United States Patent [19]

Phillips

[11] **3,796,086**

[45] **Mar. 12, 1974**

[54] **RING PAD STRESS COINING**

[75] Inventor: **Austin Phillips,** Santa Monica, Calif.

[73] Assignee: **McDonnell Douglas Corporation,** Santa Monica, Calif.

[22] Filed: **Aug. 2, 1972**

[21] Appl. No.: **277,359**

[52] **U.S. Cl.** ..... **72/377,** 29/155 R, 72/416

[51] **Int. Cl.** **B21d 31/00**

[58] **Field of Search** ..... 72/470, 416, 377; 113/15 A, 1 F; 29/155 R, 155 C, 457, 446, 183, 190, 193

[56] **References Cited**

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3,355,930 12/1967 Fedorov 72/377

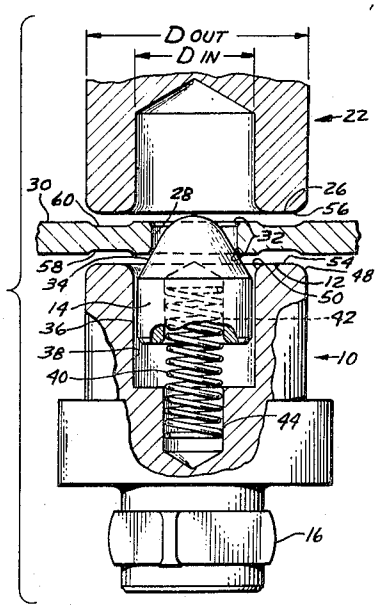
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Primary Examiner—Charles W. Lanham
Assistant Examiner—Robert M. Rogers
Attorney, Agent, or Firm—George W. Finch; Walter J. Jason; Donald L. Royer

[57] **ABSTRACT**

A method for improving the fatigue strength of a metallic structural member and the member having a discontinuity therein. A ring-shaped pad of material spaced about the aperture is cold-worked into a plastic state and then allowed to rebound into an elastic state thereby generating a region of residual compressive stress about the aperture which results in a member having improved fatigue strength.

6 Claims, 5 Drawing Figures



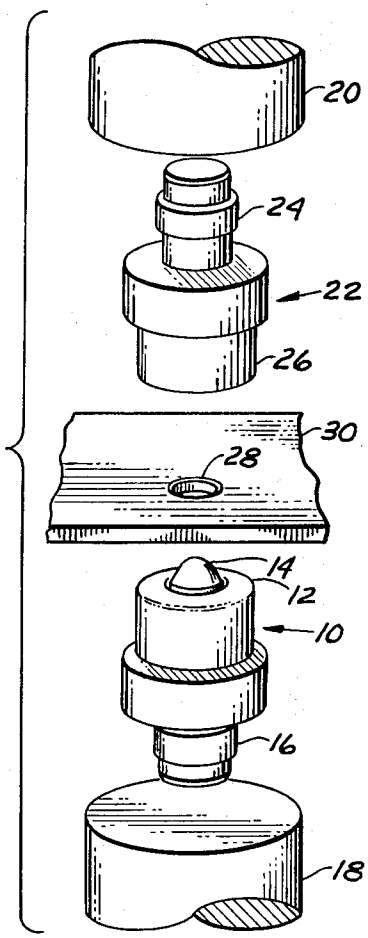


FIG. 1

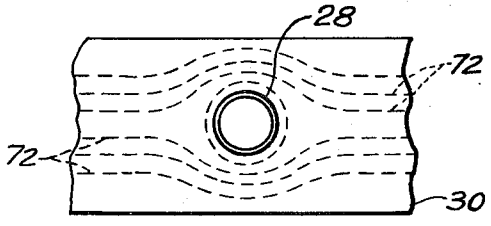


FIG. 4

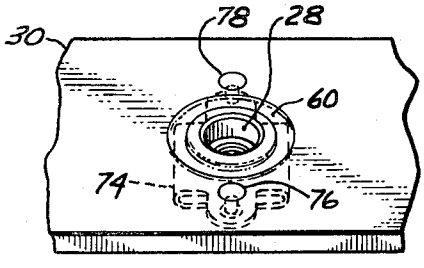


FIG. 5

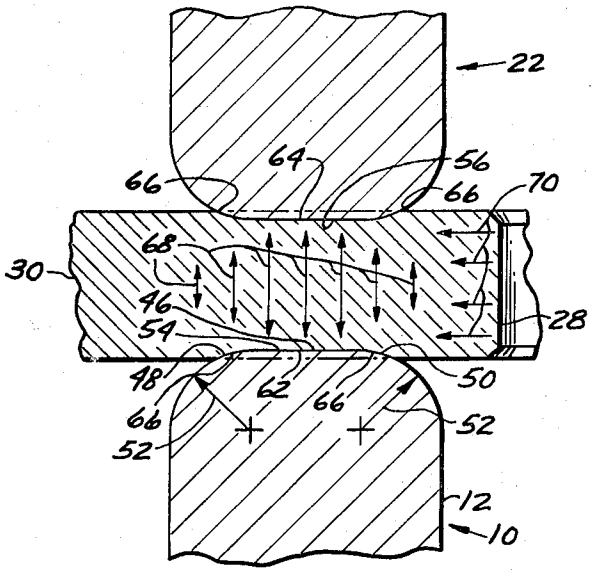


FIG. 3

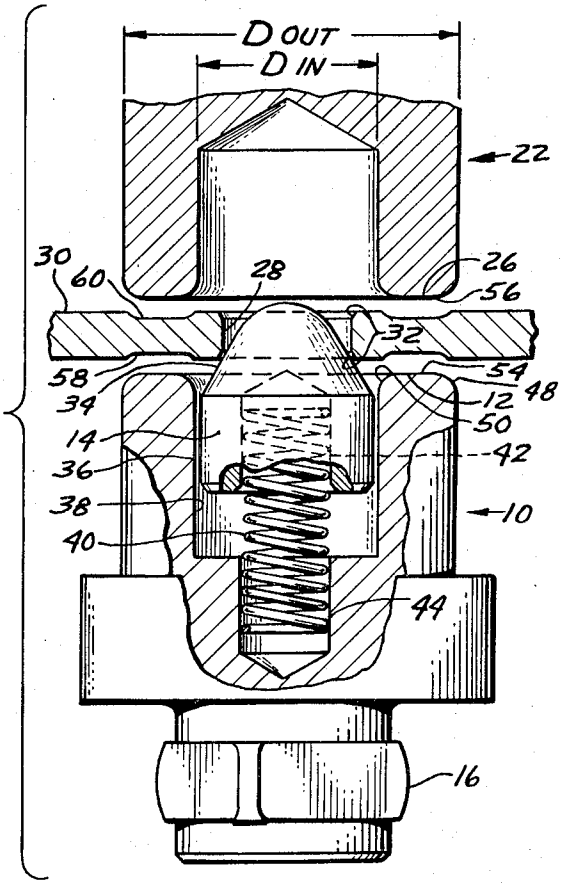


FIG. 2

RING PAD STRESS COINING

CROSS REFERENCE TO RELATED PATENTS

This application relates to the subject matter of U.S. Pat. No. 3,110,086 entitled "Coining Structural Parts" by Austin Phillips and U. S. Pat. No. 3,434,327 entitled "Stress Coining" by Eugene R. Speakman. Reference is made to the information therein as though fully set forth hereinbelow.

BACKGROUND OF THE INVENTION

In structural parts incorporating lightning holes, bolt holes, fuel transfer holes and other apertures, edge notches and other interruptions in the continuity of the parts, it is well recognized that the mere calculation of the strengths for such parts under static load is insufficient to enable design of such parts when they are expected to be subjected to fluctuating loads. This is because such parts tend to fail in fatigue even though the stress approaching the ultimate breaking load is normally never experienced in actual service. Ring groove and pad coining methods for improving the fatigue strength of parts having apertures therethrough are shown in the referenced patents. Both of the patents disclose means which establish a field of residual compressive stress about the aperture, which stress tends to measurably increase the fatigue life of the part. Unfortunately, both methods have disadvantages that preclude their universal use. For example, the ring groove coining method, as disclosed in U.S. Pat. No. 3,110,086, when used on materials below 0.065 inch thickness, tends to generate an internal shear crack in the grooved area which is unacceptable. Also, precise control of the depth of the groove is important in the ring groove method since a shallow groove results in less than optimum fatigue improvement and a deep groove can result in a doughnut-shaped punch out. In the production situation, the desired way to control the depth of the groove is by controlling the force applied to the grooving die. However, because of the shape of the dies, the groove depth can vary greatly with the same applied force. In the pad coining method disclosed in U.S. Pat. No. 3,434,327, the pilots from each die contact each other preventing coining of material in thicknesses below 0.090 inch. At the same time a substantial amount of material adjacent the aperture is plastically deformed so the aperture closes up, sometimes seizing the die pilots in the aperture. As a result, the pilots must be made undersize to compensate for aperture closure. It is therefore difficult to assure that the pad coining is concentric with the aperture. Also both prior art coining methods require extremely high force levels, especially when the material being coined is steel or titanium. The high force levels effectively eliminate the use of portable tools, which means that retrofit or repair of a pair requires its removal to a shop area.

In modern aircraft which are of fail-safe design, it is conventional practice to use thin sacrificial doublers for the attachment of leading edges or access doors to the structural spar cap flanges which support them. The sacrificial doublers are attached at one edge to the spar cap flanges with interference attachments to assure an adequate fatigue life for the spar cap flanges. The opposite edges of the doublers include clearance holes and adjacent floating nut plates to enable easy attachment of the leading edge or access doors to the doublers. Since the doublers are attached to the spar cap with interference attachments, the same stress levels present in the spar cap flanges are also present in the doublers. The uncoined clearance holes in such doublers have a very low fatigue life and cracks result in a relatively short service time. Although a crack in a doubler is of secondary importance because it cannot cause a disasterous primary failure, the cracks are bothersome and expensive since their existence requires regular replacement of the doublers based on relatively few flight hours for the aircraft. Therefore, means for increasing the fatigue life of such doublers which tend to be relatively thin have been required.

SUMMARY OF THE INVENTION

The present ring pad stress coining method was developed to fill the gaps in the prior art fatigue strength improvement methods with aluminum, steel and titanium from one-half inch thick down to foil gauges being of primary interest. The method is comprised of plastically compressing a substantially flat bottomed ring of material in one or both side surfaces of a part generally concentric with an aperture or discontinuity in the part. The tooling to perform the ring pad coining has a die surface which includes a flat portion with adjacent curved edge portions. This shape provides a relatively wide, flat band contact area between the coining die and the part which enables relatively precise depth control by control of the force applied thereto. The total depth required to generate the desired volume of residual compression stress and to provide the desired fatigue strength is reduced by such shape so that usually the total coining force can be generated by means of portable tools. The tooling can also include a resilient pilot which assures the coined ring pad is maintained concentric with the aperture it surrounds. The pilot retracts as the die is brought into engagement with the workpiece so the pilot never is locked in the aperture by the plastic deformation of the material around the aperture.

It is therefore the object of the present invention to provide means for improving the fatigue strength of relatively thin structural parts having apertures therein.

Another object of the present invention is to provide a ring coining method which can be easily calibrated to a particular coining requirement.

Another object of the present invention is to provide means for improving the fatigue strength of a metal part quickly and economically.

Another object of the present invention is to provide a method for increasing the fatigue life of a part having an aperture therein which is simple to quality inspect.

Another object of the present invention is to provide means for improving the expected fatigue life of used parts having apertures therethrough or for restoring fatigue strength to apertured parts in which failures have started to occur.

These and other objects and advantages of the present invention will become apparent after considering the following detailed specification which covers preferred embodiments thereof in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded pictorial view showing apparatus to provide ring pad stress coining;

FIG. 2 is a partial cross-sectional view of ring pad stress coining tooling after ring pad coining a workpiece;

FIG. 3 is an enlarged cross-sectional view showing the shaping details of a typical ring pad stress coining die in engagement with a workpiece;

FIG. 4 is a view depicting a stress pattern of an apertured and ring pad coined structural member showing lines of stress therein; and

FIG. 5 is a perspective view of the workpiece of FIG. 2 after a ring pad coining operation, the workpiece being shown with a floating nut plate riveted thereto.

DESCRIPTION OF THE SHOWN EMBODIMENTS

Referring to the drawing more particularly by reference numbers, number **10** in FIG. 1 refers to a ring pad coining tool for performing ring pad coining according to the present invention. The tool **10** includes a ring pad coining die **12** having a resilient pilot **14** mounted centrally therein. Attachment means **16** are provided on the opposite end of the tool **10** from the die **12** to provide means for attaching the tool **10** to suitable force applying means which are shown symbolically in FIG. 1 by cylinders **18** and **20.** The force applying means may be any of a widely known group of tools including a rivet gun in which case the cylinder **20** represents a bucking member, and a C-clamp type squeezer in which case a second coining tool **22** may be connected by its attachment means **24** to the cylinder **20.** If used, the tool **22** has a coining die **26** similar to die **12** but lacks a pilot member since C-clamp type squeezers act to maintain the dies **12** and **26** in axial and perpendicular alignment. The pilot **14** of the tool **10** is used to assure the proper concentric alignment of the dies **12** and **26** with the aperture **28** in the workpiece **30** in which the coining is to take place. FIG. **2** shows this axial and perpendicular alignment more clearly.

Before coining, the aperture **28** is usually prepared by having its edges broken about 0.010 ±0.005 inch at 45°±5°. This results in frustroconical surfaces **32,** one of which engages the pilot **14** as the tool **10** is brought against the workpiece **30.** If multiple layers of material are being coined simultaneously, the frustroconical surfaces **32** need only be formed at the outer surfaces of the apertures through the stackup.

The pilot **14** includes a rounded frustroconical end portion **34** which acts as the guiding surface and a cylindrical portion **36** which rides on an inner circumferential surface **38** of the die **12.** The pilot **14** as aforesaid is resiliently mounted to the die **12** and such mounting means are shown as a spring **40** which extends into apertures **42** and **44** in the pilot **14** and the die **12** respectively. The diameter of the spring **40** is chosen so that it frictionally and resiliently engages the surfaces of the apertures **42** and **44,** thereby retaining the pilot **14** to the tool **10.** Once the pilot **14** has engaged the break **32** of the aperture **28,** it retracts as the die **12** is forced into engagement with the workpiece **30,** thereby assuring that the die **12** is concentric with the aperture **28.**

As shown in FIG. **3,** the die **12,** which is doughnut-shaped, has a coining surface **46** comprised of first and second radius portions **48** and **50** of a predetermined radius **52** with a flat portion **54** therebetween. The relative dimensions of the radius **52** and the flat portion **54** are shown in Table I for tools for coining holes of the indicated size. The optional die **26** has a similar die surface **56.**

TABLE I

Hole diameter to coin	D out	D in	F_{84}	R_{88}
.180–.229	.462	.2750	.033	.030
.230–.291	.523	.3370	.033	.030
.292–.354	.586	.4000	.033	.030
.355–.416	.648	.4620	.033	.030

When the dies **12** and **26** are constructed, great care is used to assure that the surfaces **46** and **56** thereof are given a mirror finish since any irregularity in the die surface results in a degradation of optimal levels of fatigue strength improvement. It is then usual to further assure that the surfaces **46** and **56** are smooth by chrome plating them. When in use, the die surfaces **46** and **56** are also protected by applying heavy cutting oil metal-working lubricant such as Pems 300 manufactured by Pemco Inc., Los Angeles, California, so the die surfaces **46** and **56** are not galled or otherwise damaged when they are forced into the workpiece during the coining operation. The lubricant also reduces the friction between the dies **12** and **26** and the workpiece **30** so the temperature of the workpiece **30** is not raised substantially. Excessive heating is undesirable because it causes reduction of the residual compressive stress which must remain in the workpiece **30** to improve its fatigue strength. The lubricant also assures a more consistent result when the force applied to the dies **12** and **26** is the regulated force to control the depth of penetration of the dies to form the depressed ring pad.

The groove or grooves generated by the tool **10** and when employed, the tool **22,** follow the shape of the coining dies **12** and **26** so a concentric ring **58** or rings **58** and **60** having flat bottoms **62** and **64** with curved edge portions **66** result when the tools **10** and **22** are forced into the workpiece **30.** This is because the dies **12** and **26** are driven with sufficient force to plastically deform the workpiece **30.** As a rule of thumb, the amount of plastic deformation should equal the elastic deformation so the average workpiece rebound is one-half the total elastic and plastic deformation. The described shape of ring pad grooves has proved to be advantageous especially in thin gauges of material since it produces the desired residual compressive stress which is shown diagrammatically by the vector arrows **68** and **70** in FIG. **3.** As can be seen, the present method results in two general types of induced compressive stress. The stress represented by arrows **68** in internal surface to surface compressive stress akin to the stress generated by the prior art pad coining method while the stress represented by arrows **70** is radial and circumferential stress akin to the stress generated by the prior art ring groove coining method. It is the combined residual compressive stresses created by the present stress coining method which provides greatly improved fatigue strength for thin workpieces **30** having apertures **28** therethough.

A possible explanation of the fatigue strength improvement is shown in FIG. **4** which is a stress diagram of the workpiece **30** having an aperture **28** about which the ring pad coining operation has been performed. Stress lines **72** depict the the stress pattern of the workpiece **30** showing the effect of the ring pad stress coin-

ing operation. It should be noted that the lines of stress **72** do not converge on the aperture but seem to be fenced out instead tending to flow around the aperture similar to an aerodynamic flow pattern. In open non-coined holes, the lines of stress tend to converge toward the center of the aperture **28** to concentrate thereat which substantially reduces the fatigue strength of the workpiece.

Table II shows test results of fatigue tests taken of specimen structures of the indicated material and thicknesses having a quarter inch open hole. The maximum net area tension stresses were 35,000 psi and all tests had an R factor equal to +.2, that is, the stresses were cycled from 20 percent to the indicated load.

TABLE II

Material & Thickness	Ring Pad Depth Req'd	Actual	Coining Load (lbs)	Cycles to Failure
	.0005	.0005	7,000	35,000
.090				39,000
		.0014		*1,200,000
7075-T6	.0015	.0015	10,500	5,157,000
	.003	.003	13,000	*2,550,000
				*2,630,000
	.001	.0009		197,000
.190		.0011	11,500	238,000
	.003	.003	15,000	*1,120,000
7075-T6				874,000
	.005	.005	17,500	564,000
				750,000
	.001	.001	13,000	94,000
				127,000
.250	.003	.0035	17,000	1,830,000
				1,060,000
7075-T6	.005	.005	18,500	* 1,670,000
				*2,521,000
		.0054		795,000
	.007	.0081	19,500	*2,615,000
		.003		61,000
	.003	.004	18,000	86,000
		.005		290,000
.375	.005	.006	20,000	954,000
		.007		547,000
7075-T6	.007	.008	21,500	355,000
		.009		979,000
	.009	.010	22,500	318,000
				116,000
	.0005	.0005	5,500	75,000
0.90		.0015		621,000
	.0015	.0017	8,000	991,000
2024-T3		.0028		1,491,000
	.003	.0033	11,000	1,489,000
		.0008		134,000
	.001	.0013	8,500	182,000
.190		.0033		1,189,000
	.003	.004	12,000	490,000
2024-T3		.0055		898,000
	.005	.006	13,500	607,000
				187,000
	.001	.001	9,500	162,000
		.0030		*2,000,000
.250	.003	.0035	13,000	3,471,000
		.0045		*2,554,000
2024-T3	.005	.0053	15,000	1,089,000
		.0068		*3,580,000
	.007	.0075	16,500	*2,595,000
		.0029		78,000
	.003	.0033	13,5000	104,000
		.0050		131,000
.375	.005	.0055	15,500	143,000
		.0068		335,000
2024-T3	.007	.0073	16,400	330,000
		.0095		963,000
	.009	.010	17,750	667,000

*No Failure

As can be seen from Table II, the actual depth of the coined ring pad varied little with a given coining force. This proved coining force is an acceptable way to control the present method. The novel shape of the coining dies **12** and **26** makes control by force control practical. This is because the flat portion **54** causes high force resistive levels within the workpiece **30** which tend to limit further penetration by the die **12** and the curved portions **48** increase the contact area substantially, once the die has penetrated to the desired depth, thus also tending to limit the depth of penetration of the coining die.

Since the required amount of force applied to the tool **10** to obtain the desired penetration and thereby the depth of the coined pad depends in large measure upon the material to be coined and the treatments that the material may have sustained, it is usual practice when coining a new type of production part to make a test specimen setup using the same hole size, thickness, alloy and temper as for the production part. What is thought to be the correct force is then applied to the die or dies across the specimen and the depth of the ring pad groove is measured. Final force adjustments are then made as necessary to establish the required coin depth. Once set up, the coining tool **10** can be used to coin the production parts and the coining can be quality assured very simply by merely measuring the depth and observing the smoothness and symmetry of the ring pad groove. The depth of the groove can be directly related to the amount of fatigue strength improvement while smoothness and symmetry are a measure of the care taken during the coining operation. When a rivet gun and bucking member are used to coin only one side of a workpiece, it is usual practice to use a rivet gun with an unrestricted air inlet and full air line pressure and then apply enough blows to obtain the required depth of the ring pad groove.

FIG. **5** shows a typical application of the present ring pad coining method wherein a floating nut plate **74** is attached by rivets **76** and **78** to the coined workpiece **30** behind the aperture **28.** In such an application it is exremely convenient that the present method can be employed closely adjacent to the aperture **28** so that a standard floating nut plate **74** can be used and so the rivets **76** and **78** located as shown do not interfer with the groove **60** or **58.**

Thus, there has been shown and described a novel method for increasing the fatigue strength of workpieces having apertures therethrough which fulfill all the objects and advantages sought before. Many changes, modifications, variations and other uses and applications of the subject invention will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings. All such changes, modifications, alterations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. A cold-working period method for improving the fatigue strength of a structural member having a first face and a discontinuity therein said method comprising:

forming a first groove in the first face of the structural member adjacent said discontinuity by compressively displacing material of the structural member toward said discontinuity and away from said first face, said displacement being sufficient to create residual radial and circumferential compressive stress in the area between the periphery of said groove and the edge of the discontinuity and to create residual compressive stress in the area of said first groove;

said first groove having a planar bottom and arcuate side walls adjacent the discontinuity which are curved upwardly; and

said groove side walls being tangent to and extending from said groove bottom to said structural member first face.

2. The method defined in claim **1** wherein said groove bottom has a surface area larger than the surface area of said groove side wall and said groove walls in cross-section each forming arcs which are less than 45°.

3. The method defined in claim **1** wherein the structural member has a second face opposite the first, said method further comprising:

forming a second groove similar to said first groove in the second face of the structural member opposite said first groove.

4. The method defined in claim **1** wherein the discontinuity is a hole passing through the structural member, said method further comprising:

forming said groove concentrically about the hole.

5. The method defined in claim **1** wherein the depth of said first groove is about equal to the depth said structural member can be displaced elastically.

6. The method defined in claim **4** wherein said hole is not restrained from deformation when said first groove is being formed.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,796,086 Dated 24 May 1974

Inventor(s) Austin Phillips

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 4, line 67, the second "the" after the word 'depict' should be deleted;
Col. 5, line 40, the ninth number in the first column should be --.090--;
line 53, the fourth number from the bottom of the fourth column should be --13,500--;
Claim 1, line 1, the word "period" should be deleted.

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents