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Press-fit terminal and connector device

Abstract

A press-fit terminal includes a press-fit portion including two contact pieces facing each other with an eyehole interposed therebetween, where each of the two contact pieces includes a parallel portion, a front spring portion extending from the parallel portion in a direction in which the press-fit portion is inserted, and a rear spring portion extending from the parallel portion in a direction opposite to the direction in which the press-fit portion is inserted, the two parallel portions being parallel to each other, a thickness of the press-fit portion is 0.3 mm or more and 0.5 mm or less, when a length of the eyehole is Le [mm] and a length of the parallel portion is Ls [mm], Ls/Le is 0.57 or more and 0.65 or less, and when front spring strength is G.sub.1 [mm.sup.3] and rear spring strength is G.sub.2 [mm.sup.3], G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less.

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Background/Summary

TECHNICAL FIELD
(1) The present disclosure relates to a press-fit terminal and a connector device.
BACKGROUND ART
(2) Patent Document 1 discloses a press-fit terminal including a connection portion having a width to penetrate across front and back surfaces and including a slit portion and two beam members facing each other with the slit portion therebetween. In Patent Document 1, the beam member is formed to have thicknesses at the front end side and the rear end side of the connection portion thinner than the thickness at the center of the connection portion, and the slit portion is formed to have a length from the center to the rear end side of the connection portion shorter than the length from the center to the front end side.
(3) Patent Document 2 discloses a press-fit terminal including a guiding portion which is guided into a through hole, a pressure keeping portion connected to the guiding portion and press-fitted to be held in the through hole, and a main body portion connected to the pressure keeping portion, in which an opened portion extending in a longitudinal direction from the center of the pressure keeping portion to the main body portion side and guiding portion side is formed. In Patent Document 2, the ratio between the length in the longitudinal direction from the center of the pressure keeping portion to one end of the opened portion on the main body portion side and the length in the longitudinal direction from the center of the pressure keeping portion to the other end of the opened portion on the guiding portion side is defined within a range from 80:220 to 120:180.
PRIOR ART DOCUMENTS
Patent Documents
(4) Patent Document 1: International Publication WO 2008/038331 Patent Document 2: Japanese Patent Application Laid-Open No. 2008-165987
SUMMARY OF THE INVENTION
Problem to be Solved by the Invention
(5) A press-fit terminal is evaluated by, for example, insertion force and holding force. The insertion force is a load necessary for inserting a press-fit terminal into a through hole. The holding force is a load necessary for pulling out the press-fit terminal from the through hole. It is desired

that the press-fit terminal be easily inserted in the through hole and be hardly removed from the through hole. Therefore, the press-fit terminal is required to have a small insertion force and a large holding force.
(6) In recent years, downsizing of a connector into which a press-fit terminal is incorporated, downsizing of a substrate into which a press-fit terminal is press-fitted, and densification of a press-fit terminal are required. Accordingly, reduction in the diameter of a through hole and reduction in the thickness of a press-fit terminal are required.
(7) As described above, there is still room for further improvement in compatibility between reduction in insertion force and increasing of holding force of a thin press-fit terminal.
(8) An object of the present disclosure is to raise compatibility between reduction in insertion force and increasing of holding force.
Means to Solve the Problem
(9) A press-fit terminal according to the present disclosure is a press-fit terminal that is press-fitted into a through hole formed in a substrate and includes a press-fit portion including two contact pieces facing each other with an eyehole interposed therebetween, wherein each of the two contact pieces includes a parallel portion, a front spring portion extending from the parallel portion in a direction in which the press-fit portion is inserted, and a rear spring portion extending from the parallel portion in a direction opposite to the direction in which the press-fit portion is inserted, the two parallel portions being parallel to each other, a thickness of the press-fit portion is 0.3 mm or more and 0.5 mm or less, in the press-fit portion, when a length of the eyehole is Le [mm] and a length of the parallel portion is Ls [mm], Ls/Le is 0.57 or more and 0.65 or less, and in the press-fit portion, when a front spring strength and a rear spring strength calculated under conditions described below are respectively G.sub.1 [mm.sup.3] and G.sub.2 [mm.sup.3], G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less:
(10) [Conditions]
(11) A direction in which the press-fit terminal is inserted is a forward direction, and a direction opposite to the direction in which the press-fit terminal is inserted is a rearward direction; A position at 0.1 mm in the rearward direction from the front end of the eyehole is a front reference, and a position at 0.1 mm in the forward direction from the rear end of the eyehole is a rear reference; Assuming a front reference plane extending from an inner edge of the front spring portion at the front reference and perpendicular to an outer edge of the front spring portion, the second moment of area of the front spring portion in the front reference plane is defined as I.sub.1 [mm]; Assuming a rear reference plane extending from an inner edge of the mar spring portion at the rear reference and perpendicular to an outer edge of the rear spring portion, the second moment of area of the rear spring portion in the rear reference plane is I.sub.2 [mm.sup.4]; A length of the press-fit portion in the insertion direction from an end, on the front spring portion side, of a linear outer edge of the parallel portion to the front end of the eyehole is L.sub.1 [mm]; A length of the press-fit portion in the insertion direction from an end, on the rear spring portion side, of a linear outer edge of the parallel portion to the rear end of the eyehole is L.sub.2 [mm]; Front spring strength G.sub.1 is I.sub.1/L.sub.1 [mm.sup.3], and rear spring strength G.sub.2 is I.sub.2/L.sub.2 [mm.sup.3].
Effects of the Invention
(12) According to the present disclosure, compatibility between reduction in insertion force and increasing of holding force can be raised.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is front view illustrating a press-fit terminal according to an embodiment.

(2) FIG. **2** is an explanatory view illustrating a state in which a press-fit portion is inserted into a through hole.
(3) FIG. **3** is a cross-sectional view taken along line III-III in FIG. **2**.
(4) FIG. **4** is a cross-sectional view illustrating another press-fit terminal.
(5) FIG. **5** is an explanatory view illustrating a cross-sectional shape of a front spring portion in a front reference plane.
(6) FIG. **6** is a schematic view illustrating a connector device.
(7) FIG. **7** is a view illustrating evaluation results of the press-fit terminal.

DESCRIPTION FOR CARRYING OUT THE INVENTION

Description of Embodiments of Present Disclosure

(8) First, a series of embodiments of the present disclosure will be described.
(9) A press-fit terminal of the present disclosure is as follows.
(10) (1) A press-fit terminal that is press-fitted into a through hole formed in a substrate includes a press-fit portion including two contact pieces facing each other with an eyehole interposed therebetween, wherein each of the two contact pieces includes a parallel portion, a front spring portion extending from the parallel portion in a direction in which the press-fit portion is inserted, and a rear spring portion extending from the parallel portion in a direction opposite to the direction in which the press-fit portion is inserted, the two parallel portions being parallel to each other, a thickness of the press-fit portion is 0.3 mm or more and 0.5 mm or less, in the press-fit portion, when a length of the eyehole is Le [mm] and a length of the parallel portion is Ls [mm], Ls/Le is 0.57 or more and 0.65 or less, and in the press-fit portion, when a front spring strength and a rear spring strength calculated under conditions described below are respectively G.sub.1 [mm.sup.3] and G.sub.2 [mm.sup.3], G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less:
(11) [Conditions]
(12) A direction in which the press-fit terminal is inserted is a forward direction, and a direction opposite to the direction in which the press-fit terminal is inserted is a rearward direction; A position at 0.1 mm in the rearward direction from the front end of the eyehole is a front reference, and a position at 0.1 mm in the forward direction from the rear end of the eyehole is a rear reference; Assuming a front reference plane extending from an inner edge of the front spring portion at the front reference and perpendicular to an outer edge of the front spring portion, the second moment of area of the front spring portion in the front reference plane is defined as I.sub.1 [mm.sup.4]; Assuming a rear reference plane extending from an inner edge of the rear spring portion at the rear reference and perpendicular to an outer edge of the rear spring portion, the second moment of area of the rear spring portion in the rear reference plane is I.sub.2 [mm.sup.4]; A length of the press-fit portion in the insertion direction from an end, on the front spring portion side, of a linear outer edge of the parallel portion to the front end of the eyehole is L.sub.1 [mm]; A length of the press-fit portion in the insertion direction from an end, on the rear spring portion side, of a linear outer edge of the parallel portion to the rear end of the eyehole is L.sub.2 [mm]; Front spring strength G.sub.1 is I.sub.1/L.sub.1 [mm.sup.3], and rear spring strength G.sub.2 is I.sub.2/L.sub.2 [mm.sup.3].
(13) Since Ls/Le is 0.57 or more and 0.65 or less and G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less, compatibility between reduction in insertion force and increasing of holding force can be raised.
(14) (2) The press-fit terminal according to (1), wherein when spring strength G [mm.sup.3] is G.sub.1+G.sub.2, G may be 0.03 mm.sup.3 or more and 0.04 mm.sup.3 or less. Compatibility between reduction in insertion force and increasing of holding force can be further raised.
(15) (3) The press-fit terminal according (1) or (2), wherein the outer edge of the front spring portion may be inclined so as to be directed inward in a width direction of the press-fit portion toward a front side, and the outer edge of the rear spring portion may be inclined so as to be directed inward in the width direction of the press-fit portion toward the rear side. This makes the

front spring portion and the rear spring portion to deform easily.
(16) (4) The press-fit terminal according to any one aspect of (1) to (3), wherein an outward portion of the parallel portion may be formed in an arc shape in a view looking along the insertion direction. This increases the contact area with which the inner peripheral surface of the through hole makes contact.
(17) (5) A connector device that may include a connector including the press-fit terminal according to (4), and a substrate in which a through hole is formed, wherein the press-fit portion of the press-fit terminal may be press-fitted into the through hole, and a radius of curvature of the outward portion of the parallel portion may be equal to or smaller than an inner peripheral radius of the through hole in a view looking along the insertion direction. This increases the contact area between the press-fit portion and the inner peripheral surface of the through hole.
Details of Embodiments of Present Disclosure
(18) Specific examples of a press-fit terminal and a connector device of the present disclosure will be described below with reference to the drawings. Note that the present disclosure is not limited to these examples, but is indicated by the claims, and is intended to include meanings equivalent to the claims and all modifications within the scope of the meanings.
(19) The press-fit terminal of the present disclosure is meaningful under the following background. That is, the press-fit terminal is required to satisfy all the characteristics of holding force, contact area, and insertion force at high levels. Here, the holding force and the insertion force are as already described above. The contact area is a contact area between the press-fit terminal and the through hole in a state where the press-fit terminal is inserted into the through hole of a substrate. In order to improve electrical connection, it is desirable that the contact area be as large as possible. In a state where the press-fit terminal is inserted into the through hole, the press-fit terminal serves as a kind of spring, and both sides of the press-fit terminal are pressed against the through hole. A harder spring of the press-fit terminal provides a larger holding force and a larger contact area but with a larger insertion force. Conversely, a softer spring of the press-fit terminal provides a smaller insertion force but with a smaller holding force and a smaller contact area. Thus, the holding force, the contact area, and the insertion force depend on the hardness of the spring, and the requirement for the holding force and the contact area and the requirement for the insertion force are in a trade-off relationship.
(20) A shape that satisfies all the characteristics of holding force, contact area, and insertion force at high levels has been proposed. The thickness of a conventional press-fit terminal is about 0.64 mm. In view of the demand for downsizing, multipolarization, or the like of the press-fit terminal, reduction in the thickness of the press-fit terminal is required.
(21) When designing the shape of a press-fit terminal having a small thickness (for example, 0.4 mm thickness), for example, instead of designing a brand new shape, a shape may be designed to be similar to and smaller than an existing shape. However, a press-fit terminal having a small thickness is also small in size in a front view. Moreover, when a press-fit terminal is to be manufactured from a metal plate by press work or the like, there is a size limit for working. For these reasons, it may be difficult to work a press-fit terminal into a shape similar to and smaller than an existing shape. Therefore, for a press-fit terminal having a small thickness, it is necessary to study a new shape.
(22) Under the above-described background, in the present disclosure, for a press-fit terminal having a small thickness, a shape that can satisfy holding force, contact area, and insertion force at high levels has been studied, and as a result, the following shape of a press-fit terminal has been conceived.
EMBODIMENT
(23) A press-fit terminal according to an embodiment will be described below. FIG. **1** is a front view illustrating a press-fit terminal **20**. FIG. **2** is an explanatory view illustrating a state in which a press-fit portion **30** is inserted into a through hole **13**. FIG. **2** illustrates the press-fit terminal **20**

before being inserted into the through hole **13** and the press-fit terminal **20** inserted into the through hole **13**. FIG. **3** is a cross-sectional view taken along line III-III in FIG. **2**.

(24) The press-fit terminal **20** is a terminal that is press-fitted into the through hole **13** formed in a substrate **12**. Here, the substrate **12** is formed of an insulating plate, or the like, such as a glass epoxy plate. The through hole **13** is formed in the substrate **12** so as to penetrate from the frontside to the back side of the substrate **12**. The through hole **13** is a circular hole. The through hole **13** may be a square hole, or the like. On the inner surface of the through hole **13**, a conductive layer **13***f* of a metal such as copper is formed. In a state where the press-fit terminal **20** is press-fitted into the through hole **13**, the press-fit terminal **20** is in contact with the conductive layer **13***f* and is electrically connected to the conductive layer **13***f*. The conductive layer **13***f* may be connected to a circuit formed on a surface, or the like, of the substrate **12**.

(25) The press-fit terminal **20** is formed of a metal such as copper, a copper alloy, or the like. The press-fit terminal **20** may be formed by, for example, press-working a metal plate. Plating of tin, a tin alloy, or the like may be formed on a surface of the press-fit terminal **20**.

(26) The press-fit terminal **20** includes a press-fit portion **30**. In the present embodiment, a distal portion **22** is continuous with one end portion of the press-fit portion **30**, and a proximal portion **26** is continuous with the other end portion of the press-fit portion **30**. The distal portion **22** is a portion that is first inserted into the through hole **13** when the press-fit terminal **20** is inserted into the through hole **13**. The proximal portion **26** is a portion with which a portion to be electrically connected to the conductive layer **13***f* on the through hole **13** side is continuous. In an example illustrated in FIG. **6** described later, the proximal portion **26** is continuous with a connector terminal portion **54**. A direction in which the press-fit portion **30** is inserted is a forward direction, and a direction opposite to the insertion direction is rearward direction.

(27) The press-fit portion **30** is a portion provided between the distal portion **22** and the proximal portion **26**. Width W2 (the maximum width in this case) of the press-fit portion **30** is larger than maximum width W1 of the distal portion **22** and also larger than diameter ϕ of the through hole **13**. Therefore, the press-fit portion **30** can make contact with the inner peripheral surface of the through hole **13**. The press-fit portion **30** may be grasped as a portion for obtaining electrical contact with the conductive layer **13***f* by keeping a contact state with the inner peripheral surface of the through hole **13**.

(28) More specifically, the press-fit terminal **20** is formed as a whole in a linearly extending elongated plate shape.

(29) The distal portion **22** includes a rectangular plate portion including a continuous constant width portion. Edges on both sides of the rectangular plate portion are parallel to each other. Width W1 of the distal portion **22** is smaller than the diameter (diameter) ϕ of the through hole **13**. A most distal portion **22***a* which gradually becomes narrower toward the distal end side is provided at a distal portion (an end portion on a side opposite to the press-fit portion **30**) of the rectangular plate portion of the distal portion **22**. With presence of the most distal portion **22***a*, the press-fit terminal **20** is easily inserted into the through hole **13**. The distal portion **22** can be inserted into the through hole **13** with a gap between the distal portion **22** and the inner peripheral surface of the through hole **13**.

(30) The proximal portion **26** includes a rectangular plate portion including a continuous constant width portion. Edges on both sides of the rectangular plate portion are parallel to each other. The width of the proximal portion **26** is smaller than width W2 of the press-fit portion **30**. Here, the width of the proximal portion **26** is the same as the maximum width W1 of the distal portion **22**. The width of the proximal portion **26** may be different from the width of the distal portion **22**.

(31) The press-fit portion **30** is provided between the distal portion **22** and the proximal portion **26**. The press-fit portion **30** includes two contact pieces **34** facing each other with the eyehole **31** therebetween. The eyehole **31** is a hole elongate along a direction from one of the distal portion **22** and the proximal portion **26** to the other. The shape of the eyehole **31** is specifically, for example, a

true circle, an oval shape, a cube, or a rectangular parallelepiped. The eyehole **31** is preferably elongate along the direction in which the press-fit terminal is inserted. The contact piece **34** has a form of an elongate plate shape. One end portion of each of the two contact pieces **34** is continuous with the distal portion **22**. Another end portion of each of the two contact pieces **34** is continuous with the proximal portion **26**.

(32) Each of the two contact pieces **34** includes a parallel portion **36**, a front spring portion **35**, and a rear spring portion **37**.

(33) The parallel portions **36** of the two contact pieces **34** are disposed parallel to each other. More specifically, the outer edges **36***a* of the two parallel portions **36** are disposed linearly along the front-rear direction and in parallel to each other. The inner edges of the two parallel portions **36** may also be disposed linearly along the front-rear direction and in parallel to each other. However, depending on the shape of the eyehole **31**, some or all of the inner edges of the two parallel portions **36** may be curved.

(34) The front spring portion **35** is a portion extending from the parallel portion **36** in a direction in which the press-fit terminal **20** is inserted (forward direction). The front spring portion **35** is a portion that deforms more easily than the parallel portion **36** when the press-fit portion **30** is inserted into the through hole **13**. The outer edge **35***a* of the front spring portion **35** is inclined so as to be directed inward in the width direction of the press-fit portion **30** toward the front side. That is, the outer edge **35***a* of the front spring portion **35** is continuous with the outer edge **36***a* of the parallel portion **36** at the rear end thereof, gradually directed inward in the width direction of the press-fit portion **30** toward the front side, and continuous with the outer edge of the distal portion **22** at the front end thereof.

(35) The outer edge **35***a* of the front spring portion **35** may be linear as a whole, may be a curve as a whole, or may have a shape of a combination of a straight line and a curve. The outer edge **35***a* of the front spring portion **35** and the outer edge **36***a* of the parallel portion **36** may be continuous with a curve therebetween, or may be continuous with a corner therebetween. Similarly, the outer edge **35***a* of the front spring portion **35** and the outer edge of the distal portion **22** may be continuous with a curve therebetween, or may be continuous with a corner therebetween. Here, a middle portion of the outer edge **35***a* of the front spring portion **35** forms a straight line, and both end portions thereof each form a curve.

(36) The rear spring portion **37** is a portion extending from the parallel portion **36** in a direction opposite to the direction in which the press-fit terminal **20** is inserted (rearward direction). The rear spring portion **37** is a portion that deforms more easily than the parallel portion **36** when the press-fit portion **30** is inserted into the through hole **13**. The front spring portion **35** and the rear spring portion **37** easily deform at front and rear sides of the parallel portion **36**, so that the parallel portion **36** can be displaced inward without a large inclination. The outer edge **37***a* of the rear spring portion **37** is inclined so as to be directed inward in the width direction of the press-fit portion **30** toward the rear side. That is, the outer edge **37***a* of the rear spring portion **37** is continuous with the outer edge **36***a* of the parallel portion **36** at the front end thereof, gradually directed inward in the width direction of the press-fit portion **30** toward the rear side, and continuous with the outer edge of the proximal portion **26** at the rear end thereof.

(37) The outer edge **37***a* of the rear spring portion **37** may be linear as a whole, may be a curve as a whole, or may have a shape of a combination of a straight line and a curve. The outer edge **37***a* of the rear spring portion **37** and the outer edge **36***a* of the parallel portion **36** may be continuous with a curve therebetween, or may be continuous with a corner therebetween. Similarly, the outer edge **37***a* of the rear spring portion **37** and the outer edge of the proximal portion **26** may be continuous with a curve therebetween, or may be continuous with a corner therebetween. Here, a middle portion of the outer edge **37***a* of the rear spring portion **37** forms a straight line, and both end portions thereof each form a curve.

(38) In a view looking along the insertion direction of the press-fit terminal **20**, the outward portion

of the parallel portion **36** is formed in an arc surface **36***f* having an arc shape protruding outward. When the outward portion of the parallel portion **36** is formed into the arc surface **36***f*, the arc surface **36***f* is expected to contact the inner peripheral surface of the through hole **13** with a large area.

(39) Radius of curvature r of the arc surface **36***f* is preferably equal to or smaller than an inner peripheral radius (ϕ/2) of the through hole **13** into which the press-fit terminal **20** is inserted. When the radius of curvature r of the arc surface **36***f* is the same as the inner peripheral radius (ϕ/2) of the through hole **13**, the entire arc surface **36***f* is expected to contact the inner peripheral surface of the through hole **13**. That the radius of curvature r of the arc surface **36***f* is the same as the inner peripheral radius (ϕ/2) of the through hole **13** may include that they are the same within the manufacturing error range. For example, the radius of curvature r of the arc surface **36***f* may be the same as the inner peripheral radius (ϕ/2) of the through hole **13** within an error range of ±20%, inclusive. Even when the radius of curvature r of the arc surface is smaller than the inner peripheral radius (ϕ/2) of the through hole **13**, the curved surface portion at the center of the arc surface **36***f* is expected to contact the inner peripheral surface of the through hole **13** with a large area as compared with the case where the radius of curvature r of the arc surface **136***f* is larger than the inner peripheral radius (ϕ/2) of the through hole **13** (see range E1 in FIG. **3**). For example, as illustrated in FIG. **4**, when the radius of curvature r of the arc surface **136***f* is larger than the inner peripheral radius (ϕ/2) of the through hole **13**, both edge portions of the arc surface **136***f* are assumed to contact the inner peripheral surface of the through hole **13** with an area smaller than that in the above case (see range E2 in FIG. **4**). In a case where the radius of curvature r of the arc surface is smaller than the inner peripheral radius (ϕ/2) of the through hole **13**, the radius of curvature r of the arc surface is preferably 70% or more of the inner peripheral radius (ϕ/2) of the through hole **13**.

(40) The outward portions of the front spring portion **35** and the rear spring portion **37** are also formed in an arc surface in the same manner as described above.

(41) It is not essential that the outward portions of the parallel portion **36**, the front spring portion **35**, and the rear spring portion **37** are formed in the above-described shape in a view looking along the insertion direction of the press-fit terminal **20**. For example, the outward portions of the parallel portion **36**, the front spring portion **35**, and the rear spring portion **37** may be formed in flat surfaces. As illustrated in FIG. **4**, the case where the radius of curvature r of the are surface **136***f* is larger than the inner peripheral radius (ϕ/2) of the through hole **13** is not excluded.

(42) The press-fit portion **30** is formed to have a thickness of 0.3 mm or more and 0.5 mm or less. Preferably, the thickness of the press-fit portion **30** is 0.4 mm. In this manner, forming the press-fit portion **30** to have a small thickness of 0.3 mm or more and 0.5 mm or less allows the press-fit portion **30** to be used for a small through hole **13**. When downsizing of the through hole **13** and the press-fit portion **30** is realized, requirement for densification, multipolarization, and the like of the press-fit terminal **20** can be met.

(43) The size and shape of each part of the press-fit portion **30** are as follows.

(44) First, for the press-fit portion **30**, when the length of the eyehole **31** is Le [mm] and the length of the parallel portion **36** is Ls [mm], Ls/Le is 0.57 or more and 0.65 or less. Here, the length Le [mm] of the eyehole **31** is a distance between the front end at the foremost and the rear end at the rearmost of the eyehole **31** along the front-rear direction. The length Ls [mm] of the parallel portion **36** is the length of the linear outer edge **36***a* of the parallel portion **36** along the front-rear direction.

(45) In the press-fit portion **30**, when the front spring strength and the rear spring strength calculated under the following conditions are respectively G.sub.1 [mm.sup.3] and G.sub.2 [mm.sup.3], G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less.

(46) [Conditions]

(47) First, a position at 0.1 mm in the rearward direction from the front end of the eyehole **31** is a

front reference SF. In FIG. **1**, the front reference SF is indicated as a straight line orthogonal to the front-rear direction. Similarly, a position at 0.1 mm in the forward direction from the rear end of the eyehole **31** is a rear reference SR. In FIG. **1**, the rear reference SR is indicated as a straight line orthogonal to the front-rear direction.

(48) Front reference plane TF extending from the inner edge of the front spring portion **35** at the front reference SF and perpendicular to the outer edge **35***a* of the front spring portion **35** is assumed. Here, the front reference plane TF being perpendicular to the outer edge **35***a* of the front spring portion **35** means that the front reference plane TF is perpendicular to the outer edge **35***a* of the front spring portion **35** in a view looking the press-fit portion **30** along the thickness direction thereof. The second moment of area of the front spring portion **35** in the front reference plane TF is I.sub.1 [mm.sup.4].

(49) Similarly, rear reference plane TR extending from the inner edge of the rear spring portion **37** at the rear reference SR and perpendicular to the outer edge **37***a* of the rear spring portion **37** is assumed, and the second moment of area of the rear spring portion **37** in the rear reference plane is I.sub.2 [mm.sup.4].

(50) Among linear outer edges **36***a* of the parallel portion **36**, the length in the insertion direction of the press-fit portion **30** from the end on the front spring portion **35** side to the front end of the eyehole **31** is L.sub.1 [mm].

(51) Among linear outer edges **36***a* of the parallel portion **36**, the length in the insertion direction of the press-fit portion **30** from an end on the rear spring portion **37** side to the rear end of the eyehole **31** is L.sub.2 [mm].

(52) Front spring strength G.sub.1 is defined as I.sub.1/L.sub.1 [mm.sup.3], and rear spring strength G.sub.2 is defined as I.sub.2/L.sub.2 [mm.sup.3].

(53) [Second Moment of Area]

(54) The second moment of area in each of the front reference plane TF and the rear reference plane TR can be obtained, for example, as follows.

(55) The cross-sectional shape of the front spring portion **35** in the front reference plane TF is, for example, a shape in which a first portion A having a rectangular shape is combined with a second portion B that is a part cut out from a circle with a straight line as illustrated in FIG. **5**. Therefore, the second moment of area in the front reference plane TF can be considered as the sum of the second moment of area of the first portion A and the second moment of area of the second portion B.

(56) In this cross-sectional shape, when the thickness of the press-fit portion **30** is t [mm], the radius of curvature of the outward portion of the press-fit portion **30** is r [mm], and the dimension from the inward portion on the eyehole **31** side to the outward portion is a spring thickness h [mm], the second moment of area in the front reference plane TF is calculated by the following formula.

(57) $$I = \{(y - y_a)^2 S_a + I_a\} + \{(y - y_b)^2 S_b + I_b\}$$ where

$$I_a = \frac{t[h - r(1 - \sqrt{1 - (t/2)^2})]^3}{12} \quad I_b = \frac{r^4}{24}\{6\sin^{-1}\frac{t}{2r} - 3\sin(2\sin^{-1}\frac{t}{2r}) - 2\,(\frac{t}{2r})^2 \sin(2\sin^{-1}\frac{t}{2r})\}$$

$$S_a = t[h - r\{1 - \sqrt{1 - (t/2)^2}\}] \quad S_b = \frac{r^2}{2}\{2\sin^{-1}\frac{t}{2r} - \sin(2\sin^{-1}\frac{t}{2r})\}$$

$$y_a = \frac{h - r\{1 - \sqrt{1 - (t/2)^2}\}}{2} \quad y_b = \frac{4r}{3}\frac{(t/2r)^3}{2\sin^{-1}\frac{t}{2r} - \sin(2\sin^{-1}\frac{t}{2r})} - (r - h) \quad y = \frac{S_a y_a + S_b y_b}{S_a + S_b}$$

(58) In the above formula, I.sub.a is the second moment of area of the first portion A, and I.sub.b is the second moment of area of the second portion B. S.sub.a is the cross-sectional area of the first portion A, and S.sub.b is the cross-sectional area of the second portion B. Furthermore, y.sub.a is the position of the neutral axis of the first portion A, y.sub.b is the position of the neutral axis of the second portion B, and y is the position of the neutral axis of the whole combination of the first portion A and the second portion B.

(59) The second moment of area in the rear reference plane TR can also be determined in the same

manner as described above.
(60) The method for obtaining the second moment of area is an example. The second moment of area can be obtained by a calculation method based on the cross-sectional shape of the front spring portion **35** in the front reference plane TF, the cross-sectional shape of the rear spring portion **37** in the rear reference plane TR, and the like.
(61) In the press-fit terminal **20** configured as described above, Ls/Le is 0.57 or more and 0.65 or less, and G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less, so that compatibility between reduction in insertion force and increasing of holding force are raised.
(62) In the press-fit terminal **20** described above, when the spring strength G [mm.sup.3] is G.sub.1+G.sub.2, G may be 0.03 mm.sup.3 or more and 0.04 mm.sup.3 or less. This further improves the compatibility between reduction in insertion force and increasing of holding force.
(63) The outer edge **35***a* of the front spring portion **35** is inclined so as to be directed inward in the width direction of the press-fit portion **30** toward the front side, and the outer edge **37***a* of the rear spring portion **37** is inclined so as to be directed inward in the width direction of the press-fit portion **30** toward the rear side. Therefore, when the press-fit terminal **20** is press-fitted into the through hole **13**, the front spring portion **35** and the rear spring portion **37** respectively having the outer edges **35***a* and **37***a*-inclined with respect to the parallel portion **36** can easily deform at both end sides of the parallel portion **36**.
(64) In addition, since the outward portion of the parallel portion **36** is formed in the arc surface **36***f*, the parallel portion **36** easily contacts the inner peripheral surface of the through hole **13** with a large surface, which further increases the contact area.
(65) In particular, when the radius of curvature r of the arc surface **36***f* is equal to or smaller than the radius of the through hole **13**, the central portion of the arc surface **36***f* easily contacts the inner peripheral surface of the through hole **13** with a relatively large area, which further increases the contact area.
(66) FIG. **6** is a view illustrating a connector device **50** in which the press-fit terminal **20** is press-fitted into the substrate **12**. The connector device **50** includes the substrate **12** and a connector **60**. The connector **60** includes the press-fit terminal **20**. In FIG. **6**, a connector terminal portion **54** is integrally connected to the proximal portion **26** of the press-fit terminal **20**. The connector terminal portion **54** is continuous with the proximal portion **26** in a bent state with respect to the proximal portion **26** (in this case, bent at a right angle). The proximal portion of the press-fit terminal **20** and the connector terminal portion **54** are incorporated in a connector housing **61** of the connector **60**. The proximal portion may protrude from the connector housing **61**. The connector terminal portion **54** is disposed so as to protrude from the bottom of a space in the connector housing **61** toward the opening. Here, a plurality of press-fit terminals **20** are incorporated in the connector housing **61**. Therefore, a plurality of connector terminal portions **54** are arranged at an interval in the connector housing **61**. A plurality of press-fit terminals **20** protrudes from an outer surface of the connector housing **61**. A plurality of press-fit terminals **20** protruding from the outer surface of the connector housing **61** is press-fitted at a time into a plurality of through holes **13**. The connector **60** is mounted and fixed to the substrate **12** in a state where a plurality of press-fit terminals **20** is press-fitted into a plurality of through holes **13**.
(67) A case **52** is formed in a housing shape having a space capable of accommodating the substrate **12**. An opening **53** that exposes the connector housing **61** to the external is formed in the case **52**. The substrate **12** is fixed in the case **52** with the connector housing **61** disposed at the opening **53**. To fix the substrate **12** in the case **52**, a screwing structure, a fitting structure, a combined structure thereof, or the like may be used.
(68) In the connector device **50** as described above, a large number of connector terminal portions **54** may be incorporated into the connector **60**. In this case, work of simultaneously press-fitting a large number of press-fit terminals **20** into the through holes **13** may be needed. Such a case is effective in that the maximum value of the insertion force can be reduced while increasing the

contact load for a large number of the press-fit terminals **20**.
(69) When the radius of curvature r of the outward portion of the parallel portion **36** is equal to or smaller than the inner peripheral radius of the through hole **13**, the contact area between the press-fit portion **30** and the inner peripheral surface of the through hole **13** is large.
EMBODIMENT EXAMPLES
(70) In the present embodiment example, evaluation of insertion amount, holding force, and contact area of the press-fit terminal **20** described in the above embodiment will be described. The evaluation was derived by computer aided engineering (CAE) analysis using the finite element method.
(71) The press-fit terminal **20** was evaluated with different values of Ls/Le, G.sub.1/G.sub.2, and G (=G.sub.1+G.sub.2). The thickness of the press-fit terminal **20** is 0.4 mm, and the diameter ϕ of the through hole **13** is 0.55 mm.
(72) FIG. **7** shows evaluation results. As shown in the figure, in Embodiment Examples 1 and 2 in which Ls/Le is 0.57 or more and 0.65 or less and G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less, it can be understood that reduction in the insertion force may be compatible with increasing of the holding force and the contact area at high levels. For example, it can be understood that Embodiment Examples 1 and 2 can realized an insertion force of 63 N or less, a holding force of 20 N or more, and a contact area of 0.49 mm.sup.2 or more. In addition to this condition, even when G (=G.sub.1+G.sub.2) is 0.03 mm.sup.3 or more and 0.04 mm.sup.3 or less, reduction in the insertion force may be compatible with increasing of the holding force and the contact area at high levels. Furthermore, when G (=G.sub.1+G.sub.2) is 0.034 mm.sup.3 or more and 0.037 mm 3 or less, it can be estimated that reduction in the insertion force may be compatible with increasing of the holding force and the contact area at high levels.
(73) The configurations described in the above embodiments and modifications can be appropriately combined as long as they do not cause any contradiction.
DESCRIPTION OF REFERENCE SIGNS
(74) **12**: substrate **13**: through hole **13***f*: conductive layer **20**: press-fit terminal **22**: distal portion **22***a*: most distal portion **26**: proximal portion **30**: press-fit portion **31**: eyehole **34**: contact piece **35**: front spring portion **35***a*, **36***a*, **37***a*: outer edge **36**: parallel portion **36***f*, **136***f*: arc surface **37**: rear spring portion **50**: connector device **52**: case **53**: opening **54**: connector terminal portion **60**: connector **61**: connector housing A: first portion B: second portion TF: front reference plane TR: rear reference plane

Claims

1. A press-fit terminal that is press-fitted into a through hole formed in a substrate, the press-fit terminal comprising a press-fit portion including two contact pieces facing each other with an eyehole interposed therebetween, wherein: each of the two contact pieces includes a parallel portion, a front spring portion extending from the parallel portion in a direction in which the press-fit portion is inserted, and a rear spring portion extending from the parallel portion in a direction opposite to the direction in which the press-fit portion is inserted, the parallel portions being parallel to each other, a thickness of the press-fit portion is 0.3 mm or more and 0.5 mm or less, in the press-fit portion, when Le [mm] is a length of the eyehole and Ls [mm] is a length of the parallel portion, Ls/Le is 0.57 or more and 0.65 or less, and in the press-fit portion, when G.sub.1 [mm.sup.3] is a front spring strength and G.sub.2 [mm.sup.3] is a rear spring strength calculated under conditions defined below, G.sub.1/G.sub.2 is 0.55 or more and 1.45 or less: [Conditions] a direction in which the press-fit terminal is inserted is a forward direction, and a direction opposite to the direction in which the press-fit terminal is inserted is a rearward direction; a position at 0.1 mm in the rearward direction from a front end of the eyehole is a front reference, and a position at 0.1 mm in the forward direction from a rear end of the eyehole is a rear reference; assuming a front

reference plane extending from an inner edge of the front spring portion at the front reference and perpendicular to an outer edge of the front spring portion, second moment of area of the front spring portion in the front reference plane is I.sub.1 [mm.sup.4]; assuming a rear reference plane extending from an inner edge of the rear spring portion at the rear reference and perpendicular to an outer edge of the rear spring portion, second moment of area of the rear spring portion in the rear reference plane is I.sub.2 [mm.sup.4]; a length in the insertion direction of the press-fit portion from an end, on a side of the front spring portion, of a linear outer edge of the parallel portion to the front end of the eyehole is L.sub.1 [mm]; a length in the insertion direction of the press-fit portion from an end, on a side of the rear spring portion, of the linear outer edge of the parallel portion to the rear end of the eyehole is L.sub.2 [mm]; the front spring strength G.sub.1 is I.sub.1/L.sub.1 [mm.sup.3], and the rear spring strength G.sub.2 is I.sub.2/L.sub.2 [mm.sup.3].

2. The press-fit terminal according to claim 1, wherein when spring strength G [mm.sup.3] is G.sub.1+G.sub.2, G is 0.03 mm.sup.3 or more and 0.04 mm.sup.3 or less.

3. The press-fit terminal according to claim 1, wherein the outer edge of the front spring portion is inclined so as to be directed inward in a width direction of the press-fit portion toward a front side, and the outer edge of the rear spring portion is inclined so as to be directed inward in the width direction of the press-fit portion toward the rear side.

4. The press-fit terminal according to claim 1, wherein an outward portion of the parallel portion is formed in an arc shape in a view looking along the insertion direction.

5. A connector device comprising: a connector including the press-fit terminal according to claim 4; and a substrate in which a through hole is formed, wherein the press-fit portion of the press-fit terminal is press-fitted into the through hole, and a radius of curvature of the outward portion of the parallel portion is equal to or smaller than an inner peripheral radius of the through hole in a view looking along the insertion direction.