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(54) Method and apparatus for toughening metal strap buckles

(57) The invention relates to a metal tie buckle made from a single piece of rounded wire that has been bent into a predetermined configuration, wherein two pairs of strap engaging arms that are essentially parallel to one another are provided for securing the buckle to the strap. The buckle has been treated with a hardening process, such as carburizing, carbonitriding, nitriding and induction hardening, that strengthens and toughens the buckle. This helps to keep the arms parallel and prevents the propensity of the buckle to achieve plastic deformation, which in turn helps to prevent the strap from being pinched, or otherwise causing uneven stress on the strap, which could result in premature failure of the strap.

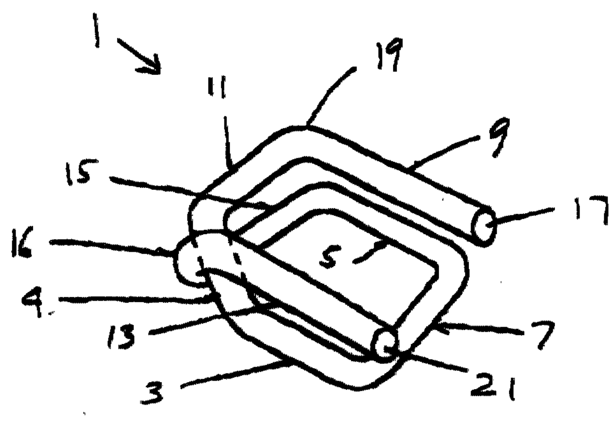

FIG. 1

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Description

Field of the Invention

[0001] The present invention relates to the field of metal buckles, and in particular, to the field of metal buckles made from a single piece of wire that has been toughened by heat treatment.

Background of the Invention

[0002] Various types of metal buckles for strapping boxes, bales, bundles (i.e., of cotton), etc., have been employed in the past. One of the most common types is often referred to as a Cotton Tie Buckle. These buckles are typically constructed of a single piece of metal wire that has been bent into a predetermined configuration.

[0003] Examples of Cotton Tie Buckles are shown in the following patents: U.S. Patent No. 686,129, issued to Ragsdale et al., U.S. Patent No.3,014,256, issued to Derrickson et al., U.S. Patent No. 3,377,666, issued to Sherman, and U.S. Patent No. 3,624,868, issued to Somann. Each of these buckles is made of a single piece of wire that has been bent into a pre-determined configuration, wherein two pairs of strap engaging arms that are substantially parallel to each other are provided to engage the strap. The buckle's engaging arms are configured such that the strap can be extended and secured through the arms, one end of the strap in each pair of arms. One end of the strap is held within one pair of engaging arms, and the other end of the strap is held within the other pair of engaging arms, wherein the intermediate part of the strap is extended tightly about the box, bale, bundle, etc., to be held.

[0004] Typically, when a strap is extended about a box, bale, bundle, etc., and tightened, the strap is placed under significant tension. This places great stress on the buckle that connects the strap ends together. A problem associated with conventional buckles of this type is that the orientation of the strap within the buckle's arms can cause the arms to bend, such that over time, the buckles can become distorted, and the arms can fall out of parallel with one another, which can cause the following to occur.

[0005] First, the arms can pinch the strap in a manner that can cause the strap to fail prematurely, i.e., they can cause the strap to tear before the strap's maximum strength capacity is reached. For example, even if the strap's maximum strength capacity is 1,200 pounds, the buckle can, if the load is high enough to cause the buckle's arms to bend and distort, cause the strap to break at 600 pounds. This significantly lowers the maximum capacity of the strap.

[0006] Second, bending of the buckle's arms such that they fall out of parallel with one another can also result in an uneven application of stress to the strap. That is, when the arms are not parallel, greater tensile stresses can be applied to an isolated location on the strap, wherein the strap can begin to tear at the over-stressed point. And, once the strap begins to tear, it is likely that it will break at loads far less than the maximum strength capacity of the strap.

[0007] Given these deficiencies, it was believed that standard Cotton Tie Buckles would need to be redesigned to prevent excessive bending and distortion, and thereby maintain the load capacity that the strap was intended for. This is particularly true given that strap materials have improved significantly to the point where much greater tensile strength capacities are possible.

[0008] One of the most common ways that the propensity of the buckle to bend was reduced was to simply increase the thickness of the wire, Although increasing wire thickness has been successful in reducing the likelihood of bending, doing so has had its disadvantages, including making the buckle heavier and bulkier, and the cost of manufacturing the buckles higher (which can lead to failure in the market place).

[0009] Other attempts to solve the problem were directed to using different buckle configurations. For example, in Derrickson et al., an attempt was made to configure the wire in a manner that allowed the buckle's arms to rest on other areas of the buckle to help prevent the wire from bending excessively. But as the maximum strength capacities of straps began to increase, the greater loads that can be applied to straps caused the arms to bend and distort, and fall out of parallel with each other, thereby resulting in premature failure. In Somann, another attempt was made to help limit bending and distortion of the load-bearing members and maintain parallelism between the arms by using detents. The disadvantage of this design was that additional time and expense were required to form the detents at precise locations on the wire. Also, the cost of having to position the detents in such manner proved to be prohibitive.

[0010] Different threading configurations have also been attempted, but have not been successful, insofar as the engaging arms would still bend and lead to premature strap failure. While various attempts have been made to overcome the deficiencies noted above, none have been very successful. What is needed, therefore, is an improvement to standard tie buckle designs which resists bending and distortion, and results in parallelism between the engaging arms, such that the buckle does not lead to premature strap failure at the joint.

Summary of the Invention

[0011] The present invention relates to a buckle made from a single piece of metal wire that has been configured such that it has two pairs of strap engaging arms that are substantially parallel to one another. The arms are so configured and constructed such that they can engage opposite ends of a tie strap to provide a secure connection for strapping boxes, bales, bundles, etc., together.

[0012] The present invention represents an improvement over previous designs in that the metal has been hardened by heat treatment. While processes for hardening the surface of metal are known, the specific manner in which the process has been applied to the present invention, to increase not only strength, but also toughness, as well as to decrease the propensity of the metal to achieve plastic deformation, is believed to be unique to the present invention. In this respect, the present invention is able to overcome the above noted deficiencies without substantially increasing cost, and without altering the configuration of the buckle design.

[0013] There are various hardening processes that can be employed to provide the benefits of the present invention. Conventional quenching of hot steel in water or oil provides surface hardening, and can harden some or all of the interior as well. Other hardening processes can also be used, such as carburizing, carbonitriding, nitriding, induction hardening and flame hardening.

[0014] Carburizing is a surface hardening process in which steel is held at a high temperature, i.e., 1,600 degrees F. (is common), for a relatively long time, i.e., six hours, in a carbonaceous environment, usually a gas mixture of carbon monoxide and carbon dioxide, with or without hydrocarbons such as methane. Carbonitriding is similar to carburizing except that nitrogen as well as carbon is diffused into the steel. Nitriding is another diffusion process in which, by using ammonia without a carbonaceous gas, nitrogen is diffused into the steel and combines with other elements, principally chromium, already contained in the steel to form nitrides that are extremely hard and wear resistant. Induction hardening is a process where the steel is briefly heated by electrical induction so that only the surface has time to get hot. The metal is then immediately cooled or quenched and the portion that was heated above the critical temperature (about 1,500 degrees F.) becomes hard. Flame hardening involves no change in the chemical composition of the steel surface, but involves a high temperature flame that impinges directly on the metal for a short time, heating the surface but not the interior of the piece.

[0015] The present invention contemplates using one of these methods to harden the metal after it has been bent into its predetermined configuration. In this respect, a large volume of tie buckles can be heat treated at one time, thereby making it possible to reduce the unit cost of manufacture. Moreover, the present invention contemplates tempering by annealing to reduce brittleness after the metal has been hardened. The present invention also contemplates that the buckles can be finished with a dry phosphate coating to prevent slippage.

Brief Description of the Drawings

[0016]

FIGURE 1 is a perspective view of the buckle design of the present invention;
FIGURE 2 is a top view of the buckle design of the present invention;
FIGURE 3 is a front view of the buckle design of the present invention;
FIGURE 4 is a side view of the buckle design of the present invention;
FIGURE 5 is a perspective view of the buckle in use with a strap;;
FIGURE 6 is a side view of the buckle in use with the strap threaded through the buckle;
FIGURE 7 is a side view of a conventional type buckle in use with the strap threaded through the buckle and a tensile load applied to the strap, wherein the buckle is shown to be deformed;
FIGURE 8 is a top view of a standard untreated buckle that has been used and where plastic deformation has occurred;
FIGURE 9 is a side view of a standard untreated buckle that has been used and where plastic deformation has occurred;
FIGURE 10 is a top view of the buckle of the present invention that has been used and where only a small amount of deformation has occurred; and
FIGURE 11 is a side view of the buckle of the present invention that has been used and where only a small amount of deformation has occurred;

Detailed Description of the Invention

[0017] Figure 1 shows the buckle of the present invention from a perspective view having two pairs of strap engaging arms formed by a single piece of wire that has been bent into a predetermined shape. While the specific configuration shown in the drawings is described below, it should be noted that the present invention is not limited to the specific configuration described below. The present invention is intended to include virtually any tie buckle configuration formed by a single piece of metal wire that has been treated in the manner specified.

[0018] In general, buckle 1, as seen in Figures 1 and 2, has four engaging arms, 3, 5, 9 and 13, that are substantially parallel to one another, wherein the parallel portions of the engaging arms are relatively straight and have widths that are sufficient to enable a conventional size strap to be threaded therethrough, as shown in Figure 5. In this manner, strap 23 is adapted to engage buckle 1 along the parallel portions of the engaging arms, wherein a relatively even distribution of stress can be applied to the strap when the strap is in tension. As discussed above, it is important that the engaging arms are maintained in a relatively parallel manner during use so that uneven stresses do not cause premature tearing of the strap, as well as uneven pinching to occur, which can result in premature failure of the strap at the joint.

[0019] Buckle 1 comprises a lower level and an upper level. On the lower level, first and second engaging arms, 3 and 5, are connected together by a relatively perpendicularly oriented connecting portion 7. The three members, 3, 5, and 7, are oriented at about a 90 degree angle in relation to each other, as shown in Figure 2. On one side, engaging arm 3 has an extended portion 4 that extends relatively upward (on the side away from connecting portion 7) in a curved manner toward engaging arm 9 on the upper level. Another connecting portion 11 extends relatively perpendicularly and upward from extended portion 4, through curved joint 19, to connect to the strap engaging arm 9, which ends at distal end 17. On the other side, extending from strap engaging arm 5 (on the side away from connecting portion 7) is another connecting portion 15 that extends substantially perpendicularly in relation to engaging arm 5. Connecting portion 15 is extended through a bent portion 16 that wraps around the outside of extended portion 4, as shown in Figure 1, and connects to the other strap engaging arm 13, which ends at distal end 21.

[0020] Strap engaging arms 3 and 5, and strap engaging arms 9 and 13, preferably extend relatively straight and substantially parallel to one another as seen in Figures 1 and 2. Engaging arm 9 is relatively parallel with engaging arm 5, and engaging arm 13 is relatively parallel with engaging arm 3. Although engaging arm 3 is slightly inclined so that it is not exactly parallel with engaging arm 13, the present invention contemplates that upon the application of tensile stress to the strap, engaging arm 3 will bend to some extent, i.e., achieve some plastic deformation, and therefore, become substantially parallel to engaging arm 13 after the load is applied, as can be seen in Figure 11. Distal end 17 is preferably extended to a point that extends outside the perimeters of engaging arm 5 and connecting portion 7 (in plan view) to help ensure that strap 23 will not slip free from buckle 1 during use. Likewise, the distal end 21 of engaging arm 13 is preferably extended to a point that extends outside the perimeters of engaging arm 3 and connecting portion 7 (in plan view) for the same reason.

[0021] Figures 5 through 7 show the buckle 1 of the present invention in use with the strap 23 extending through the engaging arms and used to tie a box 25. Figure 6 shows a specific threading configuration wherein the ends of the strap 23 are looped around the top engaging arms 9 and 13, and under the lower engaging arms 3 and 5. Figure 7 shows how the buckle can be compressed when the strap 23 is tightened and tensile loads are applied, wherein it can be seen that some pinching can occur between the respective engaging arms, 5 and 9, and arms, 3 and 13. While the tie buckle of the present invention is treated to avoid or reduce the type of bending shown in Figure 7, that drawing is provided to show how bending and distortion can occur.

[0022] Figures 8 and 9 are representative drawings of an untreated tie buckle of the kind mentioned herein, which has been bent and permanently distorted by the application of tensile loads on the strap. These are representations of an actual sample of an untreated buckle that has been used and which has been permanently bent and distorted, i.e., substantial permanent deformation has occurred. As can be seen in Figures 8 and 9, considerable plastic deformation has occurred as evidenced by the following distortions: 1) engaging arms 13 and 9 are no longer parallel to one another, i.e., distal ends 21 and 17 are closer to each other than before the load was applied, 2) both of the lower engaging arms 3 and 5 are considerably bowed outwardly due to stress, wherein it can be seen that engaging arms 3 and 13 are no longer parallel to one another, 3) as seen in Figure 9, engaging arm 13 is bent relatively downward in relation to engaging arm 9, and 4) the space between engaging arm 13 and engaging arm 3 is quite narrow, wherein engaging arm 3 is bulged such that it can create an uneven pinching stress on the strap. In this particular example, it can be seen that the engaging arms are no longer parallel to one another, and that there would likely be an uneven amount of stress applied to the strap, as well as uneven pinching between the engaging arms, thereby making it likely that premature failure will result.

[0023] Figures 10 and 11 show the buckle of the present invention which has been heat treated and then loaded using a similar test. This sample is only slightly bent and has much less distortion than the sample shown in Figures 8 and 9. For example, 1) the lower engaging arms 3 and 5 are not bowed outwardly due to stress, wherein it can be seen that engaging arms 3 and 13 still appear to be relatively parallel to one another, 2) engaging arm 13 is not bent relatively downward in relation to engaging arm 9, as can be seen in Figure 11, and 3) the distance between engaging arm 13 and engaging arm 3 is relatively constant along the lengths of the engaging arms, so that no uneven pinching of the strap is likely to occur, i.e., engaging arms 3 and 13 appear to be relatively parallel to one another.

[0024] While distal ends 17 and 21 are bent toward each other slightly, it can be seen that engaging arms 3 and 13 are even more parallel to each other than they were before the loads were applied, indicating that the buckle of the present invention has, after being used, achieved some plastic deformation, which has in turn increased its ability to resist strap breakage. This indicates that while the buckle resists plastic deformation, it nevertheless allows some plastic deformation sufficient to cause the buckle to bend in a desirable manner, i.e., so that the arms are more parallel and the likelihood of uneven stress and pinching is substantially decreased.

Heat Treatment Methods

[0025] There are various hardening processes that can be employed to provide the benefits of the present invention. Conventional quenching of hot steel in water or oil provides surface hardening, but it also usually hardens some or all of the interior as well (depending on the thickness of the material). Other forms of surface hardening methods that can be used include carburizing, carbonitriding, nitriding, induction hardening and flame hardening.

[0026] Carburizing is a surface hardening process in which steel is held at a high temperature, i.e., 1,600 degrees F. (is common), for a relatively long time, i.e., six hours, in a carbonaceous environment, usually a gas mixture of carbon monoxide and carbon dioxide, with or without hydrocarbons such as methane. This treatment causes carbon to be diffused into the steel to a depth of several thousands or hundreds of an inch and leaves the carbon content of the surface much higher than that of the core.

[0027] Carbon nitriding is similar to carburizing except that nitrogen as well as carbon is diffused into the steel.

[0028] Nitriding is another diffusion process in which, by using ammonia without a carbonaceous gas, nitrogen is diffused into the steel and combines with other elements, principally chromium, already contained in the steel to form nitrides that are extremely hard and wear resistant.

[0029] Induction hardening is a process where the steel is briefly heated by electrical induction so that only the surface has time to get hot. The metal is then immediately cooled or quenched and the portion that was heated above the critical temperature (about 1,500 degrees F.) becomes hard while the rest of the steel which was not heated by induction current remains unaffected.

[0030] Flame hardening involves no change in the chemical composition of the steel surface, but involves a high temperature flame that impinges directly on the metal for a short time, heating the surface but not the interior of the piece.

[0031] The present invention contemplates using one of these methods to harden the surface of the metal after it has been bent into its predetermined configuration. It has been found that some of the heat treating processes used in the present invention, such as quenching to full hardness, must be controlled by tempering to limit the extent to which the metal can become too brittle, in which case the benefits of heat treatment can be defeated. The present invention also contemplates that the buckles can be finished with a dry phosphate coating to prevent slippage.

The Toughness of Metal

[0032] The ultimate "strength" of a material is the maximum stress that the material is capable of developing. Strength has to do with the overall amount of stress which, when exceeded, ultimately causes the material to fail. Strength can be measured in terms of either the yield strength, which relates to the resistance of the metal to permanent deformation, or tensile strength, which is the ultimate tensile strength of the metal.

[0033] The "stiffness" of a material is defined as the relationship between the amount of deformation (i.e., strain), and the applied load (i.e., stress), and is commonly expressed in terms of the Young's Modulus, i.e., the slope of the stress-strain curve before the yield point. Stiffness has to do with the actual deformation that the metal goes through when stress is applied prior to yielding.

[0034] While "strength" and "stiffness" are relevant factors that must be considered in addressing the bending characteristics of metal, they are not necessarily the only factors, nor the most important factors, particularly in this case. For example, a strong metal, such as high carbon metal, can be very stiff, but at the same time, it can be very brittle, in which case complete failure at the yield point can occur. That is, while a strong, stiff metal can have a relatively high yield point, if the yield point is exceeded, the metal can fail completely, i.e., shatter.

[0035] "Toughness," on the other hand, relates to the energy capacity of a particular material, i.e., the Modulus of Toughness is defined as the amount of energy required to cause failure in unit volume of a material, and is thus represented by the total area under the stress-strain curve. in this respect, the term toughness is more appropriately used to describe the combination of strength and "ductility," rather than strength and "stiffness." That is, stiffness only relates to the amount of deformation that occurs prior to the yield point, while ductility relates to total deformation, i.e., before and after the yield point, that occurs before the metal fails.

[0036] In this respect, a metal that is high in strength and ductility will not only resist bending to a higher degree, but will "give" more at higher stress levels so that complete failure will not occur until relatively high stress is applied. The combination of increased strength and ductility means that the metal will have a greater ability (particularly at higher stress levels) to resist "plastic deformation," which is defined as permanent deformation, i.e., the distortion and reformation of atomic bonds. "Plastic deformation" is different from "elastic deformation," which is temporary deformation, i.e., the stretching of atomic bonds. It is the propensity of the buckle to achieve plastic deformation that the present invention is able to resist by the application of one of several types of heat treatment processes.

The Test Results

[0037] While it has been known to use heat treatment to harden metals in certain types of applications, such as to resist certain kinds of surface wear and stress, i.e., in gears and ball bearings, such processes previously had not been used to toughen metal strap fasteners such as Cotton Tie Buckles. As far as the Applicant knows, the Cotton Tie Buckle industry has never considered using heat treatment as a viable solution to the problem of bending and distortion, principally because in the past the only way it was thought that stiffness could be increased was by increasing the thickness of the wire, i.e., not by changing the grade or quality of the material. This is based on the principle that steel (which is composed primarily of iron alloyed with small percentages of carbon and different metals like nickel, chromium, manganese, etc.) has a Young's Modulus equal to about 30,000,000 psi, and therefore, the stiffness of any steel structure could not normally be significantly increased by changing the material to a higher grade (without increasing the overall size of the members). Moreover, the cost of using higher grade materials (other than cheaply fabricated and low-priced steels) for these types of fasteners was thought to be cost-prohibitive. For these reasons, previous attempts to solve the problem have focused on changing the buckle or threading configuration, or increasing the thickness of the metal, not changing the grade or quality of the metal.

[0038] The results achieved by applying heat treatment to improve the performance of the metal fasteners of the present invention were completely unexpected. When the buckles of the present invention were treated in the manner discussed above, and tested by applying tensile loads to the tie straps (to which the buckles were attached), the overall joint efficiency of the strap was improved in almost every instance by more than 40%, and in some cases, by more than 80%. In this respect, while many standard tie buckles are unable to satisfy the minimum strength capacity for joint efficiency provided by ASTM and other testing standards, the tie buckles of the present invention significantly exceeded the minimum strength capacity in each test that was performed.

[0039] In general, tests have been performed to determine the efficiency of the strap at the joint where it is connected to the buckle, i.e., the load at which the strap will break due to stress caused by the buckle at the joint, using various types of metal tie buckles, including those that have not been heat treated, and those that have been heat treated. The straps used in the tests were standard type straps, with standard widths, having a specified maximum strength capacity. The specific straps used in these tests were samples of TEXband ® straps made of woven and coated polyester cord fiber.

[0040] The straps were threaded through the buckles before the loads were applied. In this respect, various setups were used to perform the tests. One test consisted of using a threading configuration consisting of a double wrap (snub-roll) extended around the top leg with the free end inserted into the top grip. Another strap was inserted into the bottom grip and single wrapped around the bottom leg. The slack was removed and a predetermined pretension was applied using a Capstan and Windlass style strap tensioner between the buckle and the bottom grip. The loose strap at the bottom of the buckle was also split lengthwise and a square knot was tied snugly against the bottom leg of the buckle.

[0041] Another test consisted of using a threading configuration involving single wrapping one strap around the top leg and inserting the free end into the top grip. An additional strap was inserted into the bottom grip and single wrapped around the bottom leg. The slack was removed and a predetermined pretension was applied using a Capstand and Windlass style strap tensioner between the buckle and the bottom grip. No knot was tied at the bottom of the buckle.

[0042] The protocol involved in these tests called for two test applications to be made: the first with the legs of the buckle pointing to the left of the technician, and the second with the legs pointing to the right. In each case, the tensile tester, such as the Instrom 4204, was activated until the strap broke. The breaking load (the load that caused the strap to break) and failure mode for each sample was recorded. Three pulls for each test were provided. The average breaking load for each test from each of the three pulls was then calculated.

Test Number 1

[0043] This test was conducted using a strap with the designation 66XLP.HD, which has a strength of 1,625 pounds per foot. The ASTM standard for joint efficiency for this strap is 55 percent of the strap's maximum strength capacity. That is, under the ASTM standard, the expectation is that the strap will fail (at the joint where the strap is connected to the buckle) when a load equal to 55 percent of the strap's maximum strength capacity is applied. In this case, 55 percent of the maximum strength capaity is about 894 pounds per foot. The tests were conducted to determine whether this minimum standard was met.

[0044] This test was conducted using Formex B-6XHDG (galvanized) buckles with the legs pointed to the left, with the strap tension from the bottom, with no snub-roll at the top. No knot was provided at the bottom of the strap. A 300 pound pretension was applied by the tensile tester. The following results were achieved:

[0045] A standard buckle without heat treatment was tested first Wire sizes of 0.135 inch and 0.148 inch, and wire types 1008 and 1018, were used. An average break point was determined from three pulls for each test. These are the results, each indicating a joint efficiency of less than 55%.

Untreated B-6XHDG Buckle				
Buckle	Wire Size	Wire Type	Average Break Point (in pounds per foot)	Standard Deviation (in pounds per foot)
B-6XHDG	0.135	1008	642	60
B-6XHDG	0.135	1018	712	24
B-6XHDG	0.148	1018	818	49

[0046] The same Formex B-6XHDG type buckle was then heat treated by carburizing and then tested. Wire sizes of 0.135 inch and 0.148 inch, and wire types 1008 and 1018, were again used. The carburizing heat treatment process that was employed was designed to maximize toughness and increase strength, wherein the metal was hardened and tempered to about Rc 40-45. An average break point was determined from three pulls for each test. These are the results, each indicating a joint efficiency of greater than 55%.

Heat Treated (Carburized) B-6XHDG Buckle				
Buckle	Wire Size	Wire Type	Average Break Point (in pounds per foot)	Percentage of Increase
B-6XHDG	0.135	1008	1007	56.85
B-6XHDG	0.135	1018	1043	46.49
B-6XHDG	0.148	1018	1143	39.73

[0047] These tests show that the buckles that have been heat treated according to the present invention have a substantially greater strength capacity than untreated buckles of comparable size and type. The treated buckles resulted in a strap break point, i.e., the load at which the strap will fail due to stress at the joint, which is more than about 40 percent to 57 percent over that which was obtained by standard untreated tie buckles. Another way to view this information is that none of the standard untreated buckles satisfied the ASTM standard, i.e., the load capacities were anywhere from 8.5 percent to 28.19 percent below the load capacity of 894 pounds per foot On the other hand, each of the treated buckles of the present invention easily satisfied the ASTM standard, i.e., the load capacities were anywhere from 12.64 percent to 27.85 percent above the standard, which was unexpected.

Test Number 2

[0048] This test was conducted using a strap designated as 60W, which has a strength of 900 pounds per foot. The ASTM standard for joint efficiency for this strap is also 55 percent of the strap's maximum strength capacity. That is, under the standard, the expectation is that the strap will fall (at the joint where the strap is connected to the buckle) when a load equal to 55 percent of the strap's maximum strength capacity is applied. In this case, 55 percent of the maximum strength capaity Is only about 405 pounds per foot.

[0049] This test was conducted using Formex B-6X, B-6XHDG (galvanized) and B-6XHD (ungalvanized) buckles with the legs pointed to the left, with the strap tension from the bottom, with no snub-roll at the top. The strap was also not knotted at the bottom. A 250 pound pretension was applied by the tensile tester. The following results were achieved:

[0050] A standard buckle without heat treatment was tested first. Wire sizes of 0.120 inch, 0.135 inch and 0.148 inch, and wire types 1008 and 1018, were used. An average break point was determined from three pulls for each test. These are the results.

Untreated Buckle				
Buckle	Wire Size	Wire Type	Actual Break Point (in pounds per foot)	Standard Deviation (in pounds per foot)
B-6XHDG	0.120	1008	342	22
B-6XHDG	0.135	1018	372	62
B-6XHDG	0.148	1018	465	49

[0051] The same type of buckles were then heat treated with carbon nitride and carburizing and then tested. Wire sizes of 0.135 inch and 0.148 inch, and wire types 1008 and 1018, were used. The carbonitriding and carburizing heat treatment processes that were employed were designed to maximize toughness and increase strength, wherein the metal was hardened and tempered to about Rc 40. An average break point was determined from three pulls for each test These are the results, each indicating a joint efficiency of far greater than 55%.

Heat Treated Buckle				
Buckle	Wire Size	Wire Type	Actual Break Point (in pounds per foot)	Percentage of Increase
B-6XHD*	0.135	1008	578	55.37***
B-6XHD*	0.148	1008	685	47.31****
B-6X HDG**	0.148	1018	745	60.21

* These buckles were treated by carbonitriding.

** This buckle was treated by carburizing.

*** This increase is in relation to the 372 pounds per foot achieved by the untreated galvanized buckle having an equal wire size (0.135) but different wire type (1008 compared to 1018) shown in the previous chart The increase was achieved even though the type of steel used in the heat treated buckle was of a lower grade. This indicates that better performance can be achieved, while at the same time, a cost-savings can be obtained by using lower grade steel.

**** This increase is in relation to the 465 pounds per foot achieved by the untreated galvanized buckle having an equal wire size (0.148) but different wire type (1008 compared to 1018) shown in the previous chart. Again, the increase was achieved even though the type of steel used in the heat treated buckle was of a lower grade.

[0052] These tests show that the buckles that have been heat treated according to the present invention have a substantially greater strength capacity than untreated buckles of comparable size and type. The treated buckles resulted in a strap break point, i.e., the load at which the strap will fail due to stress at the joint, which was more than about 47 percent to 60 percent over that which was obtained by standard untreated tie buckles. Another way to view this information is that only one of the standard untreated buckles (the one with the largest diameter of .148 inch) was able to satisfy the ASTM standard, whereas all of the treated buckles easily satisfied the ASTM standard, some by as much as 83.95%.

Test Number 3

[0053] This test was conducted using a strap designated as 66XLP.HD, which has a strength of 1,625 pounds per foot. As discussed above, the ASTM standard for this strap is 55 percent of the strap's maximum strength capacity. Again, in this case, 55 percent of the maximum strength capaity is about 894 pounds per foot.

[0054] This test was conducted using Formex B-6XHD (ungalvanized) buckles with the legs pointed to the left, with the strap tension from the bottom, with no snub-roll at the top. The strap was also not knotted at the bottom. A 300 pound pretension was applied by the tensile tester. The following results were achieved:

[0055] A standard buckle without heat treatment was tested first Wire sizes of 0.135 inch and 0.148 inch, and a wire type of 1038, were used. These are the results.

Untreated B-6XHD Buckle				
Buckle	Wire Size	Wire Type	Average Break Point (in pounds per foot)	Standard Deviation (in pounds per foot)
B-6XHD	0.135	1038	602	75
B-6XHD	0.148	1038	753	21

[0056] The same Formex B-6XHD type buckles were then quenched and fully hardened and then tempered by annealing. A wire size of 0.135 inch with a wire type of 1038 was tested with various levels of hardening. An average break point was determined from three pulls for each test. These are the results.

Heat Treated B-6XHD Buckle				
Buckle	Wire Size	Wire Type	Actual Break Point (in pounds per foot)	Percentage of Increase
B-6XHD	0.135	1038	940	54.86*
B-6XHD	0.135	1038	948	56.18**
B-6XHD	0.135	1038	1067	75.78***

* This buckle was quenched to full hardening and then tempered to about Rc 35.

** This buckle was quenched to a hardness of Rc 52, and then tempered by annealing to about Rc 38-42.

*** This buckle was quenched to full hardening and then tempered to about Rc 38-42.

[0057] Next, buckles having a wire size of 0.148 inch with a wire type of 1038 were tested with various levels of hardening. An average break point was determined from three pulls for each test. These are the results.

Heat Treated B-6XHD Buckle				
Buckle	Wire Size	Wire Type	Actual Break Point (in pounds per foot)	Percentage of Increase
B-6XHD	0.148	1038	1018	35.19*
B-6XHD	0.148	1038	1103	46.48**
B-6XHD	0.148	1038	1170	55.38***

* This buckle was quenched to full hardening and then tempered to about Rc 35.

** This buckle was quenched to a hardness of Rc 52, and then tempered by annealing to Rc 38-42.

*** This buckle was quenched to full hardening and then tempered to about Rc 38-42.

[0058] These tests show again that the buckles that have been heat treated according to the present invention have a substantially greater strength capacity than untreated buckles of comparable size and type. The treated buckles resulted in a strap break point, i.e., the load at which the strap will fail due to stress at the joint, which was more than about 35 percent to 75 percent over that which was obtained by standard untreated tie buckles. Another way to view this information is that none of the standard untreated buckles satisfied the ASTM standard, i.e., the load capacities were in the range of about 602 to 753 pounds per foot compared to the load capacity of 894 pounds per foot. On the other hand, each of the treated buckles of the present invention easily satisfied the ASTM standard, i.e., the load capacities were anywhere from 940 to 1170 pounds per foot which is well above the standard of 894 pounds per foot.

[0059] Additional tests were conducted on buckles that were quenched to full hardening without tempering by annealing. The untempered buckles in this case were too brittle and shattered when loads were applied. The loads at which the buckles shattered varied widely, i.e., of three pulls for the same type buckle, with the ASTM joint efficiency standard being 405 pounds per foot for the strap, one buckle shattered at 693 pounds, another at 460 pounds, and another at 337 pounds. In another sample, one buckle shattered at 536 pounds, and another at 251 pounds. This-indicates that quenching without tempering does not provide a workable product.

[0060] The invention and its various embodiments have been discussed above in an exemplary manner. Accordingly, it should be apparent that the present invention is not intended to be limited to the specific embodiments discussed above. The present invention is intended to cover many variations of the buckle design, as well as various methods of heat treatment, whether or not specifically discussed above.

Claims

1. A method of improving the joint efficiency of a metal strap buckle, comprising:

providing a buckle made from a single piece of metal wire;
adapting said buckle such that it is configured with two pairs of strap engaging arms, wherein said arms are essentially parallel to one another; and
hardening said buckle such that the strength and toughness of said metal wire are increased, thereby improving the ability of said arms to remain substantially parallel to one another when tensile loads are applied to said strap, and reducing the likelihood that said engaging arms will bend and distort to cause premature breakage of said strap.

2. The method of claim 1, wherein the method comprises the step of hardening the metal by carburizing.

3. The method of claim 1, wherein the method comprises the step of hardening the metal by carbonitriding.

4. The method of claim 1, wherein the method comprises the step of hardening the metal by nitriding.

5. The method of claim 1, wherein the method comprises the step of hardening the metal by induction hardening.

6. The method of claim 1, wherein the method comprises the step of hardening the metal by flame hardening.

7. The method of claim 1, wherein the method comprises the step of quenching to full hardening, and tempering using an annealing process.

8. The method of claim 7, wherein the tempering is to Rc 38-42.

9. The method of claim 7, wherein the tempering is to Rc 35.

10. The method of claim 1, wherein the method comprises the step of quenching to a hardness of Rc 52, and tempering to Rc 38-42.

11. A metal strap buckle, comprising:

    a body portion made from a single piece of metal wire, wherein said body portion comprises:
    first and second strap engaging arms extending essentially parallel to one another, and connected together by a first connecting portion, wherein said first and second engaging arms and said first connecting portion are oriented substantially along a first level;
    third and fourth strap engaging arms formed on opposing ends of said single piece of metal wire, wherein said third engaging arm is connected to said second engaging arm by a second connecting portion, and said fourth engaging arm is connected to said first engaging arm by a third connecting portion, said third and fourth engaging arms extending essentially parallel to one another and substantially along a second level; and
    wherein said single piece of metal wire has been hardened by heat treatment

12. The buckle of claim 11, wherein the buckle has been hardened by carburizing, carbonitriding, nitriding, induction hardening, or flame hardening.

13. The buckle of claim 11, wherein the buckle has been hardened by quenching to full hardening, and tempered with an annealing process.

14. The buckle of claim 11, wherein the buckle has been hardened by quenching to Rc 52, and tempered by annealing to Rc 38-42.

15. The buckle of claim 13, wherein the buckle has been tempered to Rc 38-42.

16. The buckle of claim 13, wherein the buckle has been tempered to Rc 35.

17. A method of producing a metal strap buckle, comprising:

    providing a buckle made from a single piece of metal wire;
    adapting said buckle such that it is configured with two pairs of strap engaging arms capable of being connected to a strap;
    hardening said buckle such that the strength and toughness of said metal wire are increased; and
    allowing one or more of said strap engaging arms to bend slightly when tensile loads are applied to said strap, wherein said strap engaging arms are hardened to the extent needed to resist plastic deformation, but at the same time, to bend enough such that said strap engaging arms are able to become more parallel to each other than before said tensile loads were applied to said strap, wherein the joint efficiency of said strap is enhanced thereby.

18. The method of claim 17, wherein the method comprises the additional step of adapting said buckle such that all

but one of said strap engaging arms are essentially parallel to each other, and wherein said one strap engaging arm becomes essentially parallel to said other strap engaging arms by the application of said tensile loads, wherein said one strap engaging arm achieves plastic deformation sufficient to cause said arms to become essentially parallel to each other after said tensile loads are removed.

19. The method of claim 17, wherein the method comprises the additional step of allowing enough plastic deformation to occur to enable said strap engaging arms to extend essentially parallel to one another after said tensile loads are applied and removed.

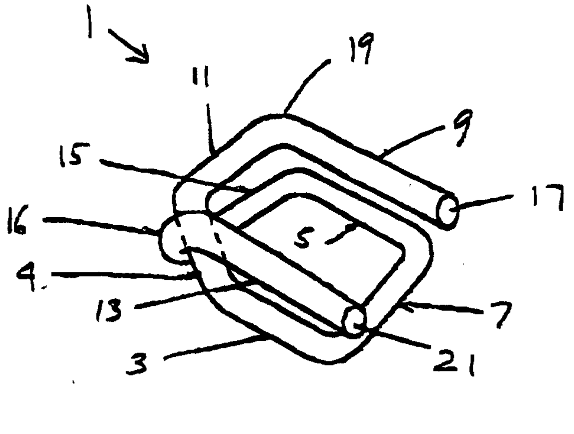

FIG. 1

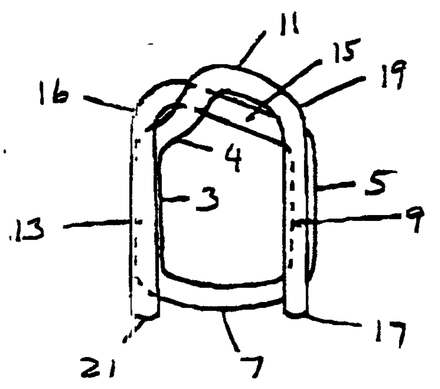

FIG. 2

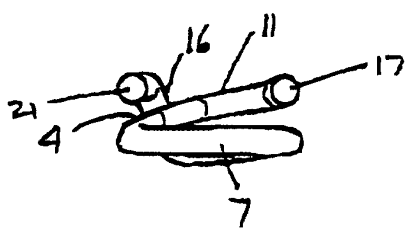

FIG. 3

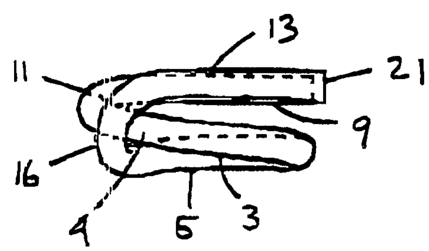

FIG. 4

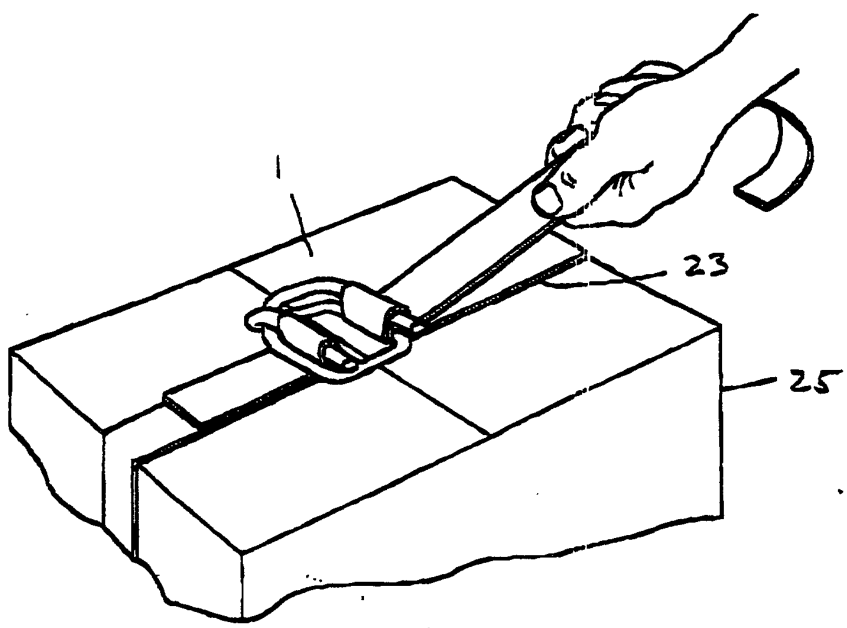

FIG. 5

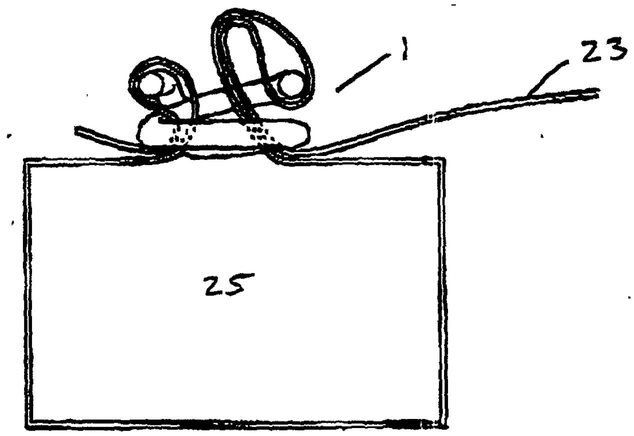

FIG. 6

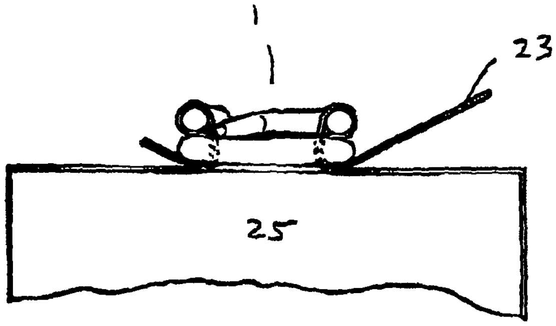

FIG. 7

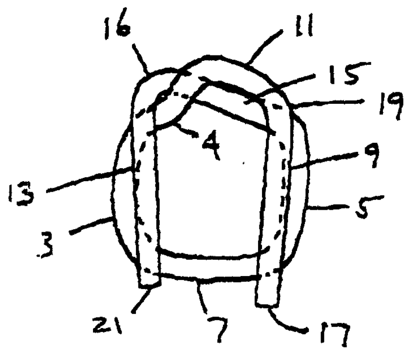

FIG.8

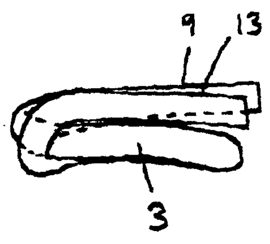

FIG.9

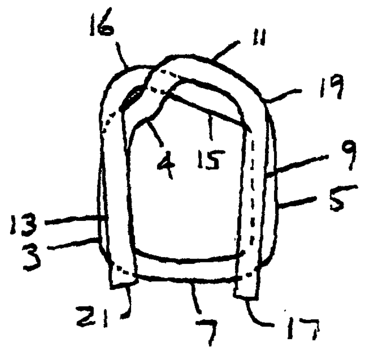

FIG.10

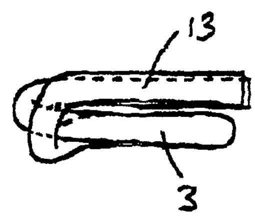

FIG.11