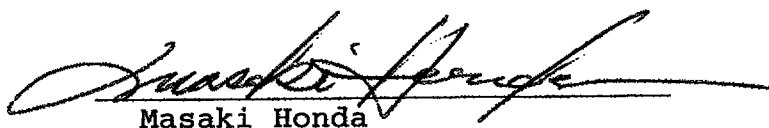


VERIFICATION OF TRANSLATION

I, Masaki Honda , c/o A. Aoki & Associates, Toranomom
37 Mori Bldg., 3-5-1, Toranomom, Minato-ku, Tokyo, Japan,
hereby declare that I am conversant with the Japanese and the
English languages and that I am translator of the documents
attached and certify that to the best of my knowledge and
belief the following is a true and correct translation of
International Application No. PCT/JP 96/00250
in the name of NIPPON STEEL CORPORATION.

This 1st day of October , 1996


Masaki Honda

PCT.

SG 9611623-1

DESCRIPTION

High-Strength Bolted Friction Joints and Steel
Materials Thereof

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TECHNICAL FIELD

This invention relates to a high-strength bolted friction joints and steel materials thereof which can be applied when the steel materials are joined in a building steel structure or other steel structures.

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BACKGROUND ART

In friction coupling by a high-strength bolt in a building steel structure, a rust surface which is allowed to naturally occur outdoors or a shot blast surface has been the standard as the friction surface of a steel material in the past.

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According to a method of generating the rust, however, the height of protuberances of concavo-convexities on the surface on which the rust occurs is about 0.07 mm, for example. Moreover, when variance of the height and the shape of the protuberances during the execution is taken into consideration, a sliding coefficient value greater than 0.45 cannot be employed for the design of a joint portion. Here, the term "sliding coefficient" means a ratio μ of a resistance force to a fastening force of the high-strength bolt.

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According to the shot-blasting method, the height of the protuberances of the concavo-convexities on the surface is maximum about 0.07 to 0.10 mm, and this method has been carried out at Rz (DIN) 0.05 to 0.07 mm. When variance is taken into consideration, it is difficult, too, to employ a sliding coefficient value greater than 0.45.

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Under such circumstances, the design value of the sliding coefficient has been set to a low value $\mu = 0.45$ according to the Japan Architecture Society JASS6 standard.

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In the case of the rust surface, a coating cannot be applied in advance to the friction surface portion of the surface of the steel material so as to attain the rust state, and adhesion of those materials which hinder the occurrence of the rust, such as oils, must be completely removed. Therefore, management of execution quality becomes extremely troublesome.

To stably obtain a large sliding coefficient, the following proposals have been made so far. Japanese Unexamined Patent Publication (Kokai) No. 51-52336 proposes a system which applies a specific coating to the friction surface of a steel material and bonds it by a high-strength bolt, and Japanese Unexamined Patent Publication (Kokai) No. 1-266309 proposes a system which applies plasma spraying treatment of ceramics to the friction surface of the steel material and bonds by a high-strength bolt. Furthermore, a system which applies aluminum spraying treatment or zinc-rich coating to the friction surface of the steel material and bonds by a high-strength bolt has also been proposed.

According to the method described in Japanese Unexamined Patent Publication (Kokai) No. 51-52336, however, a specific coating must be applied to the steel material. Therefore, the process becomes complicated. The method described in Japanese Unexamined Patent Publication (Kokai) No. 1-266309 requires a new exclusive installation for aluminum spraying and zinc-rich coating in the machining process of steel structures and involves the problem that machining and execution are complicated. Therefore, none of these methods have been employed at present.

Therefore, the inventors of the present invention have developed a high-strength bolted friction joints capable of securing relatively easily a sliding coefficient of at least 0.6 by making the surface hardness and the surface coarseness on the friction surface side of one of the steel materials friction-

bonded as it is fastened by a high-strength bolt, greater than the surface hardness and the surface coarseness on the friction surface side of the other of the steel materials, and filed this invention in Japanese

5 Unexamined Patent Publication (Kokai) No. 6-146427.

The invention disclosed in Japanese Unexamined Patent Publication (Kokai) No. 6-146427 described above can stably secure a sliding coefficient of at least 0.6 in a high-strength bolted friction joints, but the
10 maximum value slightly exceeds 0.85. This prior invention teaches to coarsen the surface by grit blast machining, but the concavo-convexities of the friction surface by grit blast are at most about 0.15 mm. Because the shapes of the concavo-convexities and their
15 distribution in terms of ten-point mean coarseness Rz (DIN) are not constant, a variance that cannot be neglected occurs in some cases in the sliding coefficient value. As a result, there remains the problem that a large sliding coefficient value, exceeding 0.85, cannot
20 be obtained.

Recently, the sheet thickness of the steel materials used has become greater with the increase of the scale of steel structures and their spans, and the strength of these steel materials has also been increased. Further,
25 simplification of machining of the joint portion, labor saving and speed-up of execution is required. Effective means for satisfying these requirements must be able to increase the yield strength of the joint portion, and at the high-strength bolted joints portion, on the other
30 hand, the strength of the high-strength bolt must be increased to increase the fastening tension, and the sliding coefficient must also be increased. To satisfy these requirements, a sliding coefficient of at least 0.9, which is twice the existing reference value, must be
35 secured.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide

a high-strength bolted joints which can stably secure a sliding coefficient value of at least 0.9, makes it possible to stabilize the quality of the friction joint surface and to simplify execution management of the friction joint surface, and can reduce the cost of the high-strength bolted friction joints portion as a whole, and steel materials for such joints.

To accomplish the object described above, the present invention provides a high-strength bolted friction joints having the following content as the gist thereof and steel materials used for the joints.

(1) High-strength bolted friction joints characterized in that the ratio of the hardness of a surface layer portion of a friction surface of one of two steel materials constituting one friction joint surface to hardness of a surface layer portion of a friction surface of the other of the steel materials is at least 2.5, a depth of the surface layer portion having higher hardness is at least 0.2 mm, a plurality of protuberances having triangular corrugations or pyramidal shapes are formed on the surface of the surface layer portion having higher hardness among the surface layer portions of both friction surfaces, a height of the protuberances is 0.2 to 1.0 mm, and maximum surface coarseness on the surface of the surface layer portion having smaller hardness is sufficiently smaller than the height of the protuberances.

(2) High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that a ratio of the hardness of a surface layer portion of a friction joint surface of at least one of steel materials constituting one friction joint surface to the hardness of a surface layer portion of a friction joint surface of the other of the steel materials is at least 2.5, a hard layer of the surface layer portion of the steel material having the hardness ratio of at least 2.5 is at least 0.2 mm, and a plurality

of protuberances having a height of 0.2 to 1.0 mm are disposed on a part, or on the entire surface, of the surface thereof.

(3) High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that a ratio of the hardness of a surface layer portion of a friction joint surface to the hardness of a surface layer portion of a friction surface of the other of the steel materials is at least 2.5, a hard layer of the surface layer portion of the steel materials having the hardness ratio of at least 2.5 is at least 0.2 mm, a plurality of protuberances having a height of 0.2 to 1.0 mm are disposed at a part, or the entire surface, of the surface thereof, and a plurality of protuberances having a height of not greater than 0.1 mm are disposed on the surface layer portion of the friction joint surface of the steel material having the hardness ratio of not greater than 2.5.

(4) High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that a range in which a plurality of protuberances are disposed on the surface of a surface layer portion of a friction joint surface of at least one of the steel materials is defined by an area between an inner circle having a radius at least three times the radius of a shaft portion of said bolt and an outer circle having a radius not greater than four times the radius of the shaft portion of said bolt with the axis of a bolt hole boned for inserting said bolt as the center of both circles, or defined by an area between an inner and outer polygon, respectively circumscribed in said inner and outer circles.

(5) Steel materials of a high-strength bolted friction joints characterized in that a ratio of the hardness of a surface layer portion of a friction surface of one of two steel materials constituting one friction joint surface to the hardness of a surface layer portion

of a friction surface of the other of the steel materials is at least 2.5, the depth of the layer having greater hardness of the surface layer portion is at least 0.2 mm, a plurality of triangular corrugation-like or square pyramidal protuberances are formed on the surface of the surface layer portion having greater hardness, the height of the protuberances is 0.2 to 1.0 mm, and maximum surface coarseness of the surface layer portion having smaller hardness is sufficiently smaller than the height of the protuberances.

(6) Steel materials for use in a high-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that a ratio of the hardness of a surface layer portion of a friction surface of at least one of the steel materials constituting one friction joint surface to the hardness of a surface layer portion of the other of the steel materials is at least 2.5, a hard layer of the surface layer portion of the steel materials having the hardness ratio of at least 2.5 is at least 0.2 mm thick, and a plurality of protuberances having a height of 0.2 to 1.0 mm are disposed at a part, or the entire surface, of the surface of the surface layer portion.

(7) Steel materials for use in a high-strength bolted friction joints surface of a plurality of steel materials coupled by high-strength bolts, characterized in that a ratio of the hardness of a surface layer portion of a friction surface of at least one of the steel materials constituting one friction joint surface to the hardness of a surface layer portion of the other of the steel materials is at least 2.5, a plurality of protuberances having a height of 0.2 to 1.0 mm are disposed at a part, or the entire surface, of the surface of the surface layer portion, and a plurality of protuberances having a height of not greater than 0.1 mm are disposed on the surface layer portion of the friction joint surface of the other of the steel materials having

the hardness ratio of not greater than 2.5.

(8) High-strength bolted friction joints surface and steel materials for a friction joint according to any of the items (1) to (7), wherein the angle of a plurality
5 of the protuberances (included angle between both slopes opposing each other) is from 60 to 120°.

(9) High-strength bolted friction joints according to any of the items (1) to (8), wherein a rust-proofing paint or oil coating layer is disposed on the friction
10 surface of one, or both, of the steel materials constituting one friction joint surface.

In the present invention, the term "high-strength bolted friction joints" means joints for effecting stress transmission by utilizing a frictional force (or a
15 sliding resistance force) occurring between the steel materials when a plurality of steel materials are fastened by a high-strength bolt. Here, the joints can be formed concretely between the members for constituting a structure and a patch, a T-shape steel, an angle steel,
20 etc, playing the role of a coupling.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an example of the shape (triangle) of protuberances in the present invention.

Fig. 2 shows an example of another shape (pyramid)
25 of the protuberances in the present invention.

Fig. 3 shows the section of the shape (triangle) of the protuberances in the present invention.

Fig. 4 shows the section of another shape (approximate triangle) of the protuberances in the
30 present invention.

Fig. 5 shows the section of the apex of a triangular protuberance in the present invention.

Fig. 6 is a plan view of the triangular protuberance in the present invention.

35 Fig. 7 is a plan view showing a square pyramidal protuberance of the present invention by changing the direction of the protuberance with respect to a

transmitting direction of a force.

Fig. 8 shows a sliding testpiece for the present invention.

5 Fig. 9 shows the result of an experiment on a sliding coefficient using a hardness ratio and a protuberance height as parameters.

Fig. 10 shows the result of an experiment on a sliding coefficient using the depth of a hard layer as a parameter.

10 Fig. 11 shows the result of an experiment on a sliding coefficient using the surface condition of a steel material having small hardness as a parameter for the purpose of explaining the present invention.

15 Fig. 12 shows an example of the distribution state of a surface pressure between friction surfaces in the proximity of a bolt hole when the materials are fastened by a high-strength bolt.

Fig. 13 is a side view (a) of another embodiment of the present invention and its plan view (b).

20 Fig. 14 is a side view (a) of another embodiment of the present invention and its plan view (b).

Fig. 15 is an explanatory view of the prior art, wherein (a) is a side view, and (b) is a plan view.

25 The shape of the protuberances disposed on the friction surface of the surface layer portion on the side having greater hardness in the high-strength bolted friction joints according to the present invention is triangular corrugation or square pyramidal, and each example is shown in Figs. 1 and 2. Fig. 1 shows the case
30 where the protuberance 1 has a triangular corrugation shape, and Fig. 2 shows the case where the protuberance 2 has a pyramidal shape (square pyramid). When the sectional shape of the protuberance 1 is triangular, the shape includes not only a perfect triangle shown in
35 Fig. 3, but also includes the case where the slope of the triangle is inwardly recessed as shown in Fig. 3(a) and the case where it is outwardly protrusive as shown in

Fig. 3(b). As to the apex of the protuberance 1 of the triangle, there are the case where the distal end is pointed as shown in Fig. 5(a), the case where the apex is flat as shown in Fig. 5(b) and the case where the apex has a radiused portion as shown in Fig. 5(c). Therefore, the term "triangle" means the triangles and the shapes similar to the triangles. This also holds true of the pyramidal shape of the protuberance.

In the present invention, a plurality of such protuberances are disposed on the surfaces. Preferably, these protuberances are disposed in such a fashion that the triangular corrugations or pyramids having the same shape and the same height repeatedly continue, or corrugations or pyramids having somewhat different heights but having similar or approximate shapes repeatedly continue. These protuberances can be shaped by cutting, laser machining, knurling, plasma machining, etc, and a group of protuberances having a constant shape at each portion are formed on the surface. The protuberances having a constant shape help to reinforce the bonding condition on the entire surface of the friction joint surface and to stably secure a high sliding coefficient.

Fig. 6 shows an example of the state where four bolt holes 4 are bored in a patch 3 as one of the steel materials and a plurality of protuberances 1 having the triangular corrugation shape are continuously formed by cutting in the longitudinal direction of the patch 3. Fig. 7 shows the arrangement of each kind (A, B, C, D) when the inclination is changed with respect to a force transmitting direction when the protuberances 2 are pyramidal. Symbol h represents the height of the protuberance, and e represents the angle of the protuberance (included angle of opposed slopes).

The difference between the hardness of the surface layer portion of the friction surface of one of the steel materials and the hardness of the surface layer portion

of the friction surface of the other steel material and the height of a plurality of protuberances disposed on the surface of the surface layer portion having the greater hardness are associated with the sliding coefficient in the high-strength bolted friction joints of the present invention. Therefore, the ratio of the hardness of one of the surface layer portions to the hardness of the other is set to be at least 2.5, and the height of the protuberances is set to 0.2 to 1.0 mm.

In conjunction with this point, the hardness ratio and the height of the protuberances were changed so as to examine their relationships with the sliding coefficient. Fig. 9 shows an example of the experiment. In the experiment shown in Fig. 9, a sliding testpiece (whose dimensions are shown in the drawing) comprising the steel material (having smaller hardness of the surface layer portion) 5, the patch (having greater hardness of the surface layer portion) 6 and the high-strength bolt 7 is used, the shape of the protuberances disposed on the friction surface of the patch 6 is a triangular corrugation, the protuberance angle is 90° , and the protuberance distal end radius is 0. The patch 6 is made of SCM435 as the steel material. After the protuberances are formed by cutting, of various hardnesses were prepared by heat-treatments. On the other hand, the steel material 5 is made of SS400. This steel material 5 is shot blasted, and its Vicker's hardness was Hv 140 and its Rz (DIN) was 70. A high-strength bolt 7 of F10TM22 is inserted through the sliding testpiece, and a standard bolt strength (22.6 ton) is applied so as to measure the sliding coefficient value.

The results are shown in Fig. 9. In other words, (1) though the sliding coefficient increases with the increase of the hardness ratio, the tendency of the increase of the sliding coefficient becomes weak when the hardness ratio exceeds 2.5. (2) The sliding coefficient increases within the protuberance height ranges of 0.1 mm

to 0.2 mm and 0.2 mm to 0.5 mm, but decreases, on the contrary, within the range of the protuberance height of 0.5 to 1.0 mm. (3) In order to secure a sliding coefficient of at least 0.9, the hardness ratio of at least 2.5 and the protuberance height of at least 0.2 mm are necessary.

From the experiments described above, the ratio of the hardness of the surface layer portions is limited to at least 2.5 and the protuberance height is limited to 0.2 to 1.0 mm. In view of the fact that even when the hardness ratio of the surface layer portions is increased, the sliding coefficient does not increase much, the upper limit of this ratio may be about 5.

Next, the depth of the layer of the surface layer portion of the friction surface having the large hardness is limited to at least 0.2 mm. The depth of the layer hereby means the length measured in the direction of the height of the protuberance from the apex of the protuberance as the start point.

The experiment was also carried out for the depth of the hard layer and the result will be explained with reference to Fig. 10. Fig. 10 represents the case where the protuberance height is 0.5 mm, and the condition for this experiment is the same as that of Fig. 9.

The following was discovered as a result. (1) The sliding coefficient drastically increased near the depth of the hard layer of the surface layer portion of about 0.2 mm, but hardly changes above 0.2 mm. (2) When the depth of the hard layer was greater than 0.2 mm, a sliding coefficient of at least 0.9 mm could be secured. (3) It is sufficient if the hardness ratio can be secured in the layer of at least 0.2 mm from the surface of the friction surface but not throughout the full thickness of the steel material. (4) From these facts, the depth of the hard layer of the surface layer portion in the present invention may be at least 0.2 mm from the surface. From the aspect of design, the depth of the

hard layer needs be at least the same as the protuberance height. As to the upper limit of the depth of the layer, a steel material having large hardness throughout the full thickness may be used, as well.

5 When cutting is employed for the protuberance, a hardening treatment of the protuberance may be preferably carried out by heat-treatment after shaping of the protuberance. Methods such as vacuum heat-treatment, carburizing hardening carburizing nitriding hardening, 10 flame hardening, etc, may be suitably selected and conducted. When the protuberances are shaped by laser machining or plasma machining, hardening is effected by quenching of the protuberance with machining. A hardenable steel such as SCM435 or S45C is used for the 15 steel material having large hardness. A high speed steel, a wear resisting steel, a composite steel sheet having a steel having large hardness on only the surface layer, etc, may also be used.

20 When the present invention is carried out, the following can be recommended for the protuberances.

(1) Since the sliding coefficient reaches maximum near the angle of protuberances (included angle between both opposed slopes) of 90° , the protuberance angle of 60° to 120° is preferred so as to secure the sliding 25 coefficient of at least 0.9. Another reason why this angle is set to 60° to 120° is as follows. If the angle is smaller than 60° , precision machining and high skill become necessary for machining the protuberance and such an angle is not suitable for mass-production, either. If 30 the angle is greater than 120° , large energy becomes necessary, and it becomes difficult to speedily machine the protuberances at a low production cost.

(2) The apex of the protuberance is preferably pointed as shown in Fig. 5(a). As to the shapes shown in 35 Figs. 5(b) and (c), the flat width W of the protuberance apex is preferably not greater than the protuberance height h as to Fig. 5(b), and the distance between the

protuberance slope and the r curve is preferably smaller than the protuberance height h (corresponding to the limit value of the flat width W of the protuberance apex) as to Fig. 5(c).

5 (3) When the shape of the protuberance is a pyramid (such as a square pyramid), the sliding coefficient becomes greater when the projection area of the pyramid in the force transmitting direction is greater. In Fig. 7, the sliding coefficient is greater in the kind B
10 than in the kind A and is greater in the kind D than in the kind C.

In the present invention, the boundary of the range in which the protuberances are disposed on the surface of the surface layer portion preferably defined by an area
15 between an inner circle having a radius at least three times the radius of a shaft portion of said bolt and an outer circle having a radius not greater than four times the radius of the shaft portion of said bolt with the axis of a bolt hole boned for inserting said bolt as the
20 center of both circles, or defined by an area between an inner and outer polygon, respectively circumscribed in said inner and outer circles. The surface pressure between the friction surfaces due to fastening of the high-strength bolt reaches maximum in the vicinity of the
25 bolt hole and progressively decreases outward from the axis of the bolt hole as the center. Therefore, even when protuberances exceeding the boundary described above are formed, the effect of increasing the sliding
coefficient does not appear. The value of at least three
30 times is set because at least about 90% of the fastening force of the high-strength bolt within the range smaller than 3.0 times is distributed as the surface pressure (kgf/mm^2) between the friction surfaces. If the value of four times is secured, almost all the regions in which
35 the surface pressure acts can be covered. The protuberances of the high-strength bolted friction joints

of the present invention can be effectively disposed at the boundary within such a range. Here, Fig. 12 shows an example of the distribution state of the surface pressure between the friction surfaces.

5 In Fig. 12, (a) represents the distribution state of the surface pressure between the friction surfaces when the thickness of the patch is 16 mm, and (b) represents the case when the thickness of the patch is 8 mm. As a test condition, F10TM22 was inserted as a high-strength
10 bolt, and was fastened at a standard bolt strength (22.6 ton). Symbol a represents the distance of a $3.0 \times$ bolt shaft portion radius (11 mm), and symbol b represents the distance of a $4.0 \times$ bolt shaft portion radius.

15 Next, the surface condition of the steel material having the small hardness at the surface layer portion as the mating material of the steel material equipped with the protuberances will be explained.

 The steel material having the small hardness is
20 SS400, SS600, etc, for example, and this material need not be as flat as a material having a machining finish surface. The material may be finished to not greater than about $70 \mu\text{m}$ in terms of ten-point mean coarseness R_z (DIN) by shot blast treatment or sanding treatment, or
25 not greater than about 0.1 mm in terms of the maximum height of the protuberance. There is the case where the steel material has a black skin surface as the surface coarseness without any specific treatment.

 Here, the surface condition of the steel material
30 having smaller hardness will be explained more concretely with reference to Fig. 11.

 Fig. 11 shows the slide test using the surface condition of a soft steel material as a parameter.

 In Fig. 11, the slide test of the slide testpiece
35 shown in Fig. 8 was carried out under the following conditions. The shape of the protuberances disposed on the side of the friction surface of a hard steel material

was a triangular corrugation, and the protuberance angle was 90°. The radius of the distal end of the protuberance was 0. On the other hand, the soft steel material was SS400 and had a hardness of Hv 140. The surface conditions were the following six levels, that is, A (as black skin), B (shot blast), C (machine finish), D (sanding + coating), E (shot blast + coating) and F (machine finish + grease). A high-strength bolt of F10TM22 was inserted through each slide testpiece, and a sliding coefficient was measured by applying a standard bolt strength (22.6 ton).

The results were as follows.

(1) In the soft steel material, a sliding coefficient of at least 0.9 could be secured irrespective of the conditions of the friction surface, i.e. in any of the surface coarseness of the black skin, shot blast, machine finish and sanding, and in the case of the existence of the coating layer or the coating and the grease (that is, irrespective of the existence of the coating).

(2) In the steel material having a high hardness, the sliding coefficient was hardly affected even when a rust-proofing treatment such as rust-proofing coating was applied to the friction surface at the stage of machining. Therefore, rust-proofing could be applied.

(3) As to the friction surface of the steel material having low hardness, there was certain flexibility in the existence/absence of the surface treatment and the surface treatment method. From these observations, a step such as a masking step of the friction surface at the time of coating of the steel material, which is essentially necessary at present, can be eliminated. Therefore, labor in machining and execution can be saved, and the production steps can be shortened. Further, since specific skills and techniques are not necessary for the management of the friction surface, execution quality can be easily secured.

In the present invention, since the protuberances fastened by the high-strength bolt catch into the surface layer portion of the steel material having the small hardness and function as a strong resistance against the slide. Therefore, a large sliding coefficient value can be obtained. Because the shape and the size of the protuberances are kept substantially constant, variance of the resistance structure formed on the friction surface with respect to the slide becomes small, and a stable sliding coefficient value can be secured.

Even when a rust-proofing coating or oil is applied to the surface on at least the friction side of one, or both, of the two steel materials together constituting one friction joint surface, the protuberances penetrate through the coating or the oil and catch into the surface portion of the steel material having the small hardness. Therefore, a rust-proofing treatment of the friction surface, that has not been carried out in the past, can be done without lowering the friction coefficient value.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, an embodiment of the present invention will be explained with reference to the drawings.

EMBODIMENTS

Example 1

This Example is shown in Fig. 13. The steel material 9 to be friction-bonded in the present invention was made of SM490 and had a size of H900 × 300 × 16 (web thickness) × 28 (flange thickness), and was a steel material having smaller hardness in the present invention. The surface layer portion of the steel material 9 to be friction-bonded was treated by shot-blasting to Rz (DIN) = 50 μm.

On the other hand, SCM435 was used for a patch 10, and triangular corrugations having a corrugation height of 0.5 mm were formed by machine cutting, and were heat-treated so as to obtain a hardness ratio of 3.5 (depth of 0.4 mm of the hard layer) at the surface layer portion.

Such steel materials were fastened by a high-strength bolt F10TM22 to impart a force to the steel materials in the longitudinal direction (in the transverse direction in the drawing). The sliding coefficient was 1.25 and the number of necessary bolts was 36.

Example 2

This Example is shown in Fig. 14. The steel material 9 to be friction-bonded in the present invention was SM490 having a size of H900 × 300 × 16 (web thickness) × 28 (flange thickness), and was the steel material 9 having the small hardness in the present invention. The surface layer portion of the steel material 9 to be friction-bonded was treated by shot-blasting to Rz (DIN) = 50 μm.

On the other hand, SCM435 was used for a patch 11, and square pyramidal shapes having a corrugation height of 0.5 mm were formed by machine cutting, and were heat-treated so as to obtain a hardness ratio of 2.5 (depth of 0.2 mm of the hard layer) at the surface layer portion.

Such steel materials were fastened by a high-strength bolt F10TM22 to impart a force to the steel materials in the longitudinal direction (in the transverse direction in the drawing). The sliding coefficient was 0.90 and the number of necessary bolts was 46.

Comparative Example

Comparative Example is shown in Fig. 14. The steel material 9 to be bonded was SCM435 (hardness Hv 170) having a size of H900 × 300 × 16 (web thickness) × 28 (flange thickness), and the material of a patch 12 was SCM435. A high-strength bolt was F10TM22, and the friction bonding surface of the steel material 9 and the patch 12 was in a rust state.

As a result, the sliding coefficient was 0.45 (as the present standard), and the number of necessary bolts was 86.

According to the present invention, the sliding coefficient can be improved, and the number of bolts can be drastically decreased.

5 The present invention provides the following effects.

(1) A sliding coefficient value of at least 0.9 can be stably secured. As a result, it becomes possible to compactly design a joint portion irrespective of a higher strength of a steel material and a great thickness of its sheet thickness, and to drastically decrease the number of necessary high-strength bolts. The joint portion becomes more compact than the existing joint portion, labor for machining and execution can be saved, the process steps can be shortened and the construction cost can be reduced.

(2) Because the sliding yield strength of the high-strength bolted friction joints portion becomes extremely large, a new joint portion design becomes possible, too, and labor saving can be attained in the joint design. For example, design of the joint portion by assuming that the full section is effective without taking the sectional deficit of the bolt hole into consideration becomes possible. A frame work having the joints according to the present invention has a more stable hysteresis at the time of an earthquake and the vibration-proof performance can be improved.

(3) Management of the surface condition of the friction surface can be made simply without any specific skill. Therefore, troublesome quality management that has been necessary in the past becomes unnecessary. Further, good performance, which is far stabler than in the prior art methods, can be obtained.



CLAIMS

1. High-strength bolted friction joints characterized in that the ratio of the hardness of a surface layer portion of a friction surface of one of two steel materials constituting one friction joint surface to the hardness of a surface layer portion of a friction surface of the other of said steel materials is at least 2.5, a depth of said surface layer portion having greater hardness is at least 0.2 mm, a plurality of protuberances having triangular corrugations or pyramidal shapes are formed on the surface of said surface layer portion having greater hardness among said surface layer portions of both friction surfaces, a height of said protuberances is 0.2 to 1.0 mm, and maximum surface coarseness on the surface of said surface layer portion having smaller hardness is sufficiently smaller than the height of said protuberances.

2. High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that the ratio of the hardness of a surface layer portion of a friction joint surface of at least one of steel materials constituting one friction joint surface to the hardness of a surface layer portion of a friction joint surface of the other of said steel materials is at least 2.5, a hard layer of said surface layer portion of said steel material having said hardness ratio of at least 2.5 is at least 0.2 mm, and a plurality of protuberances having a height of 0.2 to 1.0 mm are disposed on a part, or on the entire surface, of the surface thereof.

3. High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that the ratio of the hardness of a surface layer portion of a friction joint surface of at least one of the steel materials constituting one friction joint surface to the hardness of a surface layer portion of a friction surface of the other of said steel





materials is at least 2.5, a hard layer of said surface layer portion of said steel material having said hardness ratio of at least 2.5 is at least 0.2 mm thick, a plurality of protuberances having a height of 0.2 to 1.0 mm are disposed on a part, or on the entire surface, of the surface thereof, and a plurality of protuberances having a height of not greater than 0.1 mm are disposed on the surface layer portion of said friction joint surface of said steel material having said hardness ratio of less than 2.5.

4. High-strength bolted friction joints of a plurality of steel materials coupled by high-strength bolts, characterized in that a range in which a plurality of protuberances are disposed on the surface of a surface layer portion of a friction joint surface of at least one of said steel materials is defined by an area between an inner circle having a radius at least three times the radius of a shaft portion of said bolt and an outer circle having a radius not greater than four times the radius of the shaft portion of said bolt with the axis of a bolt hole boned for inserting said bolt as the center of both circles, or defined by an area between an inner and outer polygon, respectively circumscribed in said inner and outer circles.

5. Steel materials of a high-strength bolted friction joints characterized in that the ratio of the hardness of a surface layer portion of a friction surface of one of two steel materials constituting one friction joint surface to the hardness of a surface layer portion of a friction surface of the other of said steel materials is at least 2.5, the depth of said layer having greater hardness of said surface layer portion is at least 0.2 mm, a plurality of triangular corrugation-like or square pyramidal protuberances are formed on the surface of said surface layer portion having greater hardness, the height of said protuberances is 0.2 to 1.0 mm, and the maximum surface coarseness of said





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surface layer portion having smaller hardness is sufficiently smaller than the height of said protuberances.

5 6. Steel materials for use in a high-strength
bolted friction joints of a plurality of steel materials
coupled by high-strength bolts, characterized in that the
ratio of the hardness of a surface layer portion of a
friction surface of at least one of said steel materials
constituting one friction joint surface to the hardness
10 of a surface layer portion of the other of said steel
materials is at least 2.5, a hard layer of said surface
layer portion of said steel material having said hardness
ratio of at least 2.5 is at least 0.2 mm thick, and a
plurality of protuberances having a height of 0.2 to
15 1.0 mm are disposed on a part, or on the entire surface,
of the surface of said surface layer portion.

20 7. Steel materials for use in a high-strength
bolted friction joints surface of a plurality of steel
materials coupled by high-strength bolts, characterized
in that the ratio of the hardness of a surface layer
portion of a friction surface of at least one of said
steel materials constituting one friction joint surface
to the hardness of a surface layer portion of the other
of said steel materials is at least 2.5, a hard layer of
25 said surface layer portion of said steel material having
said hardness ratio of at least 2.5 is at least 0.2 mm
thick, a plurality of protuberances having a height of
0.2 to 1.0 mm are disposed on a part, or on the entire
surface, of the surface of said surface layer portion,
30 and a plurality of protuberances having a height of not
greater than 0.1 mm are disposed on said surface layer
portion of said friction joint surface of the other of
said steel materials having said hardness ratio of not
greater than 2.5.

35 8. High-strength bolted friction joints and steel
materials for friction joints according to any of
claims 1 through 7, wherein the angle of a plurality of

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said protuberances (included angle between both slopes opposing each other) is from 60 to 120°.

- 5 9. High-strength bolted friction joints according to any of claims 1 through 8, wherein a rust-proofing paint or oil coating layer is disposed on said friction surface of one, or both, of said steel materials constituting one friction joint surface.

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