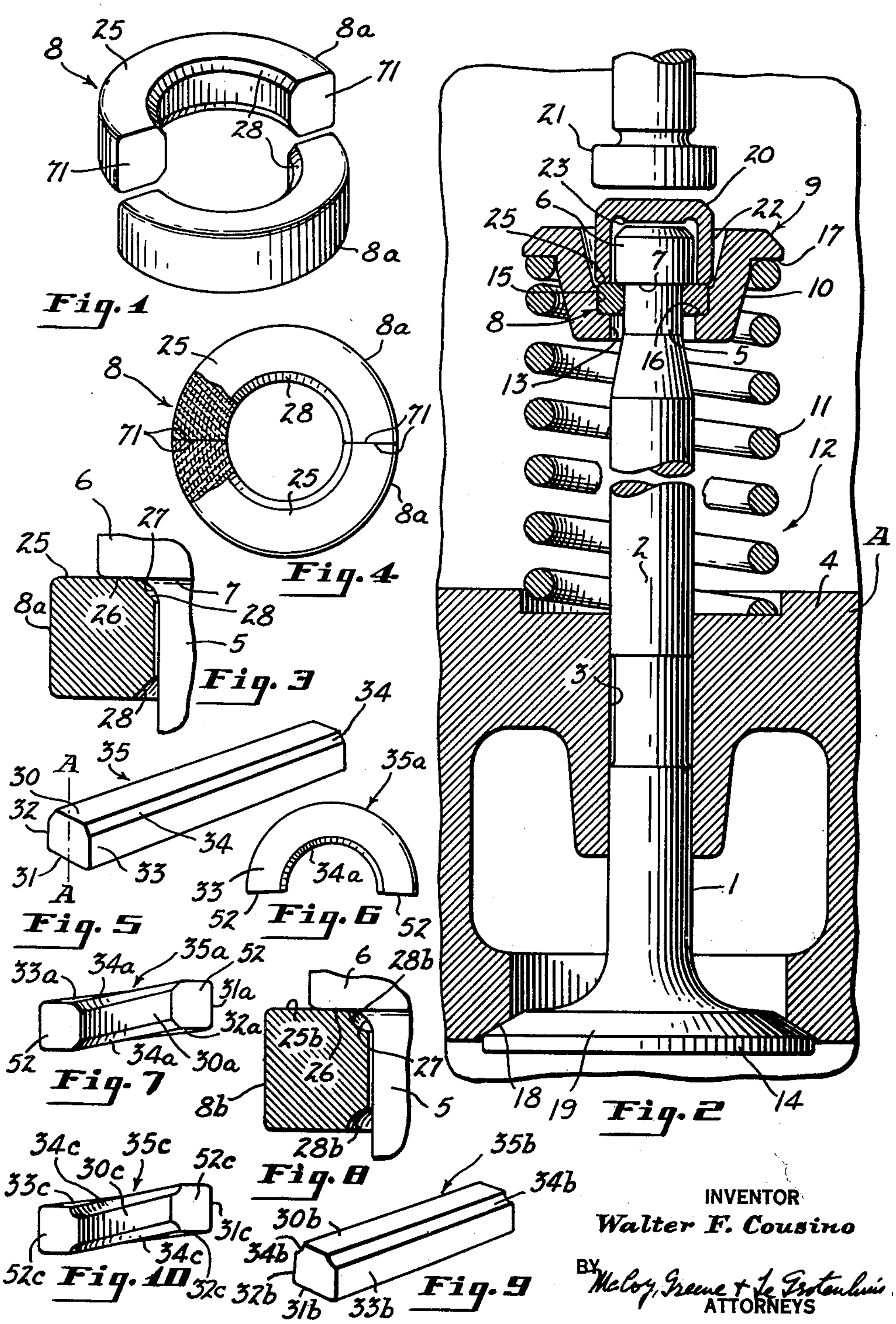
Feb. 20, 1962 W. F. COUSINO 3,021,593

METHOD OF MAKING METAL RINGS

Filed May 5, 1958

4 Sheets-Sheet 1



INVENTOR
Walter F. Cousino

BY *McCoy, Greene & LeGrotenhuis*
ATTORNEYS

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METHOD OF MAKING METAL RINGS

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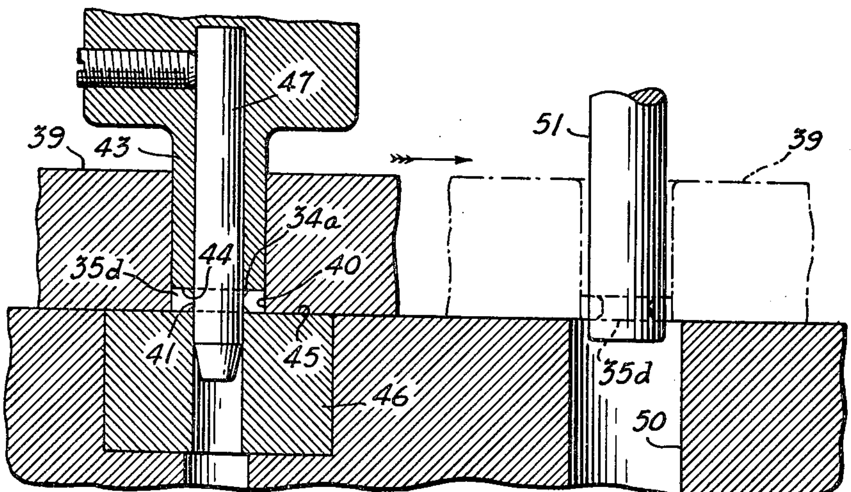

Fig. 11

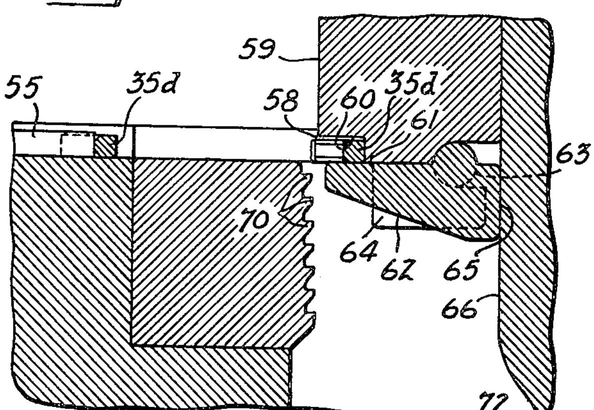

Fig. 12

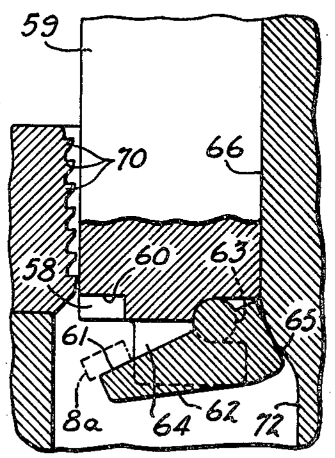

Fig. 14

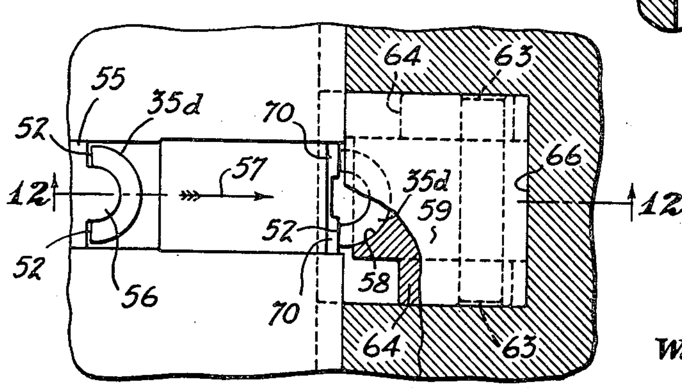

Fig. 13

INVENTOR
Walter F. Cousino

BY McCoy, Greene & Te Grotenhuis
ATTORNEYS

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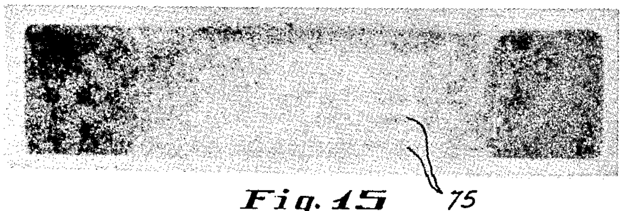


Fig. 15

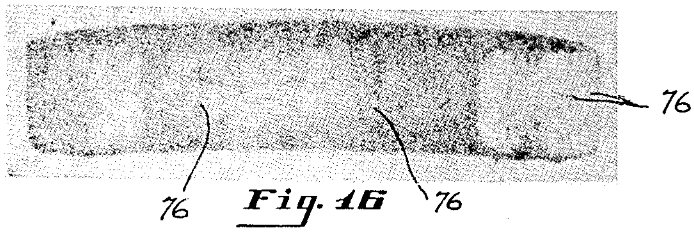
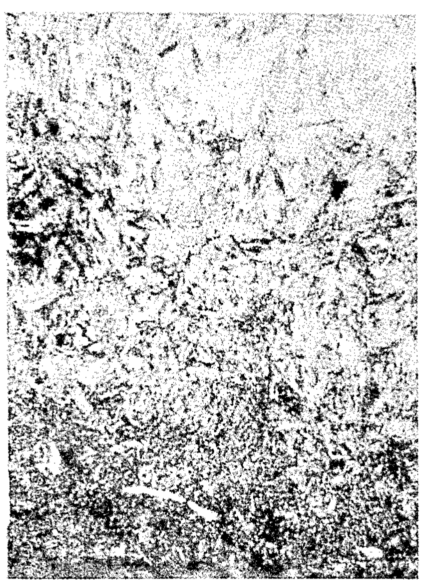


Fig. 16



MAGNIFICATION x500

Fig. 17

MAGNIFICATION x500

Fig. 18

INVENTOR
Walter F. Cousino
BY Meloy, Greene & Le Grotenhuis
ATTORNEYS

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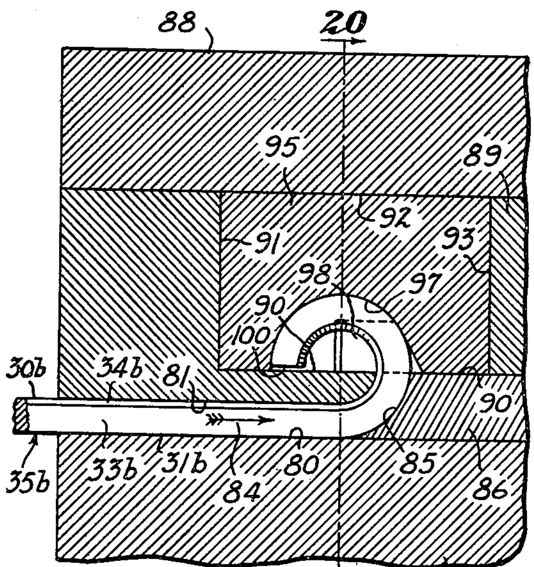

Fig. 19

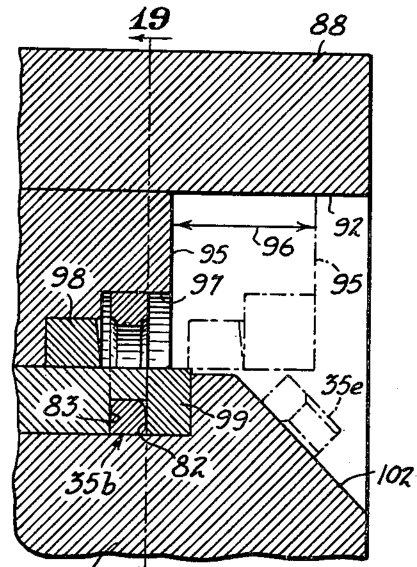

Fig. 20

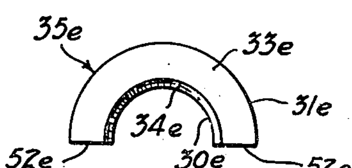

Fig. 21

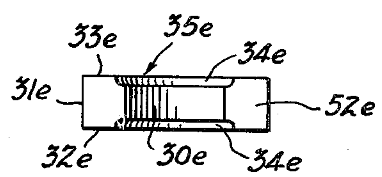

Fig. 22

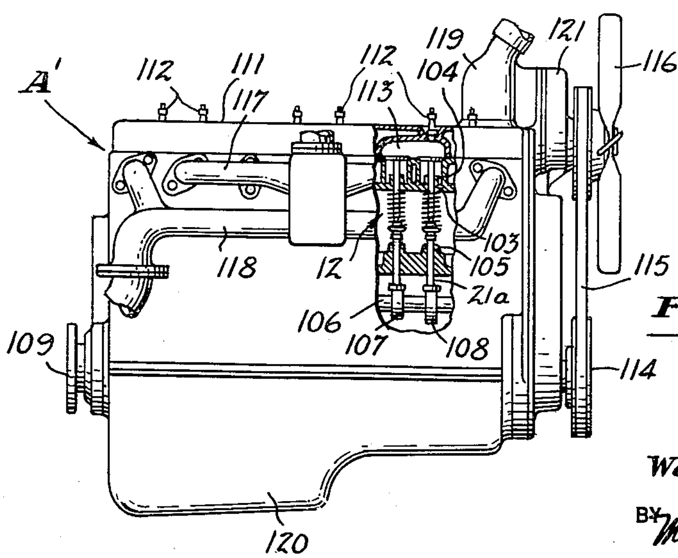

Fig. 23

INVENTOR
Walter F. Cousino

BY *McCoy, Greene & Te Grotenhuis*
ATTORNEYS

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METHOD OF MAKING METAL RINGS

Walter F. Cousino, 2160 Mount Vernon, Toledo, Ohio

Filed May 5, 1958, Ser. No. 732,989
7 Claims. (Cl. 29—417)

The present invention relates to a method for making metal rings, suitable for use, for example, as locking elements in a free rotating valve assembly.

The valve assemblies of internal combustion engines often are of the free rotating type wherein an annular locking ring, which may be formed in a plurality of segments according to the invention, is used to embrace an annular shoulder on the valve stem and means are provided to release the valve stem for rotary movement.

Because of the small area of contact and the fact that the valve shoulder and the locking ring are subjected to repeated impact, failures are apt to occur because of shear stress in said ring with the result that the valve damages the engine considerably. The locking ring is, therefore, of exceptional importance and requires close design tolerances and high strength steels. Only the highest quality rings are acceptable and even then failures will occur because of the repeated impacts on the ring.

The provision of means for moving the valve lock washer into and out of engagement with the valve stem shoulder requires lock washer segments much stronger than those previously used on non-rotating valves as shown for example in U.S. Patent No. 1,823,009 or U.S. Patent No. 1,973,227.

It is an object of the invention to provide a method for the fabrication of inexpensive durable locking rings that are subjected to repeated impacts and, for example, are reciprocated on the valve stems of an internal combustion engine.

A further object of the invention is to provide a method for fabricating a locking ring for a valve assembly which will withstand excessive wear, permit rotation of the valve and provide a greatly improved factor of safety.

A further object of the present invention is to provide a lower cost method of making segments of a valve lock washer or lock ring to very accurate dimension and having the metal thereof densified and molecularly arranged to provide an improved factor of safety over valve lock rings heretofore made.

Other objects will be apparent from the following description of the invention as illustrated by the accompanying drawing, in which:

FIGURE 1 is a perspective view of segments of a valve lock washer or lock ring prepared in accordance with the present invention;

FIG. 2 is a fragmentary view partly in section of a valve assembly 12 in an internal combustion engine A showing the valve spring, the valve lock washer, spring retainer ring, and the valve cap together with portion of the engine cylinder head in section;

FIG. 3 is an enlarged view of the portion of a valve lock washer and valve stem showing the bearing area (enlarged between the shoulder of the valve stem and the upper surface of said lock washer;

FIG. 4 is a plan view of a valve lock washer made according to the present invention with outer surface portions removed to schematically illustrate the linear molecular structure of the lock washer formed in accordance with the process herein;

FIG. 5 is a perspective view of a portion of a strip of metal wire stock prepared by rolling round wire to keystone shape and skiving it;

FIG. 6 is a plan view of spiral washer segment prepared from the strip of FIG. 5 and used as an intermediate in the preparation of valve lock washers according to the present invention;

FIG. 7 is an elevational view of the washer of FIG. 6;

FIG. 8 is an enlarged view partly in section of a portion of a modified form of valve lock washer and valve stem showing the bearing area (enlarged) between the washer and the valve stem;

FIG. 9 is a perspective view of a portion of a modified form of bar made by rolling round wire to generally keystone shape and skiving it;

FIG. 10 is an elevational view of a modified form of spiral washer segment;

FIG. 11 is a fragmentary sectional view through a portion of suitable apparatus used for coining the intermediate spiral washer segment of FIGS. 6 and 7, or of FIG. 10 to cause the required change in molecular structure and dimensions thereof to insure extremely dense material of proper size and shape;

FIG. 12 is a fragmentary sectional view through a portion of apparatus suitable for broaching or finishing the end portions of the segmental washer coined in the apparatus of FIG. 11;

FIG. 13 is a fragmentary elevational view with parts broken away of the apparatus of FIG. 12 showing the washer therein;

FIG. 14 is a view similar to the view of FIG. 12 of the portion shown in FIG. 12 illustrating the release of the lock washer of the present invention after the broaching or end finishing step;

FIG. 15 is an enlarged photograph of an etched segment of a lock washer fabricated according to the present invention showing the linear and generally horizontal grain structure and the dense characteristics of the metal;

FIG. 16 is a similar photograph of a segment of a washer etched for the same length of time as was the product of FIG. 15 but which was prepared in accordance with the prior method of cutting the washer from rod stock by means of an automatic screw machine, and showing the etched lines to indicate a grain structure parallel to the axis of the washer, rather than perpendicular thereto as in the washer of FIG. 15;

FIG. 17 is a photomicrograph of a section through a washer prepared by the automatic screw machine process used prior to the present invention;

FIG. 18 is a photomicrograph with the same magnification of a section through a washer prepared in accordance with the process of the present invention;

FIGURE 19 is a vertical sectional view through a portion of an apparatus suitable for forming the circular intermediate segments which may be used in accordance with the present invention, said view being taken on the line 19—19 of FIG. 20 and also showing a portion of the bar bent to form portions of an annulus which may be separated to form circular segments suitable for the compression and densification step;

FIG. 20 is a sectional view on the line 20—20 of FIG. 19;

FIG. 21 is a plan view of an undensified intermediate circular segment;

FIG. 22 is an elevational view of the segment shown in FIG. 21; and

FIG. 23 is a side elevational view on a reduced scale with parts broken away to show a valve assembly incorporating a locking washer made according to the present invention as employed in a six cylinder, L-head, passenger car engine.

As will be seen, referring to FIGURE 2 of the drawings, the valve 1 of each valve assembly 12 has a stem portion 2 slidably journaled in the bore 3 of the cylinder head 4 of an overhead-valve internal combustion engine A. The circular head 14 of the valve 1 has a frusto-conical surface 19 for engaging the frusto-conical valve seat 18 of the head 4 to cut off the flow of gases. A reduced portion 5 of smaller diameter is disposed between upper portion 6 and lower valve stem portion of normal diameter. The upper portion 6 terminates in an annular shoulder 7 against which the valve lock washer formed of the segments of the present invention is adapted to bear. The inner opening in the split washer 8 of the composite segments 8*a* or 8*b* is adapted to snugly receive the reduced portion 5 of the valve stem. Difference in dimension between the reduced portion 5, and upper head portion 6 determines the possible bearing area against which the lock washer 8 of the present invention is adapted to bear. A spring retainer ring 9 having a conical surface 10 of sufficient maximum dimension to retain the spring 11 centrally about the valve stem 2 has a central opening 13 of sufficient size to pass over the head portion 6 of the valve stem 2. The retainer ring 9 has adjacent the internal edge of the opening 13 a cylindrical surface 15 adapted to loosely receive the two segments 8*a* of the lock washer 8. The internal diameter of the surface 15 is insufficient to permit the segments 8*a* or 8*b* (depending on which of the two modified forms of segment is used) from separating sufficiently to permit the head of the valve to pass through the central opening in the composite washer formed of the segments 8*a* or 8*b*. At one edge of the cylindrical surface 15 is a flange 16 against which the lower portion of the valve lock washer 8 is adapted to bear. The outer conical surface 10 of the retainer ring 9 has adjacent its upper edge a flange portion 17 which is adapted to receive the thrust from the spring 11 tending to maintain the valve in the closed position shown.

The general shape of the sections cut by an axial plane thru the lock washer retaining ring 9 are Z shaped as shown. A cap 20 is adapted to fit loosely over the end portion 6 of the valve stem to receive the thrust from the downward movement of the valve lifter or tappet 21. The cap 20 has edge or marginal portions 22 which bear against the upper surface of the washer 8. The axial length of the edge portions 22 is sufficient so that a clearance 23 is provided between the upper edge end of the valve and the inside of the cap 20 so that when the valve lifter 21 is depressed, the upper surface 25 of the valve lock washer is first separated from the shoulder 7 and stress between the valve and the washer 8 is eliminated so that the valve is free to turn.

In the operation of an internal combustion engine, particularly engines of trucks and the like, there has, as aforesaid, been a number of failures which have occurred because of the shearing or wearing of the portions 8*a* or 8*b* of the composite washer 8. The shear stress is impressed between the flange 16 of the retainer ring on the one side and the shoulder 7 of the valve on the other side and is intermittent and severe when area of contact is considered. The amount of compression surface 26 between the shoulder 7 and the upper surface 25 of the lock washer is small, being limited because of design considerations. If attempts are made to increase the amount of shoulder area by reducing the size of the reduced portion 5 of the valve, difficulty is likely to occur because of weakness in the valve stem. When the fillet 27 between the reduced portion 5 and shoulder 7 of the valve stem is eliminated, an exceptionally dangerous concentration of stress in the valve stem at the juncture occurs. While elimination of such fillet 27 would permit the elimination of the relieved portion such as the chamfered portion 28 or the skived portion 28*b* of the lock washer segments 8*a* and 8*b*, respectively, and substantially increase the bearing surface against the valve shoulder, the concentration of stress in the valve stem renders such a solution impractical. In order, therefore, to provide even the minimum factor of safety in the above combination it has been the practice to make the lock washer segments of expensive chromium alloy steel such, for example, as SAE 52,100 which have inherently good characteristics but which are difficult to shape and which render the manufacture of such valve lock washer segments extremely expensive. Prior to the present invention such lock washer segments were produced by the automatic screw machine from rods or tubes of suitable size which requires waste of much expensive alloy steel.

I have found in accordance with the present invention that valve lock washer segments having a greatly improved factor of safety and greatly improved structural characteristics may be prepared from the very ordinary grades of inexpensive carbon steel such, for example, as SAE 1060 steel, providing the steel is worked so as to align its grain structure and to densify it properly in the segments.

The term "carbon steel" wherever used in the specification or claims means a steel consisting essentially of iron with a fraction of a percent of carbon, manganese, phosphorus and/or sulphur and being substantially free of (i.e., less than 0.20%) nickel, chromium, molybdenum or other expensive metals which would have a substantial effect on the properties of the steel. The method of the present invention is usually practiced with inexpensive carbon steels containing about 0.4 to 1% carbon, 0 to 1% manganese, 0 to 0.05% phosphorous and 0 to 0.06% sulphur. Such carbon steels may be cold worked according to the present invention to provide very high quality valve lock washer segments.

In accordance with the present invention a wire is first formed preferably by rolling a round wire of suitable steel so that it forms a bar 35 or 35*b* (FIGS. 5 and 9 respectively) having a section of a generally keystone shape or so that it has upper and lower relatively flat surfaces 30 and 31, respectively, which are substantially parallel. Side edge surface portions 32 and 33, respectively, which are flat surfaces, are preferably somewhat convergent so that surface 31 or the distance between the lines of intersection of the plane of the surface 31 with the planes of the side edge portions 32 and 33 is wider than surface 30. While the surfaces 30, 31 32 and 33 and the corresponding surfaces 30*b*, 31*b*, 32*b* and 33*b* form a keystone shaped bar, the corner portions at the intersection of the planes of the surface 30 (or 30*b*) with the convergent surfaces 32 (or 32*b*) and 33 (or 33*b*) are suitably relieved as by rolling or skiving a chamfer or preferably a hyperbolic groove to provide the surface portions 34 and 34*b*, respectively disposed at the side edges of the respective narrower inner or upper surface 30 (or 30*b*) and joining the upper surface with the sides. The bars 35 and 35*b* are symmetrical about the median vertical longitudinal plane, perpendicular to the surfaces 30 and 31 (and the respective corresponding surfaces 30*b* and 31*b*.

The second step in forming the segments 8*a* or 8*b* is to form the respective spiral segment 35*a* or 35*c* from the respective bar 35 or 35*b* by causing the respective bar to be bent in a helical form with the axis of the helix perpendicular to the aforementioned median plane of symmetry of the bar 35 (or 35*b*) and so that the narrower of the parallel surfaces 30 (or 30*b*) of the wire and the relieved edges 34 (or 34*b*) are disposed at the inner surface of the helix to form the surfaces 34*a* (or 34*c*). Segments which are preferably just slightly more than 180° are severed from the remainder of the helix thus formed. If more than two segments are desired in the composite washer the spiral segments should preferably together form an only slightly more than one helical turn. One form of apparatus suitable for forming the intermediate spiral segments of FIGURE 6 from the bar of FIGURE 5 is described in the Williams et al. Patent No. 2,308,579. The segments separated in accordance with the preferred process of the present process have as aforesaid slightly more than one-half helical turn. In the alternative, a helix may be formed as described in the Garrett Patent No. 1,989,750 by winding the wire or bar 35 or FIGURE 5 about a suitable mandrel and then severing segments of the desired size from the helix thus formed. The formation of the bar 35 (or 35*b*), as above described, into helical form causes thickening of the portion within the neutral axis thereof so that the distance between the edges 33a (33c in FIG. 10) and 32a (32c in FIG. 10) is adjacent the chamfered or relieved corner portions 34 (34c in FIG. 9) is greater than the corresponding distance in the respective wires 35 and 35b. The degree of convergence of the sides of the bars 35 and 35b is preferably just about sufficient to cause after thickening by winding the side edges 33a (or 33b) and 32a (or 32b) to become parallel to each other. The chamfered surfaces 34a run at an angle relative to the inner surface 30a and to the side edges 32a and 33a and separate side edge surfaces from the surfaces 30a. In accordance with the preferred modification of FIG. 10 the hyperbolic grooves 34c have side edges which run perpendicular to the adjacent flat surfaces.

In accordance with the next step of my process of forming the valve locking segments, the spiral segments 35a or 35c as desired of FIGURE 6 are disposed in a suitable cavity of a die 39 having outer side walls 40 which are generally cylindrical and of the size corresponding to the outer diameter of the lock washer segment desired.

An inner cylindrical side wall 41 which may be a suitable locating pin of a diameter corresponding to the diameter of the reduced portion 5 of the valve stem and to the inner diameter of the central opening in the composite lock washer 8 made up of the segments 8a or 8b may be carried by the punch 43 having a lower flat surface 44 adapted to contact the desired spiral segment in the die cavity. The punch and die cavity are dimensioned to have a sliding fit. The lower surface of the die cavity may be formed by the upper surface 45 of the stationary annular die block 46.

The spiral segment 35a (or 35c) is compressed between the flat surfaces 44 and 45 to form the intermediate coined segment 35d of reduced axial thickness compared to the thickness of 35a or 35c. The reduction is made without restraining flow of metal at the chamfered or relieved portions 34a (or 34c) by any contacting rigid surface of the die.

The amount of flow of metal, i.e., the reduction in thickness of the spiral segments 35a and 35c had in the forming of the flattened or coined segment 35d (raw ends) or 8a and 8b (with machined or ground ends) is extremely important. The amount of reduction is important both for structure and for stability. When the reduction is insufficient the segment does not remain flat and the cross-linking or densifying of the metal is insufficient for wear and safety. Generally a reduction of about 10% in thickness is desirable although a reduction as high as 20 or even 30% is permissible. Reductions smaller than 3% do not provide sufficient density or stability. A reduction of at least 5% is preferred.

The punch 43 together with the pin 47 may be removed from the cavity of the die 39 leaving the lock washer segment 8b disposed therein. The cylindrical portion of the die can thereupon be removed by suitable piston operated lifting means over the opening having cylindrical walls 50 which are of larger diameter than the diameter of the composite lock washer where it is removed by downward movement of the ejecting punch 51.

The end portions 52 (FIG. 6) of the spiral washer and of the flat densified segment 8b may be suitably machined to the desired flattened state by disposing the segments 35d in a suitable cavity of a broaching machine adapted to broach the ends to a flattened state. The segments 35d as shown in FIG. 9 may be disposed on the slide 55 (preferably piston operated) having a suitable curved end portion 56 of substantially the same diameter as the diameter of the segment. The slide is adapted to move in the direction of the arrow 57 to force the washer into the cavity 58 of the holder 59 which is adapted to move in a downward direction. The semi-circular cavity 58 of the holder 59 has an upper flat surface 60 and a lower flat surface 61 which is carried by the movable jaw 62 that is pivotably carried by cylindrical bearing portions 63 carried by the lugs 64 depending from the holder 59. When the holder 59 is in the upper position suitable for receiving the coined segment 8b, the end portion 65 of the jaw 62 bears against the guide 66 so that the cavity 58 securely confines the segment 8b with ends protruding therefrom for contact with broach teeth 70. Upon downward movement of the holder 59 the ends of the segments 35d are machined by the broach teeth 70 to cause the segments 8b to have the finished and flat surface 71 of the finished segments 8a.

At the bottom of the stroke of the holder 59, the side wall has an enlarged portion 72. This permits pivoting of the jaw 62 about the portions 63 to release the segments 8a thus formed from the cavity.

The segments 8a may be used with or without heat treatment. It is found that a solution heat treatment and quench or other heat treatment for the steel such as that recommended by SAE for the steel involved improves characteristics thereof without destroying the dense linear grain structure produced by the coining or densifying and drawing operations.

A case hardening of the surface of the segments may also be had by inserting the segments 8a in a suitable case hardening bath or powdered mixtures such as of potassium cyanide during the heat treatment process. The upper and lower flat surface of the washer may be ground to exact dimension if desired.

It is exceptionally important in accordance with the present invention that the relieved portions such as the respective chamfer or hyperbolic groove at the edges of the inner cylindrical surface of the spiral washers 35a and 35c be free of coining pressure during the coining or densifying operation so that both proper metal flow may be had and life of the densifying die enhanced.

The washer formed in accordance with the present invention has, as shown by the horizontal etched lines of the photograph (FIG. 15) grain boundaries which run in arcuate lines 75 which are substantially elements of the segment; whereas, segments of FIG. 16 made by the screw machine process of the prior art show vertical etched lines 76 indicating grain boundaries to be in the direction parallel to the axis of the cylindrical surfaces of the segments. The grain direction, therefore, in the segments of the present invention are as shown by FIG. 15 perpendicular to shear in the segment; whereas, the products prepared by the screw machine process are as shown by FIG. 16 in a direction parallel to the shear stress applied during use as illustrated by FIG. 2. The improved density of my segments is shown by comparison of FIGS. 17 and 18. It is seen from FIG. 18 that the metal flow in my process produced an article of fine dense compact structure; whereas, the article of FIG. 17 produced by the screw machine process has considerably less densification. The difference in grain alignment and the difference in density provides a much higher factor of safety in the articles of the present invention. While the wire drawing and flattening process causes the grain boundaries to lie in the general direction of the axis of the wire, the flow in the densifying step of FIG. 11 reducing thickness causes a cross-linking or shifting of the grain direction slightly but apparently sufficient to change the tear resistance of the material.

While it is generally preferred that the intermediate undensified segments be segments of a spiral as shown in FIGS. 7 and 10, a spiral form is unnecessary. FIGS. 19 to 22 show the formation of the intermediate washer segments by winding the bar such as bar 35b about an axis displaced from the upper flat surface to form a circular segment.

Referring particularly to FIGS. 19–22 inclusive, the bar 35b, having an upper face 30b and the lower face 31b substantially parallel and having a generally rectangular or preferably slightly keystone section as above explained except for the relieved portions or grooves 34b, is forced through the guide zone defined by the lower wall **80** and the upper wall **81** and sidewalls **82** and **83** respectively in the direction of the arrow **84** against the face **85** of the rigid die block **86**. The die block **86** is rigidly carried by the base member **87** which also carries the top **88** so that the side member **89**, the upper surface **90**, and the base surface **91** of the dieblock **86** coact with the lower surface **92** and the surface **93** of the top member **88** and side member **89** respectively to form a guide wall to guide piston **95** which is reciprocally carried therein and adapted to be reciprocated in accordance with the arrows **96**.

The piston member has a cavity defined by the arcuately shaped surface **97**, the curvate of which corresponds to the curvate of surface **85** of the die block **86**. The piston **95** also carries a cutoff tool **98**. The lower stationary cutoff tool **99** is rigidly carried by the base member **87**.

In the formation of the intermediate circular segments the piston **95** first occupies the position shown by the solid lines in FIGS. 19 and 20 so that the cavity defined by wall **97** coincides with the guiding surfaces **82** and **83**. The bar **35*b*** is, while the piston **95** is thus positioned, pushed in the direction of the arrow **84** until the end **100** thereof substantially contacts the surface **90** of the guide block **86**.

The piston **95** is thereupon moved to the position shown by the dotted lines of FIG. 19, whereupon the circular segment **35*e*** is sheared from the rod **34*b*** and is carried by the piston over the surface **102** where it is released to drop into a single container (not shown). The piston **95** is thereupon retracted to a position shown by the solid lines and the bar **34*b*** is thereupon pushed through the passage against the surface **85** and the surface **97** until the end **100** again approaches the surface **90**, whereupon another reciprocation of the piston **95** is had.

The intermediate circular segment **35*e*** has an upper substantially flat surface **33*e***, a lower substantially flat surface **32*e***, an inner cylindrical surface **30*e*** having relieved portions **34*e*** along each side thereof and an outer cylindrical surface **31*e*** which is concentric with the inner cylindrical surface **30*e*** and end portions **52*e***. The intermediate circular segment **35*e*** is coined and densified by compressing the thickness thereof preferably 5 to 30% without restraining the relieved portion **34*e*** to provide a densified and interlocked grain structure for the densified piece.

The grooves having surface **34*e*** are preferably generally hyperbolic in nature, intersecting both the surface **30*e*** and **33*e*** at right angles.

A series of valve assemblies corresponding to the valve assembly **12** shown in FIG. 2 may be employed in an L-head engine instead of in the over-head valve engine A. Twelve of such valve asemblies **12** are employed in the 6-cylinder in-line L-head water-cooled spark-ignition engine A′ shown in FIG. 23. In this engine the translational movement of the pistons is converted into rotational movement of the crank shaft **109**. The pistons are mounted to reciprocate in vertical bores in the cylinder block **110**, said block being bolted to the cylinder head **111**. The cylinder head is constructed to receive six spark plugs **112** and is shaped to provide 6 combustion chambers **113**. Two valves **1** are provided in each chamber to control the flow of gases into and out of the chamber as indicated in FIG. 23. The stems **2** of the valves are mounted to slide vertically in the bores **103** of the guide portion **104** of the cylinder block. Each valve assembly **12** of FIG. 23 is the same as the valve assembly of FIG. 2 except that it is inverted. The cylinder block has a tappet guide **105** which locates the twelve tappets **21*a*** coaxial with the twelve valves **1** and guides said tappets for vertical reciprocation. The cam shaft **106** is provided with 6 non-circular cam lobes **107** for controlling the opening and closing of the exhaust valves and has six non-circular cam lobes **108** for controlling the opening and closing of the intake valves.

During each reciprocation of a valve **1** the cap **20** moves upwardly against the bottom head **6** to move the valve lock washer **8** out of engagement with the shoulder **7** so as to free the valve for rotation. As a result the valve surface **19** rotates relative to the valve seat **18** to minimize wear and to maintain an effective gas seal for the maximum period of time.

A pulley **114** is mounted on the front end of the crank shaft **109** to receive a fan belt **115** which drives the fan **116** and the water pump **121**. Except for the valve assemblies **12** the engine A′ is of conventional construction and need not be described in any detail. It will be apparent that this engine has an intake manifold **117**, an exhaust manifold **118**, a water connection **119** enclosing the thermostat, and an oil pan **120** for receiving the lubricating oil. The novel valve construction of the present invention greatly increases the useful life of an engine of the type shown in FIG. 23 and is particularly important in L-head engines because of the greater cost of replacing valves in this type of engine.

It is to be understood that, in accordance with the provisions of the patent statutes, variations and modifications of the specific devices herein shown and described may be made without departing from the spirit of the invention.

This application is a continuation-in-part of application Serial No. 385,385, filed October 12, 1953, entitled "Valve Lock Washer," now abandoned.

What I claim is:

1. A method of making segments a plurality of which form a substantially complete circle having an inner opening to receive a reduced portion of a valve stem of a poppet valve of an internal combustion engine and a flat surface to bear against a shoulder on said valve stem through which said valve is subjected to closure pressure of the valve spring, said process comprising rolling a wire to form a bar having sections of generally keystone shape with two parallel surfaces and having linear relieved portions along each side of the narrower of said two parallel surfaces which relieved portions have a surface which intersects two flattened surfaces of said bar, bending said bar about an axis which is parallel to said two parallel flat surfaces but displaced from said narrower of said parallel surfaces, to form a helix having the said narrower surface as an inner cylindrical surface, separating segments of less than one turn from said helix to form helical segments, and compressing said segments between flat parallel surfaces in a direction generally parallel to the inner and outer surfaces of said segments to reduce the thickness of said segments and to flatten them into circular shape, said relieved portions being unrestrained by contact with rigid surfaces during the said compression.

2. A method of forming segments a plurality of which laid end to end form a circular washer with a central opening to receive a reduced portion of a valve stem, said method comprising rolling a round wire to form a bar having generally parallel upper and lower flat surfaces, substantially flat side surfaces and a groove along each side edge of said upper surface and one of said side surfaces of said bar at about right angles, bending said bar to form said upper surface thereof into a cylindrical surface and said lower surface thereof into a concentric cylindrical surface, separating portions of the thus bent bar to form curved sections of less than one complete turn, compressing side edges of said sections to reduce the thickness thereof between entirely flat paralllel surfaces, said surfaces of said grooves being free from contact with a rigid surface during said compression.

3. A method of forming segments a plurality of which laid end to end form a circular washer with a central opening to receive a reduced portion of a valve stem, said method comprising rolling a round wire to form a bar having generally parallel upper and lower flat sur-

faces, substantially flat side surfaces and along each side edge of said upper surface a relieved portion having a surface that intersects with said upper surface and the flat surface of one of the sides, bending said bar to form said upper surface thereof into a cylindrical surface and said lower surface thereof into a concentric cylindrical surface, separating portions of the thus bent bar to form curved sections of less than one complete turn, compressing side edges of said sections to reduce the thickness thereof between entirely flat parallel surfaces, said surfaces of said relieved portions being free from contact with a rigid surface during said compression.

4. A method of forming segments a plurality of which laid end to end form a circular washer with a central opening to receive a reduced portion of a valve stem, said method comprising rolling a round wire to form a bar having generally parallel upper and lower flat surfaces, substantially flat side surfaces and a groove along each side edge of said upper surface, the surface of each of said grooves intersecting the upper surface and one of said side surfaces of said bar at about right angles, bending said bar to form said upper surface thereof into a cylindrical surface and said lower surface thereof into a concentric cylindrical surface, separating portions of the thus bent bar to form curved sections of less than one complete turn, compressing side edges of said sections to reduce the thickness thereof between entirely flat parallel surfaces, said surfaces of said grooves being free from contact with a rigid surface during said compression.

5. A method of making carbon steel segments a plurality of which form a substantially complete circle having an inner opening to receive a reduced portion of a valve stem of a poppet valve of an internal combustion engine and a flat surface to bear against a shoulder on said valve stem through which said valve is subjected to closure pressure of the valve spring said method comprising the steps of working a carbon-steel wire to align its grain structure and to form an elongated bar with a grain extending longitudinally of the bar, said bar having opposite longitudinal faces of different widths and having receding chamfered portions along both sides of the narrower of said opposite faces which chamfered portions have surfaces which intersect the narrower face, bending said bar and forming an arcuate segment of not substantially more than 180 degree circumferential extent to form said opposite faces into substantially concentric cylindrical faces so that the grain follows the curvature of the segment, the narrower of said faces forming the radially inner face of said segment between the chamfered portions of said segment, and coining and compressing the segment axially to reduce its thickness 5 to 30% without restraining the chamfered portions of the segment to provide a densified and interlocked grain structure for the densified piece.

6. A method of making carbon-steel segments, a plurality of which may be arranged end to end to form a ring, said method comprising the steps of working a carbon-steel wire to align its grain structure and to form an elongated bar of generally rectangular cross section with a grain extending longitudinally of the bar, said bar being formed with opposite generally flat longitudinal faces of different widths and chamfered portions along both sides of the narrower of said opposite faces, each of said chamfered portions having a surface which intersects the narrower face and recedes away from such intersection, bending said bar and forming an arcuate segment of not substantially more than 180 degrees circumferential extent to form said opposite faces into concentric cylindrical faces so that the grain follows the curvature of the segment, the bar being bent so that the narrower of said faces forms the radially inner face of said segment between the chamfered portions of said segment, the axis of said cylindrical faces being spaced from said radially inner face but closer to the latter face than to the radially outer face, and coining and compressing said segment axially between flat parallel surfaces in a direction generally parallel to said axis to reduce the axial thickness of the segment at least 5% and to cause metal flow toward said chamfered portions, said chamfered portions being unrestrained by contact with rigid surfaces during said axial compression.

7. A method of making carbon-steel segments, a plurality of which may be arranged end-to-end to form a ring, said method comprising the steps of forming a carbon-steel wire of generally rectangular cross section, removing edge portions of the wire and working the wire to form an elongated bar having its grain structure aligned longitudinally of the bar and having generally flat longitudinal faces of different widths and chamfered portions along both sides of the narrower of said opposite faces, each of said chamfered portions having a surface which intersects the narrower face and recedes away from such intersection, bending said bar so that the narrower of said faces forms the radially inner face of an arcuate semi-circular segment having concentric cylindrical faces of different axial width and so that the grain follows the curvature of the segment, placing the segment between rigid concentric cylindrical surfaces having radii corresponding substantially to the inner radius and outer radius of the segment to prevent change in the radial dimensions of the segment while simultaneously cold coining and compressing the segment axially between flat parallel surfaces perpendicular to said last-named cylindrical surfaces to reduce the axial thickness of the segment about 5 to 30 percent and to cause metal flow toward said chamfered portions, said chamfered portions being unrestrained by contact with rigid surfaces during said axial compression.

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