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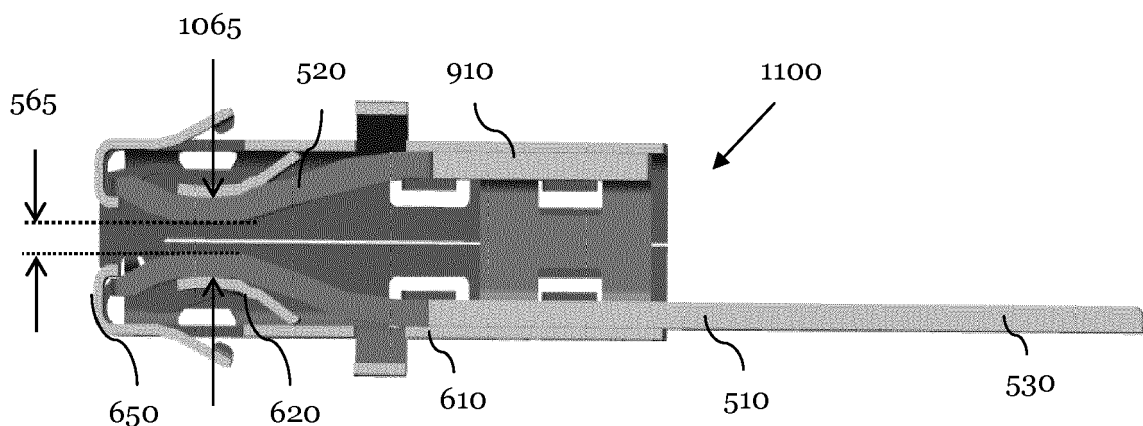
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(54) **CONTACT TERMINAL ASSEMBLED FROM AT LEAST TWO PARTS**

(57) The present invention refers to a contact terminal (910) which is assembled from at least two parts. The contact terminal (910) comprises a base part (510) having at least one contact tongue which is adapted to maintain at least one male connector pin (1210) by means of at least one contact tongue surface. Furthermore, the contact terminal (910) comprises a sleeve (610) which is adapted to be arranged at least partially over the base

part (510). The sleeve (610) has at least one spring element (620) which is adapted to contact the at least one contact tongue of the base part (510) on a side which is opposite to the contact tongue surface. Moreover, the contact tongue has an opening (560) which is equal to or larger than a thickness (1220) of the male connector pin (1210) prior to assembling the base part (510) and the sleeve (610).



**Fig. 11**

## Description

### 1. Field of the invention

5 [0001] The present invention refers to a contact terminal, and in particular to a contact terminal which is assembled from at least two parts.

### 2. Technical background

10 [0002] Connector systems are used to connect various cables, such as for example telecommunication cables, networking cables, other signaling cables or in general any electrical, optical and/or thermal wiring. Electrical connector systems are used for joining electrical circuits, wherein typically a male-ended plug or a male contact terminal is adapted to connect to a female-ended jack or a female contact terminal. In many applications a safe and in particular a reliable coupling of connectors or contact terminals is of high importance. For example, in the automotive industry more and more electronic components are added to cars and/or trucks. Due to limited space available in a car, in particular in the engine compartment, components are steadily more tightly packed in the engine compartment. As a consequence of this the temperature continuously increases in the engine compartment with each new engine generation. Higher temperatures result in higher stress of active electrical components, but also leads to higher thermal loads of passive components, as for example contact terminals. This may lead to reliability problems of contact terminals.

20 [0003] Fig. 1 schematically illustrates one aspect of this difficulty. The upper part of Fig. 1 shows the application of a load to a spring. The load applied to the spring linearly raises as a function of time up to a time  $t_0$  and is then kept constant over time. The load of the spring is well within the elasticity region of the elastic material at the time  $t_0$ , e.g. 50% or 70% of the modulus of elasticity of the spring. The lower part of Fig. 1 schematically represents the reaction of the spring to the applied load for three different temperatures, wherein the temperature raises from  $T_1$  to  $T_3$ . Fig. 1 illustrates that a spring loses a part of its elasticity or partially relaxes as a function of time and temperature. This means that a spring constant irreversibly reduces during a constant load of a spring over time.

25 [0004] Fig. 2 schematically shows a male connector pin, a connector pin or simply a pin engaged with a contact terminal, wherein a spring of the contact terminal (which is not shown in Fig. 2) provides a contact force  $F$  to maintain the connector pin at its predetermined position. The lower part of Fig. 1 illustrates that a contact terminal loses a part of its contact force generated by a spring during operation. Even more important, the reduction of the contact force is increases with increasing temperature.

30 [0005] Up to now this problem is tackled by a reinforcing spring element which is combined with a contact terminal. Fig. 3 represents in the upper part a contact terminal and a respective reinforcing spring element. The contact terminal of Fig. 3 is designed to be crimped to a cable. The lower part of Fig. 3 shows the reinforcing spring element and the contact terminal in an assembled state.

35 [0006] The approach presented in Fig. 3 has several drawbacks. At first, the assembly of the reinforcing spring element and the contact terminal is a complicated process. Further, it is difficult to insert the male connector pin in the contact terminal having two spring elements acting together to enforce each other. In particular, this is effective if the contact spring is completely closed as indicated in Fig. 3 so that a high insertion force is required for engaging a connector pin with the contact terminal. A large insertion force is needed to insert the male connector pin in the contact terminal. More important, the reinforcing spring element of Fig. 3 can reduce the loss of contact force during operation, but cannot remove it. This is illustrated by the following consideration.

40 [0007] Fig. 4 depicts the relaxation of different copper alloys having various amounts of nickel (Ni), tin (Sn), silicon (Si) and zinc (Zn) as a function of temperature. Fig. 4 is taken from the document "Technical Manual - Connector Strip Materials" of KME Germany GmbH & Co. KG, KMD Connectors Stolberg GmbH. The copper alloys are subjected to a load causing an initial stress level (50% Rp0.2) and the load is maintained for 1000 hours at different temperatures. For example, the copper alloy having 2-3.2% Ni, 0.1-0.7% Sn, 0.3-0.9 Si and 0.3-1.3% Zn - indicated in Fig. 4 by an arrow - has a remaining stress of a remaining strain of 70% after the test. In other words, the copper alloy has relaxed by 30%, and thus has lost 30% of its elasticity.

50 [0008] It is now assumed that the contact terminal essentially consists of this copper alloy. It is further assumed that in the initial state the contact terminal provides 70% and the reinforcing spring element provides 30% of the contact force exerted by the contact terminal of Fig. 3. Moreover, it is supposed that the reinforcing spring element does not have any relaxation up to a temperature of 150 °C. Under these conditions the contact force of the contact terminal of Fig. 3 is reduced by  $0.7 \times 0.3 = 21\%$  after an operation period of 1000 hours when the load of the spring of the contact terminal of Fig. 2 is similar to the stress level of the copper alloy during the test of Fig. 4.

55 [0009] As can clearly be recognized from Fig. 4, the discussed difficulty get worse by the tendency to specify operation temperatures of contact terminals which are higher than 150 °C.

[0010] It is an object of the present invention to provide a contact terminal that has a contact force which is essentially

independent from the operation time of the contact terminal. It is in particular an object of the present invention to provide a contact terminal which enables an operation at temperatures beyond 150 °C without a significant change of its contact force. It is a further object to provide a contact terminal which reverses the relaxation trend and has a contact force which increases during its operation.

[0011] These and other objects, which become apparent by reading the following description, are achieved by a connector terminal according to the subject matter of claim 1.

### 3. Summary of the invention

[0012] The present invention relates to a contact terminal which is assembled from at least two parts. Preferably, the contact terminal is fabricated from two parts which allows an automated mass production of the contact terminal. But, special contact terminals can be assembled from more than two parts and/or may manually be assembled.

[0013] The contact terminal comprises a base part having at least one contact tongue which is adapted to maintain at least one male connector pin by means of at least one contact tongue surface. The at least one contact tongue surface provides a low contact resistance to the male connector pin in order to efficiently transport an electrical and/or a thermal current between the contact tongue and the at least one male connector pin.

[0014] Furthermore, the contact terminal comprises a sleeve which is adapted to be arranged at least partially over the base part. The sleeve has at least one spring element which is adapted to contact the at least one contact tongue of the base part on a side which is opposite to the contact tongue surface.

[0015] Moreover, the contact tongue has a gap which is defined to be equal to or larger than a thickness of the male connector pin prior to assembling the base part and the sleeve.

[0016] In an inventive contact tongue the spring element of the sleeve may provide the entire contact force. It is a benefit of an inventive contact terminal to separate the two functions of providing electrical and/or thermal contact and providing a time-independent contact force to a connector pin. The contact tongue of the base part can be designed to exclusively provide an electrical and/or a thermal contact to the connector pin, whereas the spring element of the sleeve can be constructed to exclusively provide the contact force to fix the connector pin in the contact terminal. The separation of the two functions allows optimizing the contact tongue for an optimal electrical and/or thermal contact to the connector pin and/or to a cable connected to the contact terminal. The sleeve, or to be more precisely the spring element can be drafted providing a contact force which is essentially independent of the operation time and the operation temperature (at least up to a temperature of 200 °C) of the contact terminal.

[0017] Moreover, in contrast to Fig. 3, the contact terminal has a gap which is only little smaller than the thickness of the connector pin. A defined force is needed to open the gap of the contact tongue to the diameter of the connector pin. Consequently, the connector pin can reliably be engaged with the contact terminal by a predetermined insertion force.

[0018] The term "essentially" as used here and at other passages of this application denotes a statement of a measured quantities within errors margin according to the art.

[0019] In another aspect, the contact tongue comprises a contact spring.

[0020] In an assembled state of the contact terminal the contact spring of the base part and the spring element of the sleeve preload each other at least as long as a male connector is not inserted in the contact spring.

[0021] An inventive contact terminal can be designed according to two application areas. The first one in which the gap defined between the contact spring of the base part is equal to the thickness of the connector pin as long as the base part is not assembled in the contact terminal is described in the following. The second application area is described below.

[0022] If the gap of the unassembled contact spring essentially corresponds to the thickness of the male connector pin, the spring element of the sleeve preloads the contact spring of the assembled base part so that the gap of the contact terminal is smaller than the thickness of the connector pin. Inserting a connector pin into the contact terminal opens the gap of the contact spring to the thickness of the pin. However, for the contact spring, this is equivalent to the situation prior to the assembly of the base part and the sleeve to a contact terminal. Therefore, the contact spring of the base part is essentially not deflected when a connector pin is engaged in the contact terminal. Since the contact spring is not preloaded during operation of the contact terminal, the contact spring is not subjected to relaxation. Consequently, the contribution of the contact spring to the contact force is essentially not changed even at higher temperatures, as this contribution is essentially zero.

[0023] In a further aspect, the gap of the at least one contact spring is smaller than the thickness of the at least one male connector pin after assembling the base part and the sleeve.

[0024] This condition secures that the contact terminal can reliably maintain the connector pin at its predetermined position. It also enables that a defined contact force can be applied to the connector pin. Different to the prior art, the contact spring and the spring element do not augment each other, but their restoring forces act against each other at least as long as the a connector pin is not inserted in the contact terminal. The width of the gap of the contact terminal can be designed by the layout of the sleeve and the spring constant ratios of the contact spring and the spring element.

If a spring is loaded within its elasticity regime, it generates a restoring force which is proportional to the load. The restoring force acts in a direction to re-establish the equilibrium condition of the spring, i.e. its position without loading the spring.

**[0025]** The gap of a contact spring of the base part can have three different widths: A first width is the gap of the contact spring in an unassembled state of the base part. Further, a second width is the gap of the contact spring when the base part and the sleeve are assembled. Moreover, a third width comprises the gap of the contact spring when a male connector pin is inserted into the contact terminal.

**[0026]** According to another aspect, the at least one contact spring is essentially not deflected compared to it prior assembly condition when the at least one male connector pin is engaged with the contact terminal.

**[0027]** Since the contact spring is essentially not deflected from its equilibrium position during operation of the contact terminal, it does essentially not generate a restoring force. Thus, no relaxation occurs within the contact spring. Therefore, the contact terminal does essentially not show a change or reduction of its contact force due to relaxation of the contact spring of the base part.

**[0028]** In a preferred aspect, the at least one contact spring is deflected towards the at least one spring element when the at least one male connector pin is engaged with the contact terminal.

**[0029]** This configuration describes the above mentioned second application area. If the gap of the contact spring of the unassembled base part is larger than the thickness of the connector pin, the spring element of the sleeve preloads the contact spring in the contact terminal also when a male connector pin is engaged with the contact spring. However, also in this situation, the deflection of the contact spring causes a restoring force which is opposite to the force  $F$  indicated in Fig. 2. In order to generate a predetermined contact force, the spring element of the sleeve provides a restoring force which is larger than the predetermined contact force to additionally compensate the restoring force generated by the deflected contact spring as the restoring force of the contact spring has a direction which is essentially opposite to the restoring force of the spring element of the sleeve and also the contact force of the contact terminal.

**[0030]** In a further preferred aspect, the at least one spring element comprises spring steel having a modulus of elasticity  $\geq 120$  GPa, preferably  $\geq 150$  GPa, more preferably  $\geq 170$  GPa, and most preferably  $\geq 190$  GPa at room temperature.

**[0031]** In a beneficial aspect, the at least one spring element comprises spring steel having a remaining stress  $\geq 85\%$ , preferably  $\geq 90\%$ , more preferred  $\geq 95\%$ , and most preferred  $\geq 98\%$  after a load with 50% of the modulus of elasticity for 1000 hours at a temperature of 200 °C.

**[0032]** The data indicated above apply for a test temperature of 200 °C. A relaxation of the spring steel of the sleeve, and thus of the spring element is essentially not noticeable for operation temperature ranges of a contact terminal (-40 °C to 150 °C) which are usual nowadays.

**[0033]** In an advantageous aspect, the at least one contact spring comprises an electrical conductivity  $\geq 35$  MS/m, preferably  $\geq 40$  MS/m, and most preferably  $\geq 45$  MS/m, and/or a modulus of elasticity of 50 GPa to 150 GPa.

**[0034]** As already mentioned above, the material of the contact spring, and thus of the base part or more generally the material of the contact tongue can be selected to provide an excellent electrical and/or thermal contact to the connector pin of a male contact terminal. A trade-off between conductivity and elasticity of the contact tongue is removed. Thus, the base part can be fabricated from a material which is both, highly conductive and cost-effective.

**[0035]** According to still a further aspect, a spring constant of the at least one contact spring and the spring constant of the at least one spring element have a ratio of 1:0.5, preferably 1:1, more preferred 1:1.5, and most preferred 1:2.

**[0036]** If it is assumed that the contact point of the contact spring to the connector pin and the contact point of the contact spring to the spring element have a distance which essentially corresponds to the thickness of the contact spring, the amount of deflection of the contact spring is essentially inverse proportional to the spring constant ratio of the two springs when no connector pin is inserted in the contact terminal.

**[0037]** In yet a further beneficial aspect, the base part comprises a contact pad or crimping wings. According to a preferred aspect, the at least one contact spring comprises at least two contact spring parts which are adapted to contact the at least one male connector pin on opposite sides. In another advantageous aspect, the gap defined between the at least one contact spring expands towards a male connector terminal.

**[0038]** It is beneficial that an inventive contact terminal can have arbitrary means for connecting a cable. It may have means for crimping, soldering, or welding a cable. Further, it is advantageous that the base part can be fabricated from a material which is highly electrically and/or thermally conductive. Thus, an electrical and/or a thermal connection can be established between the contact terminal and a cable having a low contact resistance. Furthermore, a contact spring having at least two symmetrical contact spring parts facilitates the generation of a reliable contact force. A widening of the contact spring towards the end the male contact terminal allows a reduction of the insertion force without compromising the contact force.

**[0039]** According to still another aspect, the at least one spring element of the sleeve comprises at least two spring element parts adapted to be arranged at sides of the at least two contact spring parts opposite to the contact spring surfaces.

**[0040]** It is beneficial that the contact spring of the base part and the spring element of the sleeve have a similar symmetry so that the contact terminal exerts a contact force by two opposing spring elements which are deflected instead or one.

**[0041]** In another preferred aspect, a contact force of the contact terminal which is engaged with the male connector pin is constant within an interval of  $\pm 20\%$ , preferably  $\pm 10\%$ , more preferably  $\pm 5\%$ , and most preferably  $\pm 2\%$  after operating the contact terminal for 1000 hours at a temperature of 200 °C.

**[0042]** It is one of the major benefits that the contact force of the contact terminal can be designed to essentially not show any decrease during the operation of the contact terminal. This is achieved by configuring the base part and the sleeve so that the contact spring of the base part is essentially not stressed during operation, and thus is not subjected to relaxation. Further, it is advantageous that a constant contact force can also be achieved at elevated temperature up to 200 °C. By selecting an appropriate spring steel material, the operation range of the contact terminal can be extended beyond 200 °C.

**[0043]** In still a further beneficial aspect, the contact force of the contact terminal increases during operation of the contact terminal. According to another advantageous aspect, the contact force increases during an operation of 1000 hours at a temperature of 200 °C by  $\geq 5\%$ , preferably  $\geq 10\%$ , more preferably  $\geq 15\%$ , and most preferably  $\geq 20\%$ .

**[0044]** The term "during operation" means here as well as at other positions of this application that at least one connector pin is engaged with the contact terminal.

**[0045]** As already outlined above, if a contact spring has a gap which is larger than the thickness of the connector pin, the contact spring is deflected in a direction towards the spring element of the sleeve even if a pin is inserted in the contact spring of the assembled contact terminal. This means that the restoring force of the contact spring counteracts the restoring force of the spring element. Thus, in order to generate a predetermined contact force, the restoring force of the spring element has to be larger than the contact force of the contact terminal. As described above, the restoring force of the spring element shows essentially no relaxation as a function of time and temperature. On the other hand, as indicated in Fig. 4, the contact spring relaxes during operation and in particular at higher temperatures as it is fabricated of highly electrically and/or thermally conductive material. Therefore, the remaining stress or the restoring force of the contact spring reduces during operation. But, since the restoring forces of both springs act in opposite directions, the contact force exerted by the contact terminal on the connector pin increases during operation.

**[0046]** For example, an increase of the contact force may be used to at least partially compensating an increase of the transition resistance between the connector pin and the contact spring during operation caused by a pollution and/or corrosion.

**[0047]** According to still a further aspect, the sleeve comprises a protection against a miss fitting of the at least one male connector pin, the base part comprises CuSn<sub>0.15</sub>, the sleeve comprises X10CrNi18-8, the at least one contact spring comprises twelve contact spring parts arranged in two opposing rows, each one comprising six contact spring parts, the at least one spring element contacts a row of the contact spring parts, and/or the at least one male connector pin comprises at least one male blade.

**[0048]** In another preferred aspect, a method for assembling a contact terminal from at least two parts comprises: (a) providing a base part having at least one contact tongue, the at least one contact tongue having a gap equal to or larger than a thickness of a male connector pin; (b) providing a sleeve adapted to be arranged at least partially over the base part, the sleeve having at least one spring element, the at least one spring element being adapted to contact the at least one contact tongue on a side opposite to a contact tongue surface; and (c) assembling the base part and the sleeve by pushing the base part into the sleeve by which the at least one spring element deflects the at least one contact tongue so that the opening of the at least one contact tongue is smaller than the thickness of the male connector pin.

**[0049]** The assembly of the base part and the sleeve to the contact terminal can be performed in an automated process by aligning the sleeve and the base part and by pushing the base part into the sleeve. During the assembly process, the at least one spring element of the sleeve guides the at least one contact tongue of the base part.

**[0050]** According to a further aspect, the at least one contact tongue comprises at least one contact spring.

#### 4. Description of the drawings

**[0051]** In order to better understand the present invention and to appreciate its practical applications, the following figures are provided and referenced hereafter. It should be noted that the figures are given as examples only and in no way limit the scope of the invention.

- Fig. 1 schematically shows in the upper part a linear increase of a load applied to a spring followed by a time-independent load, the lower part depicts the elasticity of the spring as a function of time and temperature;
- Fig. 2 schematically represents a contact spring of a contact terminal engaged with a male connector pin and indicates a contact force  $F$  exerted by the contact spring to the male connector pin;
- Fig. 3 shows in the upper part a contact terminal comprising a base part and a contact spring and a sleeve spring

or a reinforcing spring and in the lower part the sleeve spring assembled with the contact terminal;

Fig. 4 represents relaxation curves or curves of remaining stress of various copper alloys as a function of temperature for a predetermined load;

Fig. 5 depicts a base part of a contact terminal with a contact spring;

Fig. 6 shows a lower portion or an upper portion of a sleeve of a contact terminal with a spring element;

Fig. 7 represents the lower part of a contact terminal assembled from the base part of Fig. 5 and the sleeve of Fig. 6;

Fig. 8 shows a cross section of Fig. 7;

Fig. 9 depicts a contact terminal;

Fig. 10 represents a cross section of a base part and a sleeve aligned to each other, wherein the base part is partially inserted into the sleeve;

Fig. 11 indicates Fig. 10 after the base part is completely inserted in the sleeve;

Fig. 12 presents the assembled contact terminal of Fig. 11, wherein a male connector pin is engaged with the contact terminal;

Fig. 13 shows an enlarged cut-out of a Fig. 12 indicating a contact area of the contact spring and the spring element and a contact spring surface contacting the connector pin;

Fig. 14 depicts the restoring forces of the contact spring and the spring element in the configurations of Figures 10 to 12;

Fig. 15 represents the strain energy stored by the contact spring of the base part and the spring element of the sleeve in the configurations of Figures 11 and 12;

Fig. 16 shows a cross check of Fig. 15 on the basis of Fig. 14; and

Fig. 17 summarizes the method steps for assembling a contact terminal from a base part and a sleeve.

## 5. Description of preferred embodiments

[0052] In the following, the present invention will now be described in more detail hereinafter with reference to the accompanying figures, in which exemplary embodiments of the invention are illustrated. However, the present invention may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and will convey the scope of the invention to persons skilled in the art.

[0053] The diagram 500 of Fig. 5 shows an example of a base part 510. In the example of Fig. 5 the base part 510 comprises a contact spring 520 as an example of a contact tongue and a contact pad 530. A cable (not shown in Fig. 5) is connected to the contact pad 530. In the example represented in Fig. 5, the contact pad 530 and the cable are connected by welding, in particular by ultrasonic welding. However, the connection of a base part 510 of a contact terminal is not restricted to welding, rather an inventive contact terminal may be connected to a cable by all usual joining techniques, as for example soldering or crimping. The contact pad 530 is adapted to the respective joining technique.

[0054] In a preferred alternative embodiment, the exemplary base part 510 of Fig. 5 has crimp wings instead of the contact pad 530 (not shown in Fig. 5).

[0055] In the example of Fig. 5, the contact spring 520 comprises an upper portion 540 and a lower portion 550 arranged symmetrically both in a horizontal and a vertical plane. This configuration of the contact spring 520 facilitates the application of a symmetrical contact force (not shown in Fig. 5). The exemplary contact spring 520 comprises six contact spring parts 555 on its upper part 540 and six contact spring parts 555 on its lower portion 550. In the example of Fig. 5, the contact spring 520 and thus the contact spring parts 555 comprise leaf springs. The contact spring 520 of the base part 510 has a gap 560 which is either designed to essentially correspond to a thickness of a male connector pin (not represented in Fig. 5) or which is larger than the thickness of the male connector pin. In the example of Fig. 5, the gap 560 is essentially 1.2 mm. The length, width and thickness of the contact spring elements 555 is 8 mm, 1.2 mm, and 0.59 mm. The contact spring parts 555 have a contact spring surface 570 which contacts an inserted connector pin. The ends of the upper 580 and lower 585 contact spring parts 555 are bound upwards and downwards, respectively, in order to facilitate the insertion of the connector pin. The gap 560 of the base part 510 is defined as the lowest distance between the upper 580 and lower 585 contact spring parts 555.

[0056] Fig. 5 just shows an example of a base part 510. The contact spring 510 may comprise two spring elements arranged symmetrically in the horizontal and vertical directions as indicated in Fig. 5. It is also possible that the contact spring 520 comprises a single spring element, for example arranged above an essentially rigid lower plate (not shown in Fig. 5). Further, it is also conceivable that a contact spring 520 comprise four contact spring elements, for example arranged on four sides of a square or a rectangle which are adapted to engage with a round, a square or a rectangular male connector pin.

[0057] The base part 510 of Fig. 5 is designed for carrying high currents which are depending on the width of the base part 510 in a range of 70 A to 140 A at a temperature of 70 °C. The contact resistance to a connector pin is specified to be < 0.15 mΩ. The base part 510 of diagram 500 comprises a copper alloy which comprises Cr, Ti and/or Sn. The copper alloy has a lower relaxation loss than pure copper.

**[0058]** The diagram 600 of Fig. 6 presents an upper part 630 or a lower part 630 of a sleeve 610. The sleeve 610 is cut in a horizontal plane. The upper or lower part 630 of the sleeve 610 comprises a spring element 630. Furthermore, the part 630 of the sleeve 610 comprises four snap-in hooks 640 having the task to fix the base part 510 in an assembled contact terminal. A complete sleeve 610 (not shown in Fig. 6) comprises two of the parts 630 depicted in Fig. 6.

**[0059]** In the example of Fig. 6, the sleeve 610 preferably comprises spring steel having a high modulus of elasticity. In Fig. 6 the sleeve 610 comprises a CrNi (chromium nickel) steel. To be more precise, the sleeve 610 of the example of diagram 600 comprises X10CrNi18-8 which has a modulus of elasticity in the range of 180 GPa to 200 GPa at room temperature. It is possible to fabricate this kind of spring steel having this modulus of elasticity up to a temperature of 300 °C. Consequently, X10CrNi18-8 does not show a significant relaxation up to a temperature of 200 °C. On the other hand, this CrNi steel has only a modest electrical conductivity.

**[0060]** The part 630 of the sleeve 610 comprises a specifically formed front end 650 which is adapted to guide a connector pin during its insertion process in the contact spring of a contact terminal. Consequently, the rounded front end 650 of the sleeve 610 provides protection against miss fitting of a connector pin.

**[0061]** Fig. 7 depicts a diagram 700 in which a lower part of the base part 510 of Fig. 5 and a lower part 630 of a sleeve 610 are combined. The base part 510 is fixed to the sleeve part 630 by the four snap-in hooks 640. Fig. 7 clearly shows the contact spring surface 570 at which a connector pin (not shown in Fig. 7) connects the contact spring 510 of a contact terminal. Further, Fig. 7 also indicates that the specifically designed front end 650 of the sleeve 610 guides a connector pin during insertion in the contact terminal.

**[0062]** The diagram 800 of Fig. 8 shows a vertical cut through the diagram 700 along its horizontal symmetry line. Fig. 8 represents the layout of the base part 510 on the sleeve 610 in an assembled state. In particular, the diagram 800 depicts the spatial arrangement of the spring element 620 of the sleeve 610 and the contact spring 520 of the base part 510. As can be recognized from Fig. 8, the contact spring surface 570 at which the contact spring 510 contacts a pin connector essentially is above the area 870 the spring element 620 exerts a force to the contact spring 520.

**[0063]** The diagram 900 of Fig. 9 represents a contact terminal 910 comprising a base part 510 and a sleeve 610. The base part 510 is fixed in the sleeve 610 by four snap-in hooks 640 on both sides of the sleeve 610.

**[0064]** In the following the assembly of a base part 510 and a sleeve 610 to a contact terminal is explained in more detail. The diagram 1000 of Fig. 10 shows a vertical cut through a base terminal 510 and a sleeve 610. The base terminal 510 and the sleeve 610 are aligned to each other and the base terminal 510 is partly inserted into the sleeve 610. This is indicated by the arrow 1050. The base part 510 is pushed into the sleeve 610 to an extent that the contact spring 520 of the base part 510 and the spring element 620 of the sleeve are not yet in contact with each other. In this position the opening 560 of the contact spring 510 is still the opening of the contact spring 510 of Fig. 5 which is essentially 1.2 mm in the example of Fig. 10. The opening 1060 of the spring element 620 of the sleeve 610 amounts to 1.82 mm in the example of Fig. 10. As already indicated above, the thickness of the contact spring 520 is essentially 0.59 mm. In this position, both the spring element 620 and the contact spring 520 are not deflected. Consequently, no restoring force occurs neither from the spring element 620 nor from the contact spring 520:  $F_{CS} = F_{SE} = 0$  N.

**[0065]** The diagram 1100 of Fig. 11 represents the configuration when the base part 510 is completely pushed into the sleeve 610, i.e. the base part 510 and the sleeve are assembled to the contact terminal 910. During the final step of pushing the base part 510 into the sleeve 610, i.e. between the configurations of Fig. 10 and Fig. 11, the spring element 620 of the sleeve 610 guides the contact spring 520 of the base part 510 in its final position. As can be seen from Fig. 11, the contact spring 520 does not abut against the front end 650 of the sleeve 610 in the assembled condition so that the contact spring 510 can freely move in the vertical direction.

**[0066]** In the assembled state of Fig. 11, the opening 1065 of the spring element 620 is 2.05 mm which means that the spring element 620 is deflected by the contact spring 520 by  $0.23\text{ mm} = 2.05\text{ mm} - 1.82\text{ mm}$ . The gap 565 of the contact spring 520 is 0.76 mm. Consequently, the contact spring surface 570 of the contact spring 520 is deflected by  $0.44\text{ mm} = 1.2\text{ mm} - 0.76\text{ mm}$ . A finite element analysis (FEA) reveals that the restoring force of the upper and lower contact spring portions 540 and 550 and the restoring force of the spring element 620 in the upper part 630 and the lower part 630 of the sleeve 610 are 12.9 N, i.e.  $F_{CS} = F_{SE} = 2 \times 12.9\text{ N} = 25.8\text{ N}$ . This means that the contact spring 520 and the spring element 620 preload each other with this force.

**[0067]** The diagram 1200 of Fig. 12 represents the contact terminal 910 of Figures 9 and 11 in which a male connector pin 1210 is inserted. The connector pin 1210 has essentially a thickness 1220 of 1.2 mm. Thus, the gap 568 essentially corresponds the thickness 1220 of the connector pin 1210. Since the gap 565 of Fig. 11 has a width of about two third of the pin thickness (0.76 to 1.2 mm) the connector pin 1210 can easily be inserted in the contact terminal 910. A reduced insertion force is achieved because the contact spring 520 works against the spring element 620 until the male connector pin 1210 is engaged with the contact terminal 910. This means that the design of insertion tools can be simplified compared to conventional preloaded springs such as the one indicated in Fig. 3. For the example represented by Fig. 12 an insertion force  $\leq 25\text{ N}$  is specified which is achieved with the contact terminal 910 of Fig. 12.

**[0068]** In the operation condition of the contact terminal 910, i.e. with an engaged male connector pin 1210, the gap 568 of the contact spring 520 corresponds to the gap 560 of the contact spring 520 of the base part 510 prior to assembling

the base part 510 with the sleeve 610 to the contact terminal 910. Consequently, the contact spring 520 is essentially not deflected and it does not generate a restoring force, i.e.  $F_{CS} = 0$  N. Since the contact spring 520 of the base part 510 is not deflected during operation, the contact spring 520 is not subjected to any relaxation. Thus, the contact terminal 910 provides a contact force which does not change during the operation of the contact terminal 910.

**[0069]** On the other hand, the opening 1265 of the spring element 620 is increased to  $2.38 \text{ mm} = 1.82 \text{ mm} + 0.56 \text{ mm}$ . The FEA mentioned above shows that spring elements 620 in the lower part 630 and the upper part 630 of the sleeve 610 each generates a restoring force of 32.5 N, i.e.  $F_{SE} = 2 \times 32.5 \text{ N} = 65 \text{ N}$ . This restoring force of the spring elements 620 of the sleeve 610 provide the contact force of the contact terminal 910. Thus, in the configuration described in Fig. 12 the spring elements 620 of the sleeve 610 essentially generate 100% of the contact force of the contact terminal. It is not necessary to increase the sleeve material thickness in order to obtain the discussed contact force. As discussed above a material having a large modulus of elasticity may be selected. Furthermore, the spring element 620 may be designed to have a high stiffness. Moreover, as already discussed above, the spring element 620 can be configured to essentially show no relaxation even at temperatures beyond  $200^\circ\text{C}$ .

**[0070]** In a further preferred embodiment of the present application (which is not shown in Figures 10 to 12), the gap 560 of an unassembled contact spring 520 is larger than the thickness of the connector pin 1210 and thus the gap 568. In order to generate a contact force which is similar to the one discussed above, the spring elements 620 in the upper and lower part 630 of the sleeve 610 have to have a larger spring constant, i.e. the spring elements 620 have to be stiffer than in the configuration of Figures 10 to 12. If this is the case, the restoring forces with which the contact spring 520 and the spring elements 620 preload each other when no connector pin 1210 is inserted in the contact terminal 910 are higher than the ones discussed in the context to Fig. 11. Then, during the operation, i.e. a connector pin 1210 is engaged with the contact terminal 910 (Fig. 12) the stiffer spring constant of the spring elements 620 exerted a restoring force which is larger than the one indicated in Fig. 12. However, this does not lead to a larger contact force than the one discussed in the context of Fig. 12. Even during operation the contact spring 520 is deflected in this configuration to act against the restoring force of the spring elements 620 of the sleeve 610 so that a portion of the restoring force of the spring elements 620 is shielded from the connector pin 1210. As discussed above, the restoring force of the contact spring 520 (preferably fabricated from a copper alloy) is subjected to relaxation whereas the restoring force of the spring elements 620 (preferably fabricated from spring steel) are essentially not changed during operation. The resulting contact force is the sum of the restoring forces of the spring element 620 and the contact spring 520. As a consequence, a contact force exerted to a connector pin 1210 slowly increases during operation in a contact terminal having such a contact spring.

**[0071]** The diagram 1300 of Fig. 13 presents an enlarged a cut-out of Fig. 12. It shows that in the contact terminal 910 the contact spring surface 570 is not precisely above the above the area 870 at which the spring element 620 exerts a force to the contact spring 520. The following considerations refer to the contact area 870 or the shoulder point 870.

**[0072]** Fig. 14 shows a diagram 1400 in which the deflections  $d$  and the restoring forces of the spring element 620 and the contact spring 520 from Figures 10 to 12 are illustrated. The following consideration apply to one of the two spring elements 620 of the sleeve 610 (the upper one or the lower one) and to one of the symmetrical portions of the spring element portions 540 or 550 of the contact spring 520. As discussed in the context of Fig. 10 (level 0) the gap 560 is 1.2 mm, the deflections  $d$  of both springs 520 and 620 are  $d_{CS} = d_{SE} = 0$  mm, and no restoring forces occur, i.e.  $F_{CS} = F_{SE} = 0$  N.

**[0073]** In the contact terminal 910 of Fig. 11 (level 1), the two springs 520 and 620 are preloaded by a restoring force of 12.9 N resulting in a gap 565 of 0.76 mm. The spring element 620 is deflected as indicated in Fig. 11 by  $d = (0.23 \text{ mm})/2 = 0.115 \text{ mm}$ . This results in a spring constant 1410 of the spring element 620 of  $k_{SE} = 12.9 \text{ N}/0.115 \text{ mm} = 112 \text{ N/mm}$ . As discussed in the context of Fig. 12, the contact spring 520 is not deflected if the male connector pin is engaged with the contact terminal 910. In this case the spring element 520 is deflected by  $d = 0.28 \text{ mm}$ . Thus, the contact spring 520 is deflected at level 1 by  $d_{CS} = 0.28 \text{ mm} - 0.115 \text{ mm} = 0.165 \text{ mm}$ . The spring constant 1420 of the contact spring 520 can be calculated to be:  $k_{CS} = 12.9 \text{ N}/0.165 \text{ mm} = 78 \text{ N/mm}$ .

**[0074]** If the connector pin 1210 is engaged with the contact terminal 910 (level 2), the gap 568 is essentially 1.2 mm, and the restoring force of the spring element 620 amounts to 32.5 N which results in a spring constant 1430 for the spring element 620  $k_{SE} = 32.5 \text{ N}/0.28 \text{ mm} = 116 \text{ N/mm}$ . This is in good agreement with the spring constant determined from the level 1 configuration presented in Fig. 11. The resulting spring constant 1440 can be calculated from  $k_{res} = 32.5 \text{ N}/0.165 \text{ mm} = 197 \text{ N/mm}$ . The contact spring 520 and the spring element 620 operate in a parallel connection in the contact terminal 910, and can thus also to be determined by:  $k_{res} = k_{CS} + k_{SE} = 78 \text{ N/mm} + 116 \text{ N/mm} = 194 \text{ N/mm}$ . The resulting spring constants 1430 and 1440 are also in good agreement.

**[0075]** The diagram 1500 of Fig. 15 presents the strain energy or the deformation energy stored in the contact spring 520 of the base part 510 and the spring element 620 of the sleeve 610 as well as the overall strain energy stored in both springs 520 and 620 in level 1 (Fig. 11) and level 2 (Fig. 12) as a function of time.

**[0076]** In level 1, indicated in Fig. 15 by the arrow 1540, the contact terminal 910 is assembled from the base part 510 and the sleeve 610, and the contact spring 520 and the spring element 620 push against each other. The spring element



620 has a spring constant ( $k_{SE} = 116 \text{ N/mm}$ ) which is higher than the spring constant stored in the contact spring 520 ( $k_{CS} = 78 \text{ N/mm}$ ), and thus is less deflected ( $d_{SE} = 0.115 \text{ mm}$ ) than the contact spring 520 ( $d_{CS} = 0.165 \text{ mm}$ ). The strain energy 1510 stored in the spring contact 520 is thus larger than the strain energy 1520 of the spring element 620, since the strain energy varies with the square of the deflection. The overall spring energy 1530 in level 1 is the sum of the deformation energies stored in both springs 520 and 620. In Fig. 15 the strain energies 1510, 520 of the base part 510, the sleeve 610 as well as of the overall strain energy 1530 are referred to the overall strain energy 1530 when a male connector pin 1210 is engaged with the contact terminal 910 which is defined as 100% of the strain energy 1530.

**[0077]** Fig. 15 depicts that the insertion process of the male connector pin 1210 in the contact terminal 910 begins at about the time indicated by the arrow 1550 in the exemplary diagram 1500. The data of Fig. 15 are obtained from FEA results. During the insertion process the deflection  $d_{CS}$  of the contact spring 520 is reduced from  $d_{CS} = 0.165 \text{ mm}$  to essentially  $d_{CS} = 0 \text{ mm}$ . The contact spring 520 releases its strain energy 1510 which is taken over by the spring element 620 of the sleeve. Due the increasing deflection of the spring element 620, the strain energy 1520 stored in the spring element 620 steeply raises during the insertion process. At level 2 (the mail connector pin 1210 is positioned at its predetermine position), denoted by the arrow 1560, the strain energy 1530 of the spring system 520 and 620 is essentially stored in the spring element 620. This means that in the example of Fig. 15 only a small share of 1.7% of the strain energy is stored in the contact spring 510 at level 2, whereas at level 1 the contact spring store the larger portion of the total strain energy 1530.

**[0078]** The diagram 1600 of Fig. 16 is a cross check of the stored strain energy in level 1 and level 2 calculated from the data of Fig. 14. The left triangle represents the strain energy 1610 stored by the spring element 620 in level 1 and amounts to  $E_{SE} = 0.74 \text{ mJ}$ . The right lower triangle depicts the strain energy 1620 stored in the contact spring 520 in level 1:  $E_{CS} = 1.06 \text{ mJ}$ . Further, the strain energy 1630 of the spring element 620 in level 2 is calculated to be  $E_{SE} = 4.55 \text{ mJ}$ . The strain energy data of Figures 14 and 16 correspond well with each other.

**[0079]** Finally, the flow chart 1700 of Fig. 17 illustrates a method for assembling a contact terminal 910. The method begins with step 1710. At step 1720 a base part 510 is provided. The base part 510 has at least one contact tongue which has a gap 560 which is equal to or larger than a thickness of a male connector pin 1210 which is adapted to be inserted in the contact terminal 910. The thickness of the male connector pin 1210 corresponds to the gap 568. Further, at step 1730, a sleeve 610 is provided. The sleeve 610 is adapted to be at least partially arranged over the base part 510. The sleeve 610 has at least one spring element 620 which can contact the at least one contact tongue on a side which is opposite to the contact tongue surface. Moreover, at step 1740, the base part 510 and the sleeve 610 are aligned with respect to each other. Then the base part 510 is pushed in the sleeve 610 by which the at least one spring element 620 deflects the at least one contact tongue so that the gap 565 of the at least one contact tongue is smaller than a thickness of the male connector pin 1210.

#### Reference chart:

#### [0080]

|          |                                                             |
|----------|-------------------------------------------------------------|
| 510      | base part                                                   |
| 520      | contact spring                                              |
| 530      | contact pad                                                 |
| 540, 550 | upper and lower portion of the contact spring, respectively |
| 555      | contact spring parts                                        |
| 560      | gap of the contact spring of the unassembled base part      |
| 565      | gap of the contact spring in the assembled condition        |
| 568      | gap of the contact spring when a connector pin is engaged   |
| 570      | contact spring surface                                      |
| 580, 585 | upper front end and lower front end of the contact spring   |
| 610      | sleeve                                                      |
| 620      | spring element                                              |
| 630      | lower part or upper part of the sleeve                      |
| 640      | snap-in hook                                                |
| 650      | front end of the sleeve                                     |
| 870      | contact area of spring element and contact spring           |
| 910      | contact terminal                                            |
| 1050     | insertion direction of the base part in the sleeve          |
| 1060     | opening of the spring element                               |
| 1065     | opening of the spring element in the assembled condition    |
| 1210     | male connector pin                                          |

|                                      |                                                                |
|--------------------------------------|----------------------------------------------------------------|
| 1220                                 | thickness of a male connector pin                              |
| 1265                                 | opening of the spring element with engaged connector pin       |
| 1410, 1420, 1430                     | spring constants of the contact spring and the spring element  |
| 1440                                 | resulting spring constant of contact spring and spring element |
| 5 1510, 1520, 1530, 1610, 1620, 1630 | strain energies                                                |

## Claims

- 10 1. A contact terminal (910) assembled from at least two parts, comprising:
  - a. a base part (510) having at least one contact tongue adapted to maintain at least one male connector pin (1210) by means of at least one contact tongue surface;
  - 15 b. a sleeve (610) adapted to be arranged at least partially over the base part (510), the sleeve (610) having at least one spring element (620), the at least one spring element (620) being adapted to contact the at least one contact tongue on a side opposite to the contact tongue surface; and
  - c. wherein a gap (560) defined between the at least one contact tongue is equal to or larger than a thickness (1220) of the male connector pin (1210) prior to assembling the base part (510) and the sleeve (610).
- 20 2. The contact terminal (910) of claim 1, wherein the at least one contact tongue comprises at least one contact spring (520).
3. The contact terminal (910) of claim 2, wherein the gap (565) of the at least one contact spring (520) is smaller than the thickness (1220) of at least one male connector pin (1210) after assembling the base part (510) and the sleeve (610).
- 25 4. The contact terminal (910) of claim 2 or 3, wherein the at least one contact spring (520) is essentially not deflected compared to its prior assembly condition when the at least one male connector pin (1210) is engaged with the contact terminal (910).
- 30 5. The contact terminal (910) of claim 2 or 3, wherein the at least one contact spring (520) is deflected towards the at least one spring element (620) when the at least one male connector pin (1210) is engaged with the contact terminal (910).
- 35 6. The contact terminal (910) of any one of the preceding claims, wherein the at least one spring element (620) comprises spring steel having a modulus of elasticity  $> 120 \text{ kN/mm}^2$ , preferably  $> 150 \text{ kN/mm}^2$ , more preferably  $> 170 \text{ kN/mm}^2$ , and most preferably  $> 190 \text{ kN/mm}^2$  at room temperature.
- 40 7. The contact terminal (910) of any one of the preceding claims, wherein the at least one spring element (620) comprises spring steel having a remaining stress  $> 85\%$ , preferably  $> 90\%$ , more preferred  $> 95\%$ , and most preferred  $> 98\%$  after a load with 50% of the modulus of elasticity for 1000 hours at a temperature of  $200^\circ\text{C}$ .
- 45 8. The contact terminal (910) of any one of the preceding claims, wherein the at least one contact tongue comprises an electrical conductivity  $> 35 \text{ MS/m}$ , preferably  $> 40 \text{ MS/m}$ , and most preferably  $> 45 \text{ MS/m}$  at room temperature, and/or a modulus of elasticity of  $50 \text{ kN/mm}^2$  to  $150 \text{ kN/mm}^2$ .
- 50 9. The contact terminal (910) of claims 2-8, wherein a spring constant of the at least one contact spring (520) and the spring constant of the at least one spring element (620) have a ratio of 1:0,5, preferably 1:1, more preferred 1:1.5, and most preferred 1:2.
- 55 10. The contact terminal (910) of any one of the preceding claims, wherein the base part (510) comprises a contact pad (530) or crimping wings.
11. The contact terminal (910) of claims 2-10, wherein the at least one contact spring (520) comprises at least two contact spring portions 540, 550 adapted to contact the at least one male connector pin (1210) on opposite sides.
12. The contact terminal (910) of any one of the preceding claims, wherein the gap between the at least one contact tongue expands towards a male connector terminal.

## EP 3 182 525 A1

13. The contact terminal (910) of claims 9-11, wherein the at least one spring element (620) of the sleeve (610) comprises at least two spring element parts adapted to be arranged at sides of the at least two contact spring portions (540, 550) opposite to the contact spring surfaces (570).

14. The contact terminal (910) of any one of the preceding claims, wherein a contact force of the contact terminal (910) engaged with the male connector pin (1210) is constant within an interval of  $\pm 20\%$ , preferably  $\pm 10\%$ , more preferably  $\pm 5\%$ , and most preferably  $\pm 2\%$  after operating the contact terminal (910) for 1000 hours at a temperature of 200 °C.

15. The contact terminal (910) of claims 2-13, wherein the contact force increases during operation of the contact terminal (910).

16. The contact terminal (910) of claim 15, wherein the contact force increases during an operation of 1000 hours at a temperature of 200 °C by  $\geq 5\%$ , preferably  $\geq 10\%$ , more preferably  $\geq 15\%$ , and most preferably  $\geq 20\%$ .

17. The contact terminal (910) of claims 2-16, wherein the sleeve (610) comprises a protection against a miss fitting (650) of the at least one male connector pin (1210), the base part (510) comprises CuSn0,15, the sleeve (610) comprises X10CrNi18-8, the at least one contact spring (520) comprises twelve contact spring parts (555) arranged in two opposing rows, each one comprising six contact spring parts (555), the at least one spring element (620) contacts a row of the contact spring parts (555), and/or the at least one male connector pin (1210) comprises at least one male blade.

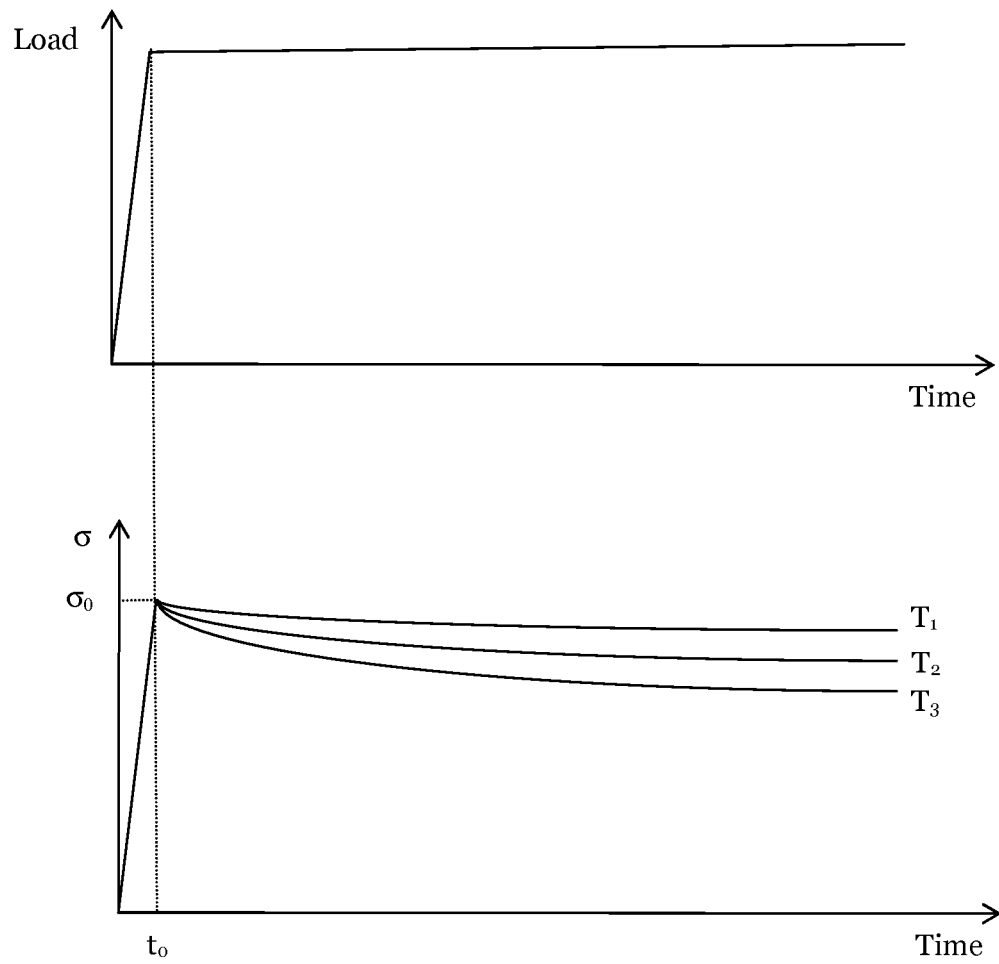
18. A method for assembling a contact terminal (910) from at least two parts, the method comprising:

a. providing a base part (510) having at least one contact tongue, the at least one contact tongue having a gap (560) equal to or larger than a thickness (1220) of a male connector pin (1210);

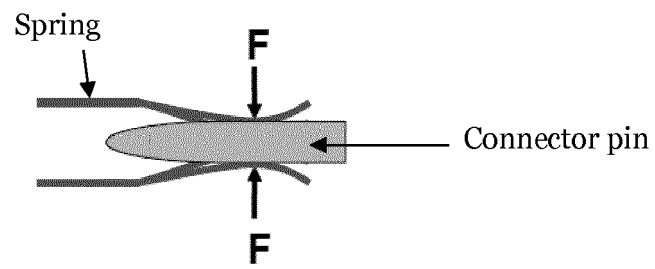
b. providing a sleeve (610) adapted to be arranged at least partially over the base part (510), the sleeve (610) having at least one spring element (620), the at least one spring element (620) being adapted to contact the at least one contact tongue on a side opposite to a contact tongue surface; and

c. assembling the base part (510) and the sleeve (610) by pushing the base part (510) into the sleeve (610) by which the at least one spring element (620) deflects the at least one contact tongue so that the gap (565) of the at least one contact tongue is smaller than a thickness (1220) of the male connector pin (1210).

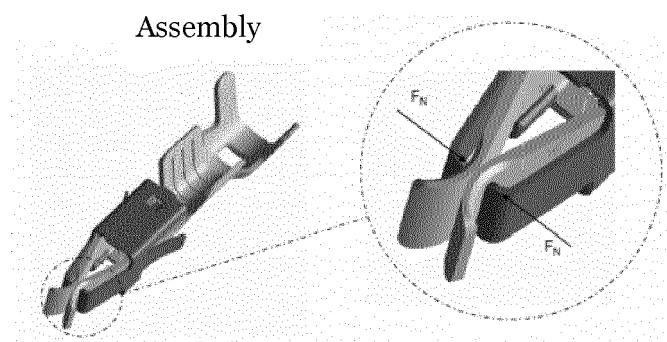
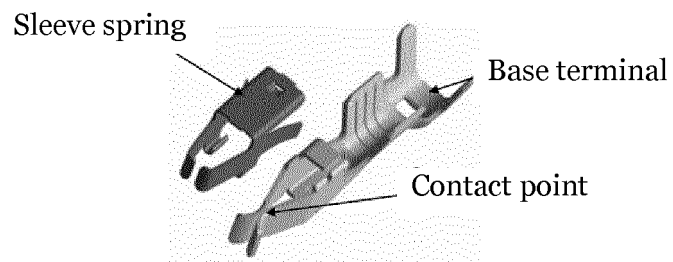
19. The method of claim 18, wherein the at least one contact tongue comprises at least one contact spring (520).



**Fig. 1 (Prior Art)**



**Fig. 2 (Prior Art)**



**Fig. 3 (Prior Art)**

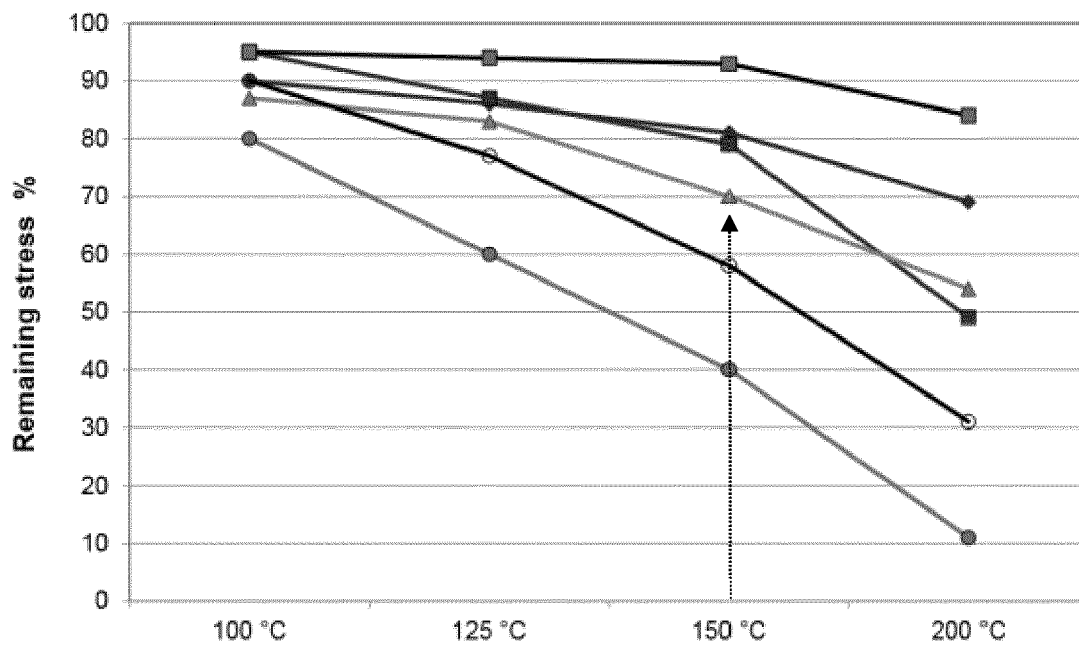


Fig. 4 (Prior Art)

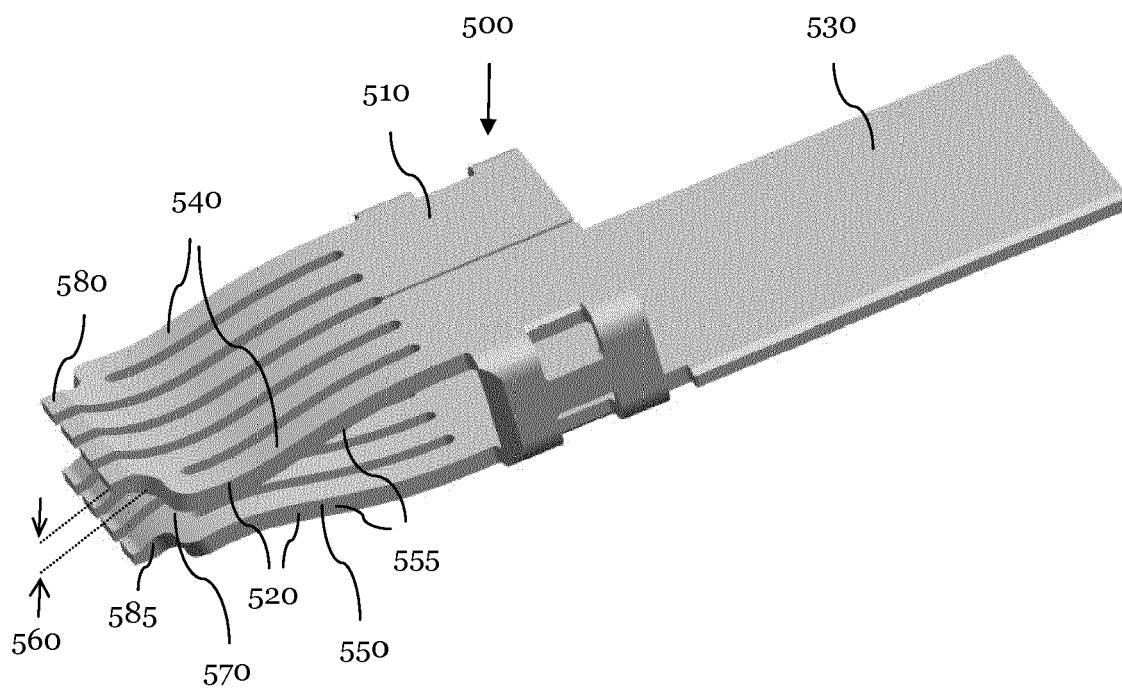


Fig. 5

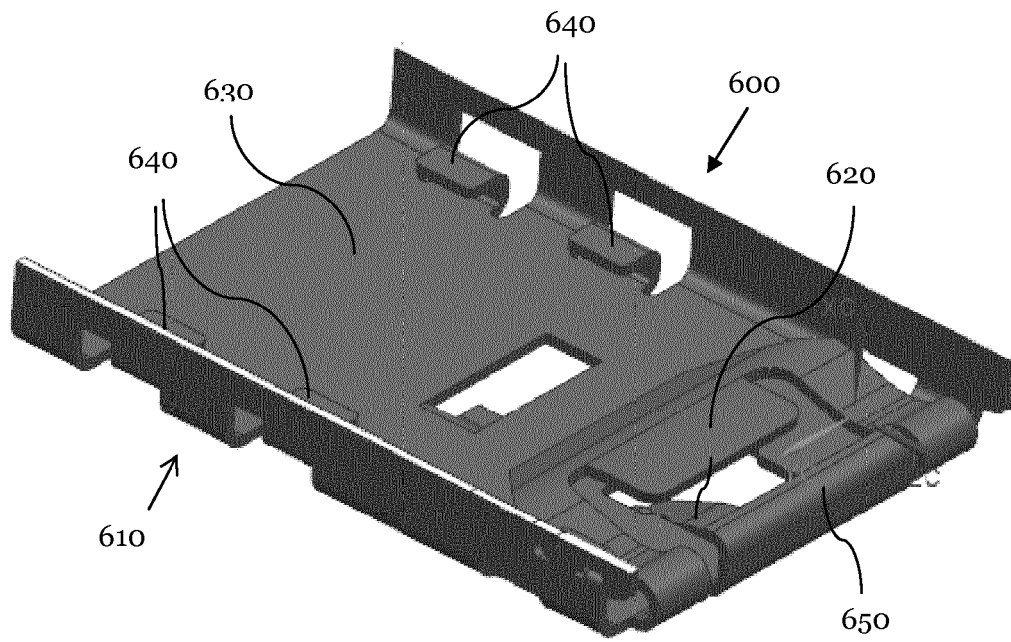


Fig. 6

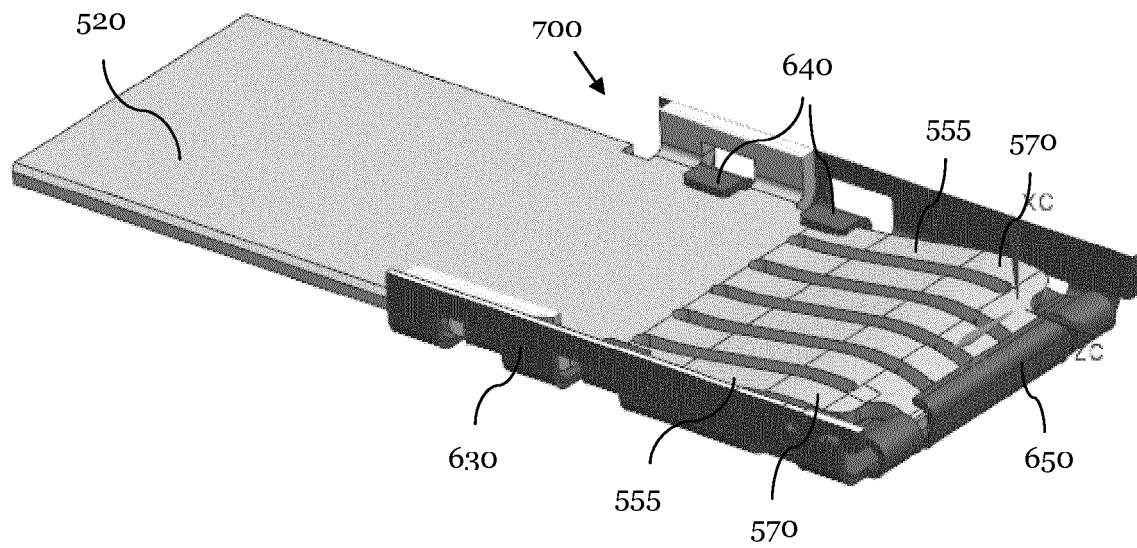
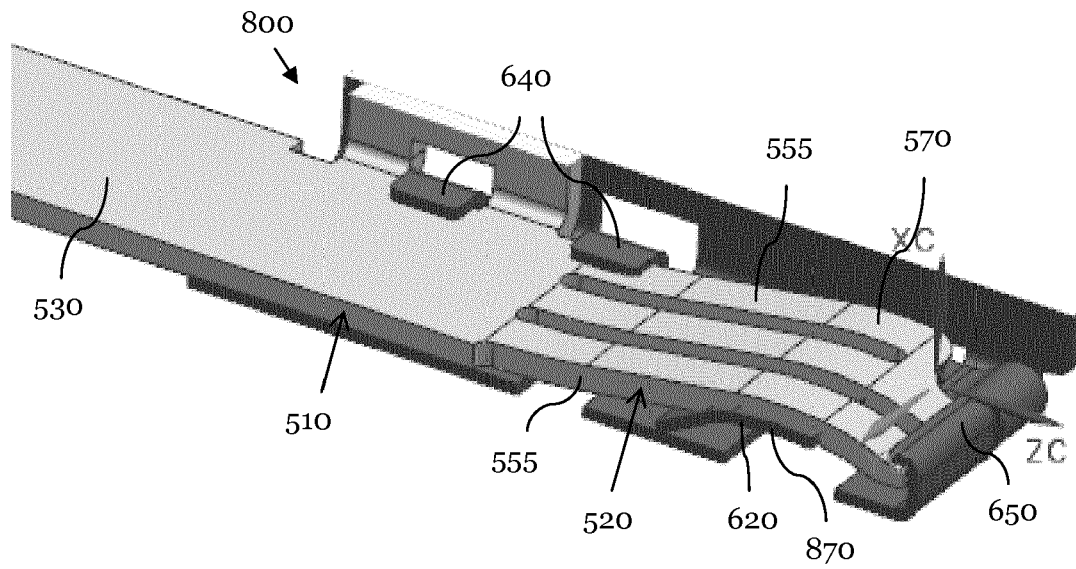
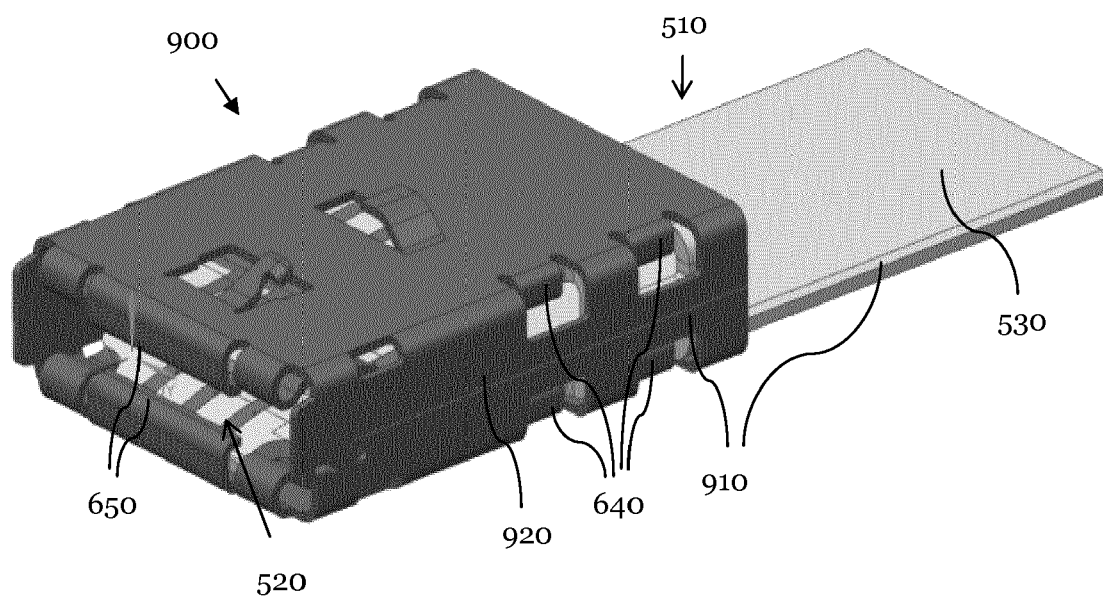


Fig. 7



**Fig. 8**



**Fig. 9**



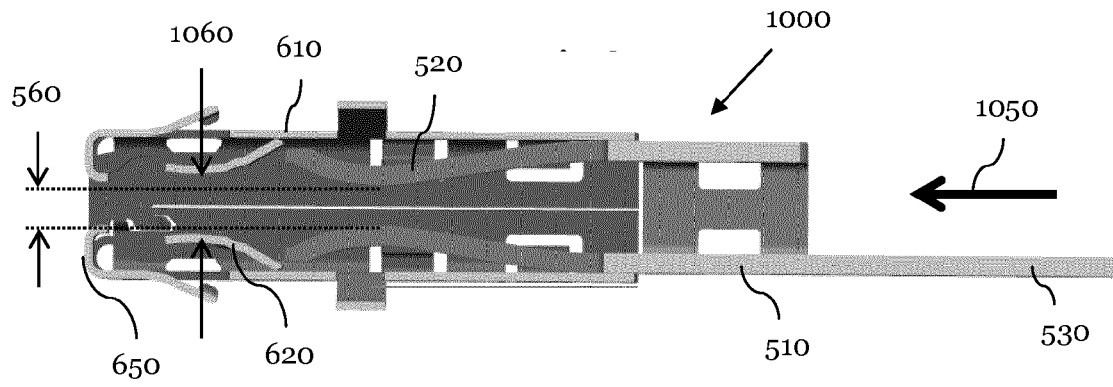


Fig. 10

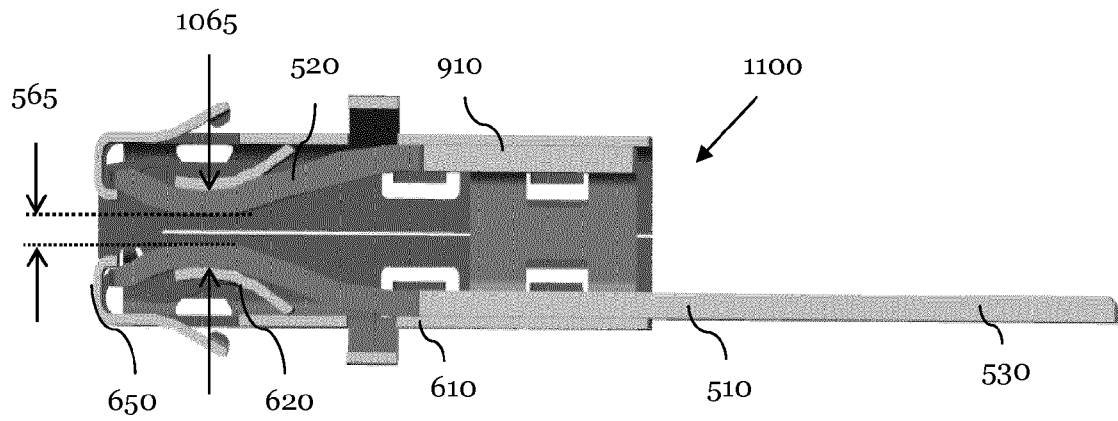


Fig. 11

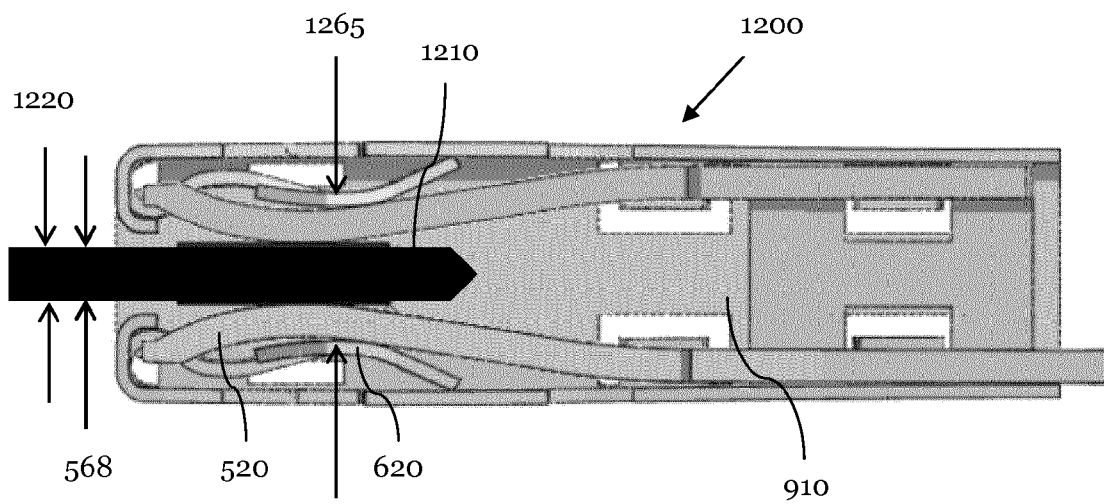


Fig. 12

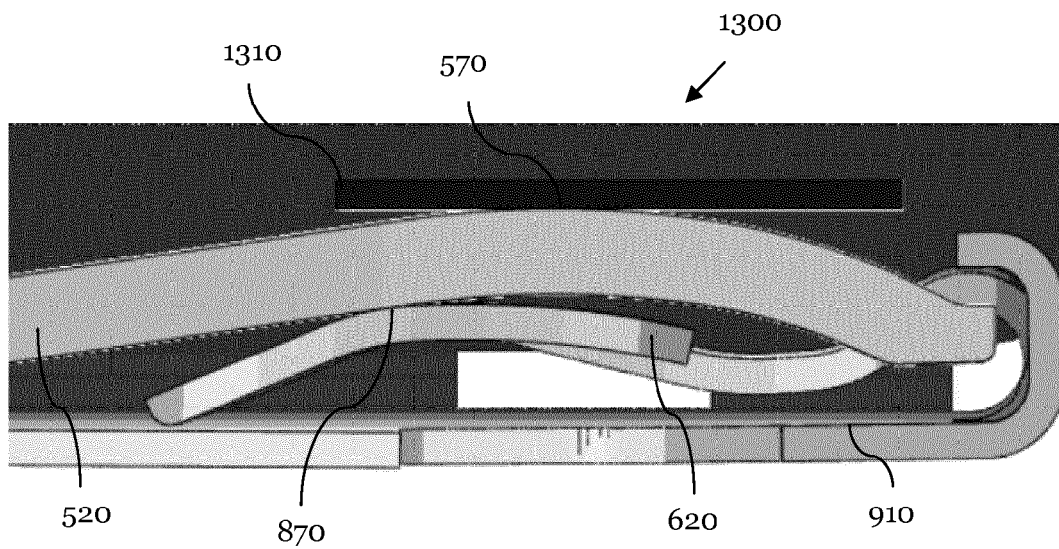


Fig. 13

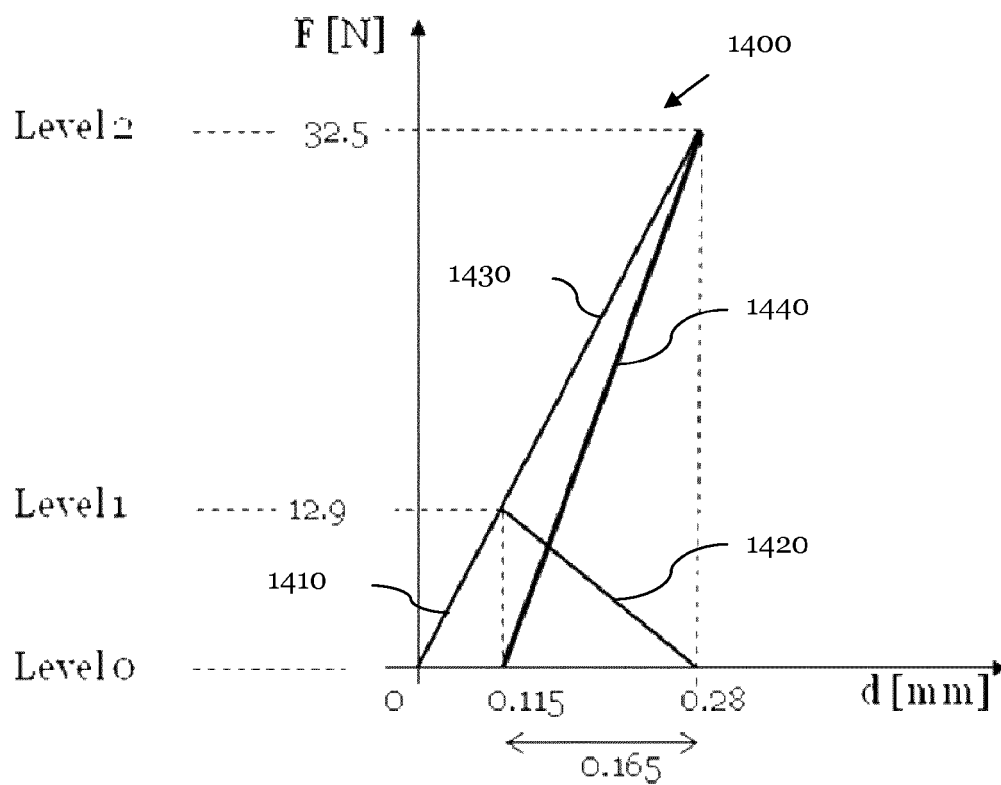


Fig. 14

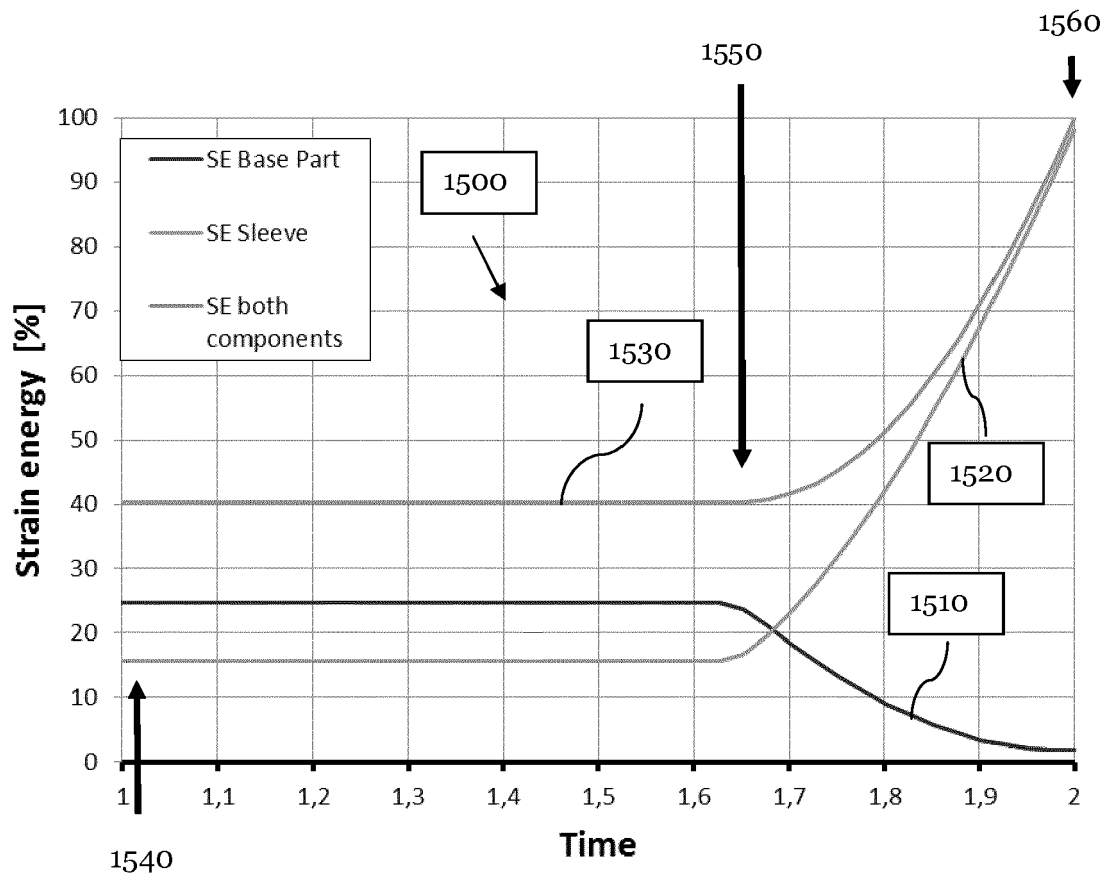


Fig. 15

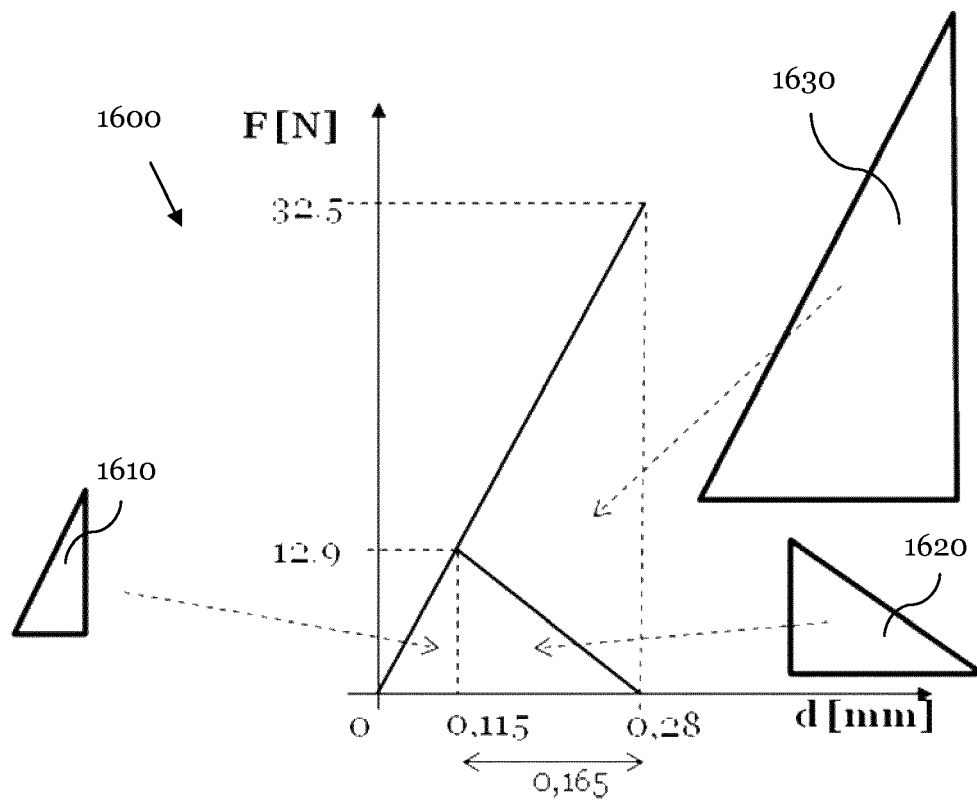
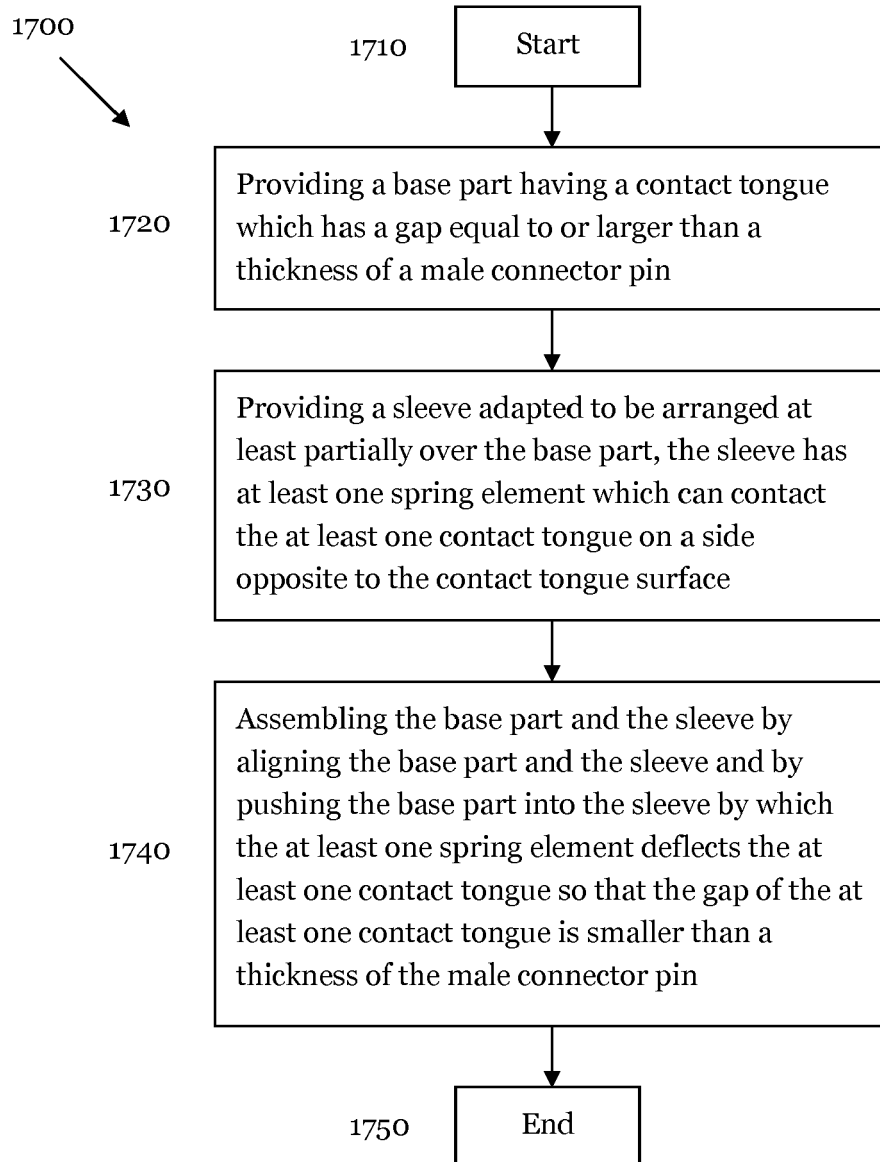


Fig. 16

**Fig. 17**



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Application Number  
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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                |                                                        |                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------|
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| Place of search<br><b>The Hague</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                | Date of completion of the search<br><b>18 May 2016</b> | Examiner<br><b>Jiménez, Jesús</b>       |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                |                                                        |                                         |

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The members are as contained in the European Patent Office EDP file on  
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