. Each finger 5 comprises a first phalanx 7.1, a second phalanx 7.2 and a third phalanx 7.3. Rotation of the phalanges 7.1, 7.2, 7.3 can be carried out around rotor axes 9' depicted in **Fig. 2**.

As a result of the rotation of the phalanges 7.1, 7.2, 7.3 around the rotor axes 9', each finger 5 can be moved along a corresponding plain E_1 , E_2 or E_3 . The plains E_1 , E_2 and E_3 are arranged parallel to each other or coplanar. Furthermore, the plains E_1 , E_2 and E_3 are sufficiently offset so that a potential collision of the fingers 5 while opening and closing the fingers 5 is at all times avoided.

Reference signs

1	Gripper Module
2	Object
3	Base member
5	Finger
7	Phalanx
7.1	First phalanx
7.2	Second phalanx
7.3	Third phalanx
7'	Rigid phalanx base
7''	Deformable gripping section
7'''	Flexible outer layer
7''''	Particles
9	Joint
9'	Joint axis
10	Pneumatic system
11	Vacuum pump
12	Gas supply pipes
20	Cable system
21	First cable
22	Second cable
22'	Protrusion
23	Servomotor
E ₁	First plane
E ₂	Second plane
E ₃	Third plane

Patent Claims

1. Gripper module (1) for an improved grasping of an object, wherein the gripper module (1) comprises a base member (3) and at least two fingers (5),
wherein each finger (5) comprises at least two phalanges (7), a first phalanx (7.1) and a second phalanx (7.2), wherein two adjacent phalanges (7) are rotatably connected to each other by a joint (9),
wherein the phalanges (7) each comprise a rigid phalanx base (7') and a deformable gripping section (7'') that is mounted to the rigid phalanx base (7'),
wherein the deformable gripping sections (7'') each comprise a flexible outer layer (7''') and particles (7'''), wherein the particles (7''') are movably arranged within the gripping sections (7'') so as to allow for geometrical adjustment of the gripping sections (7'') for an enhanced grasping of the object.
2. Gripper module (1) according to claim 1, characterized in that the gripper module (1) is detachably connectable to another apparatus, preferably to a robot or drone, by means of the base member (3).
3. Gripper module (1) according to one of the preceding claims, characterized by exactly three fingers (5) that are rotatably connected to the base member (3).
4. Gripper module (1) according to one of the preceding claims, characterized in that at least one of the fingers (5) comprises at least one third phalanx (7.3) that is rotatably connected to the second phalanx (7.2) by a joint (9).
5. Gripper module (1) according to one of the preceding claims, characterized in that the flexible outer layer (7''') is a membrane made of silicon rubber.
6. Gripper module (1) according to one of the preceding claims, characterized in that a surface of the flexible outer layer (7''') comprises at least one of a texturization and suction cups protruding towards the object or away from the rigid phalanx base (7').
7. Gripper module (1) according to one of the preceding claims, characterized by a pneumatic system (10) that comprises gas supply pipes (12), wherein each gas supply pipe (12) is fluidically connected to a deformable gripping section (7'') for controlling at least one of volume and stiffness of the deformable gripping sections

(7''), wherein a gas can be pumped into or out of the deformable gripping sections (7'').

8. Gripper module (1) according to one of the preceding claims, characterized by a cable system (20), wherein each finger (5) of the at least two fingers (5) comprise at least one of a first cable (21) for contracting or closing the finger (5) and a second cable (22) for extending or opening the finger (5).
9. Gripper module (1) according to claim 8, characterized in that the first cables (21) and the second cables (22) are connected to and controllable by a servomotor (23), wherein the servomotor (23) is attachable to the base member (3).
10. Robot (100) comprising a gripper module (1) according to one of the preceding claims.

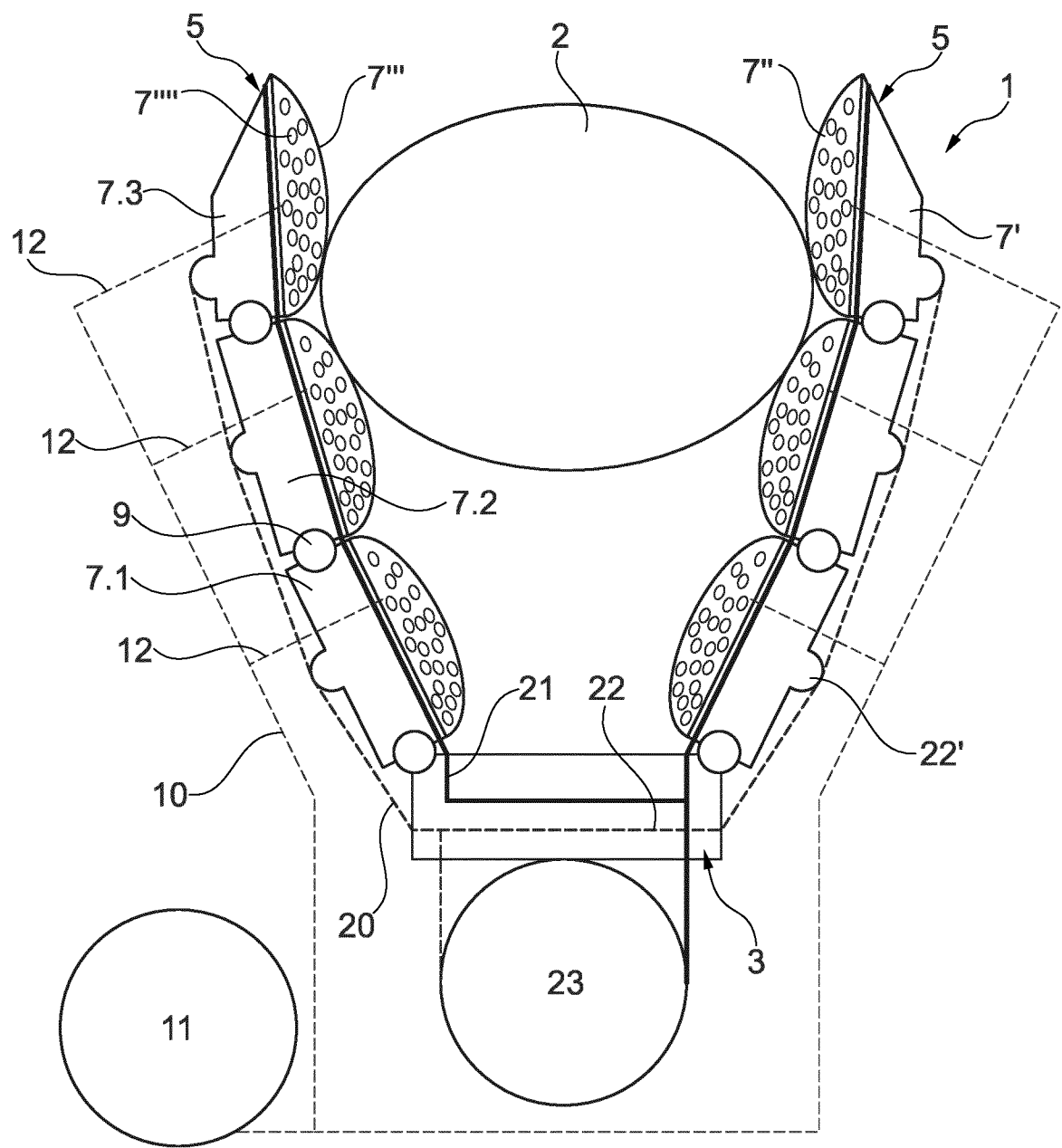


Fig. 1

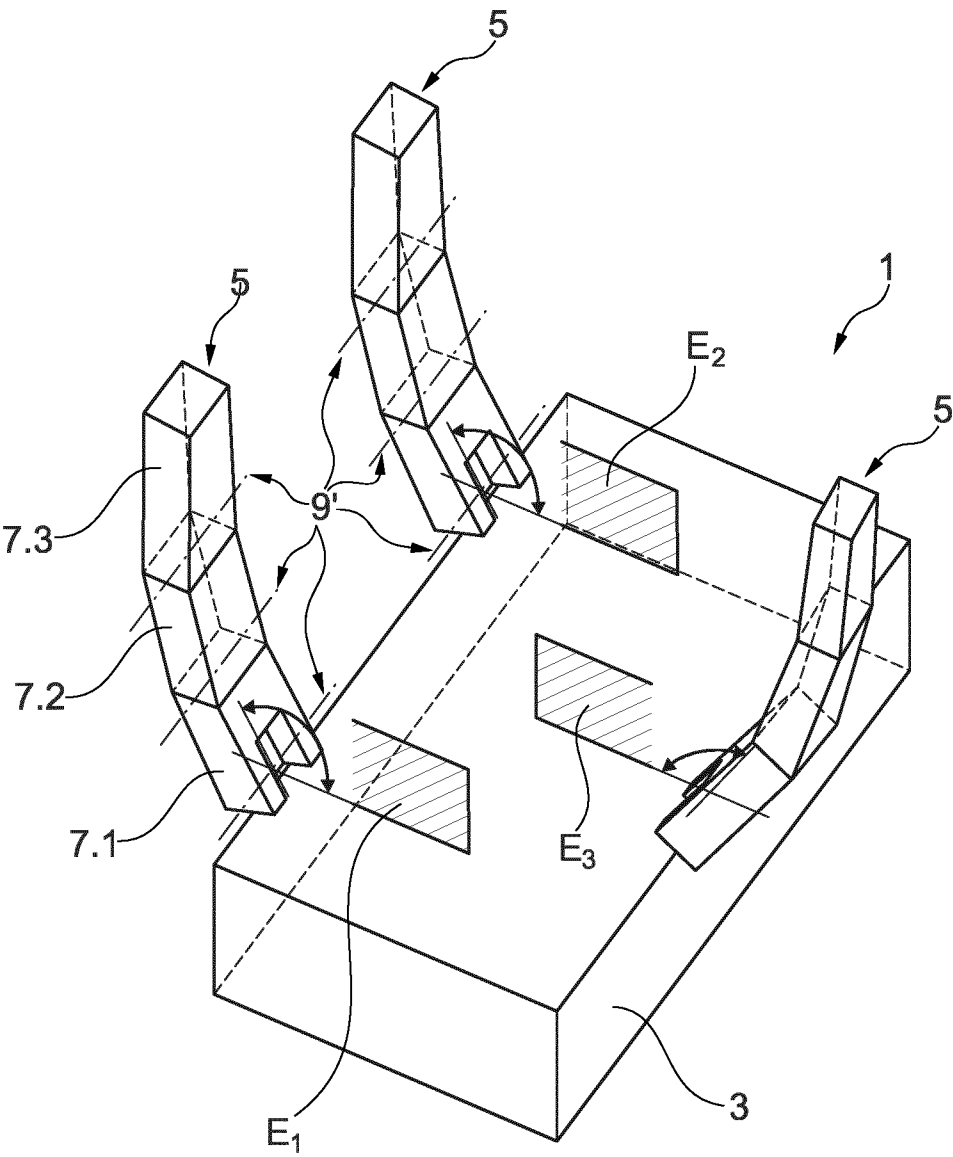


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/054129

A. CLASSIFICATION OF SUBJECT MATTER**INV. B25J15/00****ADD.**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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X	WANG XIANLI ET AL: "Design of a New Soft Phalanx with Suction Effect and Adjustable Constrained Stiffness", 2022 17TH INTERNATIONAL CONFERENCE ON CONTROL, AUTOMATION, ROBOTICS AND VISION (ICARCV), IEEE, 11 December 2022 (2022-12-11), pages 899-904, XP034268506, DOI: 10.1109/ICARCV57592.2022.10004368 [retrieved on 2023-01-10] the whole document ----- --/--	1, 3, 4, 6, 7, 10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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