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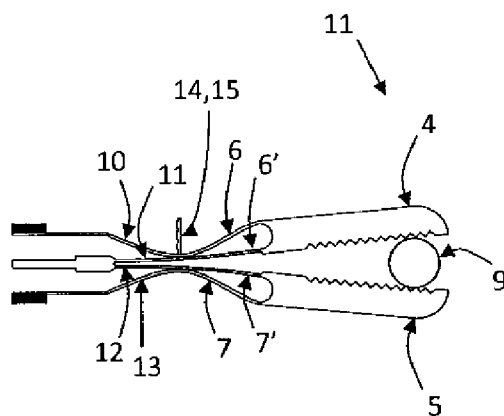


Fig. 4

(57) Abstract: Mechanical end effector (1) comprising at least two movable parts (4, 5), wherein each of the movable parts (4 resp. 5) is mounted on at least two supports (6, 6' resp. 7, 7'), wherein a relative position of the movable parts (4, 5) with respect to each other is variable by changing the relative position of the supports (6, 6'; 7, 7') with respect to each other, and wherein the supports (6, 6'; 7, 7') of the movable parts (4, 5) comprise bendable members, wherein the bendable members are equipped with mechanical properties that arrange for flexing of the bendable members when a force applied by the supports (6, 6'; 7, 7') of the movable parts (4, 5) exceeds a predefined value and the bendable members are embodied as cooperating bands (10, 11; 12, 13) to arrange that flexing of the cooperating bands (10, 11; 12, 13) provides a visual feedback to a user.

Mechanical end effector

The invention relates to a mechanical end effector comprising at least two movable parts, wherein each of the
5 movable parts is mounted on at least one support, wherein a relative position of the movable parts with respect to each other is variable by changing the relative position of the supports with respect to each other, and wherein the supports of the movable parts comprise bendable members. Usually the
10 supports of the two movable parts share a common base or base structure.

Such a mechanical end effector wherein each of the movable parts is mounted on two supports appears to be disclosed in figure 6 of WO03/026519, although this is far from
15 certain considering the obscure discussion of this figure on page 6 of this citation's description. Considering that figure 6 of WO03/026519 bears resemblance with the figures that are attached hereto to elucidate the invention, it is assumed that particular features as provided in the preamble of the main
20 claim are common to the invention and the prior art.

From US 3,527,492 a trash pickup device is known which comprises two movable parts, wherein each of the movable parts is mounted on at least one support, wherein a relative position of the movable parts with respect to each other is
25 variable by changing the relative position of the supports with respect to each other, and wherein the supports of the movable parts comprise bendable members that are equipped with mechanical properties that arrange for flexing of said members when a force applied by the supports of the movable parts ex-
30 ceeds a predefined value.

A mechanical end effector can for instance be embodied as a gripper or a cutter, and may be in use in robotics or surgical applications, particularly in minimal invasive surgery. One of the problems in using a mechanical end effector
35 that is particularly bothersome in robotics and surgical applications is the lack of sensitivity of the effector in terms of forces that may be applied to an object. A further problem is its lacking capability to provide its user of feedback on the forces that are applied with the effector on an object

which is to be manipulated or cut. This is particularly problematic in surgical applications.

It is one of the objectives of the invention to provide a solution or at least an improvement regarding the problem of lacking feedback for the user.

The mechanical end effector of the invention is provided with one or more of the features according to the appended claims.

In a first aspect of the invention the bendable members are arranged to flex and deform to an extent that is limited by a relative position of the cooperating bands with respect to each other, that restricts a room for bending of said pair of cooperating bands.

The said room between the cooperating bands is very instrumental in enabling suitable bending of at least one of the bands thus facilitating the ability to restrict or exceed a usual range of forces that may be applied with the movable parts on an object, and at the same time provide an effective means of visual and/or tactile feedback to a user that applies the forces to the movable parts. Interactions between the cooperating bands enable the usual range of forces to be restricted or exceeded through intentional contact of these bands. Exceeding or restricting a usual range of forces is valuable when performing particularly precise or robust tasks, such as manipulation of soft tissues and driving a suturing needle.

The mechanical end effector of the invention is preferably arranged such that each of the bendable members is embodied as a pair of cooperating bands predominately running parallel in an unloaded situation from a base or base structure to the movable part that the bands support, and that in a loaded situation the cooperating bands of each bendable member deform to an extent that is limited by a relative position of the cooperating bands with respect to each other, that restricts a room for bending of said pair of cooperating bands.

Suitably a further visual indicator or marker is provided on the cooperating bands that provide a visual feedback to a user when the cooperating bands are flexing. The visual feedback provides the user with reliable information on the

amount of force which is applied to the object. The predefined value that initiates flexing of the bendable members can in connection therewith be suitably chosen within a range of usual forces that are applied when the effector is used for gripping or grasping an object safely and effectively.

In some embodiments it is preferred that the visual indicator or marker is embodied as a pillar or 'needle' gauge provided on one of the cooperating bands of the bendable members which enables measuring a deflection of the cooperating bands with respect to each other which thus provides a clear indicator of the applied force. This is however only one particular embodiment and this specific choice is not the only possibility according to the invention, but helpful to explain the merits of the invention.

The ease of handling and using the mechanical end effector of the invention is promoted by arranging that the pillar or needle gauge is provided with regions showing visually discriminate patterns.

In an embodiment wherein the mechanical end effector of the invention comprises at least two movable parts embodying a jaw, and each of the movable parts is mounted on an outer support and an inner support, which outer supports extend between the said movable parts and a tube, and which inner supports extend between the said movable parts and a rod, wherein the rod is positioned in the tube and the rod and tube are longitudinally movable with respect to each other to adjust a relative position of the outer supports with respect to the inner supports so as to correspondingly adjust a relative position of the movable parts mounted on said supports, and wherein the supports of the movable parts comprise flexural members between on one end the rod and tube, and on another end the two movable parts, said flexural members arrange that a force applied by the supports to the movable parts is limited to a value which is defined by mechanical properties of the flexural members. With this construction a user is also provided with haptic feedback on the forces that are applied with the mechanical end effector, as well as visual feedback regarding these forces due to bending out of the flexural members when the applied forces exceed the said predefined value

defined by the mechanical properties of the flexural members. This is particularly beneficial when the mechanical end effector is used as a grasper in prosthetics, robotics or surgical applications, particularly in minimal invasive surgery. Haptic feedback is further provided once intentional contact between the flexural members is established.

It is found that with particular features the usefulness of the mechanical end effector of the invention can be further improved so that larger forces can be applied without sacrificing its capability to provide the user with haptic and visual feedback.

For that purpose it is preferred that the flexural members of the supports are provided with stiffening elements and/or changes in cross-sectional area (in particular thickenings) to provide for locally increased stiffness and rigidity of the flexural members. This effectively increases the possibility to apply larger forces with the mechanical end effector whilst maintaining its capability to provide visual and haptic feedback to the user.

It is preferred that there are plural stiffening elements and/or thickenings on the flexural members of the supports that are separated from each other by intermediate, in comparison with said stiffening elements and/or thickenings relatively flexible parts of the flexural members of the supports. The degree of rigidity versus flexibility of the flexural members can thus be easily tailored to the needs of the user in a particular application.

Preferably both the inner supports and the outer supports for the movable parts comprise flexural members upon which said stiffening elements and/or thickenings are provided. This provides benefits particularly in a further embodiment in which said stiffening elements and/or thickenings on any pair of an inner support and an outer support that support a movable part have cooperating teeth or interacting elements that contact or interlock with each other upon actuation of the grasper. The cooperating teeth or interacting elements further increase the amount of force that can be applied by the grasper of the invention, whilst the required flexibility is maintained.

Suitably actuation of the mechanical end effector is executed by an outer sheath wherein all supports of the movable parts are movable into and out of said sheath, wherein the outer sheath is longitudinally movable along all supports of the two movable parts between two positions, a first position in which the supports of the two movable parts are moved out of said sheath and released from restriction imposed by the outer sheath and in which the relative position of the two movable parts is determined only by the relative position of the supports, and a second position in which all supports of the two movable parts are moved into the sheath so as to restrict the relative position of said supports and to arrange that the position of the two movable parts is determined by the outer sheath only.

In quite a different embodiment of the mechanical end effector of the invention another solution is applied which is however based on the same general principle that the flexural members of the supports are provided with stiffening elements and/or thickenings to provide for locally increased stiffness and rigidity of the flexural members. In this embodiment the stiffening elements and/or thickenings are embodied as casings of and movable along the individual flexural members of the supports and positionable by an outer sheath, wherein in a first position of said sheath said casings exhibit a predefined yet variable amount of play between said casings, and wherein in a second position of said sheath play between the casings is avoided or counteracted.

The invention will hereinafter be further elucidated with reference to the drawing of an exemplary embodiment of an apparatus according to the invention that is not limiting as to the appended claims.

In the drawing:

-figure 1 shows a mechanical end effector according to a first embodiment of the invention;

-figure 2, 3 and 4 show a sequence of events that occur when the mechanical end effector of figure 1 is used to grab an object; and

-figure 5A shows a second embodiment of a mechanical end effector according to the invention, wherein figures 5B -

5E show details of visual feedback provided to the user when different amounts of force are exerted with the effector of fig. 5A.

-figure 6 shows a third embodiment of a grasper of the invention with an outer sheath retracted;

-figure 7 shows a fourth embodiment of a grasper with the outer sheath retracted;

-figure 8 shows a fifth embodiment of the grasper of the invention with an outer sheath retracted; and

-figure 9 shows the fifth embodiment of figure 8 wherein the outer sheath is moved forward.

Whenever in the figures the same reference numerals are applied, these numerals refer to the same parts.

Making reference first to figure 1 the mechanical end effector of the invention is indicated with reference 1. This mechanical end effector 1 is for exemplary purposes mounted at a distal side of a rod 2 which has on its proximal side a handle 3 which may be used for opening and closing the mechanical end effector 1. The mechanical end effector 1 of this exemplary embodiment comprises two movable parts 4, 5. The movable part 4 is mounted on two cooperating supports 6, 6', whereas the movable part 5 is mounted on two other cooperating supports 7, 7'. The supports 6, 6', 7, 7' of the two movable parts 4, 5 further share a common base or base structure 8. It is remarked however that the invention is also applicable to a construction in which both the movable part 4 and the movable part 5 are each individually mounted on a single support. This is immediately clear to the skilled person and requires no further elucidation with reference to a drawing.

Figures 2, 3, and 4 show in detail the mechanical end effector 1 shown in figure 1 when the effector is used to grasp an object 9.

Figure 2 shows the situation that the mechanical end effector 1 is in the vicinity of the object 9 which is intended to be grabbed by the mechanical end effector 1. To enable this the mechanical end effector 1 is construed such that a relative position of the movable parts 4, 5 with respect to each other is variable. Movement of movable part 4 is done by changing the relative position of the supports 6, 6' of mova-

ble part 4 with respect to each other. Movement of movable part 5 is done by changing the relative position of the supports 7, 7' of movable part 5 with respect to each other.

The supports 6, 6' and 7, 7' of the movable parts 4, 5 comprise or are embodied as bendable members. The bendable members are equipped with mechanical properties that arrange for flexing of the bendable members when a force applied by the supports 6, 6' and 7, 7' of the movable parts 4, 5 exceeds a predefined value. The flexing of the bendable members can beneficially be used to provide a visual feedback to a user as will be explained hereafter.

The flexing of the bendable members arranges that when the movable parts 4, 5 engage the object 9 as shown in figure 3, a certain degree of deformation occurs of each of the bendable members embodying the supports 6, 6' and 7, 7'. By further increasing the actuation forces applied to the supports 6, 6' and 7, 7' eventually the situation emerges as shown in figure 4. Here the largest degree of deformation of the bendable members embodying the supports 6, 6' and 7, 7' is depicted.

One of the advantages of arranging that the supports 6, 6' and 7, 7' of the movable parts 4, 5 comprise or are embodied as bendable members is that a force applied by the supports 6, 6' and 7, 7' to the movable parts 4, 5 is limited to a well-defined pre-established value which is determined by properly selecting the mechanical properties of the bendable members. The contact of the bendable members acts as a mechanical end-stop that restricts (translational) motion of the actuation member and thus restricts larger applied forces. This exemplary embodiment is very suited when gripping soft tissue, as manipulating the tissue must be done without dangerously high forces.

In the exemplary first embodiment of the mechanical end effector of the invention as depicted in figures 1 - 4, each of the bendable members is embodied as a pair of cooperating bands 10, 11 and 12, 13, which can provide visual feedback to a user. Additionally an indicator 14 or marker can assist to provide visual feedback with flexing of the cooperating bands 10, 11; 12, 13. The visual indicator 14 or marker is

preferably embodied as a pillar or needle gauge 15, provided in this exemplary embodiment on one of the cooperating bands, in particular on the band 11 of the bendable members. This is however not essential; also one of the other bands 10, 12 or 13 could be selected as support for the pillar or needle gauge. It is also possible that only the relative position of the cooperating bands 10, 11; 12, 13 are used for providing visual feedback, or that another means of visual feedback is applied. The pillar or needle gauge 15 is one example of enabling easily measuring a deflection of the cooperating bands 10, 11 with respect to each other.

Figure 5A shows a second embodiment of a mechanical end effector of the invention, wherein the instrument has two movable parts 4, 5, wherein each of the movable parts 4 resp. 5 is mounted on at least one support 6, 6' resp. 7, 7', and wherein a relative position of the movable parts 4, 5 with respect to each other is variable by changing the relative position of the supports 6, 6'; 7, 7' with respect to each other. This is in this second embodiment done by rotating of the supports 6, 6' and the supports 7, 7' with respect to each other.

Also in this second embodiment the supports 6, 6'; 7, 7' of the movable parts 4, 5 comprise bendable members embodied as cooperating bands 10, 11; 12, 13 that are equipped with mechanical properties that arrange for flexing of said members when a force applied by the supports 6, 6'; 7, 7' of the movable parts 4, 5 exceeds a predetermined value. In this case, the contact between the bendable members stiffens the individual jaw parts 4, 5. Thus further (rotational) actuation will generate larger forces that exceed the gripper's 'usual force range'. This embodiment can for instance be suitably applied when grasping a suturing needle. The contact between the jaw parts 4, 5 gives the user indication that sufficient force is being used for suturing with a needle.

The second embodiment of the mechanical end effector 1 shown in figure 5A can also be provided with an additional visual indicator 14 or marker to arrange that flexing of the cooperating bands 10, 11; 12, 13 provides a visual feedback to a user that is reproducible. The visual indicator 14 or marker is also in this embodiment provided as a pillar or needle

gauge 15 mounted in this second exemplary embodiment on both bands 11 and 12 of the bendable members.

Figures 5B - 5E show in detail the deflection of the cooperating bands 12, 13 with respect to each other when an increasing amount of force is applied going from figure 5B to figure 5E. These figures further show that suitably the pillar or needle gauge 15 is provided with regions showing visually discriminate patterns 16, 16', 16'' providing a very clear indication of the amount of the applied force by comparing the location of the position of the band 13 with respect to the discriminate patterns 16, 16', 16'' on the pillar or needle gauge 15 that is mounted on the band 12.

Turning back now to the first embodiment of the mechanical end effector of the invention depicted in figures 1 - 4, figure 2 shows the unloaded situation of the mechanical end effector 1 wherein the cooperating bands 10, 11 and 12, 13 predominantly run parallel from the base or base structure 8 to the movable part 4, 5 that the bands support. Figures 3 and 4 then show that in a loaded situation the cooperating bands 10, 11; 12, 13 of each bendable member deform to an extent that is limited by a relative position of the cooperating bands 10, 11; 12, 13 which eventually restricts a room for bending of said pair of cooperating bands 10, 11; 12, 13. This is clearly illustrated in figure 4.

In the third and fourth embodiment shown in figure 6 and figure 7 the end effector 1 of the invention is embodied as a grasper comprises two movable parts 4, 5 defining a jaw 26. The movable part 4 is mounted on an outer support 6 and an inner support 6' cooperating with the outer support 6, whereas the movable part 5 is mounted on an outer support 7 and an inner support 7' that cooperates with the outer support 7.

The outer supports 6, 7 extend between the movable parts 4, 5 and a tube 25, whereas the inner supports 6', 7' extend between the said movable parts 4, 5 and a central rod 24 wherein the rod 24 is centrally positioned in the tube 25. The rod 24 and tube 25 are longitudinally movable with respect to each other to adjust a relative position of the outer supports 6, 7 with respect to the inner supports 6', 7' so as to correspondingly adjust a relative position of the movable

parts 4, 5.

Opposite to the jaw 26 is the proximal side 27 of the grasper 1 at which side the grasper is controlled. At this proximal side 27 an outer sheath 18 is provided. For clarity purposes the outer sheath 18 is shown in a position in which the two movable parts 4, 5 of the jaw 26 are released from restriction by this outer sheath 18 so as to enable that the relative position of the movable parts 4, 5 is exclusively determined by the relative position of the supports 6, 6' and 7, 7'.

Operation of the grasper 1 with the outer sheath 18 in the retracted position is as follows. Movement of movable part 4 can be done by changing the relative position of the outer support 6 and inner support 6' of movable part 4 with respect to each other by appropriately longitudinally displacing the central rod 24 and tube 25 with respect to each other. Movement of movable part 5 can likewise be done by changing the relative position of the outer support 7 and inner support 7' of movable part 5 with respect to each other, in the same way by appropriately longitudinally displacing the central rod 24 and tube 25 with respect to each other.

In figure 6 and figure 7 the movable parts 4, 5 of the jaw 26 are moved concertedly by movement of the central supports 6' and 7' whilst the outer supports 6 and 7 remain stationary by keeping the tube 25 stationary and moving the central rod 24. Alternatively it is also possible that the movable parts 4, 5 of the jaw 2 are moved concertedly by movement of the outer supports 6 and 7 whilst the central supports 6' and 7' remain stationary by keeping the central rod 24 stationary and moving the tube 25.

In both situations shown in figures 6 and 7 the outer sheath 18 is kept in a first position in which the two movable parts 4, 5 are released from any restriction imposed by the outer sheath 18 so that the relative position of the two movable parts 4, 5 is determined by the relative position of the supports 6, 6'; 7, 7' only. This corresponds to fine or delicate grasping.

When the outer sheath 18 is moved forward to engage the outer supports 6, 7 of the movable parts 4, 5 of the jaw

2, movement of said movable parts 4, 5 is restricted and the opening and closing of the jaw 2 is controlled by positioning and moving the outer sheath 18 back-and-forth. This corresponds to coarse or firm grasping. To be precise this functionality is realized by arranging that all supports 6, 6'; 7, 7' of the movable parts 4, 5 are movable into and out of said sheath 18, wherein the outer sheath 18 is longitudinally movable along all supports of the two movable parts 4, 5 between two positions, a first position in which the supports 6, 6'; 7, 7' of the two movable parts 4, 5 are moved out of said sheath 18 and released from restriction imposed by the outer sheath 18 and in which the relative position of the two movable parts 4, 5 is determined only by the relative position of the supports 6, 6'; 7, 7', and a second position in which all supports 6, 6'; 7, 7' of the two movable parts 4, 5 are moved into the sheath 18 so as to restrict the relative position of said supports 6, 6'; 7, 7' and to arrange that the position of the two movable parts 4, 5 is determined by the outer sheath 18 only.

It is remarked that the supports 6, 6' and 7, 7' of the movable parts 4, 5 comprise or are embodied as flexural members extending between on one end the rod 24 and tube 25 and on another end the two movable parts 4, 5. One of the advantages of arranging that the supports 6, 6' and 7, 7' of the movable parts 4, 5 comprise or are embodied as flexural members is that a force applied by the supports 6, 6' and 7, 7' to the movable parts 4, 5 is limited to a well-defined pre-established value which is determined by properly selecting the mechanical properties of the flexural members. It will be clear that this only applies when the outer sheath 18 is in the retracted position, when the position of the movable parts 4, 5 is only determined by the position of their respective supports 6, 6' and 7, 7'.

According to the invention the flexural members of the supports 6, 6'; 7, 7' extending between the rod 24 and tube 25 on one end, and on another end the two movable parts 4, 5 are provided with stiffening elements and/or thickenings 19 to provide for locally increased stiffness and rigidity of the flexural members in comparison with the remainder of said

flexural members. Figure 6 shows that there are plural stiffening elements and/or thickenings 19 which are provided only on the flexural members of the outer supports 6, 7. The rigidity of the inner supports 6', 7' is not particularly increased. These stiffening elements and/or thickenings 19 are separated from each other by intermediate, in comparison with said stiffening elements and/or thickenings 19 relatively flexible parts 20 of the flexural members of the supports 6, 7 to maintain a defined flexibility of the supports 6, 7.

In the embodiment of figure 7 the flexural members of both the inner supports 6', 7' and the outer supports 6, 7 are provided with said stiffening elements and/or thickenings 19. Figure 7 further shows that said stiffening elements and/or thickenings 19 on any pair 6, 6'; 7, 7' of an inner support 6', 7' and an outer support 6, 7 that support a movable part 4; 5 have cooperating teeth 21 (on the surface of the thickenings 19 on supports 6, 6') or interacting elements (roughenings) 12 (on the surface of the thickenings 19 on supports 7, 7') that are capable to contact or interlock with each other upon actuation of the grasper 1. Such actuation is then done by moving the outer sheath 18 forward to restrict movement of the two movable parts 4, 5 and to position the grasper in the 'coarse' or 'firm' grasping mode of operation in the manner as explained here-above. Preferably the outer sheath 8 has an inner rectangular opening fitting to the supports 6, 6'; 7, 7' of the movable parts 4, 5. This provides additional stiffness against torsional/twisting loads.

The interlocking or contacting teeth 21 or roughenings 22 provided on the outer and inner supports 6, 6' and 7, 7' then further support and increase the amount of force that can be applied with the grasper of the invention. This is not further shown in the drawing considering that the manner in which this operates is perfectly clear for the skilled person. There is therefore no need for a further elucidation with reference to the drawing without compromising the skilled person's capability to work within the scope of the invention.

Figure 8 and 9 relate to a fifth embodiment of the grasper 1 of the invention, which has the feature that the stiffening elements and/or thickenings are embodied as casings

19 movable along the individual flexural members of the supports 6, 7. These casings 19 are positionable by an outer sheath 18 which can assume two separate positions. Figure 8 depicts a first position in which said sheath 18 is retracted and consequently said casings 19 exhibit a predefined yet variable amount of play 13 between said casings 19. This results in a relatively limited amount of force that can be applied with the movable parts 4, 5 that constitute the jaw 26 of the grasper. In a second and forwardly moved position of said sheath 18 as depicted in figure 9, play between the casings 19 is avoided or counteracted, and consequently flexibility of the flexural members of the supports 6, 7 is restricted. In this position relatively higher forces can be applied with the movable parts 4, 5 constituting the jaw of the grasper.

Although the invention has been discussed in the foregoing with reference to an exemplary embodiment of the mechanical end effector of the invention, the invention is not restricted to this particular embodiment which can be varied in many ways without departing from the invention. The discussed exemplary embodiment shall therefore not be used to construe the appended claims strictly in accordance therewith. On the contrary the embodiment is merely intended to explain the wording of the appended claims without intent to limit the claims to this exemplary embodiment. The scope of protection of the invention shall therefore be construed in accordance with the appended claims only, wherein a possible ambiguity in the wording of the claims shall be resolved using this exemplary embodiment.

CLAIMS

1. Mechanical end effector (1) comprising at least two movable parts (4, 5), wherein each of the movable parts (4 resp. 5) is mounted on at least one support (6, 6' resp. 7, 7'), wherein a relative position of the movable parts (4, 5) with respect to each other is variable by changing the relative position of the supports (6, 6'; 7, 7') with respect to each other, and wherein the supports (6, 6'; 7, 7') of the movable parts (4, 5) comprise bendable members that are equipped with mechanical properties that arrange for flexing of said members when a force applied by the supports (6, 6'; 7, 7') of the movable parts (4, 5) exceeds a predefined value, **characterized in that** the bendable members are embodied as cooperating bands (10, 11; 12, 13) that are arranged to flex and deform to an extent that is limited by a relative position of the cooperating bands that restricts a room for bending of said pair of cooperating bands.

2. Mechanical end effector (1) according to claim 1, **characterized in that** each of the bendable members is embodied as a pair of cooperating bands (10, 11; 12, 13) predominately running parallel in an unloaded situation from a base or base structure (8) to the movable part (4; 5) that the bands support, and that in a loaded situation the cooperating bands (10, 11; 12, 13) of each bendable member deform to an extent that is limited by a relative position of the cooperating bands (10, 11; 12, 13) that restricts a room for bending of said pair of cooperating bands (10, 11; 12, 13).

3. Mechanical end effector (1) according to claim 1 or 2, **characterized in that** the relative position of the cooperating bands (10, 11; 12, 13) provides visual feedback to a user of the force that can be applied by the supports (6, 6'; 7, 7') of the movable parts (4, 5).

4. Mechanical end effector (1) according to any one of claims 1 - 3, **characterized in that** further a visual indicator (24) or marker is provided on the cooperating bands (10, 11; 12, 13) that provide a visual feedback to a user with flexing of the cooperating bands (10, 11; 12, 13).

5. Mechanical end effector (1) according to claim 4,

characterized in that the visual indicator (24)) or marker is embodied as a pillar or needle gauge (25) provided on one of the cooperating bands (10, 11; 12, 13) of the bendable members, which enables measuring a deflection of the cooperating bands (10, 11; 12, 13) with respect to each other.

6. Mechanical end effector (1) according to claim 4 or 5, **characterized in that** the pillar or needle gauge (25) is provided with regions showing visually discriminate patterns (16, 16', 16'').

7. Mechanical end effector (1) according to any one of the previous claims 1 - 6, wherein the at least two movable parts (4, 5) embody a jaw, wherein each of the movable parts (4 resp. 5) is mounted on an outer support (6, 7) and an inner support (6', 7'), which outer supports (6, 7) extend between the said movable parts (4, 5) and a tube (25), and which inner supports (6', 7') extend between the said movable parts (4, 5) and a rod (24)) wherein the rod (24)) is positioned in the tube (25) and the rod (24)) and tube (25) are longitudinally movable with respect to each other to adjust a relative position of the outer supports (6, 7) with respect to the inner supports (6', 7') so as to correspondingly adjust a relative position of the movable parts (4, 5) mounted on said supports (6, 6'; 7, 7'), and wherein the supports (6, 6'; 7, 7') of the movable parts (4, 5) comprise flexural members between on one end the rod (24)) and tube (25), and on another end the two movable parts (4, 5), **characterized in that** the flexural members of the supports (6, 6'; 7, 7') are provided with stiffening elements and/or changes in cross-sectional area such as thickenings (19) to provide for locally increased stiffness and rigidity of the flexural members.

8. Mechanical end effector (1) according to claim 7, **characterized in that** there are plural stiffening elements and/or thickenings (19) on the flexural members of the supports (6, 6'; 7, 7') that are separated from each other by intermediate, in comparison with said stiffening elements and/or thickenings relatively flexible parts (20) of the flexural members of the supports (6, 6'; 7, 7').

9. Mechanical end effector (1) according to claim 7 or 8, **characterized in that** both the inner supports (6', 7')

and the outer supports (6, 7) for the movable parts (4; 5) comprise flexural members upon which said stiffening elements and/or thickenings (19) are provided.

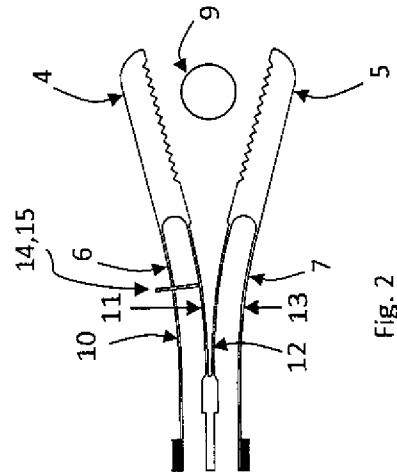
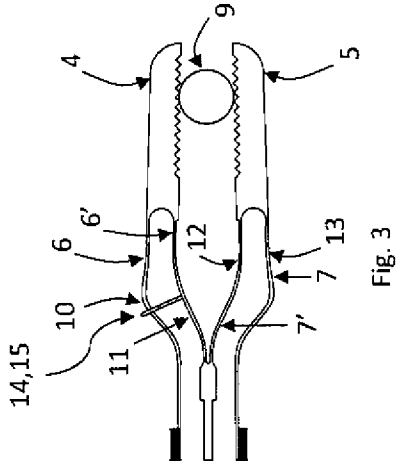
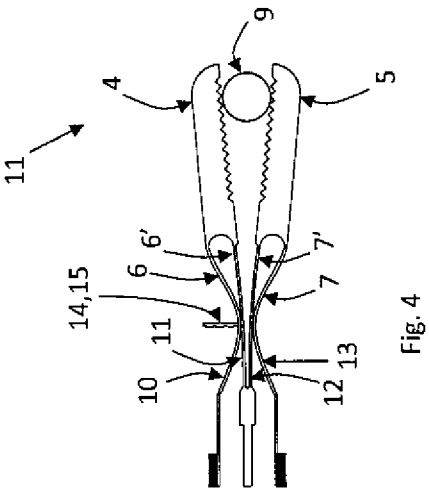
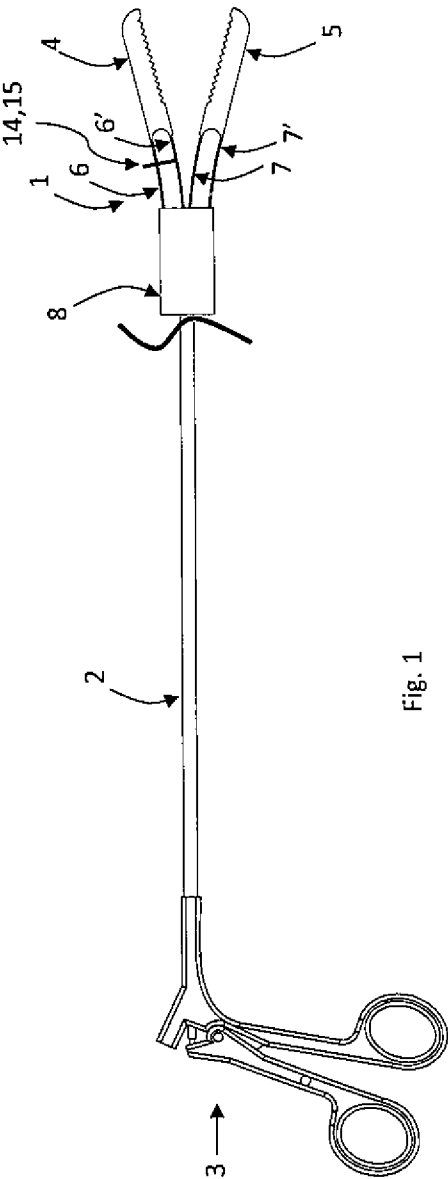
10. Mechanical end effector (1) according to claim 9,
5 **characterized in that** said stiffening elements and/or thickenings (19) on any pair (6, 6'; 7, 7') of an inner support (6', 7') and an outer support (6, 7) that support a movable part (4; 5) have cooperating teeth (21) or interacting elements such as roughenings (22) that contact or interlock with each
10 other upon actuation of the grasper.

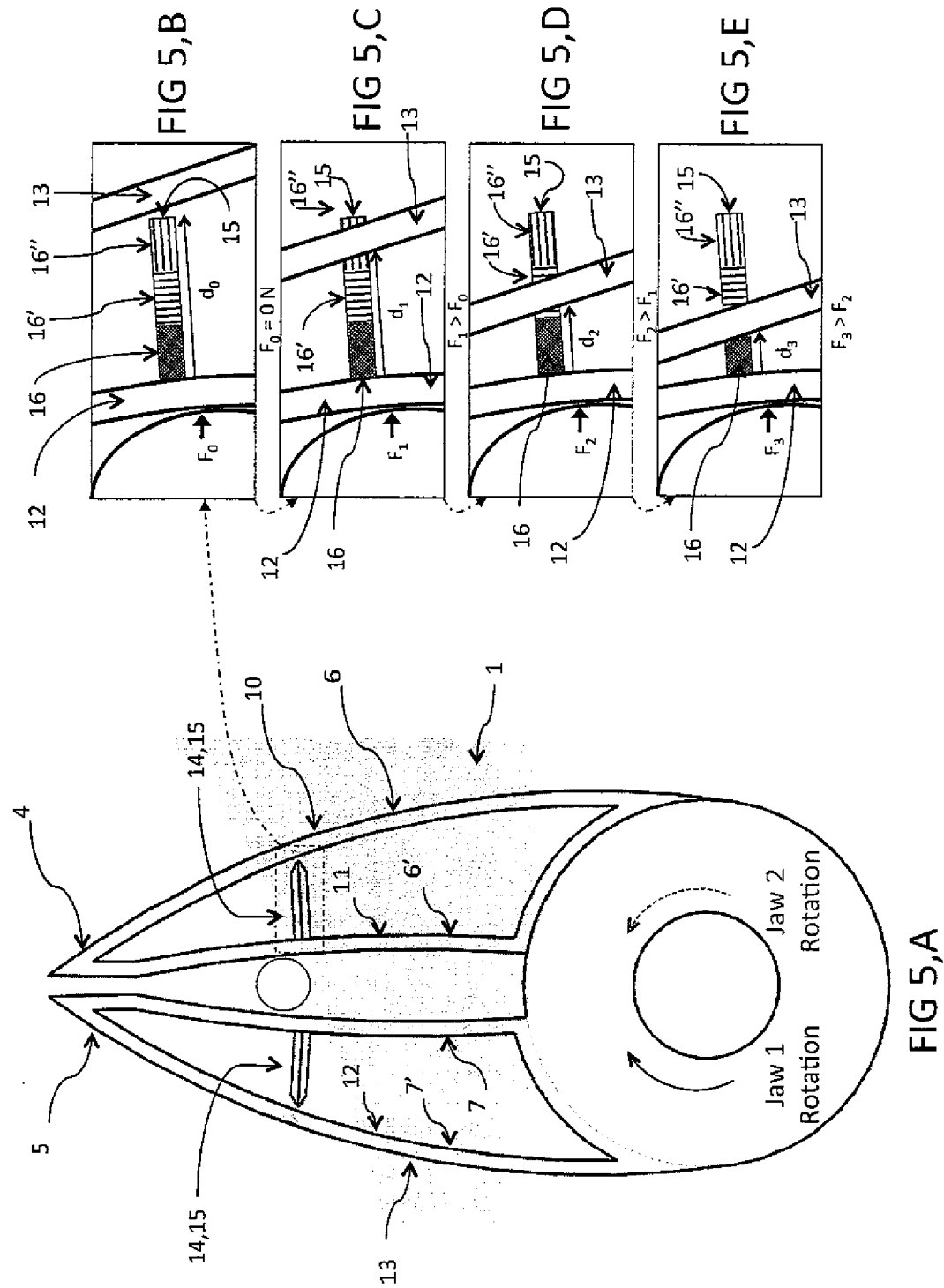
11. Mechanical end effector (1) according to claim 9 or 10, **characterized in that** actuation is executed by an outer sheath (8), wherein all supports (6, 6'; 7, 7') of the movable parts (4, 5) are movable into and out of said sheath (8),
15 wherein the outer sheath (8) is longitudinally movable along all supports of the two movable parts (4, 5) between two positions, a first position in which the supports (6, 6'; 7, 7') of the two movable parts (4, 5) are moved out of said sheath (8) and released from restriction imposed by the outer sheath
20 (8) and in which the relative position of the two movable parts (4, 5) is determined only by the relative position of the supports (6, 6'; 7, 7'), and a second position in which all supports (6, 6'; 7, 7') of the two movable parts (4, 5) are moved into the sheath (8) so as to restrict the relative
25 position of said supports (6, 6'; 7, 7') and to arrange that the position of the two movable parts (4, 5) is determined by the outer sheath (8) only.

12. Mechanical end effector (1) according to claim 11, **characterized in that** the outer sheath (8) has an inner
30 rectangular opening fitting to the supports (6, 6'; 7, 7') of the movable parts (4, 5).

13. Mechanical end effector (1) according to any one of claims 7, 9, 11 or 12, **characterized in that** the stiffening elements and/or thickenings are embodied as casings (19)
35 of and movable along individual flexural members of the supports (6, 6'; 7, 7') and positionable by an outer sheath (8), wherein in a first position of said sheath (8) said casings (19) exhibit a pre-defined yet variable amount of play (23) between said casings (19), and wherein in a second position of

said sheath (8) play between the casings (19) is avoided or counteracted.





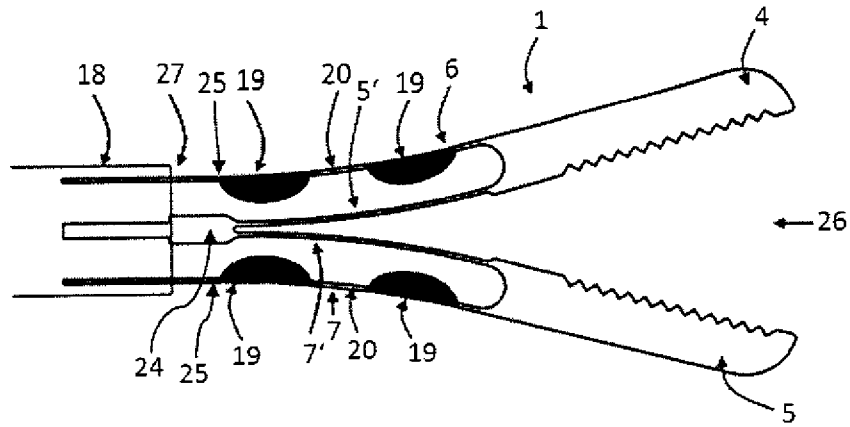


FIG. 6

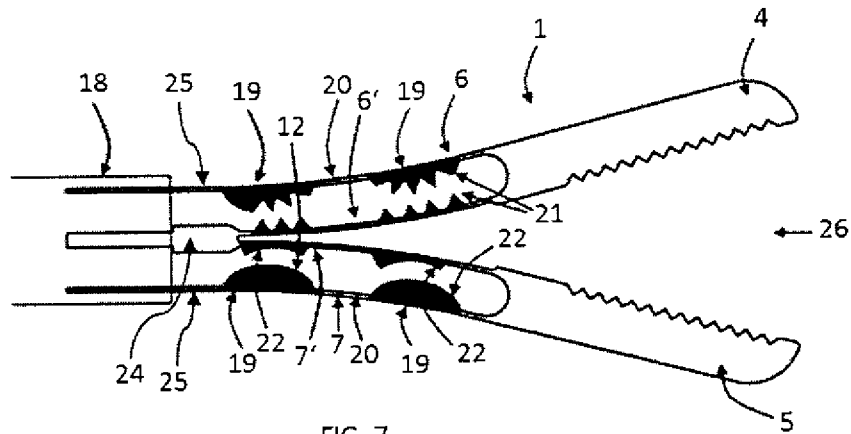


FIG. 7

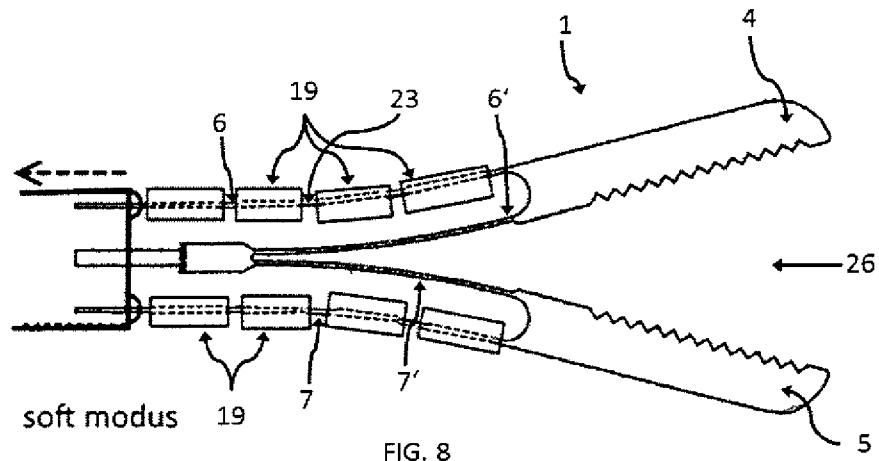


FIG. 8

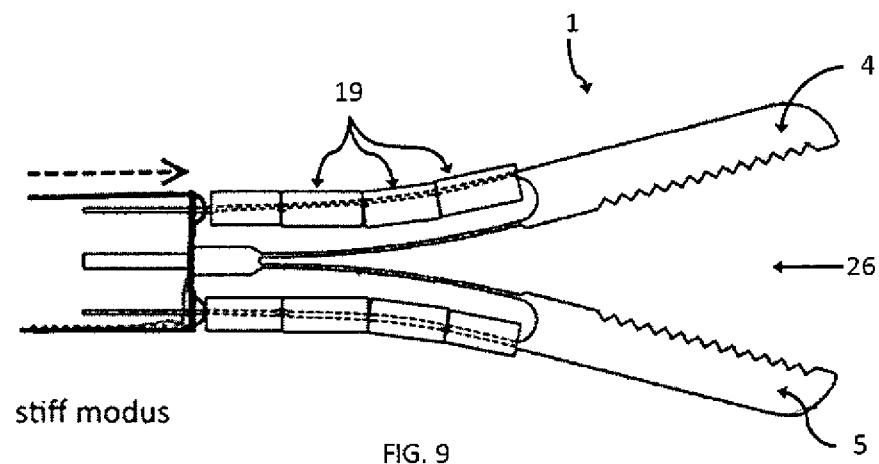


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050704

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/29
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)
A61B

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 03/026519 A1 (SENTITIC [NL]; VAN DEN BERG FREDDY PETRUS ADR [NL]) 3 April 2003 (2003-04-03) cited in the application figures 1, 6 page 6, paragraph 19 - paragraph 30 -----	1
A	NL 2 009 200 C (UNIV DELFT TECH; STICHTING TECH WETENSCHAPP) 20 January 2014 (2014-01-20) abstract; figures 1-4 -----	1
A	US 3 527 492 A (HOLLIS GRADY W) 8 September 1970 (1970-09-08) cited in the application column 1, line 52 - column 2, line 39; figure 1 ----- -/-	1



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

25 February 2016

Date of mailing of the international search report

03/03/2016

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Authorized officer

Moers, Roelof

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2015/050704

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011/288579 A1 (HYODO RYOJI [JP]) 24 November 2011 (2011-11-24) abstract; figures 1-6 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2015/050704

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 03026519	A1	03-04-2003	NL 1019041 C2 27-03-2003
			WO 03026519 A1 03-04-2003

NL 2009200	C	20-01-2014	NONE

US 3527492	A	08-09-1970	NONE

US 2011288579	A1	24-11-2011	JP 5726441 B2 03-06-2015
			JP 2011239922 A 01-12-2011
			US 2011288579 A1 24-11-2011
