

METHOD FOR PRODUCING A RAIL FASTENING, METHOD FOR INCREASING
THE VIBRATIONAL RESISTANCE OF A TENSION SPRING FOR HOLDING
DOWN A TRACK BODY ELEMENT, AND RAIL FASTENING

5 The invention relates to a method of establishing a rail
fastening, in which a track body element, such as a rail foot
of a rail, is resiliently held down by at least one hold-down
section, such as a holding arm, of a tension spring in its
final assembly position, the tension spring consisting of a
10 tempered spring steel, comprising mounting the tension spring
on a base, wherein the tension spring is brought into a
tensioned state by means of a hold-down device, in which the
tension spring is tensioned starting from a relaxed state by
deflecting the hold-down section along a spring deflection
15 path.

Furthermore, the invention relates to a rail fastening device
comprising a tension spring made of tempered spring steel and
a hold-down device which can be fastened to a base, in
20 particular a sleeper, ribbed plate or angle guide plate,
adjacent to a track body element, against which hold-down
device the tension spring can be braced or is braced in a
final assembly position of the tension spring such that,
starting from a relaxed state, the tension spring with
25 deflection of at least one hold-down section of the tension
spring along a spring deflection path can be tensioned with
the hold-down section against the track body element, in
particular a rail foot of a rail, in order to hold it down
resiliently.

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Rails of a track body are usually assembled using a spring
element, usually referred to as a tension spring or tension
clamp, and a suitable tensioning element or hold-down device

to tension the spring element. This tensioning element or hold-down device is usually a screw by means of which the spring element is braced against the base in such a way that it applies the required holding forces via its section
5 resting on the rail foot. Tensioning can be achieved, for example, by connecting the hold-down device directly to the base that supports the rail and the fastening system, or by attaching the hold-down device to an additional component, such as a plate, which is then firmly coupled to the base in
10 question.

Widely used tension springs are those with the "e" shape and those with a "ω" shape. A tension spring with the "e" shape is described, for example, in EP 313325 B1. The "ω" form can
15 be found, for example, in DE 3243895 A1.

Numerous embodiments of fastening systems with tension springs are known, in which the tension spring can be brought not only into a precisely defined final assembly position
20 relative to the rail foot and to the anchoring parts, but also into a positionally secured pre-assembly position. To achieve the pre-assembly position, the tension spring is mounted in such a way that the section intended for holding down the rail foot does not rest on the rail. In this way,
25 railroad ties can already be provided in the factory with tension springs arranged in the pre-assembly position and pretensioned, whereby the tension springs can be brought into the final assembly position and tensioned at the construction site after the rail has been laid with a certain amount of
30 effort by lateral displacement, so that the section intended for holding down the rail foot engages over it and presses it down resiliently from above.

A disadvantage of prior art tension springs is the fact that they are designed for only one installation direction or type of installation. The direction of installation is understood to be the direction in which the tension spring, which is usually already pretensioned, is pushed onto the rail foot. Most frequently, tension springs are found that are designed for transverse installation, i.e. for pushing the tension spring transversely to the longitudinal direction of the rail. In longitudinal installation, on the other hand, the tension spring is brought into its final assembly position in the longitudinal direction of the rail. Due to the limited space available, installation in the longitudinal direction of the rails is advantageous, for example, for fastening the rails in the area of switches. Conventional tension springs are adapted to their specified installation direction, particularly with regard to the arrangement of areas of different stiffness, and therefore cannot be installed in a direction deviating from this without further ado, whereby a deviating installation direction is not even possible in most cases for geometric reasons alone.

Other problems of conventional tension springs are the occurrence of fractures and the loosening of the tension springs and the associated loss of clamping force. Loosening occurs in particular with tension springs that are clamped down with a screw.

Fractures often occur in tension springs when they are subjected to excessive stress. Conventional rail fastening systems are in very few cases equipped with overload protection. The purpose of overload protection is to limit the load acting on the tension spring, which is particularly effective if the rail is subject to a strong up and down

movement or a strong tilting movement relative to the sleeper when it is passed over.

Another reason for the occurrence of tension spring fractures is insufficient fatigue behaviour. In particular, it has been observed that fractures caused by the vibration load are subject to undesirable statistical scatter, so that tension spring fractures can occur despite being designed for fatigue strength. Finally, the vibration load also leads to a reduction in the clamping force of the tension clamp.

In order to achieve an increase in strength and a higher yield point, it has already become known to subject the tension clamps to cold working during the manufacturing process. Cold working is the plastic forming of metals below the recrystallisation temperature in order to increase the dislocation density. This is described in connection with tension clamps, for example in EP 2528702 A1, DE 2411195 A1 and US 9382667 B2.

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The present invention therefore aims to improve a fastening system and a method of establishing a rail fastening in such a way that the above-mentioned disadvantages can be overcome. In particular, a tension spring is to be created which comprises an increased fatigue strength and with which the decrease of the tension force can be reduced.

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To solve this task, the invention provides, according to a first aspect, a method of establishing a rail fastening, in which a track body element, such as a rail foot of a rail, is resiliently held down by at least a hold-down section, such as a holding arm, of a tension spring in its final assembly position, the tension spring consisting of a tempered spring

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steel, comprising mounting the tension spring on a base, wherein the tension spring is brought into a tensioned state by means of a hold-down device, in which, starting from a relaxed state, the tension spring is tensioned by deflecting the hold-down section along a spring deflection path, the method being characterised in that, during mounting, the hold-down section is deflected in the direction of the spring deflection path to such an extent that the tension spring is subjected to cold working in places, after which the tension spring is at least partially relaxed.

According to the invention, a tension spring made of tempered spring steel is therefore assumed, i.e. a steel that has been subjected to a combined heat treatment consisting of hardening and subsequent tempering. The tension spring comprises at least one hold-down section, such as one or two holding arms, with which the track body element is resiliently held down in the final assembly position. The spring force is applied by resilient deflection of the hold-down section, while the tension spring is held down in a held-down section by a hold-down device.

According to the invention, work hardening is now carried out in such a way that the at least one hold-down section is deflected during the assembly of the tension spring, for example in the pre-assembly position, during the displacement of the tension spring from the pre-assembly position to the final assembly position or in the final assembly position, to such an extent that the tension spring is deformed at at least one point beyond the elastic range, i.e. into the plastic range, and is thereby subjected to a cold deformation. It is essential here that the deflection of the hold-down section is in the direction of the spring

deflection path that it also experiences in operation, i.e. for holding down the track body element. This causes cold working at the point(s) of the tension spring that is/are subject to the highest load during operation, so that
5 precisely these point(s) are subject to the desired hardening, which is/are susceptible to breakage in continuous operation as a result of a continuous oscillating load. The fact that cold working takes place during the assembly of the tension spring creates a situation similar to operation,
10 which ensures deflection of the hold-down section in exactly the same direction in which it is subjected during operation. The time-consuming and usually inaccurate simulation of the operating or assembly situation in a manufacturing environment separate from the track can therefore be
15 dispensed with.

The point of maximum load is usually on the surface of the tension clamps, so that cold working takes place at least on the surface of the wire forming the tension spring.

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The resilient deflection of the hold-down section for the purpose of cold working refers here to a relative movement of the hold-down section relative to the held-down section of the tension spring, starting from the tensioned state of the
25 tension spring into the tensioned state. The deflection can take place by the hold-down section being deflected while the held-down section is not displaced in the direction of the deflection movement, e.g. is held in place by the hold-down device. Alternatively, the deflection can be achieved by
30 deflecting the held-down section while the hold-down section is not displaced in the direction of the deflection movement, e.g. is held in place by the base or the track body element. The deflection for the purpose of cold working can thus be

achieved, for example, by changing the distance measured in the direction of the spring deflection path between the base or the track body on the one hand and the hold-down device on the other. In this way, cold working can be carried out
5 easily during the assembly process of the tension spring.

Carrying out the cold working during the assembly of the tension spring preferably means that the cold working is carried out while the hold-down device clamps down the
10 tension spring and before a rail vehicle is driven over it for the first time.

According to the invention, the tension spring is at least partially relaxed after cold working. This ensures that the
15 working range of the tension spring is brought into a range below the plastic deformation for normal operation. This is intended to prevent the tension spring from undergoing cold working again during operation or from being subjected to oscillating loads up to the plastic limit. The partial
20 relaxation therefore means that the tension spring is used in the final assembly position in a less stressed state than during cold working.

According to a preferred embodiment of the invention, this
25 can be achieved in that the maximum spring deflection path of the hold-down section in the final assembly position of the tension spring is limited by an overload protection and in that the cold working is achieved by deflection of the hold-down section over a spring deflection path that is greater
30 than or equal to the maximum spring deflection path limited by the overload protection. The overload protection can be achieved, for example, by abutting the track body element against a section of the tension spring forming a stop or by

abutting the hold-down section against a stop of the hold-down device.

The invention is based on the realisation that the
5 probability of the tension spring breaking due to the
vibration load can be significantly reduced if the tension
spring is only loaded within the elastic deformation range at
each point after it has initial been cold worked, as defined
according to the invention. In particular, this can
10 significantly reduce the scattering of the probability of
fracture around the expected value.

In this context, the invention relates, according to a
second, independent aspect, to a method for improving the
15 fatigue behaviour of a tension spring for holding down a
track body element, such as, for example, a rail foot of a
rail, the tension spring consisting of a tempered spring
steel and having at least one hold-down section, such as, for
example a supporting arm, which is deflectable along a spring
20 deflection path, for resiliently holding down the track body
element, the method being characterised in that the tension
spring is provided for installation in a track in which the
maximum spring deflection path of the hold-down section is
limited by an overload protection in such a way that no
25 plastic deformation takes place at any point of the tension
spring within the maximum spring deflection path, the said
maximum spring deflection path is determined and the hold-
down section is deflected in the direction of the spring
deflection path beyond the maximum spring deflection path or
30 up to the maximum spring deflection path, so that the tension
spring is subjected to cold working.

A preferred design also provides for the hold-down section for cold working to be deflected to such an extent that a maximum principal normal stress corresponding to the 0.5% yield point, preferably the 1% yield point, is reached or exceeded at the point of the tension spring subject to the highest load. In tests, good results were achieved when the 0.5 % to 1.5 % yield point was reached, especially the 1 % yield point. An improvement over the state of the art was also observed when the 2% yield point was reached.

For normal operation, it is preferable that the tension spring does not exceed the said maximum principal normal stress, preferably 90% of the maximum principal normal stress, in particular 85% of the maximum principal normal stress, at any point after cold working when the maximum spring deflection path has been reached.

The principal normal stress can be determined by subjecting a material sample of the wire forming the tension spring to a tensile test and creating a stress-strain diagram from this. The principal normal stress can then be measured by attaching a tension sensor in or on the tension clamp at the point where the highest load will occur. Alternatively, the principal normal stress can be determined in suitable simulation programmes using finite element methods (FEM). For this purpose, the geometry of the tension clamp, the material properties and the boundary conditions (e.g. connection points, contact surfaces, etc.) are defined in the simulation programme. The forces or stresses generated by tensioning the clamp are then applied to the model as loads and the simulation programme performs a numerical analysis and calculates the resulting stresses and deformations at each point of the model. By comparing this with the stress-strain

diagram, the deflection of the hold-down section that corresponds to the desired yield point can now be determined.

As already mentioned, the cold working according to the invention can take place in the final assembly position of the tension spring, during the displacement of the tension spring from a pre-assembly position to the final assembly position or in a pre-assembly position. The pre-assembly position is defined here as a position of the tension spring in which the tension spring is held down on the base by the hold-down device, but preferably the hold-down section of the tension spring does not extend over the track body element.

Preferably, cold working takes place during the displacement of the tension spring from the pre-assembly position to the final assembly position with the tension spring held down in the tensioned state by the hold-down device by sliding of the hold-down section on a slide surface of the base that rises at least in sections in the displacement direction. The slope of the slide surface is dimensioned in such a way that the desired cold working is achieved at the point of the tension spring subject to the highest load.

In this context, it may also preferably be provided that, when the tension spring is moved from the pre-assembly position to the final assembly position, the hold-down section drops from the slide surface over a step onto the track body element in order to assume the final assembly position. This ensures that the tension spring is at least partially released after cold working, as provided for in the invention. At the same time, the step acts as a rear stop with which the hold-down section co-operates and which prevents it from leaving the final assembly position.

According to an alternative procedure, the hold-down device is formed by a fastening screw and the cold working is carried out in the pre-assembly position or the final

5 assembly position by holding down the tension spring by means of the fastening screw, whereupon the tension spring is at least partially released by turning back the fastening screw or by sliding over the step of a slide surface.

10 Alternatively, cold working in the pre-assembly position or the final assembly position can also be carried out using a separate tool. A simple embodiment comprises a laterally extractable spacer that can be inserted between the track body element and the hold-down section in the final assembly
15 position, for example, when the tension spring is tensioned, or a temporarily adjustable raised slide surface for the hold-down section for displacement from a pre-assembly position to a final assembly position.

20 In principle, any suitable embodiments of tension springs comprising at least one resiliently deflectable hold-down section, such as, for example, a holding arm, can be used within the scope of the invention. In a particularly preferred embodiment, it is provided that the tension spring
25 comprises a U-shaped main section, which comprises a U-bend, a first leg arranged on one side of the U-bend and a second leg arranged on the other side of the U-bend, wherein a hook-shaped inwardly bent holding section, which can be braced against the hold-down device (12, 25) is formed on the first
30 leg (3) and on the second leg the hold-down section is formed as an end section of the second leg which is bent towards or away from the holding section, the U-bend forming a torsion

section so that a holding-down force can be applied to the track body element via the bent end section.

According to a third aspect, the invention relates to a rail fastening device comprising a tension spring made of tempered spring steel and a hold-down device which can be fastened on a base, in particular a sleeper, ribbed plate or angle guide plate, adjacent to a track body element, against which hold-down device the tension spring can be braced or is braced in a final assembly position of the tension spring such that, starting from a relaxed state, the tension spring with deflection of at least one hold-down section of the tension spring along a spring deflection path can be tensioned with the hold-down section against the track body element, in particular a rail foot of a rail, in order to hold it down resiliently, characterised in that the tension spring is cold-worked or can be cold-worked during assembly by deflection of the hold-down section in the direction of the spring deflection path and is at least partially relieved in the final assembly position with respect to said deflection.

In particular, the tension spring of the rail fastening system according to the invention is a tension spring whose fatigue behaviour has been improved by means of a method according to the second aspect of the invention before assembly or is increased during assembly. It is therefore a tension spring that has been tuned in such a way that it does not leave the elastic deformation range in the operating state and has previously only been brought into the plastic range once by overstressing, as a result of which cold working has taken place.

In particular, the maximum spring deflection path of the hold-down section in the final assembly position of the tension spring is limited by an overload protection and the cold working is performed by deflection of the hold-down section over a spring deflection path that is greater than or equal to the maximum spring deflection path limited by the overload protection.

As already described in connection with the method according to the first aspect of the invention, a preferred embodiment provides that the hold-down section for cold working is deflected to such an extent that a maximum principal normal stress corresponding to the 0.5 % yield point, preferably the 1 % yield point, is reached or exceeded at the most highly loaded point of the tension spring.

Preferably, the tension spring does not exceed the maximum principal normal stress at any point after cold working when the maximum spring deflection path is reached, preferably 90% of the maximum principal normal stress, in particular 85% of the maximum principal normal stress.

Cold working is preferably carried out at least on the surface of the wire forming the tension spring.

Preferably, the hold-down section is deflectable for cold working by clamping down the tension spring by means of the hold-down device.

Preferably, the tension spring can be attached to the base in a pre-assembly position in which the hold-down section does not overlap the track body element.

Preferably, the base comprises a slide surface that rises at least in sections, on which the hold-down section slides when the tension spring is held down in the tensioned state by the hold-down device during the displacement of the tension
5 spring from the pre-assembly position to the final assembly position, whereby the hold-down section can be deflected and/or partially relieved for cold working.

Preferably, the base forms a step at the end of the slide
10 surface, over which the hold-down section drops onto the track body element when the tension spring is displaced from the pre-assembly position to the final assembly position in order to assume the final assembly position.

15 Preferably, the tension spring comprises a U-shaped main section which comprises a U-bend, a first leg arranged on one side of the U-bend and a second leg arranged on the other side of the U-bend, wherein a hook-shaped inwardly bent holding section, which can be braced against the hold-down
20 device (12, 25) is formed on the first leg (3) and on the second leg the hold-down section is formed as an end section of the second leg which is bent towards or away from the holding section, the U-bend forming a torsion section so that a hold-down force can be applied to the track body element
25 via the bent end section.

Preferably, the hold-down device forms or develops a tunnel-shaped recess into which the holding section of the tension spring can be at least partially inserted.

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In the following, further preferred embodiments of the tension spring and the rail fastening device that can be used

in the context of the aspects of the invention explained above are described.

As already mentioned, the tension spring preferably comprises
5 a U-shaped main section having a U-bend, a first leg arranged on one side of the U-bend and a second leg arranged on the other side of the U-bend, wherein a hook-shaped inwardly bent holding section which can be braced against a hold-down
10 device is formed on the first leg and an end section bent towards or away from the holding section is formed on the second leg, the U-bend forming a torsion section so that a holding-down force can be applied to the track body element via the bent end section.

15 The fact that the tension spring, starting from the basic shape of a "U", has a hook-shaped holding section on the first leg of the U-shape and an end section bent towards or away from the holding section on the other leg of the U-shape achieves an asymmetrical shape which is easy to manufacture
20 and which permits installation in both the transverse and longitudinal directions. In both longitudinal and transverse installation, the bent end section forms the portion of the tension spring through which the hold-down force is applied to the track body element or rail foot.

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The design of the tension spring is similar to that of the "e" shape known from the prior art, with the difference that the end section of the "e" shape has an additional bend. This bend can be towards or away from the holding section of the
30 tension spring. Preferably, the bend runs towards the holding section of the tension spring. According to a preferred embodiment, it is provided here that the bent end section extends at an angle of 80-100°, preferably approximately 90°,

to the second leg, this applying both to the design with an end section bent towards the holding section of the tension spring and to the design with an end section bent away from the holding section. The advantages of the bent end section become apparent in both longitudinal and transverse installation in conjunction with the hold-down device, as will be explained in more detail below.

In some embodiments of the invention, the U-shape formed by the U-bend, the first leg and the second leg also includes configurations in which the first leg is reduced to a minimum so that the U-bend merges, as it were, directly into the holding section. However, in other embodiments, the first leg has a certain length, such as a length substantially corresponding to the second leg, and is particularly straight.

The hook-shaped holding section extending from the first leg of the U-shape is used to be held under tension by a hold-down device when a torsional force is applied from the bent end section to the torsion section formed by the U-bend of the tension spring. In this case, the hook-shaped holding section is bent inwards, which is to be understood as the hook being bent into the space between the two legs of the U-shape. Preferably, the hook-shaped holding section on the side of the first leg forms the end of the tension spring, i.e. that the free end of the section bent over into a hook lies between the two legs of the U-shape.

In this regard, a preferred embodiment provides that the holding section includes a free end portion connected to the first leg by a hook bend and disposed between the first leg and the second leg.

According to a preferred further embodiment of the invention, a hook bend of the holding section has a substantially 180° bend so that a free end portion of the holding section is substantially parallel to the first leg at least in sections. The expression "substantially 180° " means that the angle is 180° , but it can also be between 175° and 185° .

The hold-down force is provided at least in part by a torsional load on the torsion section formed by the U-bend of the tension spring, with a corresponding resilient deflection of the second leg extending from the U-bend to the bent end section. While the second leg thus forms a deflectable spring arm, the remaining part of the tension spring, on the other hand, can be as flat as possible in order to minimize the overall height of the tension spring and the material consumption for the tension spring.

In this context, a preferred design provides that the first leg and the free end portion of the holding section provide a planar bearing surface in the unloaded state. The planar bearing surface can serve, for example, as a support for the hold-down device, whereby the planar state refers to the unloaded state of the tension spring, since slight twisting of the holding section can occur during tensioning of the tension spring.

In the unloaded state, the first leg and the free end portion of the holding section can lie with their respective center axes, preferably over their entire extent, in a center plane that is preferably parallel to the planar bearing surface. For example, in the case of a circular cross-section, the

centerline of the corresponding sections is the centerline or axis passing through the center of the circle.

However, it may also be provided that the first leg and the holding section lie in the same plane in the unloaded state or have their respective center axes in the center plane. This also provides a planar bearing surface and precludes portions of the first leg and holding section, including the hook bend, from being bent out of said plane.

The design of the U-bend of the tension spring can also contribute to achieving the flattest possible construction, in that preferably the free end portion of the holding section, viewed in the direction of a longitudinal extension of the free end portion, covers the U-bend at least partially, preferably completely.

However, to ensure adequate spring deflection, the bent end section of the tension spring may be deflected out of said plane when unloaded. In this context, a preferred design provides for the bent end section to be at a normal distance from the center plane or the planar bearing surface in the unloaded state.

If the entire holding section including the hook bend and the first leg lie in the same plane, this means with regard to the overall height of the tension spring that the hook bend and the bent end section in the unloaded state define the maximum overall height of the tension spring measured normal to the center plane or to the planar bearing surface. This enables an extremely flat design of the tension spring.

In particular, the overall height of the tension spring in the unloaded state can correspond to 1.5 to 3 times the diameter of the wire forming the tension spring in the holding section.

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Preferably, an imaginary extension of the bent end section overlaps the hook bend in a plan view. This means that the imaginary extension of the bent end section at least partially overlaps the hook bend in the top view of the tension spring. For the transverse installation of the tension spring, this means that the hook bend comes to lie above the rail foot in the final assembly position and can form an overload protection.

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In the conventional manner, the tension spring consists of a spring rod and can therefore be manufactured in one piece from a corresponding starting product. This is produced by bending an originally straight spring rod several times. If, as is preferably provided, the hook-shaped holding section, the U-bend and the bent end section are all bent in the same direction, the tension spring can be produced in three bending steps. In the first step, the bending of the hook-shaped holding section is made, in the second step the U-bend is made, and in the third step the bent end section is made.

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The three bending steps can also be performed circumferentially in one operation if all three bends are performed in the same direction of rotation. The above bends can all be made in the same plane, or deflection of individual portions from the common plane can be made simultaneously with the bends.

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The cross-section of the tension spring is preferably circular, although other cross-sectional shapes are also conceivable, such as oval, elliptical or the like.

5 Due to the relatively simple geometry of the tension spring according to the invention, its mechanical properties can be adapted to the respective requirements in a simple manner by varying certain geometric parameters, while retaining the basic shape. For example, the length of the second leg of the
10 U-shape and thus the length of the lever arm acting on the torsion section determines the stiffness of the tension spring. With the choice of the thickness of the spring rod, the tension, the clamping force and the stiffness can be controlled. The radius of the U-bend also controls the
15 tension and stiffness of the tension spring.

In order to be able to exert a holding-down force on the rail foot via the bent end section by holding-down the holding section by means of the hold-down device and the resulting
20 torsional loading of the torsion section of the tension spring, it is preferably provided that the second leg in the unloaded state has a normal distance from the center plane or from the planar bearing surface which increases continuously in the direction of the bent end section.

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In particular, this means that the second leg in the unloaded state is inclined at an acute angle relative to the center plane or the planar bearing surface. The acute angle can be between 5° and 20° . The tightening of the tension spring
30 leads to a bending of the tension spring in such a way that the aforementioned acute angle is reduced from the unloaded state and is, for example, only 0° - 5° in the tightened state. This angle may be reduced to 5 - 10° in the case of fastening

systems with lower hold-down force. In this tensioned state, a torsional moment acts on the torsion section of the tension spring, in particular about an axis normal to the axis of the first leg and forming a tangent to the U-bend.

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The hold-down force acting on the rail foot from the bent end section and the corresponding counterforce acting on the holding section of the tension spring from the hold-down device form a pair of forces that additionally also stress
10 the torsion section to bend about an axis perpendicular to the axis of the torsional moment, resulting in a corresponding bending about this axis. Due to this bending, the bent end section of the tension spring has a different angle to the support plane at the rail foot in the unloaded
15 state than in the loaded state. In accordance with a preferred embodiment of the invention, in order for the bent end section to be oriented substantially horizontally when loaded to provide a corresponding bearing surface on the rail foot, the bent end section is provided with a bearing surface
20 for bearing on the track body element which, when unloaded, extends upwardly at an acute angle relative to the center plane or planar bearing surface. The angle between the bent end section and said plane may preferably be 2° - 8° , in particular 5° - 7° . The angle decreases under load due to the
25 above-mentioned bending moment and is preferably 0° - 1° in the loaded state.

When the invention refers to an angle between two sections of the tension spring or to a plane in which the sections lie,
30 this refers to the centerline of the corresponding sections, i.e., in the case of a circular cross-section, to the centerline or axis passing through the center of the circle.

The tension spring according to the invention is designed to be usable with various types of hold-down devices.

In a first installation variant, the holding section of the tension spring can be inserted transversely to the longitudinal direction of the rail into a tunnel-shaped recess of the hold-down device towards the rail, so that the hook bend preferably extends over the rail foot in a final assembly position of the tension spring.

In a second installation variant, the holding section of the tension spring can be inserted parallel to the longitudinal direction of the rail into a tunnel-shaped recess of the hold-down device so that the second leg preferably overlaps the rail foot.

In terms of design, the first and second installation variants can preferably be realized in that a gap is arranged between the bent end section and the free end portion of the holding section on the side of the free end portion facing the second leg, as seen in a longitudinal extension of the free end portion and in a plan view, i.e. in a normal projection onto the center plane or the planar bearing surface.

In a further installation variant, a free space can be provided between the first leg and the free end portion of the holding section, which free space can be penetrated by a screw shank of a fastening screw forming the hold-down device and in which free space the fastening screw can be displaced in the longitudinal direction of the first leg, the screw shank of the fastening screw having a diameter which is greater than the diameter of a wire forming the tension

spring in the holding section, and preferably the inner radius of the hook bend being greater than or equal to the radius of the screw shank. The aforementioned displaceability allows the tension spring to be moved from a pre-assembly
5 position to a final assembly position and back when held down by the fastening screw. If the inner radius of the hook bend is greater than or equal to the radius of the screw shaft, a maximum displacement is provided.

10 Overall, a compact, low-profile tension spring that can be used flexibly and can also be manufactured inexpensively due to the low material requirements, is provided. Preferably, it is provided here that the tension spring, in a plan view, in particular in a normal projection onto the center plane or
15 the planar bearing surface, lies within a minimally surrounding rectangle which has an aspect ratio of 1:1.5-1:1, preferably 1:1.1-1:1.

According to a further preferred embodiment, the diameter of
20 the wire forming the tension spring is at least $1/7$, preferably at least $1/6$, of the shorter side of a rectangle minimally surrounding the tension spring in a plan view.

In particular, the bent end section is located within a
25 square corner area of a rectangle minimally surrounding the tension spring in a plan view, which has at most $1/9$ of the area of the surrounding rectangle.

With regard to the rail fastening device, a further
30 development provides that this comprises a tension spring according to one of the embodiments described above and a hold-down device which can be fastened adjacent to a rail on a base, in particular a sleeper, ribbed plate or angle guide

plate, on which the holding section is supported in the mounted state of the tension spring in such a way that the bent end section can be spring-loaded to hold down a track body element, in particular a rail foot of the rail.

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In this case, it is preferable that the hold-down device not only engages over the free end area of the holding section when the tension spring is mounted, but also at least partially over the first leg.

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The tension spring can be clamped down without a screw or by means of a screw. For the realization of the screwless alternative, a preferred design provides that the hold-down device has or forms a tunnel-shaped recess into which the holding section of the tension spring can be at least partially inserted.

15

Depending on whether the tension spring is to be installed transverse to the longitudinal direction of the rail or in the longitudinal direction of the rail, the holding section of the tension spring can be inserted into the tunnel-shaped recess transverse to the longitudinal direction of the rail or parallel to the longitudinal direction of the rail.

20

In a design with a tension spring that can be inserted transversely to the longitudinal direction of the rail, the tunnel-shaped recess is preferably open on the side facing the track body element, in particular the rail foot, and the hook bend protrudes from the tunnel-shaped recess in the final assembled state of the tension spring and engages over the track body element, in particular the rail foot. In this way, the hook bend forms an overload protection in its state projecting beyond the track body element. For this purpose,

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the hook bend is arranged in such a way that there is a vertical distance between the track body element to be held down, in particular the rail foot, and the hook bend of the tension spring. Upward movements of the track body element that are within the vertical distance are resiliently absorbed by the bent end section of the tension spring. However, should excessive upward movement occur, the track body element to be held down will butt against the hook bend and thus be prevented from rising further without overloading the tension spring within its allowable travel.

In the variant with a tension spring that can be inserted transversely to the longitudinal direction of the rail, a pre-assembly position of the tension spring can be realized in a simple manner by initially inserting the tension spring only to the extent that it is securely received in the tunnel-shaped recess, but that the hook bend does not yet protrude from the tunnel-shaped recess on the side facing the track body element to be held down and the bent end section does not yet come to rest on the track body element. Only for assuming the final assembly position is the tension spring driven further in the direction of the track body element until the bent end section presses on the track body element from above.

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In both the variant with a tension spring that can be inserted transversely to the longitudinal direction of the rail and the variant with a tension spring that can be inserted in the longitudinal direction of the rail, it is preferable for the hold-down device to have a ramp that rises in the insertion direction and on which the bent end section rests in a sliding manner during insertion. This causes the

bent end section to become increasingly preloaded during insertion.

Particularly preferably, the ramp has a first rising ramp
5 portion and a second rising ramp portion and an intermediate
portion therebetween on which the bent end section rests in a
pre-assembly position of the tension spring. For example, the
intermediate portion may have a recess into which the bent
end section of the tension spring can engage to remain in the
10 pre-assembly position.

In this connection, a preferred further development provides
that a step is formed at the end of the ramp, via which the
bent end section reaches the final assembly position, in
15 which the end section rests on the track body element, in
particular the rail foot, the step forming a rear stop which
secures the end section against leaving the final assembly
position.

20 In the variant with a tension spring that can be pushed in in
the longitudinal direction of the rail, overload protection
can be achieved by the hold-down device having a stop that
overlaps the bent end section at a distance when the tension
spring is mounted. Such a stop has the effect of limiting the
25 rise of the bent end section.

The fastening system can also be used in the area of a switch
for fixing stock rails, whereby the hold-down device on the
side of the stock rail facing the tongue rail can be combined
30 or connected with a slide chair, preferably in such a way
that the hold-down device forms at least part of the slide
surface for the tongue rail. In this context, a preferred
embodiment provides that the fastening system comprises a

slide chair associated with the stock rail and having a slide surface for a tongue rail, the hold-down device having a further slide surface preferably flush with the slide surface. Alternatively, the upper surface of the hold-down device can also be arranged lower than the slide surface of the slide chair.

Preferably, the further slide surface is extended in the same way as the slide chair itself in the direction of the stock rail in such a way that the further slide surface overlaps the rail foot of the stock rail at a distance.

Preferably, the hold-down device associated with the slide chair and the hold-down device disposed on the opposite side of the stock rail may be integrally formed with a slide chair plate.

As already mentioned, one advantage of the tension spring is its universal applicability. Thus, as already mentioned, the tension spring can be fastened not only without screws, but also with a sleeper screw. In this context, the fastening system according to the invention is preferably designed in such a way that the hold-down device is formed by a fastening screw which can be screwed into the base, in particular a sleeper or plate, or by a hooked bolt with nut which is suspended in the base, in particular a ribbed plate, the screw shank and/or thread of which passes through a free space between the first leg and the free end portion of the holding section of the tension spring in order to hold down the tension spring in the region of the holding section and, if appropriate, of the first leg.

A pre-assembly position is also possible in a simple way with this type of fastening. This can be done in such a way that the tension spring is first screwed down in the pre-assembly position. The rail is then inserted, whereupon the tension
5 spring is brought into the final assembly position in the screwed-down state. For this purpose, it is no longer necessary to loosen the screw after inserting the rail and tighten it to final tightening torque after pushing the tension spring into the final assembly position, because the
10 tension spring, even with a screw tightened to final tightening torque in the pre-assembly position, can be easily displaced from the pre-assembly position to the final assembly position with a hand or machine tool.

15 In order to ensure that the tension spring remains displaceable between the pre-assembly position and the final assembly position in the screwed-down state, a preferred embodiment of the invention provides that a stop limiting the screw-in depth of the hold-down device and preferably
20 cooperating with the screw head or the nut of the fastening screw is arranged on the base and/or on the hold-down device, so that a hold-down force on the tension spring can be limited. The stop thus serves to define the screwed-down state of the tension spring or the tightened state of the
25 screw in such a way that the tension spring remains movable between the pre-assembly and the final assembly positions. Preferably, the stop defines a minimum vertical distance between the hold-down device and the base which is equal to or greater than the unloaded diameter of the wire forming the
30 tension spring in the region of the hold-down device, the vertical distance preferably being no more than 1.2 times the wire diameter.

A deviation of the final tightening torque or the clamping force of the screw achieved with the final tightening torque does not have any further negative effect on the desired tension state of the tension spring once it has been

5 tensioned against the stop. This means that in the final assembly position, there is no need to check the distances between the tension spring and the rail foot, as is required, for example, with some common fastening systems with tension springs.

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The stop can also preferably compensate for a predominantly one-sided load on the screw, in that the stop provides the screw with at least one contact point via which, when the screw or nut is tightened to the final tightening torque, a

15 force acts on the screw that at least partially compensates for the one-sided load on the screw.

Different variants are possible for displacing the tension spring from the pre-assembly to the final assembly position.

20 In particular, the tension spring with its bent end section can be rotated or displaced transversely to the longitudinal direction of the rail between the pre-assembly position and the final assembly position when the hold-down device is tightened, i.e. in particular in the tension state defined by

25 the stop described above.

Preferably, the base is designed in the area of the contact surface swept by the tension spring during displacement in such a way that when the tension spring is displaced on the

30 base from the pre-assembly position to the final assembly position along the displacement path, no or only gradual increases in the pretension of the tension spring occur, so that when the tension spring is displaced, damaging stress,

especially due to shear, is ruled out for all components subjected to stress in the process. For this purpose, a possible design of a base on the contact surfaces swept by the tension spring on the base during displacement is free of
5 grooves and indentations transverse to the displacement direction of the tension clamp.

In order to prevent automatic or unintentional displacement of the tension spring from the final assembly position to the
10 pre-assembly position, it is preferably provided that the base forms a step which slopes in the displacement direction of the tension spring and from which the bent end section descends onto the rail foot when the tension spring is displaced from the pre-assembly position to the final
15 assembly position. The step thus forms a rear stop for the bent end section, preventing it from leaving the final assembly position.

In the pre-assembly position, the tension spring is
20 advantageously arranged on the base in such a way that the insertion of a rail between pre-assembled tension springs is not hindered. This means that sleepers can be fitted with preassembled tension springs before the rails are laid, so that after the rails have been laid the tension springs only
25 need to be moved to the final assembly position using a suitable tool. This is preferably achieved by the base having a lateral contact surface for the rail foot and the hold-down device or fastening screw being arranged in such a way that the tension spring does not project beyond the contact
30 surface in the pre-assembly position.

In particular, the distance between the screw shank and the lateral contact surface can be equal to or greater than the diameter of the wire forming the tension spring.

- 5 For safety reasons, it should be ensured that there is no unintentional loosening of the fastening screw when moving the tension spring from the pre-assembly position to the final assembly position. For this purpose, the circumstance can be exploited that the asymmetrical tension spring
- 10 according to the invention is tensioned in the tensioned state towards the screw head or nut predominantly on one side of the screw, while on the other side of the screw it is supported on the base.
- 15 If the direction of rotation of the screw thread and the installation position or asymmetry of the tension spring are matched, a shift of the tension spring from the pre-assembly position to the final assembly position results in the screw being loaded in the sense of the screw being tightened. In
- 20 other words, it is provided that the fastening screw or the nut of the hook bolt predominantly holds down the free end portion of the holding section of the tension spring and the first leg of the tension spring is supported on the base and that the tightening direction of rotation of the thread of
- 25 the fastening screw or of the hook bolt is designed in such a way that the free end portion of the holding section directly or indirectly applies a torque in the tightening direction of rotation to the fastening screw or the nut of the hook bolt when the tension spring is displaced transversely with
- 30 respect to the longitudinal direction of the rail from the pre-assembly position into the final assembly position.

For a fastening system with a tension spring that can be rotated between a pre-assembly position and a final assembly position, it is envisaged that the rotation from the pre-assembly position to the final assembly position takes place in the tightening direction of rotation of the fastening screw or the nut of the hook bolt, so that the latter is thereby indirectly or directly subjected to a torque in the fixed direction of rotation.

The invention is explained in more detail below with reference to schematic examples of embodiments shown in the drawing. Therein, Fig. 1 shows a perspective view of a tension spring that can be used within the scope of the invention, Fig. 2 a top view of the tension spring according to Fig. 1, Fig. 3 a view according to arrow III of Fig. 2, Fig. 4 a view according to arrow IV of Fig. 2, Fig. 5 a first design of a rail fastening device using the tension spring according to Fig. 1, Fig. 6 a detailed view of Fig. 5, Fig. 7 a second design of a rail fastening device using the tension spring according to Fig. 1, Fig. 8 a detailed view of Fig. 7, Fig. 9 a hold-down device according to Figs. 7 and 8 in a perspective view, Fig. 10 a side view of the hold-down device according to Fig. 9, Fig. 11 a third design of a rail fastening device using the tension spring according to Fig. 1, Fig. 12 a modified design of the rail fastening device of Fig. 11, Fig. 13 a fourth design of a rail fastening device using the tension spring according to Fig. 1, Fig. 14 a design according to Fig. 12 with a modified angle guide plate, Fig. 15 a view of the angle guide plate according to Fig. 14, Fig. 16 a front view of the angle guide plate according to Fig. 14, Fig. 17 a bottom view of the angle guide plate according to Fig. 14 in an exploded view, Fig. 19 the rail fastener according to Fig. 12 in a final assembly

position, Fig. 18 the rail fastening device according to Fig. 12 in a pre-assembly position, Fig. 21 a cross-sectional view of the rail fastening device according to Fig. 19, Fig. 20 a cross-sectional view of the rail fastening device according to Fig. 18, Fig. 22 an alternative design of the rail fastening in a pre-assembly position, Fig. 23 the rail fastening device according to Fig. 22 in a final assembly position, Fig. 24 a cross-sectional view of the rail fastening device according to Fig. 22, Fig. 25 a cross-sectional view of the rail fastening device according to Fig. 23, Fig. 26 a perspective view of the angle guide plate used in the rail fastening device according to Figs. 22-25, Fig. 27 another cross-sectional view of the rail fastening device according to Fig. 19 and Fig. 28 the cold deformation of the tension spring using a stress-strain diagram.

Fig. 1 shows the tension spring 1, comprising a U-shaped main section which has a U-bend 2, a first leg 3 arranged on one side of the U-bend 2 and a second leg 4 arranged on the other side of the U-bend 2, a holding section 5 which is bent inwards in the form of a hook and can be braced against a hold-down device being formed on the first leg 3, and an end section 6 which is bent towards or away from the holding section 5 being formed on the second leg 4. The bent end section 6 forms a hold-down section for holding down the rail foot of a rail. The holding section 5 includes a free end portion 7.

In Fig. 2, it can be seen that a gap x is arranged between the bent end section 6 and the free end portion 7 of the holding section 5, as seen in a plan view, on the side of the free end portion 7 facing the second leg 4. The gap allows the holding section of the tension spring 1 to be inserted,

hook bend first, into a tunnel-shaped recess in the hold-down device (see Fig. 5-8).

In Figs. 3 and 4, it can be seen that the first leg 3 and the holding section 5, including the free end portion 7, lie in the same plane so that they form a planar bearing surface a. Since the tension spring 1 is bent from a wire with a circular cross-section, this also means that the center axis of said sections lie in a common center plane b. In the unloaded state, it is further provided that the free end portion 7 of the holding section 5 completely covers the U-bend 2 as viewed in the direction of a longitudinal extension of the free end portion 7 (Fig. 3). In other words, starting from the first leg 3, the U-bend also lies in the same plane as the first leg 3 and the holding section 5, including the free end portion 7, at least until said overlap with the free end portion 7.

However, in the further course of the U-bend 2, i.e. in the direction towards the second leg 4, the U-bend 2 is bent downwards out of the plane a or b, so that the normal distance of the second leg 4 from the plane a or b increases up to the bent end section 6. In Fig. 4 it can be seen that the second leg 4 with its center axis c encloses an acute angle β with the plane a or b of the holding section 5 and the first leg 3. This gives the bent end section 6 the spring deflection required for resiliently holding down the track body element or rail foot. The direction of the spring deflection path is labelled with the arrow z in Fig. 4. This is the direction in which the bent end section 6 is deflected to such an extent that cold working takes place at the point with the highest load on the tension spring, which increases the fatigue strength of the tension spring.

In Fig. 3 it is further shown that the bent end section 6 has a bearing surface d for bearing on the track body element, which in the unloaded state is inclined slightly upwards as seen in the direction of the arrow III, so that there is an acute angle α between the bent end section 6 or the bearing surface d and the plane a or b of the holding section 5 and the first leg 3.

Fig. 5 shows a rail 8 fixed to a sleeper 11 with the interposition of a plate 10 arranged on a base plate 9. The fastening is made on each side of the rail 8 by means of a tension spring 1 as shown in Fig. 1, which is inserted into a tunnel-shaped recess 13 of a hold-down device 12. In the final assembly position of the tension spring 1 shown in Fig. 5, the spring presses with its bent end section 6 on the rail foot 16 of the rail 8, with the optional interposition of an insulator. The hold-down device 12 is suitably attached to the plate 10. For example, the plate 10 and the hold-down device 12 are made in one piece and are bolted to the sleeper 11. Alternatively, an anchor may be formed on the underside of the plate 10, which is concreted into the sleeper 11 when it is cast from concrete.

Fig. 6 is an enlarged view of the tension spring 1 inserted in the tunnel-shaped recess 13. It can be seen that the tension spring has been inserted into the tunnel-shaped recess 13 with its holding section 5 in the direction of the arrow 14, i.e. in the longitudinal direction of the rail, so that the bent end section 6 rests on the rail foot 16. During insertion in the direction of arrow 14 from the pre-assembly position not shown to the final assembly position shown in Figure 6, the bent end section 6 slides on a ramp 17 rising

in the direction of insertion 14 until it falls over a step formed at the end of the ramp 17 onto the rail foot 16. On the side of the hold-down device 12 facing the rail foot 16, a stop 18 is also formed which overlaps the bent end section 6 at a distance and acts together with the end section 6 as an overload protection device.

The ramp 17 is designed in such a way that the bent end section 6 is deflected at the highest point of the ramp 17 to such an extent that the tension spring 1 reaches the plastically deformed area at least at its most heavily loaded point and is thus subjected to cold working. When it falls onto the rail foot 16, the tension spring 1 is partially released. The above-mentioned overload protection limits the spring deflection path of the bent end section 6 during operation in such a way that plastic deformation no longer occurs at any point on the tension spring 1.

Figs. 7 and 8 show an alternative design of the rail fastening device in which the tension spring 1 is inserted into the tunnel-shaped recess 13 (see Fig. 9) of the hold-down device 12 transversely to the longitudinal direction of the rail, i.e. in the direction of arrow 14. As it is pushed in the direction of arrow 14, the bent end section 6 again slides along the ramp 17 formed on the outside of the hold-down device 12 until the bent end section 6 drops down onto the rail foot 16 over a step 19 formed at the end of ramp 17. An insulator 15 can be arranged between the tension spring 1 and the rail foot. In the final assembly position shown in Fig. 8, the holding section 5 emerges from the tunnel-shaped recess 13 on the side facing the rail 8 and forms a stop overlapping the rail foot 16 with optional insulator 15 at a distance, which forms an overload protection.

The ramp 17 is designed in such a way that the bent end section 6 is deflected at the highest point of the ramp 17 to such an extent that the tension spring 1 reaches the
5 plastically deformed area at least at its most heavily loaded point and is thus subjected to cold working. When it falls onto the rail foot 16, the tension spring 1 is partially released. The above-mentioned overload protection limits the spring deflection path of the bent end section 6 during
10 operation in such a way that plastic deformation no longer occurs at any point of the tension spring 1.

The hold-down device 12 used in Figs. 7 and 8 is shown in more detail in Figs. 9 and 10, where it can be seen in
15 particular that the ramp 17 consists of three sections following one another in the insertion direction 14. The ramp 17 comprises a first rising ramp portion 20 and a second rising ramp portion 22 and an intermediate portion 21 without slope lying therebetween, on which the bent end section 6 of
20 the tension spring 1 rests in a pre-assembly position. Furthermore, Figs. 9 and 10 show an anchor 31 with which the hold-down device can be concreted or cast into a concrete sleeper 11 or, for example, plastic sleeper 11.

25 Fig. 11 shows a modified design in which the tension spring 1 is tensioned by a hold-down device in the form of a fastening screw 25. The fastening screw 25 is hooked to the rib 24 as a hook bolt or screwed into the sleeper 11 in such a way that its screw shank or thread passes through a free space between
30 the first leg 3 and the free end portion 7 of the holding section 5 of the tension spring 1. The free space between the first leg 3 and the free end portion 7 of the holding section 5 is slot-shaped in this case, so that the tension spring 1

can be moved between a pre-assembly position and the final assembly position shown in Fig. 12. In the illustrated embodiment, the rail base 10 is in the form of a ribbed plate, the ribs 24 of which define the position of the rail foot 16 of the rail 8 on the sleeper 11.

In the modified design shown in Fig. 12, the fastening system comprises an angle guide plate 26 on each side of the rail 8, which engages in a groove 27 of the sleeper 11 with a rib formed on the underside.

Fig. 13 shows the use of a rail fastening device according to the invention in the area of a switch, which has a stock rail 8 and a tongue rail 28 that can be displaced between a remote and a contact position. In this case, the tongue rail 28 slides with its rail foot on a slide chair 29, the hold-down device 12 having on its upper side a further slide surface flush with the slide surface of the slide chair 29. The hold-down devices 12 arranged on both sides of the stock rail 8 can be formed in one piece with a base plate 30.

The design according to Fig. 14 corresponds essentially to the design according to Fig. 12, but the angle guide plate 26 has a two-part design. As shown in Figs. 15 and 17, the angle guide plate 26 comprises a first part 32 facing away from the rail and a second part 33 facing toward the rail. The first part 32 carries a rib 34 which engages the groove 27 when installed, the rib 34 preferably having a trapezoidal cross-section and having at least one guide surface 38. The first and second parts 32,33 are movable relative to each other along guide surfaces 38,39 (Fig. 17) which are inclined relative to the longitudinal direction of the rail, thereby enabling adaptation to the respective track gauge. The second

part 33 further comprises a plate-shaped support element 41 on which the tension spring 1 rests and which overlaps the upper surface of the first part 32. As can be seen in Fig. 17, the plate-shaped support element 41 has at least one oblique guide groove 40 on its underside, in which guide pins or the like (not shown) formed on the upper side of the first part 32 engage in order to hold the two parts 32,33 together, particularly in the unloaded state. Furthermore, it can be seen that the second part 33, in particular the plate-shaped support element 41, has a through hole 35 through which the screw 25 passes in the assembled state of the tension spring 1. The through hole 35 is formed as an oblong hole perpendicular to the longitudinal direction of the rail. For lateral guidance of the tension spring 1, the second part 33, in particular the plate-shaped support element 41, has two walls 37 which run in the insertion direction 14 of the tension spring 1. The tension spring 1 is also guided by the elevation 36, which is arranged between the first leg 3 and the free end 7 of the holding section 5 of the tension spring 1.

The tension spring 1 can be moved between the final assembly position shown in Fig. 14 and a pre-assembly position not shown, in which the tension spring 1 does not overlap the rail foot. The design is such that the screw 25 does not have to be loosened in order to move the tension spring 1 from the pre-assembly position to the final assembly position. The displacement can be performed, for example, by means of a lever-type tool.

Figs. 18 and 19 show the displaceability of the tension spring 1 between the pre-assembly position (Fig. 18) and the final assembly position (Fig. 19) on the basis of the design

according to Fig. 12, whereby reference signs from Figs. 14-17 have also been retained insofar as corresponding components are concerned. Figs. 20 and 21 each show a cross-section of Figs. 18 and 19, respectively, along lines XX and XXI, respectively.

In the cross-sectional view shown in Figs. 20 and 21, it can be seen that the fastening screw 25 has a screw head 42 and a screw shank 43, with the screw head 42 clamping down the tension spring with the interposition of a washer 44. Here, the elevation 36 of the angle guide plate 26 forms a stop 45 with which the screw head 42 or the washer 44 interacts and which thus limits the screw-in depth of the fastening screw 25. The stop 45 is used here to define the screwed-down state of the tension spring 1 or the tightened state of the fastening screw 25 in such a way that the tension spring 1 remains displaceable between the pre-assembly and final assembly positions. The stop 45 here defines a minimum vertical distance h between the washer 44 and the bearing surface of the angle guide plate 26, which is equal to or greater than the unloaded diameter of the wire forming the tension spring in this area.

Fig. 20 shows that the angle guide plate 26 has a lateral contact surface 46 for the rail foot 16 and the fastening screw 25 is arranged in such a way that the tension spring 1 does not project beyond the contact surface 46 in the pre-assembly position.

Furthermore, Figs. 18 and 19 show a ramp 47 formed on the angle guide plate 26, which is arranged in such a way that the bent end section 6 of the tension spring 1 slides on it when it is moved from the pre-assembly position to the final

assembly position. The ramp is level or ascending in the direction towards the rail foot 16, the end of the ramp forming a step descending towards the rail foot over which the bent end section 6 descends onto the rail foot 16 when the tension spring 1 is displaced from the pre-assembly position to the final assembly position (see Fig. 27).

Figs. 22 and 23 show an alternative design in which the tension spring 1 can be moved from the pre-assembly position (Fig. 22) to the final assembly position (Fig. 23) by rotating it about the screw axis. Figs. 24 and 25 are sectional views of Figs. 22 and 23. For the rotation of the tension spring 1, a rotatable intermediate piece 48 is provided as a stop 45, which is penetrated by the screw shank 43 and engages between the first leg 3 and the free end portion 7 of the tension spring 1 and is pressed there against the angle guide plate 26 by the fastening screw 25, so that the intermediate piece 48 thereby forms a rotatable stop 45, which both limits and transmits the screw-in depth of the fastening screw 25 and its tensioning force to the tension spring 1, which is why the intermediate piece 48 could also be understood as a component of a hold-down device.

The rotatable stop 45 serves in a comparable manner to the previously described displaceable design to define the screwed-down state of the tension spring 1 or the tightened state of the fastening screw 25 in such a way that the tension spring 1 remains rotatable between the pre-assembly position and the final assembly position. The intermediate piece 48 includes a portion overlapping the first leg 3 and the free end portion 7, whereby the tension spring is tightened when tightening the fastening screw 25. Here, the

area of the intermediate piece 48 overlapping the first leg 3 and the free end portion 7 defines as a stop 45 a minimum vertical distance h between the contact surface of the tension spring on the angle guide plate 26 and its opposite
5 contact surface of the intermediate piece 48, which is equal to or greater than the unloaded diameter of the wire forming the tension spring in this area. Furthermore, the intermediate piece 48 comprises an extension 49 which engages behind the end face of the free end portion 7 of the tension
10 spring 1 or engages in the free space between the free end portion 7 and the U-bend 2. The extension 49 acts as a safeguard against horizontal displacement of the tension spring 1 and as a driver to transmit the rotational movement applied by a tool to the intermediate piece 48 or stop 45 to
15 the tension spring 1.

The angle guide plate 26 of Figures 22 to 25 is shown in more detail in Fig. 26, and it can be seen that an elevation 50 is formed on the side 46 facing the rail foot 16, which
20 elevation has a contoured edge to provide both a first holding surface 53 for the position of the pre-assembly position, and a second holding surface 54 for the position of the final assembly position of a rotationally displaceable tension spring 1. Further, the contact surface 46 forms a
25 step 52 extending from the upper edge of the contact surface 46 and descending to a rail foot. In order for the hold-down force to be fully transmitted to the rail foot in the final assembly position, there must be the required vertical movement clearance between the second leg and the angle guide
30 plate 26 for a tension spring 1. A recess 51 ensures that the upper edge of the contact surface 46 or step 52 is lowered at the appropriate point.

Fig. 27 shows the section S-S through the step 52 from Fig. 19, which drops by the distance Y from the rail foot. To ensure that the deflection of the bent end section 6 in the final assembly position does not lead to plastic deformation of the tension spring 1 over its entire maximum spring deflection path, the vertical distance shown in Fig. 21 between the holding section 5 acting as overload protection and the rail foot 16 is less than or equal to the vertical distance y between the highest point of the ramp 47 and the rail foot 16 shown in Fig. 27.

Fig. 28 uses a stress-strain diagram determined in a tensile test to show the stress applied during cold working and the stress range maintained during normal operation within the spring deflection path limited by the overload protection. The diagram shows the 0.2% yield point $R_{p0.2}$, the 1.0% yield point $R_{p1.0}$ and the 2.0% yield point $R_{p2.0}$. With a stress of $R_{p2.0}$, for example, a permanent plastic elongation of 2% is achieved when this stress is reached for the first time. As shown with a thickened line, the tension spring is loaded at the point of maximum stress by deflection of the bent end section 6 in the direction of the spring deflection path up to the stress $R_{p1.0}$. After the resulting cold working, the tension spring 1 is partially relieved up to the tension σ_u , namely via the path y (see Fig. 27), and in this state holds the rail foot down resiliently. The overload protection limits the spring deflection path upwards in such a way that the maximum tension $\sigma_o = R_{p1.0}$ can occur until it is reached. In the range between σ_u and σ_o , this ensures that the tension spring 1 is only loaded in the elastic deformation range at any point during normal rail operation, preferably with $\sigma_o < R_{p1.0}$.

The following table shows an overview of several series of tests in which the wire for the tension spring shown in Fig. 1-4 was subjected to a plastic preload corresponding to the 0.2 % yield point $R_{p0.2}$ and the 2.0 % yield point $R_{p2.0}$ in order to induce cold deformation. The mean stress amplitude for fatigue strength (MW [MPa]) and the standard deviation (Stabw [MPa]) were then determined using the extended staircase method according to Hück in order to visualise the differences in fatigue strength. The number of tests was increased, especially for higher standard deviations, in order to be able to make valid statements. According to the results, the average stress amplitude for fatigue strength (MW [MPa]) is significantly increased compared to $R_{p0.2}$ and the associated standard deviation is reduced compared to $R_{p0.2}$, especially with stronger cold working with a preload $R_{p2.0}$ and a subsequent tensile sleeper test with a maximum stress $\sigma_o = (0.85 \cdot R_{p2.0})$.

Preload	Uniaxial(Tensile- Swell)			
	$R_{p0.2}$		$R_{p2.0}$	
Maximum stress σ_o	85% $R_{p0.2}$	97% $R_{p0.2}$	85% $R_{p2.0}$	97% $R_{p2.0}$
Number of tests	15	20	15	23
MW [MPa]	366	358	381	309
Stabw [MPa]	43	97*	25	111*

Claims:

1. Method for establishing a rail fastening, in which a track body element, such as for example a rail foot (16) of a rail (8), is resiliently held down by at least one hold-down section (6), such as for example a holding arm, of a tension spring (1) in its final assembly position, wherein the tension spring (1) consists of a tempered spring steel, comprising mounting the tension spring (1) on a base (11), wherein the tension spring (1) is brought into a tensioned state by means of a hold-down device (12, 25), in which the tension spring (1) is tensioned starting from a relaxed state by deflecting the hold-down section (6) along a spring deflection path (z), characterised in that the hold-down section (6) is deflected in the direction of the spring deflection path (z) during mounting to such an extent that the tension spring (1) is subjected to cold working, after which the tension spring (1) is at least partially relaxed.
2. Method according to claim 1, characterised in that the maximum spring deflection path of the hold-down section (6) in the final assembly position of the tension spring (1) is limited by an overload protection (5, 18) and in that the cold working takes place by deflecting the hold-down section (6) over a spring deflection path which is greater than or equal to the maximum spring deflection path limited by the overload protection (5, 18).
3. Method according to claim 1 or 2, characterised in that the hold-down section (6) for cold working is deflected to such an extent that a maximum principal normal stress corresponding to the 0.5% yield point, preferably the 1%

yield point, is reached or exceeded at the point of the tension spring (1) subjected to the highest load.

4. Method according to claim 3, characterised in that the tension spring (1) does not exceed the said maximum principal normal stress, preferably 90% of the maximum principal normal stress, in particular 85% of the maximum principal normal stress, at any point after cold working when the maximum spring deflection path has been reached.

5. Method according to any one of claims 1 to 4, characterised in that the cold working is carried out at least on the surface of the wire forming the tension spring (1).

6. Method according to any one of claims 1 to 5, characterised in that the step of mounting the tension spring (1) comprises fixing the tension spring (1) in a pre-assembly position in which the hold-down section (6) does not extend over the track body element.

7. Method according to any one of claims 1 to 6, characterised in that the cold working takes place in the pre-assembly position, during the displacement of the tension spring (1) from the pre-assembly position to the final assembly position or in the final assembly position.

8. Method according to claim 6 or 7, characterised in that the cold working during the displacement of the tension spring (1) from the pre-assembly position into the final assembly position takes place with the tension spring (1) held in the tensioned state by the hold-down device (12) by sliding of the hold-down section (6) on a slide surface (17)

of the base which rises at least in sections in the displacement direction.

9. Method according to any one of claims 6 to 8,

5 characterised in that the hold-down section (6) drops from a slide surface (17) via a step (19, 52) onto the track body element when the tension spring (1) is displaced from the pre-assembly position to the final assembly position in order to assume the final assembly position.

10

10. Method according to any one of claims 1 to 7,

characterised in that the hold-down device is formed by a fastening screw (25) and the cold working is carried out in the pre-assembly position or the final assembly position by

15 clamping down the tension spring (1) by means of the fastening screw (25), whereupon the tension spring (1) is at least partially relaxed by turning back the fastening screw (25).

20 11. Method according to any one of claims 1 to 7,

characterised in that the cold working is carried out in the pre-assembly position or the final assembly position with the aid of a separate tool.

25 12. Method according to any one of claims 1 to 11,

characterised in that the tension spring (1) comprises a U-shaped main section, which comprises a U-bend (2), a first leg (3) arranged on one side of the U-bend (2) and a second leg (4) arranged on the other side of the U-bend (2), wherein
30 a hook-shaped inwardly bent holding section (5) which can be braced against a hold-down device (12, 25) is formed on the first leg (3) and on the second leg (4) the hold-down section (6) is formed as an end section of the second leg (4) which

is bent towards or away from the holding section (5), wherein the U-bend (2) forms a torsion section so that a holding-down force can be applied to the track body element via the bent end section (6).

5

13. Method for improving the fatigue behaviour of a tension spring (1) for holding down a track body element, such as, for example, a rail foot (16) of a rail (8), wherein the tension spring (1) consists of a tempered spring steel and
10 has at least one hold-down section (6), such as, for example a holding arm, which is deflectable in a resilient manner along a spring deflection path (z) for resiliently holding down the track body element, characterised in that the tension spring (1) is provided for installation in a track,
15 in which the maximum spring deflection path of the hold-down section (6) is limited by an overload protection (5, 18) in such a way, that no plastic deformation takes place at any point of the tension spring (1) within the maximum spring deflection path, the said maximum spring deflection path is
20 determined and the hold-down section (6) is deflected in the direction of the spring deflection path (z) beyond the maximum spring deflection path or up to the maximum spring deflection path, so that the tension spring (1) is subjected to cold working.

25

14. Rail fastening device, in particular produced by a method according to any one of the claims 1 to 12, comprising a tension spring (1) made of tempered spring steel and a hold-down device (12, 25) which can be fastened adjacent to a
30 track body element (8) on a base, in particular a sleeper (11), ribbed plate or angle guide plate against which hold-down device (12, 25) the tension spring (1) can be braced or is braced in a final assembly position of the tension spring

(1) in such a way that the tension spring (1), starting from a relaxed state, with deflection of at least one hold-down section (6) of the tension spring (1) along a spring deflection path (z) can be tensioned with the hold-down
5 section (6) against the track body element, in particular a rail foot (16) of a rail (8), in order to hold it down resiliently, characterised in that the tension spring (1) is cold-worked by deflection of the hold-down section (6) in the direction of the spring deflection path (z) or can be cold-
10 worked during assembly and is at least partially relieved in the final assembly position with respect to said deflection.

15. Rail fastening device according to claim 14, characterised in that the maximum spring deflection path of
15 the hold-down section (6) in the final assembly position of the tension spring (1) is limited by an overload protection (5, 18) and in that the cold working is effected by deflection of the hold-down section (6) over a spring deflection path which is greater than or equal to the maximum
20 spring deflection path limited by the overload protection (5, 18).

16. Rail fastening device according to claims 14 or 15, characterised in that the hold-down section (6) for cold
25 working is deflected to such an extent that a maximum principal normal stress corresponding to the 0.5% yield point, preferably the 1% yield point, is reached or exceeded at the point of the tension spring (1) subjected to the highest load.

30

17. Rail fastening device according to claim 16, characterised in that the tension spring (1) does not exceed the maximum principal normal stress, preferably 90% of the

maximum principal normal stress, in particular 85% of the maximum principal normal stress, at any point after cold working when the maximum spring deflection path has been reached.

5

18. Rail fastening device according to any one of claims 14 to 17, characterised in that the cold working is carried out at least on the surface of the wire forming the tension spring (1).

10

19. Rail fastening device according to any one of claims 14 to 18, characterised in that the hold-down section (6) is deflectable for cold working by tensioning down the tension spring (1) by means of the hold-down device (12, 25).

15

20. Rail fastening device according to any one of claims 14 to 19, characterised in that the tension spring (1) can be fastened to the base in a pre-assembly position in which the hold-down section (6) does not extend over the track body element.

20

21. Rail fastening device according to claim 20, characterised in that the base comprises a slide surface (17) which rises at least in sections and on which the hold-down section (6) slides when the tension spring (1) is held in the tensioned state by the hold-down device (12) during the displacement of the tension spring (1) from the pre-assembly position into the final assembly position, whereby the hold-down section (6) can be deflected and/or partially relieved for cold working.

25

30

22. Rail fastening device according to claim 20 or 21, characterised in that the base forms a step (19, 52) at the

end of a slide surface (17), over which the hold-down section (6) drops onto the track body element when the tension spring (1) is displaced from the pre-assembly position to the final assembly position in order to assume the final assembly position.

23. Rail fastening device according to any one of the claims 14 to 22, characterised in that the tension spring (1) comprises a U-shaped main section, which comprises a U-bend (2), a first leg (3) arranged on one side of the U-bend (2) and a second leg (4) arranged on the other side of the U-bend (2), wherein a hook-shaped inwardly bent holding section (5), which can be braced against a hold-down device is formed on the first leg (3) and on the second leg (4) the hold-down section (6) is formed as an end section of the second leg (4) which is bent towards or away from the holding section (5), wherein the U-bend (2) forms a torsion section so that a holding-down force can be applied to the track body element via the bent end section (6).

24. Rail fastening device according to any one of claims 14 to 23, characterised in that the hold-down device (12) comprises or forms a tunnel-shaped recess (13) into which the holding section (5) of the tension spring (1) can be at least partially inserted.