FAN CASE REINFORCEMENT IN A GAS TURBINE JET ENGINE

Related applications

[0001] This application is a continuation-in-part application of pending PCT International application No. PCT/2005/33564, filed September 20, 2005, which is a continuation-in-part application of application Serial No. 10/947,923, filed September 23, 2004 and entitled "Method and Apparatus for Improving Fan Case Containment and Heat Resistance in a Gas Turbine Jet Engine."

BACKGROUND

[0002] In a full test of a gas turbine jet engine, a fan blade is deliberately released from the hub at a maximum engine rotation speed by an explosive bolt positioned at the base of the fan blade. This test is used to demonstrate the engine carcass's ability to contain the impact of the fan blade and handle the resulting out-of-balance forces. This impact is absorbed as vibration through the fan case containment system which surrounds the engine. The fan case is an element in a fan case containment system and is typically the heaviest component of a gas turbine jet engine due to its size, and due to the strength requirements the fan case may possess for containment purposes. In gas turbine jet engines susceptible to backfiring, heated air travels backward from the combustor to the fan area, increasing the temperature within the fan case and causing a rise in fan case temperature. These higher temperatures may be a factor in determining from what material the fan case is to be constructed. Maintaining or reducing the weight of the fan case, while at the same time maintaining or improving fan case containment strength and utilizing fan case materials that can withstand the fan case temperatures is a demonstrated need in the art.

[0003] BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a schematic diagram of the overall strueture of a typieal gas turbine jet engine with a fan casing typical of the prior art.

FIG. 2 shows a cross section of a forging for a fan casing typical of the prior art.

FIG. 3 shows a cross section of a forging for a fan casing for fan case containment in an embodiment of the present description.

FIG. 4 shows a cross section of a machine finished fan casing having two stiffener rings (**FIGS. 5A, 5B** and **6A, 6B**) and a containment ring (**FIGS. 7A, 7B**) that have been shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 5A shows a cross section of a forging for a first stiffener ring for the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 5B shows the first stiffener ring of **FIG. 5A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 6A shows a cross section of a forging for a second stiffener ring for the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 6B shows the second stiffener ring of **FIG. 6A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 7A shows a cross section of a forging for a containment ring for the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 7B shows the containment ring of **FIG. 7A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description.

FIG. 8 shows a schematic diagram of the airflow through a typical gas turbine jet engine.

FIG. 9 shows a schematic diagram of the airflow through a typical gas turbine jet engine susceptible to backfiring.

FIG. 10 shows a cross section of a forging for a fan casing for improved heat resistance in an embodiment of the present description.

FIG. 11 shows a cross section of a machine finished fan casing having a ring of heat resistant material that has been shrink interference fit to the fan casing of **FIG. 10** in an embodiment of the present description.

FIG. 12 shows a schematic cross-sectional diagram of a fan case having an inner containment ring in an embodiment of the present description.

FIG. 13 shows a schematic cross-sectional diagram of a fan case having an outer containment ring in an embodiment of the present description.

FIG. 14 shows a cross section of a machine finished fan casing of an alternative embodiment having two stiffener rings and a containment ring that have been shrink interference fit to a fan case with the fan case disposed between them.

FIG. 15 shows a schematic cross-sectional diagram of the fan case of Fig. 14 having an inner containment ring opposite outer stiffener rings.

FIG. 16 shows a schematic diagram illustrating a blade strike containment region of a fan case in an embodiment of the present description.

FIG. 17 shows a schematic cross-sectional diagram of the fan blade of the fan case of FIG. 16.

DETAILED DESCRIPTION

[0004] Referring now to the Figures, in which like reference numerals and names refer to structurally and/or functionally similar elements thereof, **Figure 1** shows a schematic diagram of the overall structure of a typical gas turbine jet engine with a fan casing typical of the prior art. Referring now to **FIG. 1**, Gas Turbine Jet Engine **100** has Fan **102** having a plurality of Fan Blades **104** housed within Fan Case **106**. The Fan 104 rotates on an axis of rotation along a centerline 107 to provide air intake and thrust Booster **108** is a low pressure compressor which feeds inlet air to High Pressure Compressor Rotor **110** and its attached blades and stators, which force air into Combustor **112**, increasing the pressure and temperature of the inlet air. High Pressure Turbine Rotor **114** and its accompanying blades and stators are housed within High Pressure Turbine Case **116**. Low Pressure Turbine Rotor **118** and its accompanying blades and stators are housed within Low Pressure Turbine Case **120**. Low Pressure Turbine Rotor **118** and its accompanying blades and stators extracts energy from the high-pressure, high-velocity gas flowing from Combustor **112** and transfers energy to Low Pressure Turbine Shaft **122**, which in turn drives Fan **102**, providing most of the thrust for Gas Turbine Jet Engine **100**.

[0005] **Figure 2** shows a cross section of a forging for a fan casing typical of the prior art. Referring now to **FIG. 2**, Fan Case Forging **200** after machining yields Fan Case **202**, shown in dotted line outline. In this example, Fan Case Forging **200** is forged from a titanium cylinder in one piece. The operating temperatures and load characteristics of the particular gas turbine jet engine that Fan Case **202** is designed for may require that Fan Case **202** be made of titanium. The forging weight for this particular Fan Case Forging **200** is approximately 3,347 pounds. After machining, Fan Case **202** has a flight weight of approximately 975.2 pounds. On gas turbine jet engines, the fan case may also be made of aluminum, steel, or manufactured from composite materials. Composite materials typically include a core material, a reinforcing material, and a resin binder. Core materials are typically wood, foam, and honeycomb. Reinforcing materials include fiberglass, carbon fiber, and Kevlar®. The resin component typically includes polyesters, vinyl esters, and epoxies. As technology improves, and temperatures go up in the gas turbine jet engines, aluminum cases are often wrapped with Kevlar® to give added strength for fan case containment purposes. For even higher operating temperatures not appropriate for aluminum or steel,

titanium is used, which may also by wrapped with Kevlar® if so needed for additional strength.

[0006] Structural features of the machined Fan Case **202** include First Stiffening Ring **204** and Second Stiffening Ring **206**. These two stiffening rings help prevent Fan Case **202** from going oval under the load and temperature conditions experienced during engine operation. Accessory Flange **208** will have holes drilled through it and various engine components hung from it, such as gear boxes, tubes, wiring, etc. First Containment Ring **210** encircles the outside of Fan Case **202** and provides additional strength for fan case containment. Second Containment Ring **212** circles the inside of Fan Case **202** and also provides additional strength for fan case containment. The section of Fan Case **202** between First Containment Ring **210** and Second Containment Ring **212** is the fan blade strike containment region where a fan blade, such as Fan Blade **104** (**FIG. 1**) will likely strike should it break loose from its hub. Due to the size of the Fan Blades **104**, which typically are the largest fan blades in a gas turbine jet engine, this section of Fan Case **202** is often designed to be exceptionally strong. Thus, First and Second Containment Rings **210, 212** provide additional strength.

[0007] **Figure 3** shows a cross section of a forging for a fan casing in an embodiment of the present description. Referring now to **FIG. 3**, a fan casing of the present description can be substituted for Fan Case **202** for use in the same gas turbine jet engine for which Fan Case **202** was designed either in a retrofit of an existing engine or in a newly manufactured engine. Features of the present description are applicable to a Fan case of a gas turbine jet engine used in a variety of applications in which a fan intakes air and produces thrust. Such applications include aviation, amphibious and other applications. Fan Case Forging **300** after machining yields Fan Case **302**, shown in dotted line outline. In this example, Fan Case Forging **300** is also forged from a titanium cylinder in one piece. In this example, the forging 300 has a simpler shape which simplifies the forging process, but it is appreciated that the shape may vary, depending upon the particular application. The forging weight for Fan Case Forging **300** is, in this embodiment, approximately 2,595 pounds, 752 pounds lighter than Fan Case Forging **200**. After machining, Fan Case **302** has a flight weight of approximately 751.3 pounds, 223.9 pounds lighter than Fan Case **202**. It is appreciated that the materials, weight and features of the forging 300 may vary, depending upon the particular application.

[0008] Structural features of the machined Fan Case **302** include First Stiffening Ring Notch **304** and Second Stiffening Ring Notch **306** located in a middle portion of Fan Case **302**. Two stiffening rings from two additional forgings (see **FIGS. 5A, 5B, 6A,** and **6B**) will be seated in First Stiffening Ring Notch **304** and Second Stiffening Ring Notch **306** (see **FIG. 4**) to help prevent Fan Case **302** from going oval under the load and temperature

conditions experienced during engine operation. Depending upon the design of a particular fan case, more or less stiffening ring notches may be utilized, and they may be located in various positions on a surface of the fan case. Although the stiffener rings 502, 602 are depicted as being seated on an outer surface of the fan case 302, it is appreciated that one or more of the stiffener rings may be installed on an inner surface of the fan case, depending upon the particular application. Accessory Flange **308** towards the back end of Fan Case **302** may have holes drilled through it or other attachment surfaces formed on it, and various engine components supported by it, such as gear boxes, tubes, wiring, etc.

[0009] Containment Ring Notch **310** circles the inside of Fan Case **302** circumferentially at the front end. A containment ring from an additional forging (see **FIGS. 7A** and **7B**) will be seated in Containment Ring Notch **310**. FIG. 12 shows a cross-sectional schematic diagram of the fan case 302 fitted with a containment ring 702 seated in the inner containment ring notch 310. The section of Fan Case **302** spanning the width of the Containment Ring Notch **310** is the fan blade strike containment region where a fan blade, such as Fan Blade **104** (**FIG. 1**) will likely strike should it break loose from its hub. This section of Fan Case **302** is in this embodiment, relatively strong, and the containment ring from the additional forging, machined to a predetermined shape to match with Containment Ring Notch **310**, provides additional strength and containment function. Fan Case **302** has no structure comparable to First Containment Ring **210** which may be omitted from the Fan Case **302** of the present description due to the additional strength provided by the containment ring 702. It is appreciated that in other embodiments, a second or additional containment rings may be added, depending upon the particular application.

[00010] **Figure 5A** shows a cross section of a forging for a first stiffener ring for the fan casing of **FIG. 3** in an embodiment of the present description, and **Figure 5B** shows the first stiffener ring of **FIG. 5A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description. Referring now to **FIGS. 5A** and **5B**, First Stiffening Ring Forging **500**, after machining to a predetermined shape to match with First Stiffening Ring Notch **304**, yields First Stiffening Ring **502**, shown in dotted line outline in **FIG. 5A**. In this example, First Stiffening Ring Forging **500** is forged from an aluminum ring in one piece. The forging weight for First Stiffening Ring Forging **500** is approximately 154 pounds. After machining, First Stiffening Ring **502** has a flight weight of approximately 41 pounds.

[00011] In this example, First Stiffening Ring **502**, fabricated separately from the fan case 302, is shrink interference fit into First Stiffening Ring Notch **304**. At ambient temperature, the inside diameter of First Stiffening Ring **502** will be slightly smaller than the outside diameter of First Stiffening Ring Notch **304**. First Stiffening Ring **502** is heated, which causes First Stiffening Ring **502** to expand, increasing the inside diameter to a diameter

that is greater than the outside diameter of First Stiffening Ring Notch **304**, and giving rise to First Ring Clearance **504**, enabling First Stiffening Ring **502** to be positioned as shown in First Stiffening Ring Notch **304**. In this position, First Stiffening Ring **502** is allowed to cool, which shrinks in diameter and seats itself circumferentially into First Stiffening Ring Notch **304**. At ambient temperature, due to First Stiffening Ring **502** attempting to return to its smaller inside diameter, but being prevented from doing so due to the larger outside diameter of First Stiffening Ring Notch **304**, a shrink with an interference fit results, with radially compressive circumferential force being applied to Fan Case **302** by First Stiffening Ring **502**, and tensile circumferential force is applied to First Stiffening Ring **502** by Fan Case **302**. In one embodiment, the radially compressive forces may be centered on the axis of rotation defined by center line 107. Also, the radially compressive forces are applied continuously around the entire circumference of the First Stiffening Ring 502 without interruption.

[00012] **Figure 6A** shows a cross section of a forging for a second stiffener ring for the fan casing of **FIG. 3** in an embodiment of the present description, and **Figure 6B** shows the second stiffener ring of **FIG. 6A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description. Referring now to **FIGS. 6A** and **6B**, Second Stiffening Ring Forging **600**, after machining to a predetermined shape to match with Second Stiffening Ring Notch **306**, yields Second Stiffening Ring **602**, shown in dotted line outline in **FIG. 6A**. In this example, Second Stiffening Ring Forging **600** is forged from an aluminum ring in one piece. The forging weight for Second Stiffening Ring Forging **600** is approximately 148 pounds. After machining, Second Stiffening Ring **602** has a flight weight of approximately 40.6 pounds.

[00013] In this example, Second Stiffening Ring **602**, fabricated separately from the fan case 302, is shrink interference fit into Second Stiffening Ring Notch **306**. At ambient temperature, the inside diameter of Second Stiffening Ring **602** will be slightly less than the outside diameter of Second Stiffening Ring Notch **306**. Second Stiffening Ring **602** is heated, which causes Second Stiffening Ring **602** to expand, increasing the inside diameter to a diameter that is greater than the outside diameter of Second Stiffening Ring Notch **306**, and giving rise to Second Ring Clearance **604**, enabling Second Stiffening Ring **602** to be positioned as shown in Second Stiffening Ring Notch **306**. In this position, Second Stiffening Ring **602** is allowed to cool, which shrinks in diameter and seats itself circumferentially into Second Stiffening Ring Notch **306**. At ambient temperature, due to Second Stiffening Ring **602** attempting to return to its smaller inside diameter, but being prevented from doing so due to the larger outside diameter of Second Stiffening Ring Notch **306**, a shrink with an interference fit results, with radially compressive circumferential force being applied to Fan Case **302** by Second Stiffening Ring **602**, and tensile circumferential force is applied to Second Stiffening Ring **602** by Fan Case **302**. In one embodiment, the radially compressive

forces may be centered on the axis of rotation defined by center line 107. Also, the radially compressive forces are applied continuously around the entire circumference of the Second Stiffening Ring 602 without interruption. Also, each stiffener ring is, in one embodiment, fabricated as a solid, unitary or one-piece continuous or seamless member forged or machined in a closed loop shape. In another embodiment, a stiffener ring may be fabricated using an open loop-shaped member and bonding the ends together by welding, for example, to form a closed loop shape.

[00014] It is appreciated that the stiffener rings may be located at other positions of a fan case, depending upon the application. It is further appreciated that the sizes, dimension, shapes, materials and clearances may vary, depending upon the particular application. It is appreciated that due to various factors such as nonperfect roundness, a stiffener ring such as the First Stiffening Ring 502 may not engage 100% of the circumference of the outer surface of the Fan Case 302. For example, the First Stiffening Ring 502 may contact 70% of the circumference of the outer surface of the Fan Case 302, but the amount of contact may vary, depending upon the particular application. Nonetheless, it is considered that the First Stiffening Ring 502 applies radially compressive forces along the length of the circumference of the inner circumferential surface of the First Stiffening Ring 502 when the First Stiffening Ring 502 is shrink interference fit to the Fan Case 302.It is further appreciated that in some applications, it may be appropriate to provide a liner material between a stiffener ring shrink interference fit to a fan case such that the compressive forces between the stiffener ring and the fan case are transmitted through the liner material. In one embodiment, the liner material may be made of compressible material. It is appreciated that the liner material may in other embodiments be relatively stiff or may have other properties.

[00015] **Figure 7A** shows a cross section of a forging for a containment ring for the fan casing of **FIG. 3** in an embodiment of the present description, and **Figure 7B** shows the containment ring of **FIG. 7A** about to be shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description. Referring now to **FIGS. 7A** and **7B**, Containment Ring Forging **700**, after machining to a predetermined shape to match with Containment Ring Notch **310**, yields Containment Ring **702**, shown in dotted line outline in **FIG. 7A**. In this example, Containment Ring Forging **700** is forged from a ring of nickel-base super alloy, such as Inconel 718, in one piece. The forging weight for Containment Ring Forging **700** is approximately 467 pounds. After machining to the predetermined shape, Containment Ring **702** has a flight weight of approximately 138.1 pounds. It is appreciated that the containment ring may be located at other positions of a fan case, depending upon the application. It is further appreciated that the sizes, dimension, shapes, materials and clearances may vary, depending upon the particular application. For example, the Containment Ring 702 may be made of other super alloys, steel, titanium or other appropriate materials to contain the blade.

Also, the containment ring is, in one embodiment, fabricated as a solid, unitary or one-piece continuous or seamless member forged or machined in a closed loop shape. In another embodiment, a containment ring may be fabricated using an open loop-shaped member and bonding the ends together by welding, for example, to form a closed loop shape.

[00016] In this example, Containment Ring **702**, fabricated separately from the fan case 302, is shrink interference fit into Containment Ring Notch **310**. At ambient air temperature the outside diameter of Containment Ring **702** will be slightly larger than the inside diameter of Containment Ring Notch **310**. Fan Case **302** is heated, which causes Fan Case **302** to expand, increasing the inside diameter to a diameter that is greater than the outside diameter of Containment Ring **702**, and giving rise to Containment Ring Clearance **704**, enabling Containment Ring **702** to be positioned as shown in Containment Ring Notch **310**. In this position, Fan Case **302** is allowed to cool, which shrinks in diameter and allows Containment Ring **702** to seat itself circumferentially into Containment Ring Notch **310**. At ambient temperature, due to Fan Case **302** attempting to return to its smaller inside diameter, but being prevented from doing so due to the larger outside diameter of Containment Ring **702**, a shrink with an interferenee fit results, with radially compressive circumferential force being applied to Containment Ring **702** by Fan Case **302**, and tensile circumferential force is applied to Fan Case **302** by Containment Ring **702**. In one embodiment, the radially compressive forces may be centered on the axis of rotation defined by center line 107 as schematically represented by arrows in FIG. 12. In one embodiment, the radially compressive forces are applied continuously around the entire circumference of the Containment Ring Notch 310 of the Fan case 202 without interruption. It is appreciated that due to various factors such as nonperfect roundness, a containment ring such as the Containment Ring 702 may not engage 100% of the circumference of the inner surface of the Fan Case 302. For example, the Containment Ring 702 may contact 70% of the circumference of the inner surface of the Fan Case 302, but the amount of contact may vary, depending upon the particular application. Nonetheless, it is considered that the Fan Case 302 applies radially compressive forces along the length of the circumference of the inner circumferential surface of the Containment Ring Notch 310 when the Fan Case 302 is shrink interference fit to the Containment Ring 702. It is further appreciated that in some applications, it may be appropriate to provide a liner material between a containment ring shrink interference fit to a fan case such that the compressive forces between the containment ring and the fan case are transmitted through the liner material. In one embodiment, the liner material may be made of compressible material. It is appreciated that the liner material may in other embodiments be relatively stiff or may have other properties.

[00017] For a fan case manufactured from composite material, Containment Ring 702 may be cooled with liquid nitrogen to reduce its outside diameter giving rise to Containment

Ring Clearance **704**, enabling Containment Ring **702** to be positioned as shown in Containment Ring Notch **310**. In this position, Containment Ring **702** is allowed to warm up to ambient temperature, increasing in diameter, and seating itself circumferentially into Containment Ring Notch **310**. At ambient temperature, due to Containment Ring **702** attempting to return to its greater outside diameter, but being prevented from doing so due to the smaller inside diameter of Containment Ring Notch **310**, an interference fit results, with radially compressive circumferential force being applied to Containment Ring **702** by Fan Case **302**, and tensile circumferential force is applied to Fan Case **302** by Containment Ring **702**. One skilled in the art will recognize that a combination of heating Fan Case **302** along with cooling Containment Ring **702** may also be employed in certain situations to effect a shrink fit.

[00018] In one embodiment of the description, Containment Ring Notch **310** is machined circumferentially with a reverse taper such that the inside diameter of Fan Case **302** at point **A** is less than the inside diameter of Fan Case **302** at point **B**. The taper may vary from fan case to fan case, ranging from just greater than 0° for a cylindrical case to an appropriate degree that would depend upon the specific geometry of a conical fan case. Containment Ring **702** is machined circumferentially on its outside surface to match this same reverse taper. Even though Containment Ring **702** is shrink interference fit onto Fan Case **302**, the taper can add extra security to retard the Containment Ring **702** from slipping axially on Fan Case **302**.

[00019] In addition, the machining for Fan Case **302** may be done in a first direction, such as radially, and the machining for Containment Ring **702** may be done in a second direction, such as axially, which is more or less perpendicular to the first direction. Since machining leaves a spiral, or record, continuous groove on the machined surfaces, the grooves on each surface will align in a cross-hatch manner to each other, increasing the frictional forces between the two surfaces and reducing the potential for spinning of Containment Ring **702** within Containment Ring Notch **310**. The plurality of grooves on Containment Ring **702**, which may be made of a nickel-base super alloy, for example, can be harder than the plurality of grooves on Containment Ring Notch **310** of Fan Case **302**, which may be made of titanium, or in other fan casings, possibly steel or aluminum, for example. The nickel-base super alloy grooves can dent into the softer titanium, steel, or aluminum grooves. Alternatively, Containment Ring **702** could simply be spot welded in one or more locations to Containment Ring Notch **310**, or bolted to one or more flanges secured to Containment Ring Notch **310**, to keep Containment Ring **702** from spinning in relation to Containment Ring Notch **310**. Machining in cross directions may also be applied or omitted, as appropriate, depending upon the application.

[00020] **Figure 4** shows a cross section of a machine finished fan casing having two stiffener rings (**FIGS. 5A, 5B, 6A,** and **6B**) and a containment ring (**FIGS. 7A** and **7B**) that have been shrink interference fit to the fan casing of **FIG. 3** in an embodiment of the present description. Referring now to **FIG. 4**, Containment Ring **702** can replicate part of the structure comparable to Second Containment Ring **212**, and can obviate utilization of First Containment Ring **210** fully or partially, depending upon the application. By shrink interference fitting Containment Ring **702** on the inside diameter of Fan Case **302**, as opposed to the outside, the harder super alloy of Containment Ring **702** can provide an initial striking surface should a blade break off. The softer titanium, steel, or aluminum, of Fan Case **302** on the outside of Containment Ring **702** can act as a shock absorber due to the different expansion rates between the two materials. As the super alloy of Containment Ring **702** begins to move, it can push against the titanium, steel, or aluminum of Fan Case **302** with a different coefficient of expansion. This is like having two nets close to each other. The super alloy of Containment Ring **702** can take the initial blow, and some of the force be transferred to the titanium, steel, or aluminum Fan Case **302** like a shock absorber.

[00021] First Stiffening Ring **502** and Second Stiffening Ring **602** are shown seated in First Stiffening Ring Notch **304** and Second Stiffening Ring Notch **306** respectfully. First Stiffening Ring **502** and Second Stiffening Ring **602** provide stiffening to prevent Fan Case **302** from deforming out-of-round, or going oval, during operation of the engine under temperature and load conditions.

[00022] In this particular example, **Table 1** below shows a comparison of the forge and flight weights, and costs, of prior art Fan Case **202** compared to Fan Case **302** of the present description.

Table 1

Part/ Material	**Forge Wt. (lbs)**	**Flight Wt. (lbs)**	**Cost/lb**	**Total Cost**
Fan Case **202** Titanium	3,347.0	975.2	$8.00	$26,776.00
Fan Case **302** Titanium	2,595.0	751.3	$8.00	$20,760.00
First Stiffening Ring **502** Aluminum	154.0	40.5	$1.50	$231.00
Second Stiffening Ring **602** Aluminum	148.0	40.6	$1.50	$222.00
Containment Ring **702** Inconel 718	467.0	138.1	$7.00	$3,269.00
Total	3,364.0	970.5	$7.28	$24,482.00
Savings	-17.0	4.7	$0.72	$2,294.00

[00023] Thus, in this example, though the forge weight is 17 pounds more, the flight weight is 4.7 pounds less. In addition, the average cost per pound of the materials for Fan Case **302** is $0.72 per pound less than that of Fan Case **202**, resulting in a total savings of $2,294.00. Also, in this example, it is believed that Fan Case **302** is considerably stronger than Fan Case **202**.

[00024] In other applications, the savings could be more significant. For example, for a fan casing that requires Kevlar® reinforcement, a fan casing of the present description may be sufficiently stronger so as to eliminate the need for the Kevlar® reinforcement, which would be a substantial savings in both materials cost and labor. The present description could also be used with Kevlar® reinforcement to attain higher fan case containment strength. For gas turbine jet engines that currently use steel or titanium for the fan casings, the present description may enable aluminum to be substituted for the steel or titanium, and the strength needed for containment provided for by the containment ring of nickel-base super alloy or other suitable material. Since the same volume of aluminum or titanium is about 30%-55% of the weight of the same volume of steel, substantial weight savings can result. This weight savings may translate into increased cargo carrying capability or reduced fuel costs or a combination of both.

[00025] In the gas turbine jet engine industry, the trend is toward making fan blades longer to increase thrust. The tips of the fan blades can rotate at supersonic speeds, while the base of the fan blades rotate at subsonic speeds. This can cause a harmonic vibration in the blades resulting in the tips of the blades breaking off. To counter this problem, instead of making straight fan blades, the blades are shaped more like wide paddles. These wider and longer blades result in more mass that must be contained within the fan casing. Also, as engines become more efficient, they tend to operate at hotter temperatures, potentially adding more difficulty to the containment problem. It is believed that the present description can greatly assist in meeting these challenges for greater fan case containment strength and potentially less overall weight and lower cost, as well as provide other features in addition to or instead of, depending upon the particular application.

[00026] **FIG. 8** shows a schematic diagram of the airflow through a typical gas turbine jet engine. Referring now to **FIG. 8**, for a gas turbine jet engine not readily susceptible to backfiring, Air Flow **824** flows into Fan Case **806** and into Booster **808**. High Pressure Compressor Rotor **810** compress Air Flow **824** as it enters Combustor **812**. After passing through the high pressure and low pressure turbines, Air Flow **824** flows out of the back of Gas Turbine Jet Engine **800**. The heated Air Flow **824** in Combustor **812** travels on through and out of the back of Gas Turbine Jet Engine **800**.

[00027] **FIG. 9** shows a schematic diagram of the airflow through a typical gas turbine jet engine susceptible to backfiring. Referring now to **FIG. 9**, in contrast to **FIG. 8**,

Gas Turbine Jet Engine **900** is susceptible to backfiring, which causes a portion of Air Flow **924**, Heated Air **926** represented by dotted lines, to flow backwards through Gas Turbine Jet Engine **900** and into the area of Fan **902**. Heated Air **926** causes the temperature within Fan Case **906** to rise, which also elevates the temperature of Fan Case **906** itself in the area designated generally by Area **928**. Temperature is of course one of the primary factors in determining from what material Fan Case **906** is to be constructed. When fan case temperatures rise above 800 degrees, aluminum may no longer be suitable. More expensive heat tolerant materials, such as steel, titanium, or super alloys, may be appropriate.

[00028] **FIG. 10** shows a cross section of a forging for a fan casing for improved heat resistance in an embodiment of the present description. Referring now to **FIG. 10**, for gas turbine jet engines susceptible to backfiring, it is believed that a fan casing of the present description can be used to counteract the heat problems and improve the heat resistance of Fan Case **1002**. Fan Case Forging **1000** is similar to Fan Case Forging **300** shown in **FIG. 3**. Fan Case Forging **1000** after machining yields Fan Case **1002**, shown in dotted line outline, which is similar to Fan Case **302**. In this example, Fan Case Forging **1000** is forged from aluminum in one piece.

[00029] Structural features of the machined Fan Case **1002** are similar to that shown in **FIGS. 3** and **4** but also include Heat Resistance Ring Notch **1012** which circles the inside of Fan Case **1002** circumferentially at the location defined generally by Area **928** in **FIG. 9**. A ring of heat resistant material will, with a shrink interference fit in this example, be seated in Heat Resistance Ring Notch **1012**. The section of Fan Case **1002** spanning Heat Resistance Ring Notch **1012** is the region where the heated air from backfiring can cause increased fan case temperatures.

[00030] It is appreciated that the heat resistance ring may be located at other positions of a fan case, depending upon the application. It is further appreciated that the sizes, dimension, shapes, materials and clearances may vary, depending upon the particular application.

[00031] As described above, the machining for Fan Case **1002** may be done in a first direction, such as radially, and the machining for Heat Resistance Ring **1112** may be done in a second direction, such as axially, which is more or less perpendicular to the first direction. Since machining can leave a spiral, or record, continuous groove on the machined surfaces, the grooves on each surface may align in a cross-hatch manner to each other, increasing the frictional forces between the two surfaces and reducing the potential for spinning of Heat Resistance Ring **1112** within Heat Resistance Ring Notch **1012**. The plurality of grooves on Heat Resistance Ring **1112**, which is made of titanium, may be harder than the plurality of grooves on Heat Resistance Ring Notch **1012** of Fan Case **1002**, which is made of aluminum. The titanium grooves can dent into the softer aluminum

grooves. Alternatively, Heat Resistance Ring **1112** could simply be spot welded in one or more locations to Heat Resistance Ring Notch **1012**, or bolted to one or more flanges secured to Heat Resistance Ring Notch **1012**, to keep Heat Resistance Ring **1112** from spinning in relation to Heat Resistance Ring Notch **1012**. Machining in cross directions may not be needed in this case or may be applied in addition thereto.

[00032] **FIG. 11** shows a cross section of a machine finished fan casing having a ring of heat resistant material that has been shrink interference fit to the fan casing of **FIG. 10** in an embodiment of the present description. Referring now to **FIG. 11**, Heat Resistance Ring **1112** is shown shrink interference fit on the inside diameter of Fan Case **1002** in Heat Resistance Ring Notch **1012**. In this example, Heat Resistance Ring **1112** is made of titanium, but may also be made of other materials that have a combination of heat resistant properties and strength properties to maintain the structural integrity required for Fan Case **1002** such as steel, steel alloy, or any number of commonly used aerospace super alloys. Heat Resistance Ring **1112** may be fabricated from titanium sheet material that is cut, bent into a cylindrical shape, welded along the seam, and formed to match the inside diameter of Heat Resistance Ring Notch **1012**. Heat Resistance Ring **1112** may also be forged as described above.

[00033] The shrink with interference fit may be accomplished, as described above, by heating Fan Case **1002**, causing it to expand in diameter and allowing Heat Resistance Ring **1112** to be slid into place, where upon cooling, Fan Case **1002** and Heat Resistance Ring **1112** apply force to each other in a shrink interference fit. Alternatively, Heat Resistance Ring **1112** may be cooled with liquid nitrogen, reducing its outside diameter and enabling Heat Resistance Ring **1112** to be slid into Heat Resistance Ring Notch **1012**. Also, a combination of heating Fan Case **1002** and cooling Heat Resistance Ring **1112** may be employed to secure the shrink interference fit. The titanium of Heat Resistance Ring **1112** is not weakened structurally by the fan case temperatures, and serves as a buffer to the aluminum Fan Case **1002** due to the different expansion rates between the two materials. The titanium of Heat Resistance Ring **1112** is exposed to internal fan case temperatures, and some of the heat is transferred to the aluminum Fan Case **1002**. The titanium provides the strength needed that the aluminum lacks at the higher temperatures. Containment Ring **1102** may be made from a super alloy. It is appreciated that due to various factors such as nonperfect roundness, a heat resistance ring such as the Heat Resistance Ring 1112 may not engage 100% of the circumference of the outer surface of the Fan Case 1002. For example, the Heat Resistance Ring 1112 may contact 70% of the circumference of the inner surface of the Fan Case 1002, but the amount of contact may vary, depending upon the particular application. Nonetheless, it is considered that the Fan Case 1002 applies radially compressive forces along the length of the circumference of the inner circumferential surface of the Heat Resistance

Ring Notch **1012** when the Fan Case 1002 is shrink interference fit to the Heat Resistance Ring **1112**. It is further appreciated that in some applications, it may be appropriate to provide a liner material between a heat resistance ring shrink interference fit to a fan case such that the compressive forces between the heat resistance ring and the fan case are transmitted through the liner material. In one embodiment, the liner material may be made of compressible material. It is appreciated that the liner material may in other embodiments be relatively stiff or may have other properties such as enhanced heat insulation properties to protect the fan case further.

[00034] First Stiffening Ring Notch **1104** and Second Stiffening Ring Notch **1106** may be made of aluminum, titanium, or steel, for example. Depending upon the specific gas turbine jet engine being considered, a containment ring and one or more stiffening rings may not be necessary with a heat resistance ring, and a heat resistance ring may not be necessary with a containment ring and one or more stiffening rings. The present description gives the engine designer many options regarding materials, weights, strengths, and heat resistance that can be combined to come up with an optimum design for a specific engine's goals and requirements. For example, the Fan Case 302 may be made of a relatively lightweight but relatively inexpensive material such as aluminum and the containment ring 702 may be made of a material having a relatively higher containment strength (such as a super alloy Inco 718) as compared to the material of the fan case. However, since the Containment Ring 702 may be made substantially smaller in mass than that of the Fan Case 302, the material of the Containment Ring 702 can be more expensive or more heavy than the material of the Fan Case 302 and yet achieve savings in overall weight or expense or both, depending upon the particular application. Similarly, the Fan Case 1002 may be made of a relatively low heat resistance material such as aluminum and the Heat Resistance Ring 1102 may be made of a material having a relatively higher heat resistance property (such as titanium, for example) as compared to the material of the fan case. However, since the Heat Resistance Ring 1112 may be made substantially smaller in mass than that of the Fan Case 1002, the material of the Heat Resistance Ring can be more expensive or more heavy than the material of the Fan Case 1002 and yet achieve savings in overall weight or expense or both, depending upon the particular application.

[00035] As previously mentioned, FIG. 12 schematically illustrates a containment ring 702 seated in a containment ring notch 310 formed in an inside surface of the fan case 302. Referring now to FIG. 13, it is appreciated that a containment ring 702a may be seated in a containment ring notch 310a formed in an outside surface of a fan case 302a as shown in FIG. 13. In this example, the containment ring 702a applies radially compressive forces directed toward the axis of rotation defined by center line 107 as schematically represented by arrows in FIG. 13. In one embodiment, the radially compressive forces are applied

continuously around the entire circumference of the Containment Ring 702a without interruption.

[00036] As previously mentioned, the Stiffener Rings may be placed in a variety of locations along the fan case 302. FIG. 14 shows an example in which a pair of stiffener rings 502, 602 are placed opposite a containment ring 702b. As shown in the cross-sectional diagram of FIG. 15, the stiffener ring 502 and the containment ring 702b are each shrink interference fit to the fan case 302 with the fan case 302 positioned between the stiffener ring 502 and the containment ring 702b. The stiffener ring 602 is similarly shrink interference fit to the fan case 302 with the fan case 302 positioned between the stiffener ring 602 and the containment ring 702b. The stiffener rings 502, 602, in addition to their stiffening functions, may in this embodiment, provide further containment strength to supplement that of the containment ring 702b.

[00037] Again, the Fan Case 302 may be made of a relatively lightweight but relatively inexpensive material such as aluminum and the stiffener rings 502, 602 may be made of a material having a relatively higher containment or stiffening strength (such as a super alloy Inco 718 or other super alloys, steel, titanium or other appropriate materials) as compared to the material of the fan case. However, since the stiffener rings 502, 602 may be made substantially smaller in mass than that of the Fan Case 302, the material of the stiffener rings 502, 602 can be more expensive or more heavy than the material of the Fan Case 302 and yet achieve savings in overall weight or expense or both, depending upon the particular application.

[00038] As schematically shown in FIG. 16, the section of Fan Case **302** spanning the width of the Containment Ring **702** is the fan blade strike containment region 1600 where a fan blade, such as Fan Blade **104** (**FIG. 1, 16**) or a portion of a fan blade may strike should it or a portion of it break loose from its hub 102 or the remaining blade portion. In this embodiment, the fan blade strike containment region 1600 extends from a hook portion 1601 at the forward end of the containment ring 702 to an aft end 1603 of the containment ring 702. The containment region 1600 may be determined by appropriate computer modeling and/or empirically through laboratory testing of the likely or potential trajectory of a separated fan blade or fan blade portion. It is appreciated that in some embodiments, the width of the containment ring may exceed the width of the potential strike area.

[00039] Within the fan blade strike containment region 1600 is a region 1602 in which a fan blade or blade portion is likely to or potentially may first strike the fan case 302. As shown in FIG. 16, it is believed that, for many engine designs, the width of the first strike region 1602 extends from a line forward of the leading edge 1604 of the fan blade 104, to a line aft of the trailing edge 1608 of the fan blade 104. The forward direction is the direction towards the front of the fan case 302 in which the air is taken in. The aft direction is the

direction in which the air is exhausted from the engine to provide thrust in the forward direction.

[00040] As best seen in the cross-sectional view of FIG. 17 of the fan blade 104, the leading edge 1604 is the portion of the fan blade 104 which extends the farthest in the forward direction. Conversely, the trailing edge 1608 of the fan blade 104 is the portion of the fan blade 204 which extends the farthest in the aft direction. In the illustrated embodiment, the width of the containment ring 702 spans at least the width of the fan blade first strike region 1602. Hence, the width of the containment ring 702 when installed in an engine, extends at least from a line forward of the leading edge 1604 of the fan blade 104, to a line aft of the trailing edge 1608 of the fan blade 104. It is appreciated that a fan blade strike containment region 1600 and the width of the containment ring 702 may extend in one or both of the forward and aft directions beyond the boundaries of a first strike region 1602 as shown in FIG. 16.

[00041] In the illustrated embodiment, the containment ring 702 has a thickness T (FIG. 16). The thickness T of the containment ring 702 is, in the illustrated embodiment, sufficient to prevent piecing of the containment ring 702 by a separated blade 104 or blade fragment. The thickness may be determined by appropriate computer modeling or empirical testing based upon the projected or observed mass and velocity of the blade or blade fragments and the strength of the material of the containment ring 702.

[00042] In the described embodiments, the rings such as the rings 702, 702a, 702b, 502, 602, 1112 are each described as being seated in an associated notch. It appreciated that one or more of the rings fabricated separately from the fan case 302, may be affixed to the fan case to reinforce the fan case without utilizing an associated notch.

[00043] In the described embodiments, the rings such as the rings 702, 702a, 702b, 502, 602, 1112 are each described as being seated in a shrink interference fit with the fan case 302, 302a. It appreciated that one or more of the rings fabricated separately from the fan case 302, may be affixed to the fan case to reinforce the fan case such that radially compressive forces are applied between a ring and the fan case without utilizing a shrink interference fit.

[00044] Having provided the present description, it will be understood by those skilled in the art that many changes in construction and widely differing embodiments and applications of the description will suggest themselves without departing from the scope of the present description.

CLAIMS

What is claimed is:

1. A method, comprising:

encircling an outer circumferential surface of one of a containment ring and a fan blade containment region of fan case of a gas turbine jet engine having a turbine case having a turbine adapted to rotate along an axis of rotation within said fan case, and a fan having fan blades coupled to said turbine and adapted to rotate along an axis of rotation within said fan case, each fan blade having a leading edge and a trailing edge, using an inner circumferential surface of the other of the containment ring and the fan blade containment region of the fan case of a gas turbine jet engine; and

applying radially compressive forces to said outer circumferential surface along the length of the circumference of said inner circumferential surface and along the width of the fan blade containment region extending at least forward of the leading edge of each fan blade and at least aft of the trailing edge of each fan blade, using said encircling inner circumferential surface.

2. The method of claim 1 wherein said radially compressive force applying includes shrink interference fitting said containment ring to said fan case.

3. The method of claim 1 wherein said radially compressive force applying includes seating said containment ring within a notch defined by said fan case and shaped to secure said containment ring against displacement in a direction longitudinal to said fan case.

4. The method of claim 1 wherein said radially compressive forces are directed to a center located on said axis of rotation.

5. The method of claim 1 further comprising machining a containment ring notch circumferentially into an inner surface towards a front end of the fan case; and wherein said encircling and applying includes seating said containment ring in said containment ring notch through a shrink interference fit.

6. The method of claim 1 further comprising machining a containment ring notch circumferentially into an outer surface towards a front end of the fan case; and wherein said encircling and applying includes seating said containment ring in said containment ring notch through a shrink interference fit.

7. A method according to claim 5 wherein said machining further comprises

machining said containment ring notch into said inner surface of the fan case in a first direction, wherein a plurality of grooves are formed and aligned on said inner surface in said first direction.

8. A method according to claim 7 further comprising:

prior to said notch machining , forging said containment ring in one piece; and

machining said containment ring to a predetermined shape to match with said containment ring notch.

9. A method according to claim 8 wherein said containment ring is forged from a containment material in one piece wherein said material is selected from the group consisting of steel, titanium, nickel-base super alloy.

10. A method according to claim 8 wherein said containment ring machining further comprises machining an outer surface of said containment ring in a second direction, wherein a plurality of grooves are formed and aligned on said outer surface in said second direction;

wherein when said inner surface of said containment ring notch and said outer surface of said containment ring are seated together, said plurality of grooves on said inner surface of said containment ring notch and said plurality of grooves on said outer surface of said containment ring align in a cross-hatch manner to each other, increasing the frictional forces between said containment ring notch and said containment ring and reducing the potential for spinning of said containment ring within said containment ring notch.

11. A method according to claim 8 further comprising:

spot welding said containment ring to said containment ring notch in at least one location to retard said containment ring from spinning in relation to said containment ring notch.

12. A method according to claim 8 further comprising:

bolting said containment ring to at least one flange secured to said containment ring notch to retard said containment ring from spinning in relation to said containment ring notch.

13. A method according to claim 8 wherein said containment ring machining further comprises machining said containment ring with a reverse taper, wherein a first outside diameter of said containment ring at a first point towards a front end is less than a second inside diameter of said containment ring at a second point away from said front end.

14. A method according to claim 5 wherein said machining further comprises machining said containment ring notch with a reverse taper, wherein a first inside diameter of the fan case at a first point of said containment ring notch towards said front end is less than a second inside diameter of the fan case at a second point of said containment ring notch located away from said front end.

15. A method according to claim 5 wherein said seating further comprises:

heating the fan case to cause an inside diameter of said containment ring notch to increase to a second diameter that is larger than an outside diameter of said containment ring at an ambient temperature;

positioning said containment ring in said containment ring notch; and

allowing the fan case to cool to said ambient temperature, causing said containment ring notch to want to decrease from said second diameter toward said inside diameter, but resisted from doing so by said outside diameter of said containment ring at said ambient temperature, giving rise to said shrink interference fit.

16. A method according to claim 5 wherein said seating further comprises:

heating the fan case to cause an inside diameter of said containment ring notch to increase to a second diameter;

cooling said containment ring to cause an outside diameter of said containment ring to decrease to a second diameter, wherein said second diameter of said containment ring is smaller than said second diameter of said containment ring notch;

positioning said containment ring in said containment ring notch; and

allowing the fan case to cool to an ambient temperature causing said containment ring notch to decrease from said second diameter toward said inside diameter, and allowing said containment ring to warm up to said ambient temperature causing said containment ring to increase toward said outside diameter, giving rise to said shrink interference fit.

17. A method according to claim 5 wherein said seating further comprises:

cooling said containment ring to cause an outside diameter of said containment ring to decrease toward a second diameter, wherein said second diameter of said containment ring is smaller than an inside diameter of said containment ring notch;

positioning said containment ring in said containment ring notch; and

allowing said containment ring to warm up to said ambient temperature causing said containment ring to increase toward said outside diameter, but resisted from doing so by said inside diameter of said containment ring notch at said ambient temperature, giving rise to said shrink interference fit.

18. A method according to claim 5 further comprising:

machining at least one stiffening ring notch circumferentially into a surface of the fan case; and

seating a stiffening ring in said at least one stiffening ring notch, wherein said stiffening ring resists the fan case from going oval under a load and temperature conditions experienced during operation of the gas turbine jet engine.

19. A method according to claim 18 wherein said stiffening ring notch is machined in an outer surface of the fan case and said seating said stiffener ring further comprises:

heating said stiffening ring to cause a first inside diameter of said stiffening ring to increase to a second inside diameter that is larger than an outside diameter of said at least one stiffening ring notch at an ambient temperature;

positioning said stiffening ring in said at least one stiffening ring notch; and

allowing said stiffening ring to cool to said ambient temperature, causing said stiffening ring to decrease from said second inside diameter toward said first inside diameter, but resisted from doing so by said outside diameter of said at least one stiffening ring notch, giving rise to said shrink interference fit.

20. The method of claim 1 wherein said fan case is made of a first material having a first containment strength and said containment ring is made of a second material having a second containment strength higher than that of the first material.

21. The method of claim 20 wherein said first material is aluminum and said second material is a nickel-based super alloy.

22. The method of claim 18 wherein said fan case is made of a first material having a first strength and said stiffener ring is made of a second material having a second strength higher than that of the first material.

23. The method of claim 22 wherein said first material is aluminum and said second material is a nickel-based super alloy.

24. The method of claim 1 wherein said containment ring has a thickness sufficient to prevent piercing of said containment ring by a separated blade.

25. An apparatus for use in a gas turbine jet engine having a turbine case having a turbine adapted to rotate along an axis of rotation within said fan case, and a fan having fan blades coupled to said turbine and adapted to rotate along an axis of rotation within said fan case, each fan blade having a leading edge and a trailing edge, the apparatus comprising:

a fan case having an inner circumferential surface which includes a fan blade containment region; and

a containment ring having an outer circumferential surface, said containment ring being positioned around said fan case within said fan case containment region to contain said fan blades in the event said fan blades become separated from said fan, said containment ring extending forward of at least the leading edge of each fan blade and aft of at least the trailing edge of each fan blade;

wherein said fan blade containment region of said fan case is adapted to apply radially compressive forces to said outer circumferential surface of said containment ring, along the length of the circumference of said fan blade containment region of said inner circumferential surface.

26. The apparatus of claim 25 wherein said containment ring has a thickness sufficient to prevent piercing of said containment ring by a separated blade.

27. An apparatus for use in a gas turbine jet engine having a turbine case having a turbine adapted to rotate along an axis of rotation within said fan case, and a fan having fan blades coupled to said turbine and adapted to rotate along an axis of rotation within said fan case, each fan blade having a leading edge and a trailing edge, the apparatus comprising:

a fan case having a front end which includes a fan blade containment region, and an inner surface and an outer surface towards said front end of the fan case wherein one of said inner and outer surfaces defines a containment ring notch machined circumferentially into said one fan case surface and within said fan blade containment region; and

a containment ring adapted to be seated in said containment ring notch and extending forward of at least the leading edge of each fan blade and aft of at least the trailing edge of each fan blade, to provide radially compressive forces applied from one of said fan case and said containment ring to the other of said fan case and said containment ring.

28. The apparatus of claim 27, wherein said containment ring is adapted to be seated through a shrink interference fit.

29. The apparatus of claim 28 wherein said containment ring notch is machined circumferentially into said fan case inner surface towards a front end of the fan case.

30. The apparatus according to claim 27 wherein said containment ring is forged from a containment material in one piece and is machined to a predetermined shape and wherein said material is selected from the group consisting of steel, titanium, nickel-base

super alloy.

31. The apparatus according to claim 29 wherein an outside diameter of said containment ring is slightly larger than an inside diameter of said containment ring notch at an ambient air temperature, and the fan case is heated to cause said inside diameter of said containment ring notch to increase to a second diameter that is larger than said outside diameter of said containment ring, enabling said containment ring to be positioned in said containment ring notch giving rise to said shrink interference fit when the fan case cools to said ambient temperature.

32. The apparatus according to claim 31 wherein said containment ring notch is machined with a reverse taper such that a first inside diameter of the fan case at a first point towards said front end is less than a second inside diameter of the fan case at a second point away from said front end, and further wherein said containment ring is machined circumferentially on its outside surface to match said reverse taper.

33. The apparatus according to claim 29 wherein an outside diameter of said containment ring is slightly larger than an inside diameter of said containment ring notch at an ambient air temperature, and the fan case is heated to cause said inside diameter of said containment ring notch to increase to a second diameter, and said containment ring is cooled to cause an outside diameter of said containment ring to decrease to a second diameter, wherein said second diameter of said containment ring is smaller than said second diameter of said containment ring notch, enabling said containment ring to be positioned in said containment ring notch giving rise to said shrink interference fit when the fan case cools and said containment ring warms up to said ambient temperature.

34. The apparatus according to claim 29 wherein an outside diameter of said containment ring is slightly larger than an inside diameter of said containment ring notch at an ambient air temperature, and said containment ring is cooled to cause an outside diameter of said containment ring to decrease to a second diameter, wherein said second diameter of said containment ring is smaller than an inside diameter of said containment ring notch, enabling said containment ring to be positioned in said containment ring notch giving rise to said shrink interference fit when said containment ring warms up to said ambient temperature.

35. The apparatus according to claim 29 further comprising:

a plurality of grooves aligned in a first direction on a machined inner surface of said containment ring notch; and

a plurality of grooves aligned in a second direction on a machined outer surface of

said containment ring;

wherein when said inner surface of said containment ring notch and said outer surface of said containment ring are interference shrink fit together, said plurality of grooves on said inner surface of said containment ring notch and said plurality of grooves on said outer surface of said containment ring align in a cross-hatch manner to each other, increasing the frictional forces between said containment ring notch and said containment ring and reducing the potential for spinning of said containment ring within said containment ring notch.

36. The apparatus according to claim 27 further comprising:

a spot weld in at least one location welding said containment ring to said containment ring notch to prevent said containment ring from spinning in relation to said containment ring notch.

37. The apparatus according to claim 27 further comprising:

at least one flange secured to said containment ring notch, wherein said containment ring is bolted to said at least one flange to retard said containment ring from spinning in relation to said containment ring notch.

38. The apparatus according to claim 27 further comprising:

at least one stiffening ring notch machined circumferentially into a surface of the fan case; and

a stiffening ring seated in said at least one stiffening ring notch, wherein said stiffening ring is seated through a shrink interference fit, wherein said stiffening ring resists the fan case from going oval under a load and temperature conditions experienced during operation of the gas turbine jet engine.

39. The apparatus according to claim 38 wherein said stiffening ring is forged from aluminum in one piece.

40. The apparatus according to claim 27 wherein said stiffening ring notch is machined into an outer surface of the fan case and an inside diameter of said stiffening ring is slightly smaller than an outside diameter of said at least one stiffening ring notch at ambient air temperature, and said stiffening ring is heated to cause said inside diameter of said stiffening ring to increase toward a second diameter that is larger than said outside diameter of said at least one stiffening ring notch, enabling said stiffening ring to be positioned in said at least one stiffening ring notch giving rise to said shrink interference fit when said stiffening ring cools to said ambient temperature.

41. The apparatus according to claim 27 wherein the fan case is forged from one of steel, titanium, and aluminum.

42. The apparatus according to claim 27 wherein the fan case is manufactured from one of steel, titanium, and aluminum.

43. The apparatus according to claim 27 wherein the fan case is manufactured from a composite material.

44. The apparatus according to claim 43 wherein an outside diameter of said containment ring is slightly larger than an inside diameter of said containment ring notch at an ambient air temperature, and said containment ring is cooled to cause said outside diameter of said containment ring to decrease to a second diameter that is smaller than said inside diameter of said containment ring notch, enabling said containment ring to be positioned in said containment ring notch giving rise to an interference fit when said containment ring warms to said ambient temperature.

45. The apparatus of claim 27 wherein said fan case is made of a first material having a first containment strength and said containment ring is made of a second material having a second containment strength higher than that of the first material.

46. The apparatus of claim 45 wherein said first material is aluminum and said second material is a nickel-based super alloy.

47. The apparatus of claim 38 wherein said fan case is made of a first material having a first strength and said stiffener ring is made of a second material having a second strength higher than that of the first material.

48. The apparatus of claim 47 wherein said first material is aluminum and said second material is a nickel-based super alloy.

49. A gas turbine jet engine, comprising:

a fan case having an inner circumferential surface which includes a fan blade containment region;

a turbine case having a turbine adapted to rotate along an axis of rotation within said fan case;

a fan having fan blades coupled to said turbine and adapted to rotate along an axis of rotation within said fan case, each fan blade having a leading edge and a trailing edge; and

a containment ring having an outer circumferential surface, said containment ring being positioned around said fan to contain said fan blades in the event said fan blades become separated from said fan, said containment ring extending forward of at least the leading edge of each fan blade and aft of at least the trailing edge of each fan blade;

wherein said fan blade containment region of said fan case is adapted to apply radially compressive forces to said outer circumferential surface of said containment ring, along the length of the circumference of said fan blade containment region of said inner circumferential surface.

50. The engine according to claim 49 further comprising:

at least one flange secured to fan case, wherein said containment ring is bolted to said at least one flange to retard said containment ring from spinning in relation to said fan case.

51. The engine according to claim 50 further comprising:

at least one stiffening ring notch machined circumferentially into a surface of the fan case; and

a stiffening ring seated in said at least one stiffening ring notch, wherein said stiffening ring is seated through a shrink interference fit, wherein said stiffening ring resists the fan case from going oval under a load and temperature conditions experienced during operation of the gas turbine jet engine.

52. The engine of claim 49 wherein the fan case has a middle portion having an inner surface which defines a heat resistance ring notch machined circumferentially into said fan case surface, the engine further comprising a heat resistance ring adapted to be seated in said heat resistance ring notch to provide radially compressive forces applied from said fan case to said heat resistance ring.

53. The engine of claim 52, wherein said heat resistance ring is adapted to be seated through a shrink interference fit.

54. A method of retrofitting a gas turbine jet engine, comprising:

removing a fan case from the jet engine; and

installing a substitute fan case on said jet engine, wherein said substitute fan case has a containment ring seated in an inner circumferential surface of the substitute fan case through a shrink interference fit and adapted to contain fan blades striking said substitute fan case, said containment ring extending forward of at least the leading edge of each said fan blade and aft of at least the trailing edge of each said fan blade when housed within the substitute fan case;.

55. The method of claim 54 further comprising seating said containment ring in a circumferential notch of said inner circumferential surface of the substitute fan case through a shrink interference fit, prior to installing said substitute fan case.

56. A method of operating a gas turbine jet engine, comprising:

rotating fan blades of a fan housed within a fan case using a turbine along an axis of rotation to provide air intake and thrust; and

applying radially compressive forces to an outer circumferential surface of one of a containment ring and a fan blade containment region of the fan case using an inner circumferential surface of the other of the containment ring and the fan blade containment region of the fan case encircling said outer circumferential surface, said radially compressive forces being applied along the length of the circumference of the inner circumferential surface and along the width of the fan blade containment region extending at least forward of the leading edge of each fan blade and at least aft of the trailing edge of each fan blade, and directed to a center positioned on said axis of rotation

57. The method of claim 56 further comprising applying radially compressive forces to an outer circumferential surface of the fan case using an inner circumferential surface of a stiffener ring encircling said fan case outer circumferential surface.

58. The method of claim 56 further comprising applying radially compressive forces to an outer circumferential surface of a heat resistance ring using an inner circumferential surface of the fan case encircling said heat resistance ring outer circumferential surface.

59. An apparatus for use in a gas turbine jet engine having a turbine case having a turbine adapted to rotate along an axis of rotation within said fan case, and a fan having fan blades coupled to said turbine and adapted to rotate along an axis of rotation within said fan case, each fan blade having a leading edge and a trailing edge, the apparatus comprising:

a fan case having a front end and an inner surface and an outer surface towards said front end of the fan case wherein said inner surface defines a fan blade containment region and a backfire heatable region wherein said fan case is made of a first material having a first containment strength and a first heat resistance;

a containment ring having an outer circumferential surface, said containment ring being positioned within said fan case containment region to contain said fan blades in the event said fan blades become separated from said fan, said containment ring extending forward of at least the leading edge of each fan blade and aft of at least the trailing edge of each fan blade, wherein said fan blade containment region of said fan case is adapted to apply radially compressive forces to said outer circumferential surface of said containment ring, wherein said containment ring is made of a second material having a second containment strength higher than that of the first material;

a stiffening ring adapted to be seated on said fan case outer surface aft of said containment ring to provide radially compressive forces applied from said stiffening ring to said fan case outer surface and wherein said stiffener ring is made of a material having a strength higher than that of the first material; and

a heat resistance ring adapted to be seated on said fan case inner surface within said backfire heatable region to provide radially compressive forces applied from said fan case backfire heatable region to said heat resistance ring and wherein said heat resistance ring is made of a third material having a second heat resistance higher than that of the first material.

60. The apparatus of claim 59 wherein said first material is aluminum, said second material is a nickel-based super alloy, said stiffener ring material is a nickel-based super alloy and said third material is titanium.