Sept. 5, 1967 R. S. KOMARNITSKY 3,339,908

TAPERED LEAF SPRINGS

Filed April 20, 1965 3 Sheets-Sheet 1

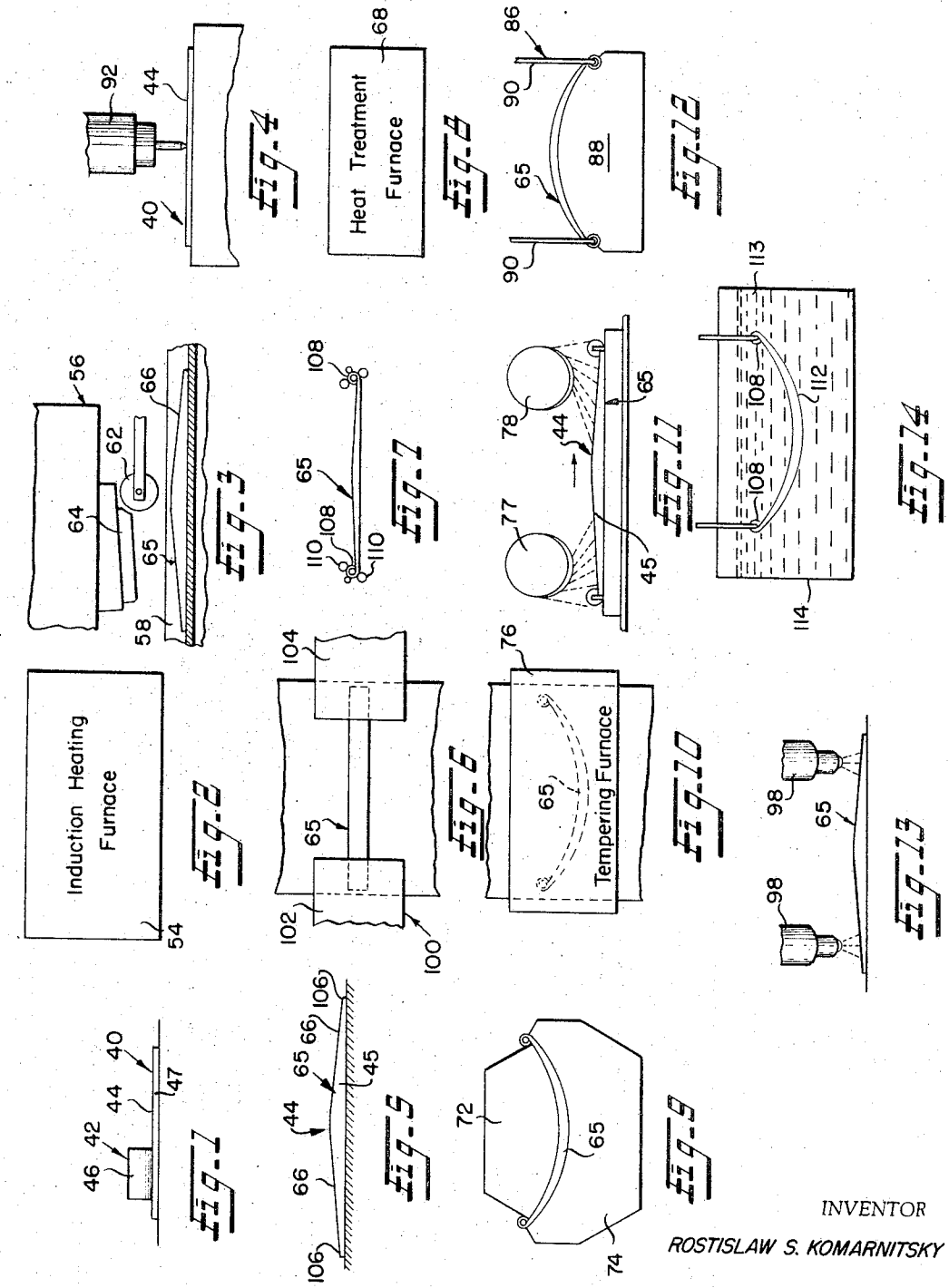



Fig. 1 Fig. 2 Fig. 3 Fig. 4 Fig. 5 Fig. 6 Fig. 7 Fig. 8 Fig. 9 Fig. 10 Fig. 11 Fig. 12 Fig. 13 Fig. 14

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TAPERED LEAF SPRINGS

Filed April 20, 1965 3 Sheets-Sheet 2

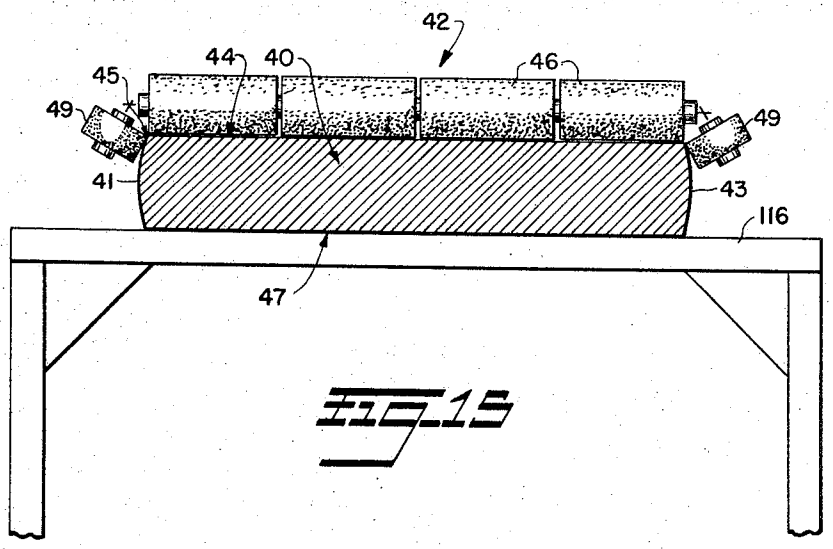



FIG 15

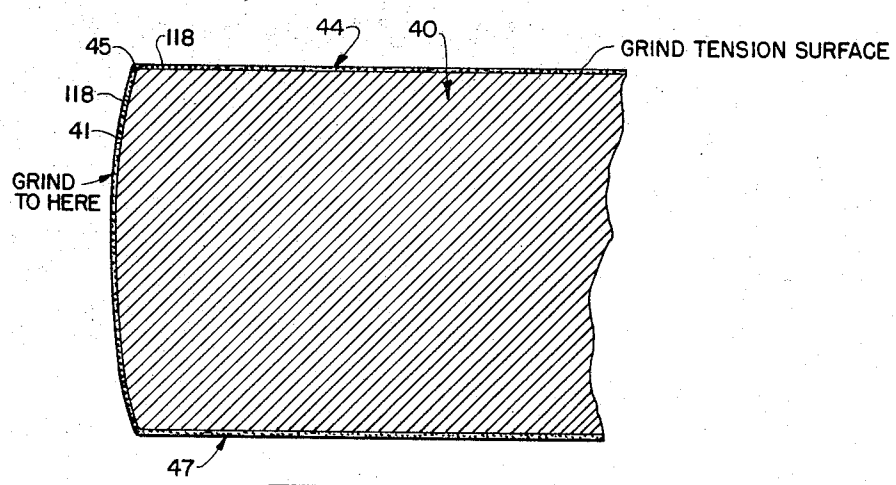



FIG 16

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TAPERED LEAF SPRINGS

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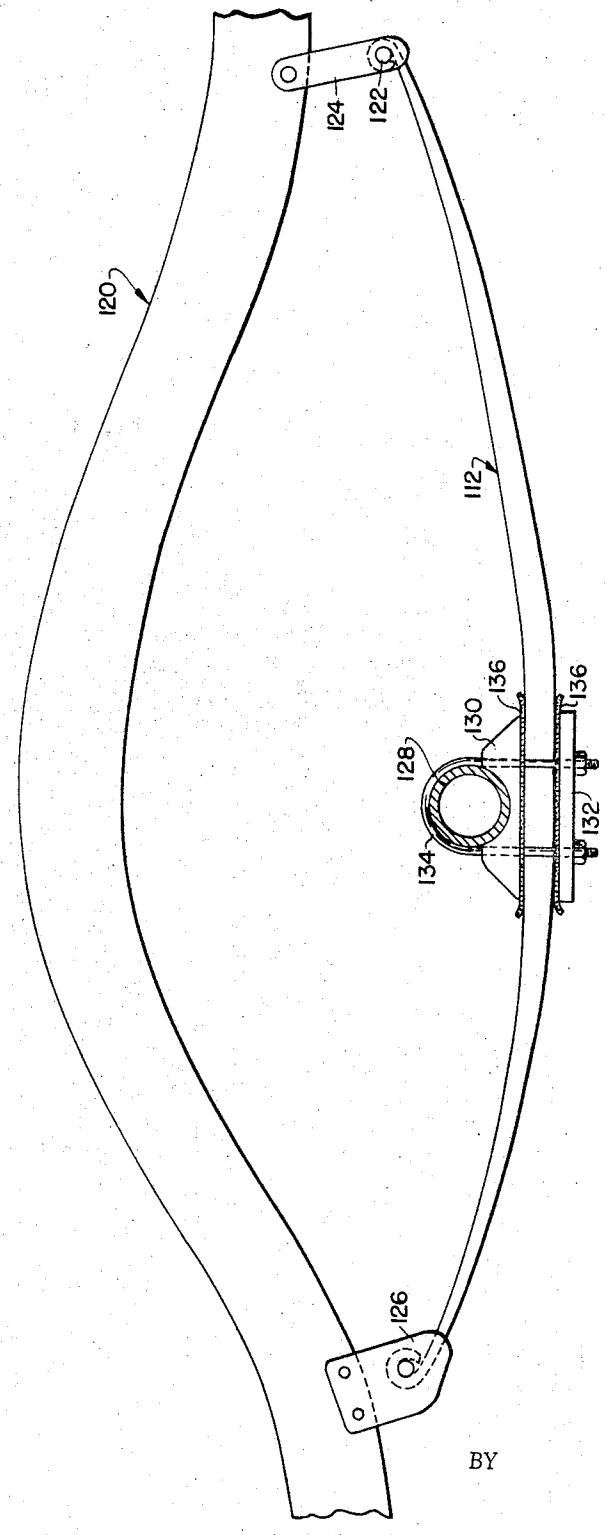



FIG. 1

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United States Patent Office 3,339,908 Patented Sept. 5, 1967



3,339,908

# TAPERED LEAF SPRINGS

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Filed Apr. 20, 1965, Ser. No. 449,486
11 Claims. (Cl. 267—47)

## ABSTRACT OF THE DISCLOSURE

A finished steel spring leaf preferably formed by taper rolling and having the side which is to be the tension surface in operation, as well as the opposite edge surfaces extending adjacent and along said tension surface, ground and subsequently stress peened.

The present invention relates to improved tapered leaf springs and particularly relates to special leaf spring structure for single or multiple taper leaf spring assemblies for vehicles.

Over the years, it has been standard practice to use conventional multileaf spring bundles in vehicles for absorbing road shocks. While such spring bundles are generally satisfactory for absorbing a large percentage of normal road shocks, they are undesirably heavy and they produce a considerable amount of interleaf friction which objectionably affects the spring deflection by increasing the spring rate. Another serious objection of multileaf springs is that it is generally impossible to obtain a uniform spring rate under various road conditions wherein the same incremental variation in load produces the same incremental spring deflection.

In an effort to eliminate these problems existent with multileaf springs, recent efforts have been directed to the development of parabolic tapered leaf steel springs, and the present invention is concerned wth a further improvement of such springs to materially increase the fatigue life thereof.

Among the chief factors to which reduction of spring fatigue resistance and consequent failures are generally attributed are decarburization of metal surface layers, surface irregularities including rolled-in scale and oxide penetrations, and the effect of certain mechanical treatments.

To improve fatigue resistance, prior to this invention spring leaves were stress peened following heat treatment. However, the expected percentage increase in the useful life of the spring leaf afforded by stress peening was not fully obtained in prior fabricating methods.

The present invention contemplates novel improved tapered leaf springs wherein the spring leaf has been subjected to grinding operations at least on certain surfaces to remove decarburization films, surface imperfections, scale and oxide prior to the taper rolling and shot or strain peening operation after heat treatment. It has been found that by so grinding the blank before taper rolling and shot or strain peening, a tapered leaf spring of unexpectedly and immensely increased fatigue life is obtained particularly in comparison to the life of tapered spring leaves which are shot or strain peened without the novel grinding operation. With the present invention, therefore, preparatory grinding is utilized to great advantage in prolonging the useful life of the spring leaf. While it is preferred to carry out the grinding operation prior to the sequential operations of taper rolling, heat treating and shot or strain peening, the grinding operation may alternatively follow the taper rolling operation.

The invention herein is an improvement over that disclosed in U.S. Letters Patent No. 3,238,072 issued Mar. 1, 1966, to Greene et al. and assigned to Rockwell-Standard Corporation, assignees of the present application. Said Patent No. 3,238,072 and the present application were copending in the Patent Office.



Related to the present application is the inventor's Ser. No. 449,585 filed Apr. 20, 1965, which claims the method phase of the invention.

It is the primary object of the present invention to provide a novel tapered leaf spring made from a spring steel blank that has been sequentially roll tapered and shot or strain peened at least on the side thereof which is the tension surface in the finished spring leaf, and wherein said tension surface is subjected to a grinding operation prior to shot or strain peening so that the shot or strain peened surface is substantially free of decarburized metal and surface imperfections.

A further object of the invention is to provide a novel spring leaf wherein the tension surface and the adjacent side edges are ground prior to shot or strain peening the tension surface.

Another object of the invention resides in a vehicle suspension assembly in the provision of spring liners attached to the spring leaf of the present invention at the intended intermediate clamp area to prevent the formation of high stress concentrations in that area.

Further objects of the invention will appear as the description proceeds in connection with the appended claims and the annexed drawings wherein:

FIGURE 1 is a diagrammatic view illustrating the preliminary surface grinding operation of a flat spring steel blank in accordance with the present invention;

FIGURE 2 is a diagrammatic view of an induction heating furnace for heating the ground spring leaf blank to hot working temperature;

FIGURE 3 is a diagrammatic view of a taper rolling apparatus;

FIGURE 4 is a diagrammatic view of an optional spring leaf piercing and drilling apparatus which is used when a spring leaf is provided with a locating hole if required;

FIGURE 5 is an elevation of a tapered spring leaf following the taper rolling operation and piercing;

FIGURE 6 is a diagrammatic view of an optional heating furnace for preparing the spring leaf for an attachment eye forming operation if so required;

FIGURE 7 is a diagrammatic view of an optional apparatus for forming attaching eyes if so required;

FIGURE 8 is a diagrammatic view of a furnace for heating a spring leaf preparatory to a cambering operation;

FIGURE 9 is a diagrammatic view of a spring leaf cambering apparatus;

FIGURE 10 is a diagrammatic view of a spring leaf tempering furnace;

FIGURE 11 is a diagrammatic view of a spring leaf strain peening apparatus;

FIGURE 12 is a diagrammatic view of a pre-setting apparatus;

FIGURE 13 is a diagrammatic view of a leaf inspection station;

FIGURE 14 is a diagrammatic view of a spring leaf coating station for applying a corrosion resistant film to the finished spring leaf;

FIGURE 15 is an enlarged cross section view through the spring leaf of the present invention illustrating more in detail the grinding operation;

FIGURE 16 is a further enlarged partial cross section of one side of a leaf spring shown prior to the grinding operation;

FIGURE 17 shows the finished novel spring leaf in installed position on a vehicle with the novel spring liners inserted between the leaf and the clamp.

Referring to FIGURE 1, a flat sided spring steel blank or billet **40** cut to proper length is placed in a grinding apparatus **42** for grinding the surface **44** of blank **40** which will be the tension surface of the spring leaf as finally formed. Apparatus **42** preferably comprises grinding belts **46** which are adapted to engage surface **44**. The grinding apparatus **42** also includes grinding belts or the like (see FIGURE 15) for grinding both edge surfaces **41** and **43** adjacent the tension surface of the blank. While for some springs it may be acceptable to grind only the tension surface for the purpose it has been discovered as a very important part of the invention that grinding of both the tension surface **44** and portions of edge surfaces **41** and **43** adjacent the edge **45** is extremely beneficial to further increase the fatigue life of the spring. Other forms of grinding machines (not shown) may also be used, such as, for example, grinding wheels. Grinding of surface **44** and edge surfaces **41** and **43** in accordance with the present invention removes any decarburization films, surface imperfections, scale and oxide to provide smooth flat surfaces. For example a typical spring steel leaf was found to have a decarburized surface layer about 0.015" deep which ranged in hardness from an outer surface hardness of about 30 Rockwell C to the inner uniform leaf hardness of about 46 Rockwell C. This harmful layer was removed from the tension surface and adjacent edges by the grinding operation to produce a leaf spring of high quality.

With particular reference to FIGURES 15 and 16 the blank **40** shown in cross section comprises a lower surface **47** which will become the compression surface and an upper surface **44** which will become the tension surface. Both surfaces are laterally connected by opposite edge surfaces **41** and **43** respectively.

To grind the tension surface **44** the blank **40** is placed on the grinding machine table, conveyor, or the like **116** with its tension surface up and a number of grinding discs, belts, etc. **46** are brought in contact with the tension surface **44**. The outer most **49** of the grinding devices extend around the edges **45** of the edge surfaces **41** and **43** to simultaneously grind the upper portions of the sides immediately adajacent the tension surface **44**.

Referring to FIGURE 16 the blank **40** when it comes from the rolling mill shows a surface layer of decarburized material **118** which may extend continuously around all surfaces or only part of the surfaces. This surface decarburization is harmful and prevents effective surface treatment of the leaf spring blank such as taper rolling, shot peening, etc. especially at the side which is to become the tension surface. As for instance during taper rolling, flakes of hard mill scale may be pressed into the surface and thus cause the occurrence of stress raisers in the tension surface layer, which may become the nuclei of fatigue cracks and lead to early fracture of the leaf spring.

Although the decarburization may be removed by grinding all surfaces of the blank it is necessary only to remove it from the side which is to become the tension surface and portions of the edge surfaces immediately adjacent the tension surface as indicated in FIGURE 16 since these portions of the edges extending from the tension surface are subject to tension stresses and if only the tension surface would be ground leaving decarburization on the edge surfaces **41** and **43** early fatigue failures may occur due to the surface imperfections at the highly stressed portions of the edge surfaces adjacent the tension surface.

Preferably the extent of side edge grinding indicated in FIGURE 16 is about 35% of the distance downwardly from edge corners **45**, which latter are preferably rounded to eliminate sharp edges where stresses may concentrate.

The side **47** of blank **40** opposite from tension surface **44** which is to become the compression surface also may be ground in the same manner as surface **44** although not necessary or it may be shot blasted before final thermal



treatment to clean the blank and remove any scale left from the steel mill rolling operation. However, grinding or shot blasting of the side **47** of blank **40** opposite from tension surface **44** will normally not be necessary, since, presence of decarburized layer and stress raisers on the surfaces, which are subjected only to compression stresses, are not detrimental to the longevity of the spring.

Following the grinding operation, blank **40** is then heated in a suitable furnace **54** (FIGURE 2) to a temperature of from 1200° F. to 2250° F. in preparation for a hot taper rolling operation. Heating of blank **40** is advantageously, though not necessarily, accomplished by induction heating to produce a gradual increase of temperature extending towards the ends of blank **40** depending upon the amount of hot rolling to be done in the tapering operation. This treatment minimizes grain growth in spring blank regions subjected to comparatively little hot working in the rolling operation and is readily accomplished by special design of induction heating units.

After blank **40** is heated to its hot working temperature it then is conveyed to a taper rolling machine **56** (FIGURE 3) where it is hot taper rolled. Alternatively, surface **44** and adjacent edge surfaces **41** and **43** may be ground following the heat treatment in furnace **54** and preceding the taper rolling operation in machine **56**.

In tapered leaf springs, the spring must be designed so that the operating stresses are uniformly distributed throughout the length of the leaf. In other words, the leaf must be of variable thickness or variable width, or both. To facilitate manufacture and reduce cost and for other reasons, it is preferred to produce a tapered spring leaf which varies in thickness only. The taper extends preferably from a maximum thickness at or near the axle mounting or spring seat portion towards a minimum thickness at or near the end or ends. The leaf ends may be of constant thickness to form attachment eyes.

To obtain the foregoing tapered configuration, blank **40** may be preferably roll tapered by the method and apparatus disclosed in United States Letters Patent No. 3,145,591 issued Aug. 25, 1964, to F. R. Krause, to which reference should be made for complete details, such method and apparatus being only schematically illustrated in FIGURE 3 to an extent deemed necessary to understand the present application. The foregoing apparatus is suitable to produce heavy duty spring leaves, however, for light duty spring leaves a taper roll machine as disclosed in copending application Ser. No. 205,333 filed June 26, 1962, now matured in U.S. Letters Patent No. 3,233,444 dated Feb. 8, 1966, assigned to applicants assignee, may be adapted.

To produce a single leaf spring having satisfactory suspension qualities over an appropriate range of deflection, the thickness tolerance of the spring throughout its taper must be held to plus or minus 0.005 inch from a desired theoretical parabolic contour. For this reason, among others, the surface of blank **40** to be tapered which may become either the tension or compression surface must be essentially free from stress raising surface defects and must be maintained in this condition as the forming roll advances over it. In actual application the taper formation may appear on either the tension surface or the compression surface of the leaf spring.

As shown in FIGURE 3, the hot blank is placed in a die **58** seated on a support base of machine **56**. A forming roll **62**, mounted for rotation about an axis transverse to the longitudinal axis of blank **40**, is then rolled longitudinally along the blank starting from the central portion of the blank and traveling first towards one end and then towards the other end. As previously mentioned, the spring leaf may terminate at both ends in a uniform thick portion in order to form attachment eyes. If a single forming roll **62** is used, the taper on one half of blank **40** is formed. The position of blank **40** is then reversed end for end and the other half of blank **40** is tapered. In a double end machine reversal of the blank

is not necessary. Roll **62** is pressed against blank **40** by means of a contoured cam **64** which is suspended above die **58** and which is mounted for movement longitudinally of the blank. As cam **64** moves to the right as viewed in FIGURE 3, it forces the roll **62** against blank **40** which is held against movement. Roll **62** is thus advanced over surface **44** of blank **40** by frictional engagement between roll **62** and blank **40** and between cam **64** and cam follower rollers (not shown) integral with and at each end of roll **62**.

To maintain the accuracy of the taper, it is very important that no scale or other dirt come between the contacting surfaces of forming roll **62** and blank **40** or cam **64** and the cam follower rollers. The contour of cam **64** is such that, as it engages and advances roll **62**, roll **62** shapes blank **40** to the desired tapered form described above, thus providing a tapered spring leaf indicated at **65** in FIGURES 4 and 3 and having tapered tension surfaces **66**. When it is desired to have the leaf of constant width and tapered only in thickness, the die **58** will be provided with a longitudinal cavity such that it effectively prevents the metal from spreading out laterally on the sides, as more fully described in the above referred to Krause patent.

Following the taper rolling operation, the semi-finished tapered leaf **65** is conveyed to a heating furnace **68** (FIGURE 8) where it is heated to austenitizing temperature as a preliminary step to a subsequent camber forming and quenching operation. As shown in FIGURE 9, the camber is formed by mounting and clamping the thus heated spring leaf between curved complementary upper and lower die fixtures **72** and **74**. Fixtures **72** and **74** are so formed relative to the desired curvature of the final spring leaf as to allow for changes in height of the camber particularly during a presetting operation to be described later on. The assembly comprising die fixtures **72** and **74** with the spring leaf **65** clamped in place is immersed in quenching oil for a period of time sufficient to obtain a martensitic transformation on the order of 95% or more. While this transformation is taking place, the semi-finished spring leaf **65** is retained under high clamping pressure between fixtures **72** and **74** to prevent distortion.

After removal from the quenching oil, spring leaf **65** is released from the fixtures **72** and **74** and is conventionally tempered in a conveyor type tempering furnace **76** (FIGURE 10) to relieve stresses imposed upon the spring during the forming and quenching operations.

Following the taper rolling, cambering and tempering operations, spring leaf **65** is shot or strain peened at least on its ground tension surface **44** and also on and along both longitudinal ground adjacent portions of edge surfaces **41** and **43**. The peening apparatus may be of any conventional construction and may contain one or more shot throwing wheels, two of which are indicated at **77** and **78** in FIGURE 11. The tension surface **44** is pelted with shot from wheels **77** and **78** while the spring leaf is held by suitable clamps in a stressed condition wherein it is subjected to longitudinal bending. These wheels may be posiitoned at an angle to simultaneously peen the tension surface **44** and adjacent edge surfaces **41**, **43**, or added wheels may be provided for thise purpose. When the strain under which the leaves are to be peened is specified, it is preferably at a stress which is as close to the yield point of the steel as conditions will permit.

The spring leaf **65** which is cambered prior to the shot or strain peening operation, is preferably clamped in a substantially flat position by any suitable means. It will be appreciated that other conventional forms of shot peening apparatus may be employed, such as, for example, air nozzles. Shot peening relieves harmful residual tension stresses which could be present in the surface layer and introduces beneficial compressive stress.

Following the shot or strain peening operation the spring leaf is preferably transferred to a presetting or "bulldozing" assembly **86** illustrated in FIGURE 12. Assembly **86** comprises a rigid fixture **88** having a curved top surface over which the cambered spring leaf is reversely deflected in the direction of service loading by push rods **90** or other suitable means. The spring leaf is deflected by an amount exceeding the designed maximum service deflection and the yield point of the material. In this presetting or "bulldozing" operation, the cambered spring leaf is deflected from its curved unloaded configuration, through a flat configuration, to the reversely curved configuration shown in FIGURE 12. The presetting operation readjusts the normal camber height, reduces the possibility of permanent set from occuring in the spring leaf during service, and introduces residual compression stresses in the tension surface layer in addition to that introduced by the shot or strain peening operation. The spring leaf when released from the presetting fixture returns to a cambered shape which is slightly relaxed from the cambered shape shown in FIGURE 9.

After the initial grinding operation and before taper rolling, at least the ground tension surface **44** and portions of the adjacent edge surfaces **41** and **43** of blank **40** may be treated to resist the formation of scale and oxide particularly while the blank is being taper rolled. This may be effectively accomplished for instance by contacting the ground blank with lithium vapor while the blank is being heated in furnace **54**. The lithium vapor sticks to and coats the blank with a film which, in addition to preventing formation of scale and oxide, also acts as a lubricant in the rolling process.

Following the scale prevention treatment and before or after hot rolling, blank **40** may in certain instances be provided with a locating or anchor bolt hole or other known locating or centering means as shown in FIGURE 4. For reasons stated below in the fabrication of single spring leaves, the prior conventional locating or anchor bolt hole is preferably omitted and instead the leaf is provided with one or more impressions, dimples or studs preferably on the neutral axis of the side edge surfaces of the leaf or on the compression surface for locating and centering purposes to reduce the high stress raising effect caused by the conventional center bolt hole in the anchor area, as more fully illustrated and explained in copending application Ser. No. 411,285 filed Nov. 16, 1964, since issued as U.S. Letters Patent No. 3,305,231 dated Feb. 21, 1967.

After the taper rolling operation the partly finished spring leaf **65** may be optionally subjected to a further grinding operation to remove any surface imperfections caused by the taper rolls particularly on the tension surface indicated at **44** and the adjacent edge surfaces **41** and **43**. The spring leaf **65** then may be conveniently conveyed to a taper inspecting station (FIGURE 13) where the contour of the spring leaf taper is checked as by means of accurate electronic thickness measuring devices **98** or by any other conventional measuring apparatus. As explained above, maintenance of accurate thickness dimensions throughout the taper is very important.

Prior to cambering, spring attachment eyes may be formed, if desired, as shown in FIGURES 6 and 7 by first heating spring leaf **65** in conveyor type right-hand and left-hand dual furnace **100** shown in FIGURE 6 and comprising two opposed heating units **102** and **104** respectively located on opposite sides of a conveyor **105**. Leaf spring **65** is moved laterally between furnace units **102** and **104** to heat the spring end regions indicated at **106**. To facilitate formation of eye attachments, end regions **106** are preferably of uniform thickness.

Furnace units **102** and **104** may be of any suitable and conventional type and are preferably gas-fired to provide high intensity heat. Immediately after heating, the spring leaf end regions are formed simultaneously into attachment eyes **108**, as shown in FIGURE 14. The eye forming operation is performed by any conventional auto-

matic double-end three-pass forming machine having forming rolls indicated at **110** in FIGURE 7.

After the presetting operation, the finished spring leaf indicated at **112** in FIGURE 14 is advantageously provided with a corrosion and scar resistant coating by immersing the spring leaf in a suitable coating solution **113** contained in a tank **114**.

While it is preferred to grind tension surface **44** and the adjacent edge surfaces **41** and **43** before the taper rolling operation, these surfaces may alternatively be ground after taper rolling to the form of FIGURE 5 and preceding the shot or strain peening operation.

The feature of the invention residing in grinding and stress peening the side edge surfaces adjacent and along the tension surface over and above the grinding and stress peening of the tension surface disclosed and claimed in said Patent No. 3,238,072 results in elimination of any tendency for the finished spring to crack at those edges during operation, and so it contributes materially to even greater useful life of the spring.

With further reference to FIGURE 17 the finished spring leaf **112** is shown installed at the rear axle of a vehicle indicated by the vehicle frame **120**.

The rear spring end **122** of the spring leaf **112** is attached to a shackle **124** pivotally suspended from the frame **120** and the front end is attached to a hanger bracket **126** depending from the frame **120**.

Intermediate its ends the spring leaf of the present invention is supported on the vehicle axle **128** on a spring seat **130** attached to the axle to which the leaf is clamped by means of a lower pressure plate **132** and secured thereto by U-bolts **134**.

Due to the high stress concentration at the intermediate mounting block area it is further proposed within the purview of the present invention to provide spring liners **136** of plastic material (such as polyethylene or the like) between the spring seat **130** and the upper surface of the spring leaf and between the pressure plate **132** and the lower surface of the spring leaf. As will be noted from the figure the liners **136** preferably extend a distance beyond the mounting block area to assure complete coverage over the entire high stress area. The mounting block liners are preferably bonded to the spring leaf and thus form an inherent part of the leaf itself.

The liners in the present invention do not merely serve as a means to prevent corrosion and fretting at the mounting block area but are provided for the main purpose of redistributing the stresses in this area more evenly to avoid high localized stresses. The liners **136** are surface bonded along the upper and lower surfaces of the spring leaf at the mounting block region and they may flex with spring movement. It has been discovered that use of these liners, besides the foregoing protective action considerably contributes to unexpectedly improve the useful spring lite and further prevent premature failure at this region.

This premature failure at the mounting block area was due to the high residual compressive stresses introduced by the clamping members to which is added the working stress (either compression or tension) during spring flexure causing peaks of extremely high stress concentrations especially immediately adjacent the U-bolts. The liners **136** provided in this area effectively redistribute the stress concentrations more evenly throughout the mounting block area.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed and desired to be secured by Letters Patent is:

**1.** A finished spring leaf comprising a mechanically worked heat treated length of steel having one surface taper rolled to desired contour, and its tension surface and adjacent longitudinal side edge surfaces ground and mechanically worked to introduce beneficial residual stresses.

**2.** A finished spring leaf comprising a mechanically worked heat treated length of steel having its tension surface and its adjacent longitudinal edge surfaces ground and shot peened.

**3.** A finished spring leaf comprising a mechanically worked heat treated length of steel having a flat taper rolled surface and adjacent opposite longitudinal edge surfaces, all of said surfaces being ground and strain peened after grinding.

**4.** In the finished spring leaf defined in claim **3**, said taper rolled surface being the tension surface of the spring.

**5.** A finished spring leaf comprising a length of steel having an accurately rolled taper along one side, and a tension surface, said surface being ground to remove decarburized layers and surface imperfections and provide a smooth surface and said smooth ground surface being strain peened, and the opposite edge surfaces of said spring leaf adjacent said tension surface being ground to provide edge surfaces that are free of decarburized layers and surface imperfections and stress peened after grinding.

**6.** A steel spring leaf that has been successively ground on the tension surface and its adjacent edge surfaces to remove decarburization, scale and surface imperfections and irregularities, hot taper rolled on said tension surface, and then strain peened on said ground and taper rolled surfaces.

**7.** In combination: a vehicle axle, a mounting block on said axle, a single spring leaf having a compression surface and ground tension and adjacent edge surfaces which are taper rolled and strain peened, the combination comprising liners of plastic material between said single spring leaf and said spring mounting block.

**8.** A spring leaf as defined in claim **3** wherein both opposite surfaces at the area of maximum thickness of said spring leaf are provided with liners of plastic material permanently bonded to said surfaces.

**9.** A finished steel spring leaf comprising a single length of steel of uniform width having a taper rolled surface on the side which is to be the tension surface in operation, said surface and the opposite longitudinal side edge surface areas immediately adjacent and along the length of said surface being ground smooth to remove decarburized layers and surface imperfections, and said ground surfaces being strain peened.

**10.** The spring leaf defined in claim **9** wherein said ground longitudinal side edge areas extend away from the corners where they intersect said tension surface a distance of about 35 percent of the thickness of the spring leaf.

**11.** The spring leaf defined in claim **9**, wherein the thickest section of said leaf comprises the spring seat mounting region, the side opposite said tension surface is the compression surface in operation and wherein liners of solid flexible plastic material are surface bonded to said tension surface and the opposite compression surface of said spring at said region.

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