

[54] TENSION INDICATING FASTENER

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[58] Field of Search..... 85/1 T, 61, 62; 73/88 A, 73/88 F

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[57] ABSTRACT

Fasteners such as mine bolts are provided with tension indicators to directly read tension in the shank of the bolt. The preferred tension indicators comprise an elongated pin disposed in a bore formed in the bolt and connected at the bottom of the bore to the bolt shank to be tensioned thereby. The tension indicator further comprises a cross bar attached to the other end of the pin and extending laterally into engagement with another portion of the bolt, such as the head of the bolt, to be bent upon tensioning of the pin. Preferably, a photoelastic member is attached to the cross bar and bending stresses in the cross bar are manifested in the photoelastic member in the form of photoelastic fringes for reading by a reflection polariscope.

12 Claims, 4 Drawing Figures

[56]

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3,718,066	2/1973	Dally.....	85/62

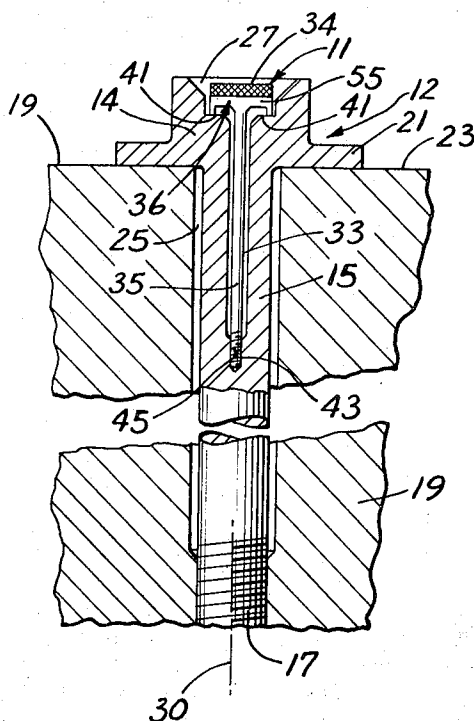


FIG. 2

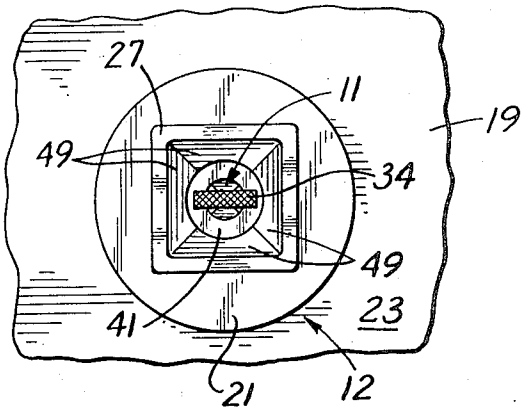


FIG. 1

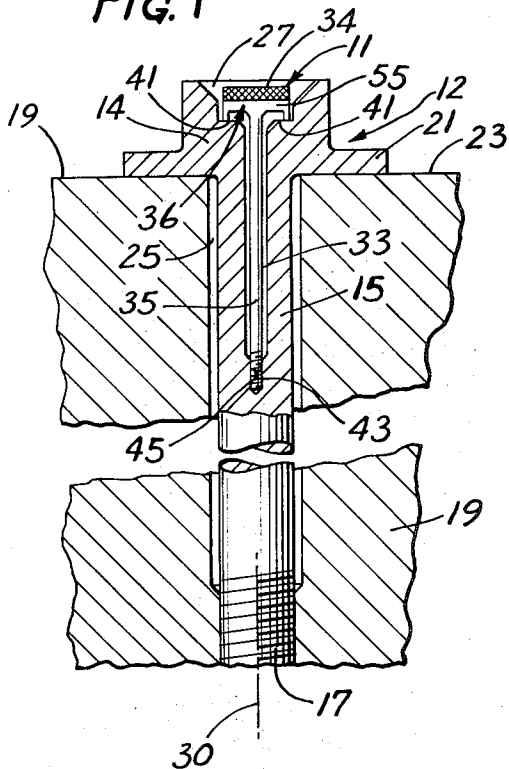


FIG. 3

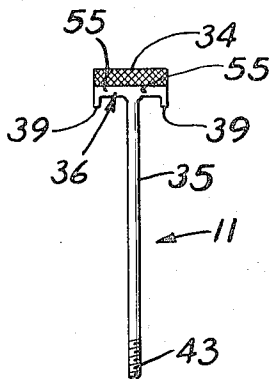
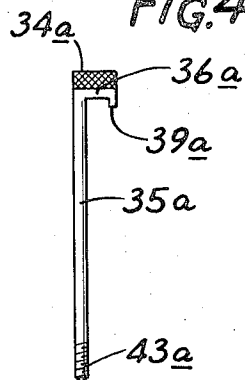


FIG. 4



TENSION INDICATING FASTENER

This application is related to co-pending application of Theodore Liber entitled "Tension Indicating Fastener," Ser. No. 101,298, filed Dec. 24, 1970, now U.S. Pat. No. 3,718,065.

This invention relates to a means for indicating tension in fasteners such as bolts.

In the aforementioned U.S. Pat. No. 3,718,065, there is described a photoelastic method for analyzing the tension in a shank of a fastener. In the method described therein, a photoelastic strip is fastened to a head of the fastener and the fastener head is bent with tensioning of the shank of the bolt. The photoelastic strip manifests by means of photoelastic fringes, which can be viewed with a reflection polariscope, the bending stresses created in the head during tensioning of the shank. By means of calibration curves, these photoelastic fringes are directly related to the tension in the bolt. To increase sensitivity and ease of calibration, the photoelastic strip was, in the preferred embodiment of the invention, isolated from transverse stresses by attaching it to a ridge formed on the outer side of the fastener head.

The present invention will be described in connection with, although the invention is not limited to, the use of a photoelastic strip as the stress indicator because other forms of stress indicators may be used with the fasteners. The present invention also will be described in connection with mine bolts used in mine construction and to so-called "mine roof bolts" used to support mine shaft roofs, but the present invention may be used with other kinds of fasteners. These mine roof bolts are several feet in length, e.g., 36 inches, and about one-half inch in diameter with a head at one end and a thread at the opposite end. Typically, these bolts are installed by drilling holes in the mine roof and then inserting the bolts and threading the threaded bolt ends into the holes. The bolts are threaded until washer plates on the bolts are tightened against the roof. In order to ascertain the effectiveness of the bolt in supporting the roof, it is desired to know the level of tension in the bolt. From a safety standpoint, the tension in bolt should be known initially and at a later time to assure the continued effectiveness of the bolt in supporting the roof. Thus, it is desirable to be able to quickly and easily monitor the bolt tension to assure that the roof is being held by the respective bolts.

In contrast to machine bolt fasteners made to meet various standards having small tolerance variations for the major, minor or pitch diameters, these mine bolts have large variations in diameters along the length of a given bolt and also large variations in diameters between different bolts. Also, the mine bolt head is not always exactly symmetrically located relative to its shank as the mine bolt head is usually formed by a hot offsetting or forging in a die. Also, such mine roof bolts have a very deep indentation in the center thereof in the shape of an inverted four-sided pyramid. This deep indentation makes it difficult to form, at low cost, as can be done for the usual machine bolts, a ridge on the bolt head to which to attach a photoelastic member. Even if the ridges were formed on these mine bolt heads, the variations in the bolt head locations relative to the axis of the bolt would still render calibration of these bolts on a batch basis more difficult than similarly

calibrating bolts made to established or international standards for machine bolts.

Accordingly, a general object of the invention is to provide a new and improved tension indicating means and fasteners of the above-described kind having such tension indicating means.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a roof bolt with a tension indicating means therefor and embodying the novel features of the invention;

FIG. 2 is a plan view of FIG. 1;

FIG. 3 is an elevational view of the tension indicating means shown in FIG. 1;

FIG. 4 is an elevational view of another tension indicating means constructed in accordance with a further embodiment of the invention.

As shown in the drawings for purposes of illustration, the invention is embodied in a tension indicating means, hereinafter called a tension indicator 11, and a fastener in the form of a bolt 12 having a head 14 and a shank 15 threaded at one end 17 into a roof 19 of a mine or the like. The illustrated bolt 12 is a mine roof bolt which is a very large bolt, for example, 36 inches in length and a nominal one-half inch in diameter. Such bolts are often provided with an integral washer 21 which is generally circular and abuts the roof surface 23 about the hole 25 bored in the mine roof 19 to accept the bolt 12. Often mine roof bolts of this kind are formed with a deep depression 27 in the center of the bolt head 14 such as the inverted generally pyramidal shape depression 27 illustrated herein.

In order to assure that the mine roof bolts 12 are properly functioning and supporting the mine roof 19, it is desirable to ascertain at the time of installation that the bolt 12 is properly tensioned. While torque wrenches and other devices can be used to give some indication of a torque in the head of the bolt, they do not always accurately read the actual tension in the bolt shank 15 and the holding force of the mine roof bolt because of variations in the coefficients of friction between the bolt head and the various mine roof surface abutted by the bolt heads 14. Moreover, it is often desired at a later time to inspect the existing mine roof bolts to ascertain whether or not they have loosened and to what extent they are still in tension and supporting the roof. Thus, some tension indicators, e.g., which have frangible indicators thereon, will not provide a continuing or later indication of the bolt shank tension.

Particularly complicating the calibration of large size batches of mine roof bolts on an economical basis is the fact that the bolts are roughly formed as to dimensions with the typical bolt having a shank 15 of a nominal diameter, for example one-half inch, but which varies in outer diameter along the length thereof and has sections thereof offset from a longitudinal axis 30 for the bolt. Also, the bolt heads 14 are formed by a hot upsetting process and likewise are not always centered on the axis 30. Also, the formation of the relatively deep pyramidal depressions 27 in the bolts 12 makes it difficult to form a ridge on the fasteners such as disclosed in the preferred embodiments of the above-described co-pending application.

In accordance with the present invention, the bolts 12 are provided with separately-formed, tension indicators 11 which are inserted into a central bore 33 drilled in the bolt shank 15 and connected to the bolt shank to directly read tension by means of a stress indicating member such as a photoelastic member 34 carried by the tension indicator. More specifically, the tension indicator 11 comprises an elongated rod or pin 35 which is connected to the bolt shank 15 at the root of the bore 33, and a beam in the form of a cross bar 36 for bending by the pin 35 when the pin is tensioned with elongation of the bolt shank. Herein, the cross bar 36 is integrally connected to the pin 35 with the cross bar extending into engagement with another portion of the bolt. The photoelastic member 34 is attached to the cross bar 36 and bending stresses in the cross bar are manifested in the form of photoelastic fringes in the photoelastic member 34 which can be read by a reflection polariscope. On the other hand, the stress indicating member may be a frangible member which breaks upon being stressed or deflected by the bending of the cross bar. Also, the stress indicating member 34 may be a member which changes color when the cross bar bends and is stressed.

The cross bar 36 is substantially isolated from the effects of bending stresses in the bolt head 14 or from transverse stresses in the bolt head 14 by having only a small limit contact between the cross bar 36 and the bolt head. Preferably, the cross bar 36 is spaced generally throughout its length from the bolt head 14 with only an end support or end supports 39 abutting the bolt head 14. Also, to reduce the effects of any bending in head 14, the cross bar 36 abuts the bolt head at a location within the shank diameter. That is, the cross bar 36 is formed with a length equal to or less than the shank diameter and is mounted to engage the head 14 at a point on a support platform 41 on the head located within a radius equal to shank radius from the bolt axis 30 so that any bending of the outer portion of the bolt head has a reduced effect on the cross bar.

The illustrated tension indicator 11 is made of steel and is a small easily made piece which can be mass produced at low cost. The indicator 11 may be readily attached merely by threading its threaded end 43 into a thread 45 formed at the root of the bore 33. The tension indicator 11 is threaded into the shank thread until the end supports 39 abut the support platform 41. As the machining of the bolt to provide the support platform 41, the bore 33 and thread 45 is uncomplicated, this machining represents an inexpensive reworking of a conventional mine roof bolt. As the tension indicators are produced to give quite accurate readings and because the tension indicators directly read shank tension, a small number of bolts 12 from a given batch of bolts may be used to quickly develop the calibration curves.

Referring now in greater detail to the illustrated tension indicator 11, it is generally formed to be a small, inexpensive fastener-like member in that it has a shank-like pin 35 with threaded end 43 and a head-like cross bar 36. The indicator 11 is preferably made of steel and can be inexpensively produced to relatively close dimensions with reproducible elastic properties so that it and the photoelastic member 34 will provide very constant fringe order readings when subject to individual loads. Any main deviations or errors involved should arise from the differences in the individual bolts 12

rather than from the closely calibrated tension indicators 11.

Herein, the threaded end 43 of the pin 35 is about one and one-half diameters in length with the pin having a diameter of about one-sixteenth inch. Preferably, the threaded hole 45 is slightly longer in length than the threaded end 43 and is made to assure that the cross bar 36 is seated on the support platform 41 of the bolt head 14 before the threaded end 43 bottoms in the threaded hole 45. In this embodiment of the invention, the pin-receiving bore 33 has a length of about two inches and a diameter of about three thirty-seconds of an inch to assure that the pin 35 fits loosely in the bore and is not bent by the bolt shank 15 but is only elongated with tension forces received from the bolt shank 15 through the threaded end 43 of the pin 35. It is to be understood that the pin 35 could be attached in another manner such as by a force fit or by a bonding material to the bolt shank 15 rather than being threaded thereto as illustrated herein.

With a simple machining operation, the support platform 41 may be readily cut from the downwardly converging pyramidal walls 49 which define the central depression 27 in the bolt head 14. The support platform 41 is preferably formed with a diameter slightly larger than the cross bar 36 and centered on the bolt axis 30 and is formed with a flat planar surface disposed in a plane perpendicular to the bolt axis 30.

Transverse bending or torque stresses on the bolt head 14 are substantially isolated from acting on the cross bar 41 by limiting the length of the cross bar 41 to less than the diameter of the shank 29 so that the cross bar 36 bends mainly from stressing and tensioning of the shank 15. To facilitate simply bending of the cross bar 41, it is preferred that it be provided with depending end supports 39 in the form of small depending flanges at opposite ends of the cross bar 36 with lower surfaces of the end supports abutting the support platform 41. Portions 55 of the cross bar 36 intermediate the end supports 39 and the pin 35 will thus be spaced inwardly from the support platform 41 for ready bending with a centrally located downward pull from the tension pin 35. Preferably, the pin 35 is connected to the cross bar at the center thereof and is located coaxially with the longitudinal bolt axis 30. The cross bar 36 may be quite small, for example, about one-half inch in length, about one-eighth inch in width and about one-sixteenth inch thick.

In this embodiment of the invention, the photoelastic member 34 is generally coextensive with the top surface of the cross bar 36 and is secured thereto by a suitable, conventional reflecting adhesive. As described in considerable detail in the aforementioned co-pending application, the strip of photoelastic material receives bending stresses and strain from the cross bar 36 to which it is attached and the strip becomes birefringent in direct proportion to the intensities of stress or strain. The birefringent strip thereby manifests in the form of photoelastic fringes the bending stresses created in the cross bar 36. As explained in detail the aforementioned co-pending application, the term "fringes" is a general description of bands, rings, lines or other configurations. These photoelastic fringes can be viewed and linearly related to the bolt tension so that bolt tension can be readily determined. The birefringent strip may be relatively thin, for example 0.08 inch, and may be fas-

tened with several reflecting adhesives such as epoxy materials.

Also, as described in the aforementioned application, the fringes on the photoelastic member 34 are read by a reflection polariscope which measures changes in the index of reflection by reflected polarized light on the surface of the strip, but to which the photoelastic strip and reflecting adhesive have been applied. While not shown, the reflected polariscope generally comprises a light source which passes through a polarizer and the birefringent strip to be reflected from the glare of adhesive mounting the strip to the cross bar, which is birefringent after passing through the photoelastic strip, and is directed through an analyzer which is rotated by the viewer relative to the polarizer to determine the degree of fringe order. Once the degree of fringe order is determined by direct reading of the amount of rotation of the analyzer, a calibration curve may be made to graph the degree of fringe order against the amount of tension in the bolt head. Initially, the bolt tension may be related to the fringe order empirically by other methods such as using force washers, torque wrenches, or other conventional devices. Having established a curve for a given batch of bolts 12, the tension in a particular bolt should be readily determined by reading the fringes with the polariscope and finding the tension from the calibration curve.

By varying the geometric and physical parameters of the tension indicator 11 within practical limits, the sensitivity thereof may be adjusted and for one set of parameters this sensitivity may be at a maximum. This set of parameters (e.g., pin length, pin diameter, bar thickness, bar width, photoelastic strip thickness, etc.), can be determined from the interaction equation between the tension indicator 11 and the bolt 12. For the illustrated bolt 12 and tension indicator 11, the equation is:

$$\left(\frac{P}{N}\right) = \left(\frac{\lambda}{K}\right) \frac{E_2}{(1 + \mu_2)} \left(\frac{4S}{Td_1}\right) \left[1 + \frac{d_1^3 E_3 A_3}{48HL_3} + \frac{E_3}{E_1} \left(\frac{L_1 A_3}{L_3 A_1} + \frac{L_8 A_3}{L_3 A_8}\right)\right] \quad (1)$$

where

P = tensile load in bolt 12

N = fringe order in photoelastic strip 34 at bolt load P

λ = wave length of light used to view the fringes (for white light $\lambda = 22.7 \times 10^{-6}$ in.)

K = sensitivity coefficient for the photoelastic plastic (a constant supplied by the manufacturer)

E_2 = elastic modulus for the photoelastic plastic

μ_2 = Poisson's ratio for the photoelastic plastic

d_1 = length of indicator cross bar 36

E_3 = elastic modulus of the bolt material

A_3 = net cross sectional area of the bolt shank 15 at the hole for the indicator

L_3 = length of bore 33 in the bolt shank 15 (length between the underside of head to beginning of threads)

E_1 = elastic modulus of the indicator material

A_1 = cross sectional area of the indicator pin 35

L_1 = length of indicator pin 35 (from underside of cross bar to beginning of threads)

L_8 = length of cross bar end supports 39

A_8 = total cross sectional area of both cross bar supports 39.

The parameters T , H and S are defined by the following expressions:

$$T = t_2 \left(1 + \frac{h}{t_2 + h}\right) \quad (2)$$

$$h = 0.5 t_2 (1 - c) \quad (3)$$

$$c = (1 + t_1/t_2)/(1 + t_2 E_2/t_1 E_1) \quad (4)$$

$$H = E_1 I_1 + E_2 I_2 \quad (5)$$

$$I_1 = (bt_1^3/12) + bt_1(0.5 t_1 - h)^2 \quad (6)$$

$$I_2 = (bt_2^3/12) + bt_2(0.5 t_2 + h)^2 \quad (7)$$

$$S = H/[0.5 t_2 (1 + c)E_2] \quad (8)$$

where

t_2 = thickness of photoelastic strip 34

t_1 = thickness of cross bar 36

b = width of cross bar 36 also of photoelastic strip 36

(P/N) in Eq. (1) represents bolt load per fringe of tension indicator 11 response. Therefore, minimizing this parameter will result in maximizing the response of the tension indicator. This corresponds to the selection of that set of practical indicator dimensions and physical properties which minimizes the expression on the right-hand side of Eq. (1). Such minimization can readily be done mathematically or by trial and error.

The present invention is particularly useful for fasteners having shanks which can accommodate long pins 35 as the sensitivity of the tension indicator 11 decreases with a shortened pin 35. Manifestly, the fasteners may have various lengths, diameters, and shapes of heads other than illustrated herein and be used with nuts and in other environments other than mines.

The particular indicator 11 described above is generally T-shaped although it may have other shapes from that of a T with the cross bar taking various general other shapes. By way of example, an indicator 11a, which functions in a manner similar to the tension indicator 11, is illustrated in FIG. 4 as comprising a pin 35a having a threaded end 43a with a cantilever cross bar 36a on the upper surface of which is a photoelastic member 34a. In this form of the invention, the pin 35a is attached at one end of the cross bar 36a and the other end thereof has an end support 39a. The pin 35a bends the cross bar 36a which manifests the bending stress therein in the form of fringes on the photoelastic member 34a.

From the foregoing, it will be seen that the present invention provides a simple and economical manner of indicating the stress in a fastener. The preferred photoelastic member and method result in a simple and direct reading of bolt tension which can be read at various times to indicate the load level supported by the bolt. While a preferred embodiment has been shown and described, it will be understood that there is no intent to limit the invention by such disclosure but, rather, it is intended to cover all modifications and al-

ternate constructions falling within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A tension indicator for indicating the tension in a shank of a bolt comprising an elongated pin having means at one end for connection to a bolt shank, an elongated cross bar integral with and joined directly to said pin at the other end of said pin, an end support on at least one end of said cross bar for engagement with another portion of said bolt and for holding said cross bar free of said bolt for bending by said pin, and a stress indicating means mounted on said cross bar for visually manifesting the bending stress created in the cross bar during tensioning of said pin by said bolt shank.

2. A bolt tension indicator in accordance with claim 1 in which said pin is joined substantially centrally of said cross bar, and end supports are provided on opposite ends of said cross bar causing said cross bar to deflect centrally thereof between opposite end supports with tensioning of said pin.

3. A bolt tension indicator in accordance with claim 1 in which said end support comprises a depending flange integral with said cross bar and said means at one end of said pin is threaded for threading engagement into a portion of said bolt.

4. A bolt tension indicator in accordance with claim 1 in which said end support is at one end of said cross bar and in which said cross bar is attached at its other end to said pin.

5. A tension indicator for indicating the tension in the shank of a bolt having a bore therein and a support platform in a depression in said head of the bolt, said bolt tension indicator comprising: an elongated pin having a predetermined cross section for loosely fitting within the bore, a thread on one end of said pin for threading into the bolt shank for tensioning the pin with tensioning of the shank of the bolt, an elongated cross bar integrally joined directly with and to said pin at the other end of the pin and extending laterally from said pin, at least one end support on said cross bar depending from said cross bar to engage the support platform in the bolt and space the cross bar from said bolt head for facilitating bending of said cross bar by said pin, and a photoelastic strip fastened to the upper side of said cross bar for manifesting in the form of photoelastic fringes the bending stresses created in the cross bar during tensioning of said pin by said bolt shank.

6. In the combination of a bolt and a tension indicator, the bolt having a bolt head and a shank with a central bore therein, said pin being loosely fitted within

said bore and having an inner end fastened to said bolt shank to be tensioned thereby, the improvement comprising: a support platform formed in said bolt head, a cross bar integral with said pin and extending laterally therefrom into engagement with said support platform for bending by said pin and stress indicating means on said cross bar for visually manifesting the bending stresses created in the cross bar during the bending thereof by said pin.

7. The combination in accordance with claim 6 in which said cross bar has a length about or less than the diameter of the shank of said bolt to reduce the effects of any bending of said bolt head on said photoelastic member.

8. A combination in accordance with claim 7 in which said bolt head is formed with a depression therein, said support platform in a flat planar surface in the lower portion of said depression, and at least one end support is formed on said cross bar for resting on said support platform and spacing said cross bar from the remainder of said bolt head.

9. The combination in accordance with claim 8 in which said depression is pyramidal in shape, said cross bar extends generally across said opening in said shank and said pin is joined centrally to said cross bar to deflect the center portion thereof.

10. The combination in accordance with claim 9 in which said cross bar has a length substantially equal to or less than the diameter of said shank.

11. The combination in accordance with claim 8 in which the top of said cross bar is below the top surface of said bolt head and is thereby in a protected space.

12. In the combination of a bolt and tension indicator in which the bolt has a head and a shank with a bore therein, and in which the indicator comprises a pin having an inner end fastened to the bolt and extending longitudinally in said bore the improvement comprising: a support platform formed in said bolt head, a threaded end on said indicator pin for fastening to said bolt shank, a cross bar integral with said pin and extending substantially normal thereto for bending with tension in said pin, a depending end support on said cross bar for engaging said bolt head in a depression in said bolt head, and means including a photoelastic member on said cross bar for manifesting in the form of photoelastic fringes bending stresses created in the cross bar during tensioning of said pin and said bolt shank.

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