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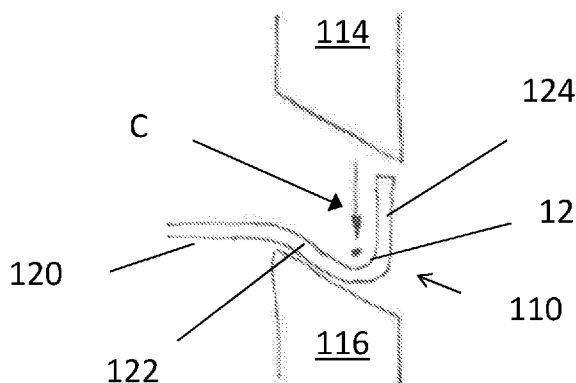
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(54) Title: A CRIMP AND METHOD FOR LOADING A WIRE THEREIN

Fig. 2a



(57) Abstract: We describe a crimp for forming an electrical connection to a wire, an actuator assembly comprising a pair of crimps and a crimp closing mechanism. We also describe methods of assembling an actuator assembly. The crimp (110) comprises a first generally planar portion (120); a second portion (122) connected to and set at an angle to the first portion; and a third portion (124) connected to the second portion to define a channel between the second and third portions. The channel is configured to receive a wire (12). The third portion is foldable relative to the second portion to secure the received wire (12) within the crimp (110).



A Crimp and Method for Loading a Wire Therein

The present techniques generally relate to a crimp, for example a crimp which is used to form an electrical and mechanical connection with a shape memory alloy (SMA) wire, as well as a method for assembling an actuator assembly comprising the wire, e.g. the SMA wire, in the crimp.

SMA actuator assemblies may further comprise a static part and a moveable part which is moveable with respect to the static part. The crimps may be used to fix the SMA wire to one or both of the static part and the moveable part. The SMA actuator assembly may be, or may be provided in, any one of the following devices: a smartphone, a protective cover or case for a smartphone, a functional cover or case for a smartphone or electronic device, a camera, a foldable smartphone, a foldable image capture device, a foldable smartphone camera, a foldable consumer electronics device, a camera with folded optics, a periscope camera, an image capture device, an array camera, a 3D sensing device or system, a servomotor, a consumer electronic device (including domestic appliances such as vacuum cleaners, washing machines and lawnmowers), a mobile or portable computing device, a mobile or portable electronic device, a laptop, a tablet computing device, an e-reader (also known as an e-book reader or e-book device), a computing accessory or computing peripheral device (e.g. mouse, keyboard, headphones, earphones, earbuds, etc.), an audio device (e.g. headphones, headset, earphones, etc.), a security system, a gaming system, a gaming accessory (e.g. controller, headset, a wearable controller, joystick, etc.), a haptics device, a robot or robotics device, a medical device (e.g. an endoscope), an augmented reality system, an augmented reality device, a virtual reality system, a virtual reality device, a wearable device (e.g. a watch, a smartwatch, a fitness tracker, etc.), an autonomous vehicle (e.g. a driverless car), a vehicle, a tool, a surgical tool, a remote controller (e.g. for a drone or a consumer electronics device), clothing (e.g. a garment, shoes, etc.), a switch, dial or button (e.g. a light switch, a thermostat dial, etc.), a display screen, a touchscreen, a flexible surface, and a wireless communication device (e.g. near-field communication (NFC) device). It will be understood that this is a non-exhaustive list of possible apparatus.

Figure 1a illustrates a known method for creating the electrical and mechanical connection between a crimp 10 and a wire 12 using a crimp closing mechanism having a punch 14 and anvil 16. The crimp 10 comprises a first portion 20 and a second portion 22 which is foldable over the first portion 20. The first portion 20 is a generally planar portion and in this arrangement is generally horizontal. The second portion 22 is set an angle of approximately 45 degrees to the first portion 20 to define a generally V-shaped channel into which the wire 12 is received.

The method typically comprises several stages. In a first stage, the wire 12 is advanced across the crimp 10. The wire 12 is then lowered onto the crimp 10 as indicated by Arrow A, in particular onto the first portion 20. In a third stage, the wire 12 is moved into the crimp as indicated by Arrow B by sliding the wire 12 over the first portion. In this arrangement, this is a horizontal movement. The wire 12 is within the crimp 10, i.e. positioned between the first and second portions 20, 22. The crimp can then be closed by moving the punch 14 towards the anvil 16 (or vice versa) whereby the second portion 22 is folded towards the first position and encloses the wire 12.

An example of an actuating module that uses SMA actuator wires is described in more detail in WO2011/104518, the contents of which are herein incorporated by reference. In such an actuating module, as illustrated schematically in Figure 1b, a pair of crimps 310a, 310b may be arranged so that the generally V-shaped channels in to which the wire 12 is inserted face in opposite directions. As above, the wire 12 is first advanced across one crimp 310a. The wire 12 is then lowered onto the crimp 310a as indicated by Arrow E, and then moved into the crimp as indicated by Arrow F by sliding the wire 12 in a first horizontal direction. Part of the wire 12 is thus within the first crimp 310a. The wire 12 may then be advanced across the second crimp 310b. The wire 12 is then lowered onto the crimp 310b as indicated by Arrow G, and then moved into the crimp as indicated by Arrow H by sliding the wire 12 in a second horizontal direction which is in the opposite direction to the first horizontal direction. Once the wire is in both crimps, the crimps can then be closed simultaneously or one at a time.

The present applicant has identified the need for an improved crimp and/or method of assembling an actuator comprising at least one crimp.

According to a first approach of the present techniques, there is provided a
5 crimp for forming an electrical connection to a wire, the crimp comprising a first generally planar portion extending along a plane; a second portion connected to the first portion and set at an angle to the plane; and a third portion connected to the second portion to define a channel between the second and third portions, wherein the channel is configured to receive a wire and wherein the third portion
10 is foldable relative to the second portion to secure the wire within the crimp.

According to a second approach of the present techniques, there is provided an actuator assembly comprising a pair of crimps described above.

15 According to a third approach of the present techniques, there is provided a crimp closing mechanism for closing the crimp described above, the crimp closing mechanism comprising a punch and an anvil wherein the second portion of the crimp is supported on a contacting surface of the anvil and a contacting surface of the punch is moveable relative to the contacting surface of the anvil to fold the
20 third portion of the crimp towards the second portion of the crimp.

According to a fourth approach of the present techniques, there is provided a method of assembling an SMA actuator assembly, the method comprising inserting an SMA wire in the channel in a crimp described above; and closing the
25 crimp by folding the third portion towards the second portion.

According to a fifth approach of the present techniques, there is provided a method of assembling an SMA actuator assembly described above, the method comprising inserting one or more SMA wires in the channel in each crimp in the
30 pair of crimps; and simultaneously closing the pair of crimps.

Preferred features are set out in the appended dependent claims.

Implementations of the present techniques will now be described, by way
35 of example only, with reference to the accompanying drawings, in which:

Figure 1a illustrates a side view of a known apparatus for closing a standard crimp around a wire;

5 Figure 1b illustrates a schematic view of a pair of standard crimps around a wire;

Figure 2a illustrates a side view of a first arrangement of apparatus for closing a first arrangement of a crimp;

10

Figure 2b is a side view of the crimp of Figure 2a;

Figure 3 illustrates a side view of a second arrangement of apparatus for closing a standard crimp;

15

Figure 4 illustrates a side view of the arrangement of Figure 3 incorporating an obstruction;

Figure 5 illustrates a side view of a third arrangement of apparatus for closing the crimp of Figure 2a;

20

Figures 6a and 6b illustrate schematic views of alternative arrangements for a pair of crimps around a wire;

Figure 7a illustrates a schematic view of an alternative arrangement for multiple pairs of crimps;

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Figure 7b is a schematic view of part of the arrangement of Figure 7a;

Figure 8 is a first method for assembling an actuator assembly; and

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Figure 9 is a second method for assembling an actuator assembly.

As described above in relation to Figure 1a, a standard crimp has a first generally planar portion and a second angled portion and thus loading a wire, e.g.

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an SMA wire, into the crimp requires several steps. SMA actuator wires are themselves very thin, typically of the order of $25\mu\text{m}$ in diameter, to ensure rapid heating and cooling. Similarly, the crimps are typically small, e.g. have a width of the order of between 250 to $750\mu\text{m}$, for example approximately $500\mu\text{m}$. The crimp width w is the size of the crimp in the direction perpendicular to the wire 'exit' direction. Accurate alignment of the wire with the crimp is important but may be difficult with such small dimensions.

The present techniques describe how the standard crimp may be adapted to improve the method of loading a wire into the crimp. The crimps described below may thus be small in width and may be used with small SMA wires, e.g. of the order of $25\mu\text{m}$ in diameter. The crimp closing mechanism may also be adapted as described below and it will be appreciated that the different adaptations of Figures 2a and 5 may be interchanged as appropriate and may be used with the paired arrangements of Figures 6a to 7b.

The crimp and wire together may be considered to form an actuating assembly. The actuating assembly may be a component within an actuating module which may comprise: a support structure, for example, for supporting a moveable component; a moveable platform; an integrated circuit chip or processor for controlling the movement of the actuating module; the moveable element; etc. The crimp may be used to couple the wire to another component which may be any component of the actuator module, e.g. the moveable component or the static component. Both ends of the SMA actuator wire may be coupled to the same component of the actuator module, or each end of the SMA actuator wire may be coupled to different components of the actuator module. The term is also used to cover the possibility that both ends of the SMA wire are coupled to a fret, where the fret is coupled to the actuating module.

Figure 2a shows a first arrangement of a crimp 110 which has been adapted to improve the method of loading the wire 12 into the crimp 110 and Figure 2b is a close-up of the crimp itself. In this arrangement, the crimp 110 comprises a first portion 120, a second portion 122 and a third portion 124 which is foldable over the second portion 122. The second portion 122 is between and thus connects the first and third portions 120, 124. The first portion 120 may be a

generally planar portion and in this arrangement is generally horizontal. The second portion 122 may be set an angle α to the first portion 120 whereby it may be considered that a "bend" is introduced into the crimp 110. For example, the angle α may be between 100 to 135 degrees, for example approximately 120 degrees. The third portion 124 is set at an angle θ to the second portion 122 to define a channel into which the wire 12 is received. For example, the angle may be between approximately 20 to 60 degrees, for example approximately 40 degrees. In some arrangements, the third portion 124 may be set at an angle β of between 10 to 45 degrees from the vertical (or a plane at right angles to the first portion). In the arrangement shown in Figure 2a, the third portion 124 may be generally perpendicular to the first portion 120 and in this arrangement extends generally vertically. The channel may be generally V-shaped.

By introducing a "bend" into the crimp 110, the wire 12 may be inserted into the crimp 110 by moving the wire 12 in the direction of arrow C only. In other words, after the wire has been advanced across the crimp, the wire is simply lowered into the crimp. There is no need to move the wire in another direction, e.g. horizontally, to ensure the wire is within the crimp. Once the wire 12 is within the generally V-shaped channel of the crimp 110, the crimp 110 may then be closed by activating the crimp closing mechanism, i.e. to move the punch 114 and anvil 116 of the crimp closing mechanism towards each other to fold the third portion of the crimp towards the second portion of the crimp.

In addition to adapting the crimp, in this arrangement, the crimp closing mechanism has also been adapted. The contacting surfaces of the punch 114 and anvil 116 are adapted to match the shape of the crimp 110. As illustrated, the crimp 110 rests on a contacting face of the anvil 116 and the contacting face of the anvil 116 is sloped so that the plane of the contacting face has an angle which matches the angle of the second portion 122 of the crimp 110 relative to the first portion 120 of the crimp 110. A contacting surface of the punch 114 has a similar angle or slope. A tip (or leading edge) of the contacting surface punch 114 contacts the upper edge of the third portion 124 as the punch and anvil are moved relatively closer to one another to close the crimp. The tip of the punch 114 forces the third portion 124 downwards so that the sloping surface of the punch 114 can contact a larger surface area of the third portion 124 to fold the third

portion 124 over the second portion 122 to form the mechanical and electrical connection between the wire and the crimp.

Figure 3 illustrates an alternative arrangement for providing a single
5 direction of movement of the wire into the crimp 10. In this arrangement, a standard crimp 10 together with a standard punch 14 and anvil 16 such as that shown in Figure 1 is used. However, in this arrangement, the wire loading mechanism (not shown) is configured to feed the wire 12 into the V-shaped channel between the first and second portions 20, 22 of the crimp 10 at an angle
10 as illustrated by the Arrow D. Preferably, the angle of insertion of the wire is less than that of the angle between the first and second portions 20, 22, e.g. the direction of wire insertion does not extend parallel to the second portion 22. As an example, the angle between the first and second portions 20, 22 may be 30° and the angle of insertion may be 20° with respect to the first portion 20.
15 Advantageously, such an arrangement may allow for manufacturing and bending tolerance of the crimp 10. In other embodiments, the angle of insertion of the wire is generally parallel to the plane of the second portion 22 or in other words may bisect the gap between the first and second portions 20, 22. Thus, after the wire has been advanced across the crimp, the wire is simply placed into the crimp in a
20 single direction of movement. Thereafter, the crimp 10 may be closed around the wire 12 by folding the second portion 22 onto the first portion 20 using the punch 14 and anvil 16.

Figure 4 illustrates an arrangement in which the proposed solution of Figure
25 3 is not viable. In Figure 4, there is an obstruction 30 adjacent to standard punch 14 and anvil 16 which prevents the wire 12 being inserted along the angle of Arrow D into the V-shaped channel between the first and second portions 20, 22 of the crimp 10. The obstruction 30 may result from another part of the actuator assembly which houses the crimp or another part of the punch and anvil
30 mechanism.

Figure 5 illustrates an alternative arrangement for providing a single
direction of movement of the wire into the crimp when there is an obstruction 30
as illustrated in Figure 4. The Figure 5 arrangement uses a "bent" crimp 110 as
35 shown in Figure 2a. The crimp 110 thus comprises first, second and third portions

120, 122, 124 as described in Figure 2a. The wire 12 is inserted into the V-shaped channel between the second and third portions 122, 124 by moving the wire in a single direction, which as illustrated is vertically downwards in this arrangement.

5 As in Figure 2a, the crimp closing mechanism has also been adapted to facilitate closure of the crimp. In contrast to the arrangement in Figure 2a which has sloping contacting faces of the crimp and anvil, the whole crimp closing mechanism of Figure 5 is set at an angle relative to the standard arrangement of a crimp closing mechanism to achieve the matching angle between the contacting
10 surfaces of the punch and the anvil and the second portion of the crimp. In other words, the planes of the contacting faces of the punch 214 and anvil 216 are generally perpendicular to the relative direction of motion between the punch 214 and anvil 216 when closing the crimp. The second portion 122 of the crimp 110 rests on the angled contacting surface of the anvil 216. Once the wire is inserted
15 into the crimp, in the single direction of Arrow C, the crimp is closed by bringing the angled contacting surface of the punch 214 closer to the anvil 216 (or vice versa by bringing the anvil closer to the punch).

 As described above in relation to Figure 1b, a pair of standard crimps may
20 be arranged in opposite directions and thus loading a wire, e.g. an SMA wire, into the crimp requires several steps. Figure 6a shows an arrangement in which a pair of the crimps described in Figure 2a have been used to improve the method of loading the wire 12 into a pair of crimps which are facing in opposite directions. The distance between the pair of crimps may be between 5 to 20mm. Each crimp
25 110a, 110b comprises first, second and third portions 120, 122, 124 with a generally V-shaped channel defined between the second and third portions 122, 124. When the crimps are closed, the opposed surfaces of the second and third portions 122, 124 are in contact with one another.

30 The V-shaped channels of each of the pair of crimps 110a, 110b are aligned, i.e. the wire extends in a straight line through both channels. In this arrangement, the crimps are arranged in the opposite directions so that the third portions 124 of each of the pair of crimps 110a, 110b are on opposite sides of the wire 12. In other words, the surface of the third portion 124 which contacts the second portion
35 122 in the first crimp 110a is arranged to face the surface of the third portion 124

which contacts the second portion 122 in the second crimp 110b. The alignment of the channels means that the wire 12 may be inserted into both crimps simultaneously by moving the wire 12 in a single direction which as illustrated in this arrangement is a downward vertical direction (arrow C).

5

Figure 6b shows an alternative arrangement in which a pair of the crimps described in Figure 2a have been used to improve the method of loading the wire 12 into a pair of crimps which are facing in the same direction. As before, each crimp 210a, 210b comprises first, second and third portions 120, 122, 124 with a generally V-shaped channel defined between the second and third portions 122, 124. The V-shaped channels of each of the pair of crimps 210a, 210b are aligned, i.e. the wire extends in a straight line through both channels. In this arrangement, the crimps are arranged in the same direction so that the third portions 124 of each of the pair of crimps 210a, 210b are on the same side of the wire 12. The alignment of the channels means that the wire 12 may be inserted into both crimps simultaneously by moving the wire 12 in a single direction which as illustrated in this arrangement is a downward vertical direction.

Figure 7a shows an automated crimping machine using a continual strip 140 on which pairs of crimps 310a, 310b are arranged. As shown more clearly in Figure 7b, each pair of crimps comprises a first crimp 310a and a second crimp 310b which are arranged in opposite directions to one another, i.e. the first portions 120 of each crimp are attached on opposite sides of the strip 140 so that ends of the first portions are adjacent. Each of the first crimps 310a are in line with one another on one side of the strip and similarly each of the second crimps 310b are in line with one another on one side of the strip. Two continuous wires 112a, 112b are provided.

As illustrated in Figure 7a, the open crimps 310a, 310b move through an arch, coming up to join the pair of wires 112a, 112b. A first wire 112a is moved into the V-shaped channel of a first open crimp 310a with the third portion 124 on a first side of the wire (e.g. the right side of the wire in this arrangement). A second wire 112b is moved into the V-shaped channel of a second open crimp 310b with the third portion 124 on an opposed side of the wire (e.g. the left side of the wire in this arrangement). Thus, in this arrangement, the channels of each

crimp in a pair of crimps are spaced laterally apart and are not aligned so that a single wire can be placed in each pair of crimps. Each of the first crimps are aligned along an axis of the first wire and similarly each of the second crimps are aligned along an axis of the second wire.

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As the strip 140 continues around the arch, both wires are eventually in place in the corresponding crimps. Both crimps may then be simultaneously closed. It will be appreciated that this automated crimping machine achieves wire loading without the need for moving wire guides.

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Any suitable material which forms a mechanical and electrical connection may be used for the crimps described above, e.g. phosphor bronze or stainless steel.

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Figure 8 is a flowchart for assembling an actuator assembly comprising a crimp and wire as described above. The actuator assembly may be a component which is used in the actuator. The method may comprise inserting the wire in the channel in the crimp S100. As described above, in the method according to the present techniques, the insertion is achieved by moving the wire in a single direction rather than the multi-step movements of the known art. It will be appreciated that reducing the number of motions required in automation may be a cost saver.

20

The next optional step S102 may be used for example if there are a pair of crimps or if there is a continuous line of crimps, e.g. on a strip. The same wire, or a different wire, may be inserted into the channel of the second crimp. Once the wire(s) are inserted in the appropriate channel(s), the or each crimp may be closed S104. If there are multiple crimps, they may be closed simultaneously or in pairs.

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Figure 9 is a flowchart for assembling an actuator assembly comprising a pair of crimps and a single wire as described above. The method may comprise inserting the wire simultaneously in both channels in the crimp S200. As described above, in the method according to the present techniques, the insertion is achieved by moving the wire in a single direction rather than the multi-step

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movements of the known art. The pair of crimps may then be closed simultaneously S202.

Those skilled in the art will appreciate that while the foregoing has described
5 what is considered to be the best mode and where appropriate other modes of
performing present techniques, the present techniques should not be limited to
the specific configurations and methods disclosed in this description of the
preferred embodiment. Those skilled in the art will recognise that present
10 techniques have a broad range of applications, and that the embodiments may
take a wide range of modifications without departing from any inventive concept
as defined in the appended claims.

CLAIMS

1. A crimp for forming an electrical connection to a wire, the crimp comprising
a first generally planar portion extending along a plane;
5 a second portion connected to the first portion and set at an angle to the
plane; and
a third portion connected to the second portion to define a channel between
the second and third portions, wherein the channel is configured to receive a wire
and wherein the third portion is foldable relative to the second portion to secure
10 the received wire within the crimp.
2. The crimp of claim 1, wherein the channel is generally V-shaped.
3. The crimp of claim 1 or claim 2, wherein the angle between the first and
15 second portions is between 100 to 135 degrees.
4. The crimp of any preceding claim having a width of approximately 250 to
750 μ m.
- 20 5. An actuator assembly comprising a pair of crimps according to any one of
claims 1 to 4.
6. The actuator assembly of claim 5, wherein the channels of each crimp in the
pair of crimps are aligned.
- 25 7. The actuator assembly of claim 5 or claim 6, wherein each crimp in the pair
of crimps are arranged in the opposite direction to one another.
8. The actuator assembly of claim 5 or claim 6, wherein each crimp in the pair
30 of crimps are arranged in the same direction.
9. A crimp closing mechanism for closing the crimp of any one of claims 1 to 4,
the crimp closing mechanism comprising a punch and an anvil wherein the second
portion of the crimp is supported on a contacting surface of the anvil and a
35 contacting surface of the punch is moveable relative to the contacting surface of

the anvil to fold the third portion of the crimp towards the second portion of the crimp.

10. The crimp closing mechanism of claim 9, wherein at least one of the contacting surfaces of the punch and the anvil is angled to match the angle of the second portion of the crimp.

11. The crimp closing mechanism of claim 10, wherein both of the contacting surfaces of the punch and the anvil are angled.

12. The crimp closing mechanism of claim 11, wherein the punch and the anvil are set at an angle relative to a direction of motion between the punch and the anvil and the contacting surfaces of the punch and the anvil are generally perpendicular to the direction of motion between the punch and the anvil.

13. The crimp closing mechanism of claim 12, wherein the contacting surfaces of the punch and the anvil are sloped.

14. A method of assembling an SMA actuator assembly, the method comprising:
inserting an SMA wire in the channel in a crimp as claimed in any one of claims 1 to 4; and
closing the crimp by folding the third portion towards the second portion.

15. A method of assembling an SMA actuator assembly as claimed in any one of claims 5 to 8, the method comprising:
inserting one or more SMA wires in the channel in each crimp in the pair of crimps; and
simultaneously closing the pair of crimps.

16. The method of claim 15, further comprising simultaneously inserting a single SMA wire into the channel in each crimp in the pair of crimps.

Fig. 1a

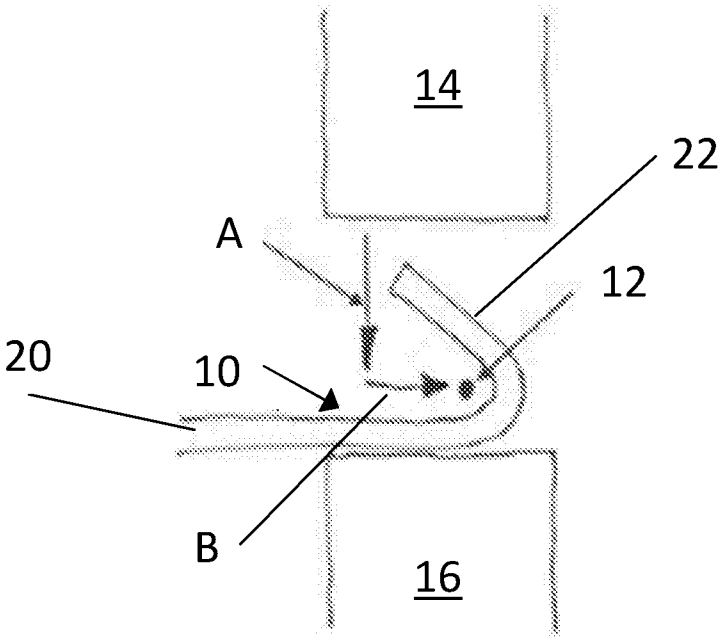
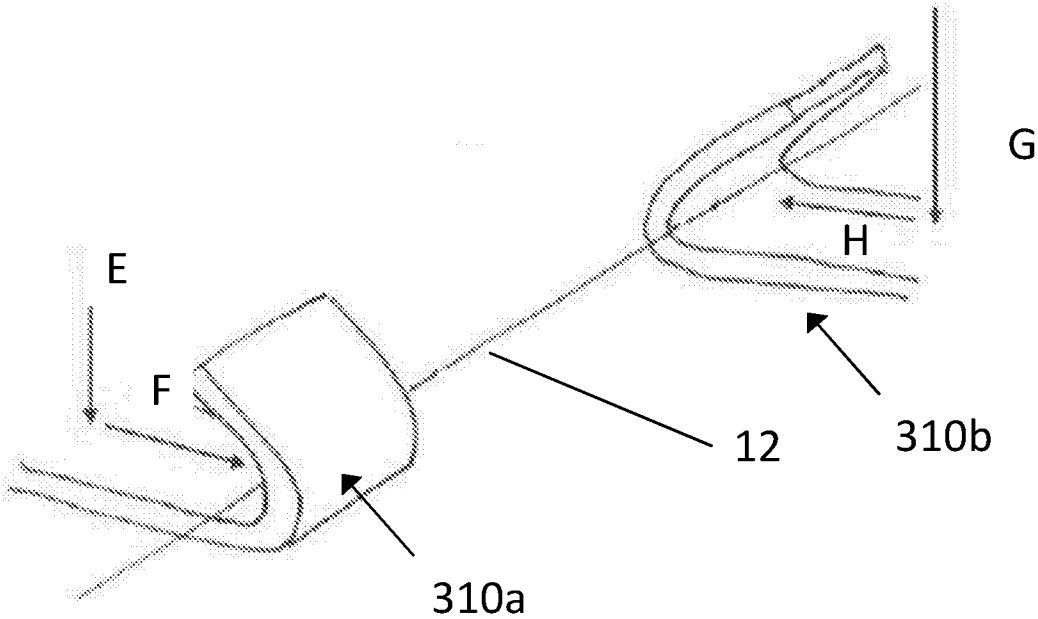


Fig. 1b



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Fig. 2a

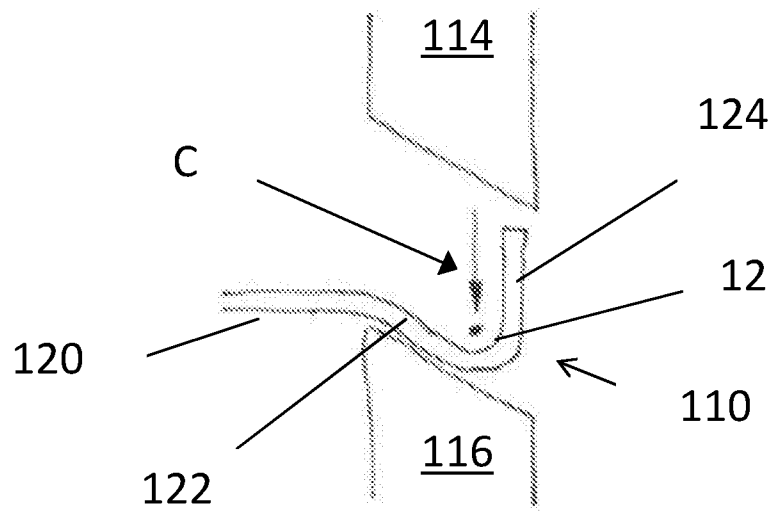


Fig. 2b

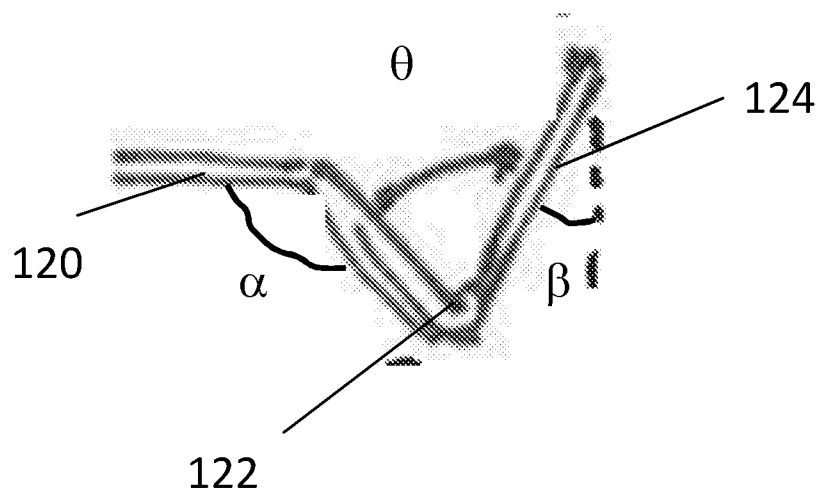
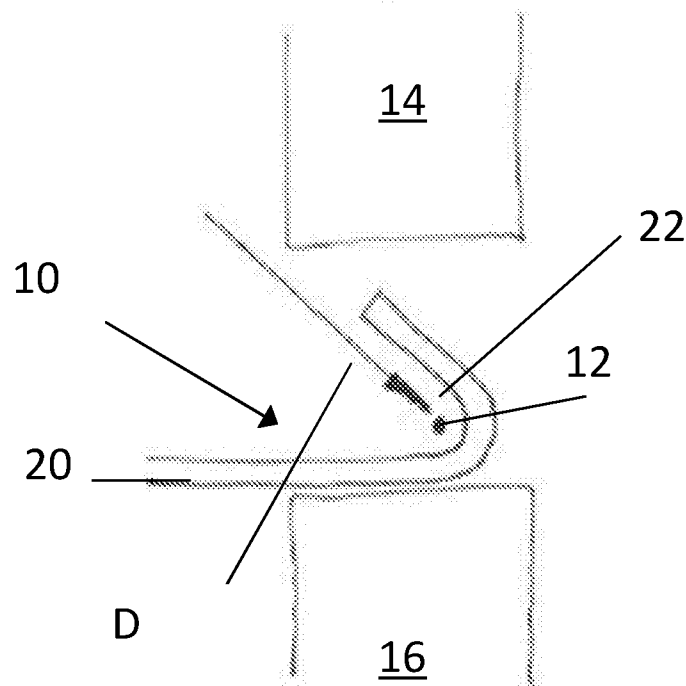


Fig. 3



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Fig. 4

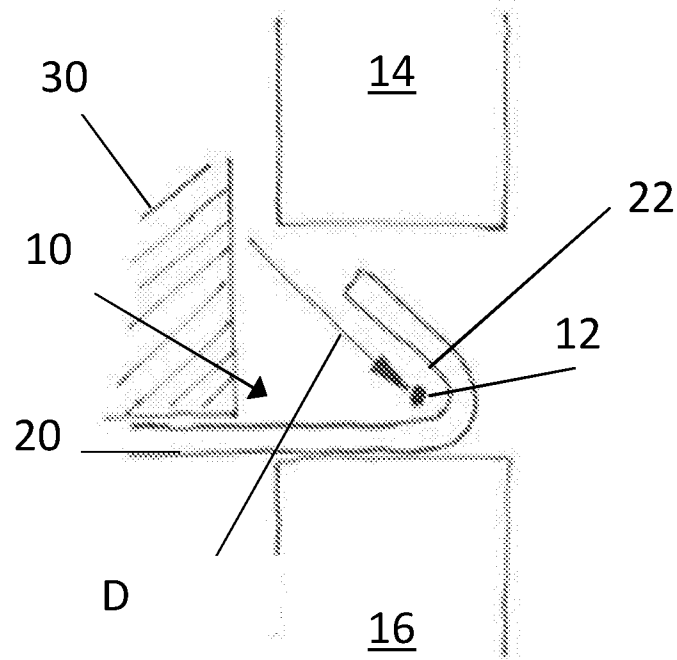


Fig. 5

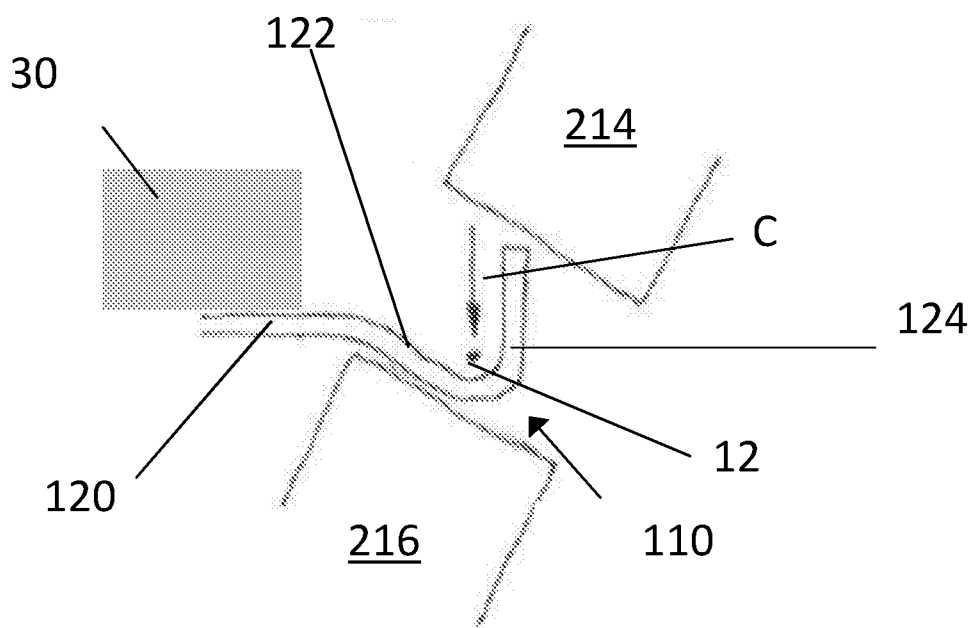


Fig. 6a

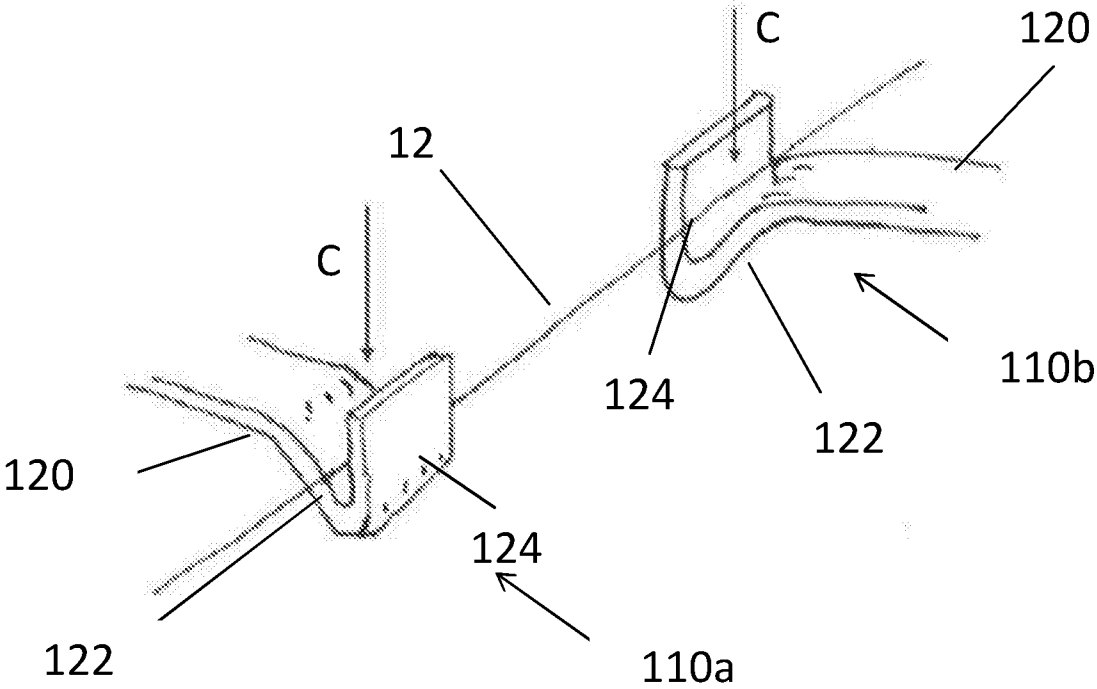
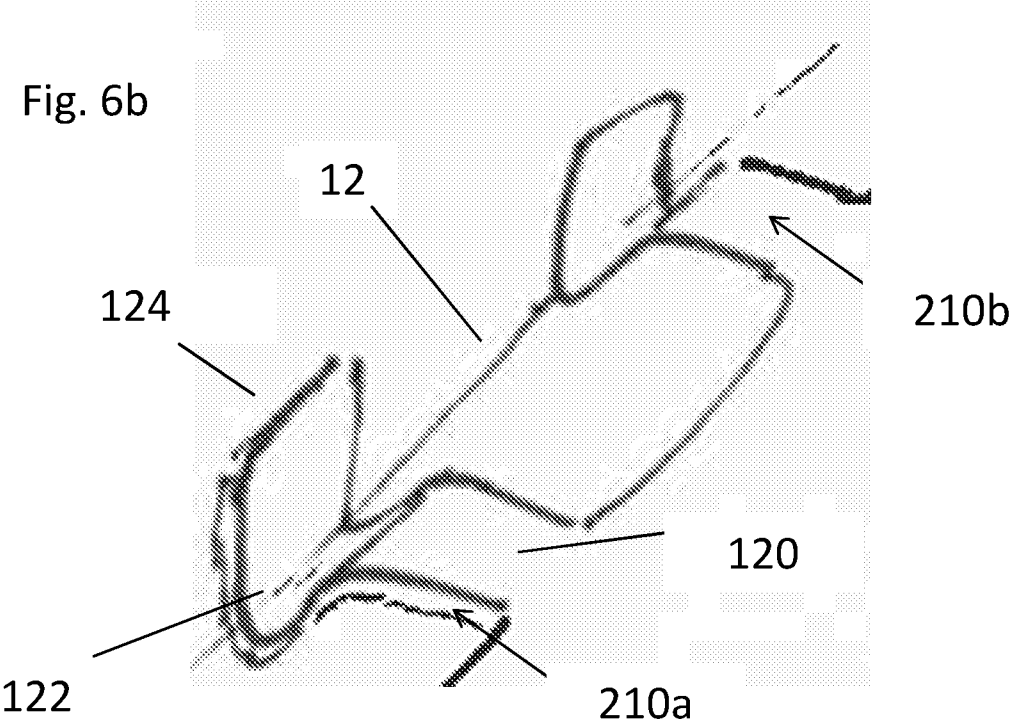


Fig. 6b



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Fig. 7a

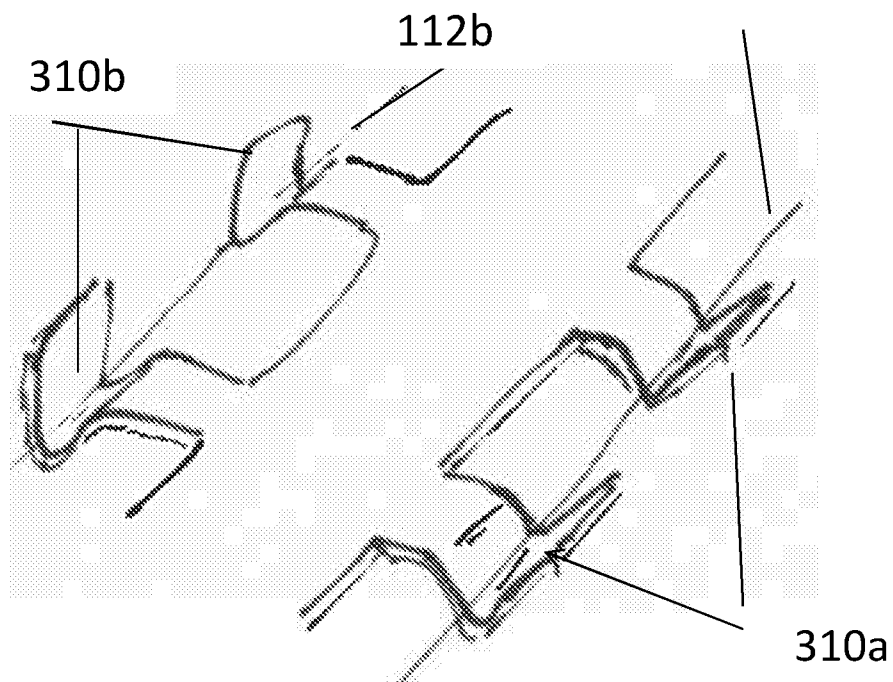
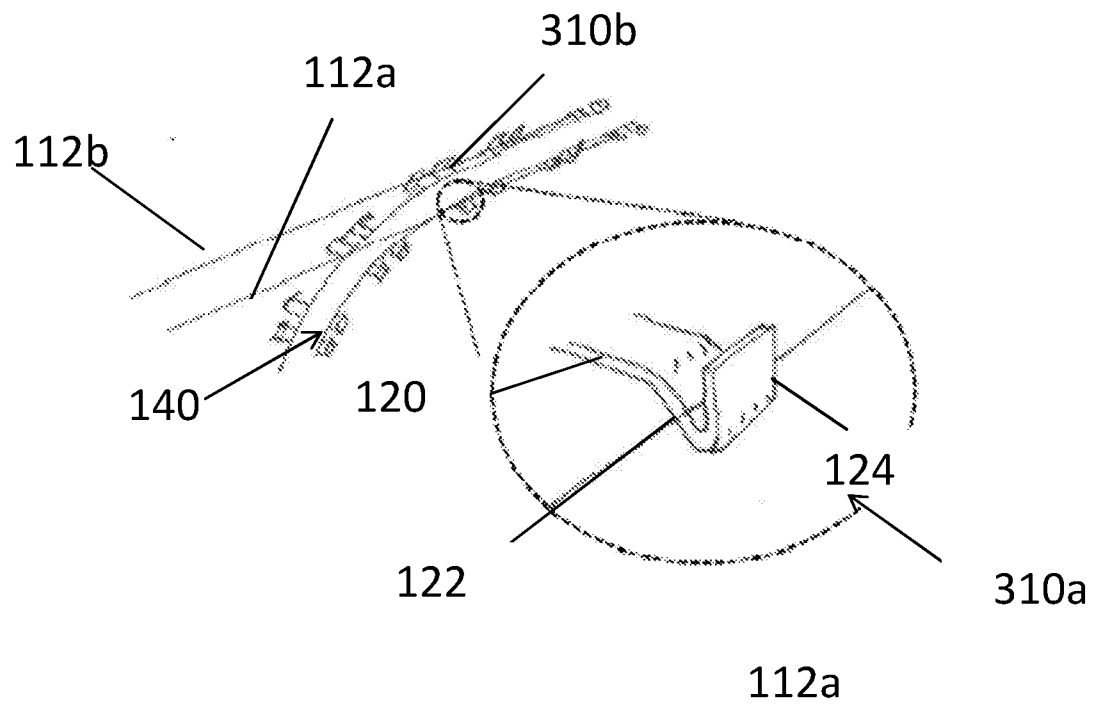


Fig. 7b

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Fig. 8

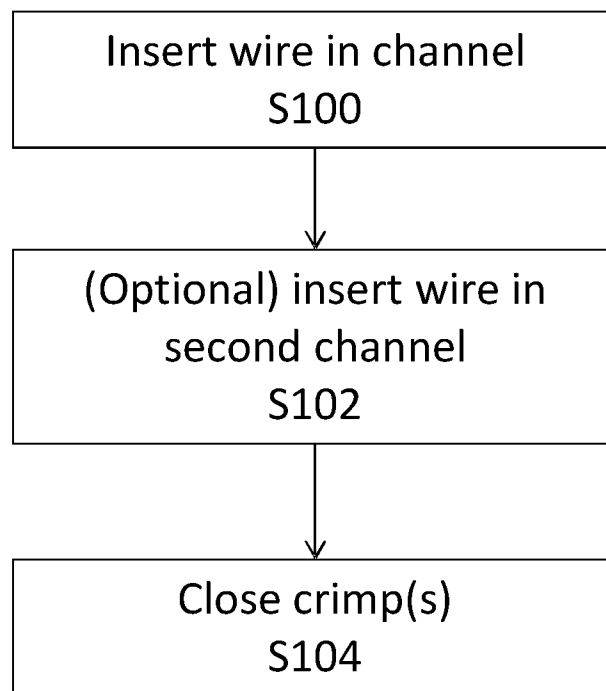
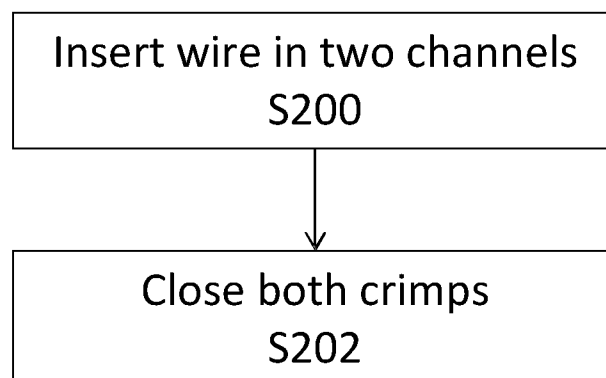


Fig. 9



INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2020/050889

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F03G7/06 H01R4/18
 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)
 F03G H01R

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.
X	WO 2018/073585 A1 (CAMBRIDGE MECHATRONICS LTD [GB]) 26 April 2018 (2018-04-26) page 14, line 20 - line 34; figure 11 -----	1-16
X	US 2018/149142 A1 (BUNTING STEPHEN MATTHEW [GB] ET AL) 31 May 2018 (2018-05-31) paragraph [0051] - paragraph [0066]; figure 9 -----	1-16
X	US 2017/219842 A1 (HOWARTH JAMES [GB] ET AL) 3 August 2017 (2017-08-03) paragraph [0074]; figures 2, 9 -----	1-16
X	GB 896 807 A (KENT MFG CORP) 16 May 1962 (1962-05-16) figures 2,9 -----	1-4,9-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"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

9 June 2020

Date of mailing of the international search report

23/06/2020

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/050889

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