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**(54) BIPOD FLEXURE RING**

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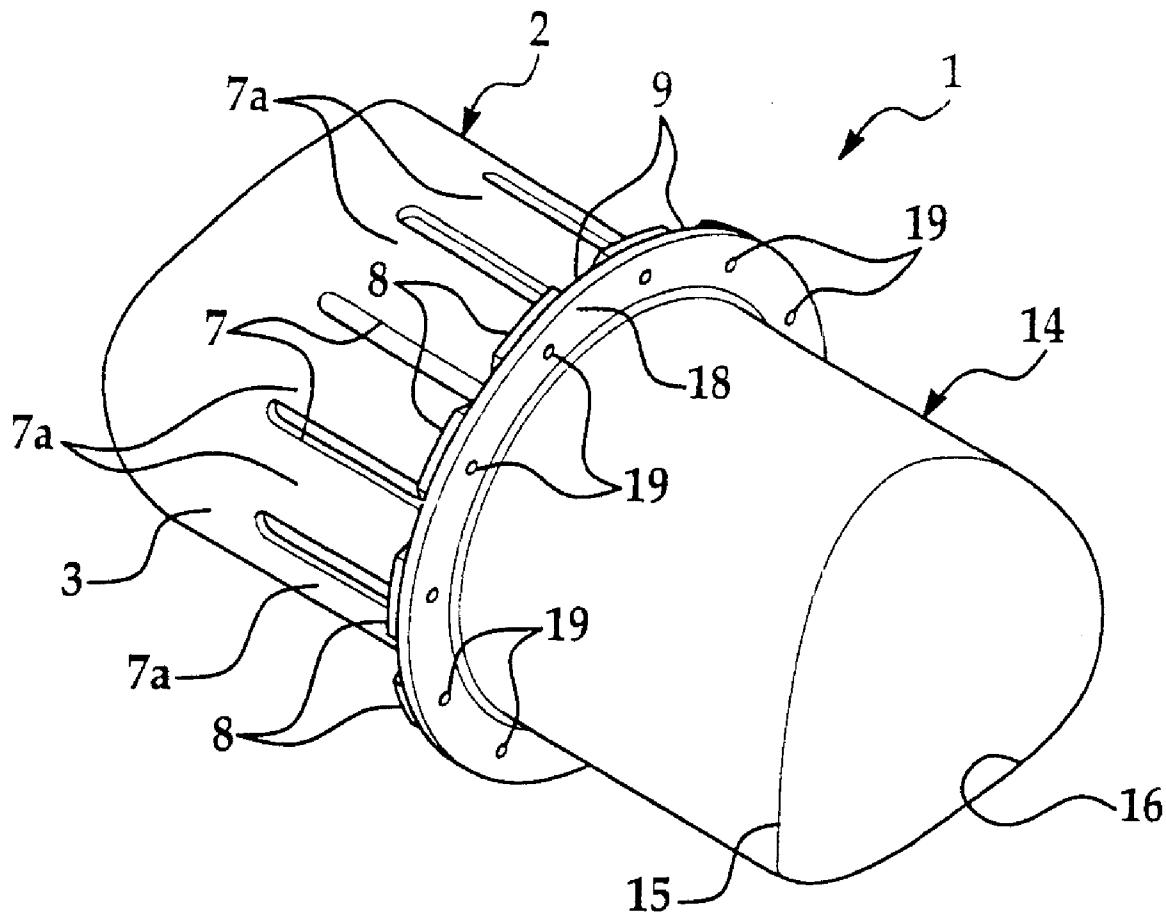
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## ABSTRACT

A thermal coupling includes a first structure having a first coefficient of thermal expansion; a second structure having a second coefficient of thermal expansion lower than the first coefficient of thermal expansion; a plurality of thermal expansion fingers provided in the first structure; a plurality of thermal expansion flanges extending from the plurality of thermal expansion fingers, respectively; and a flange extending from the second structure and attached to the plurality of thermal expansion flanges.



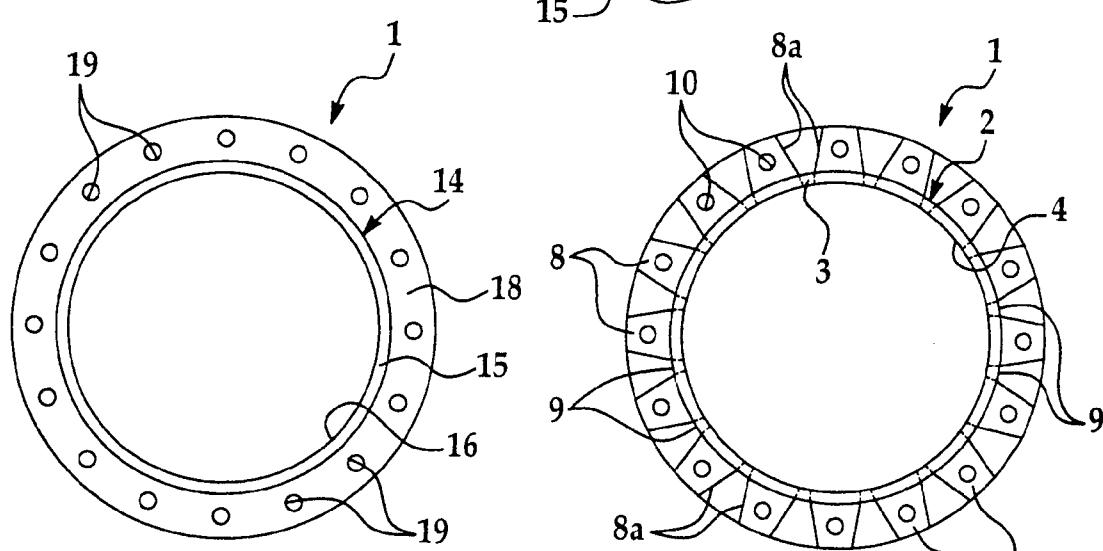
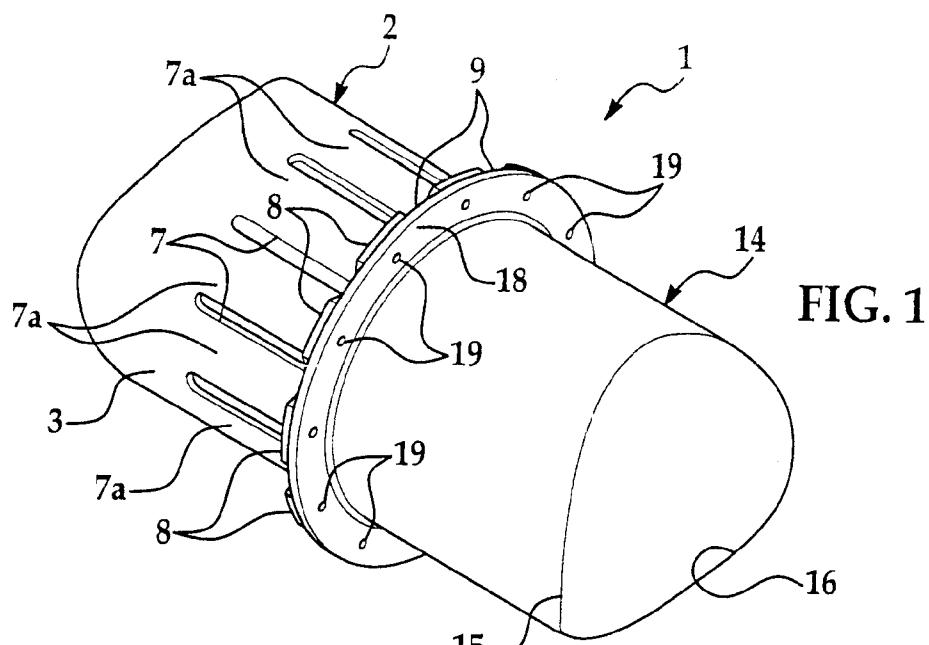
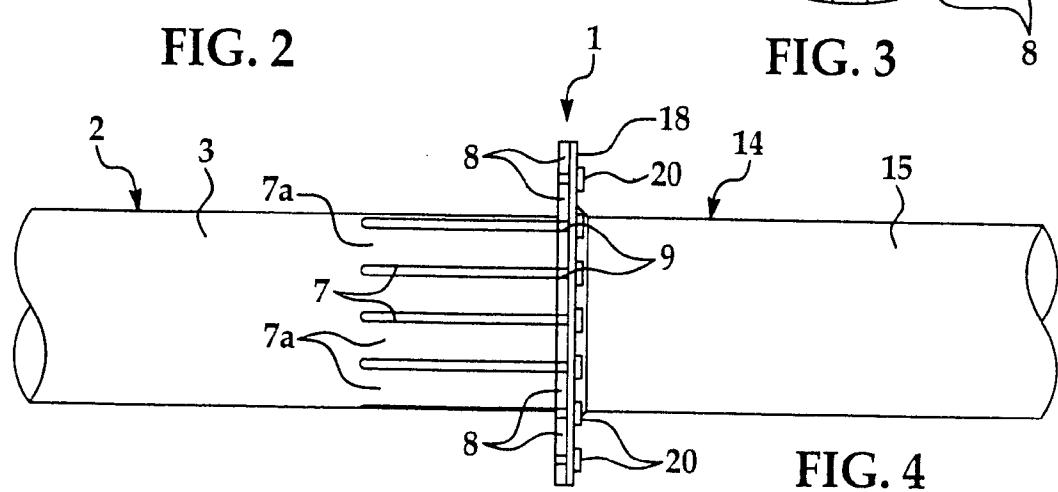


FIG. 3



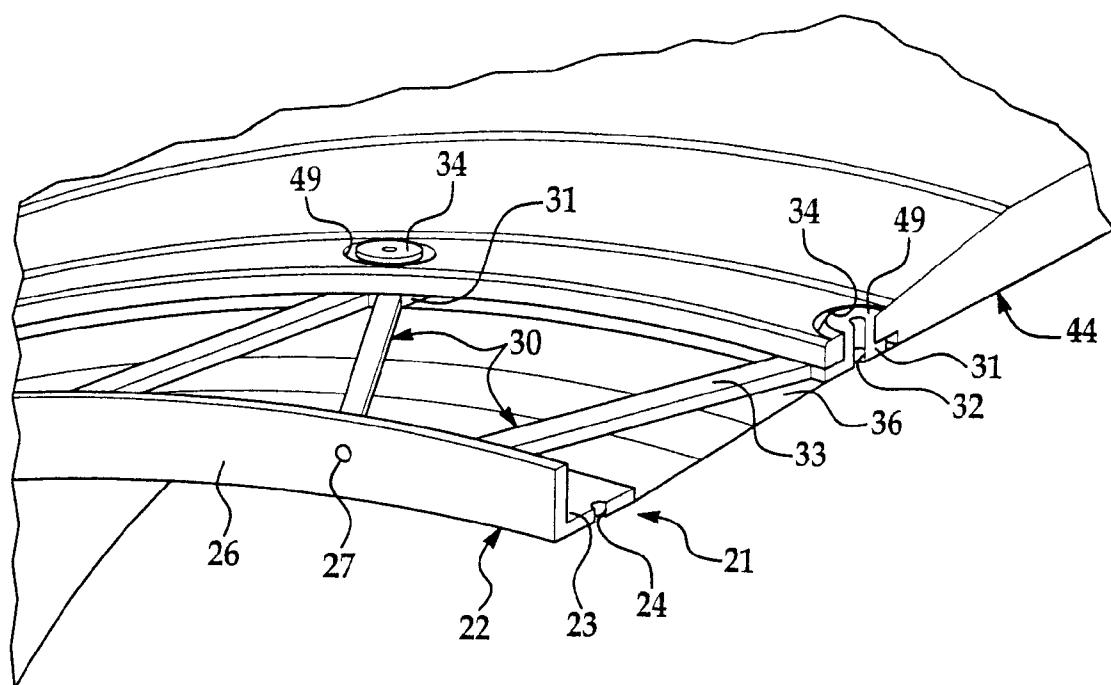


FIG. 5

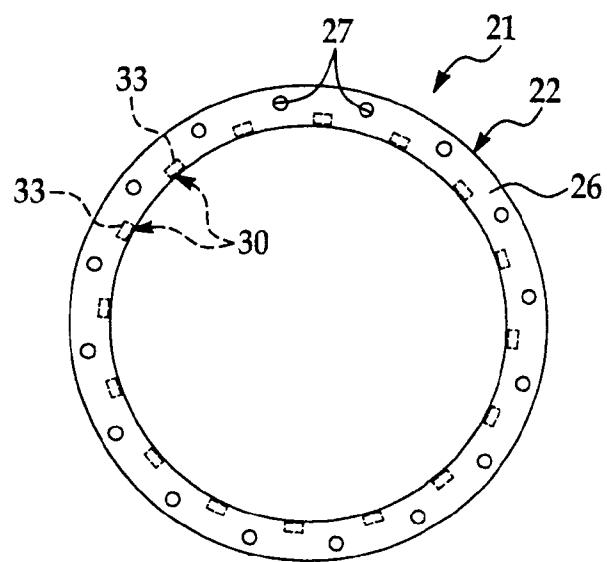


FIG. 6

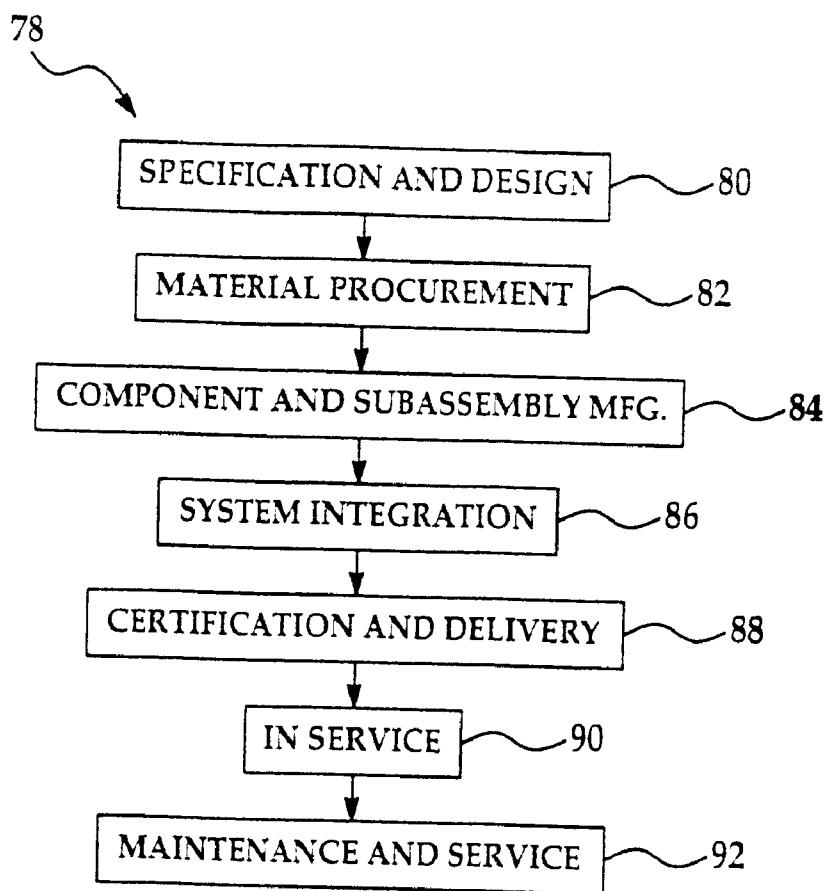


FIG. 7

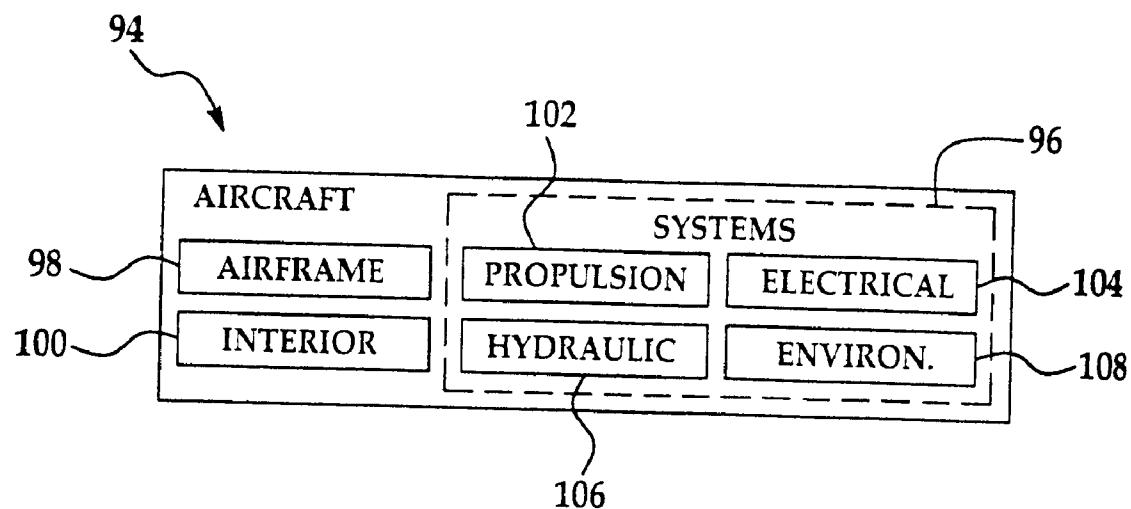


FIG. 8

## BIPOD FLEXURE RING

## TECHNICAL FIELD

[0001] The present disclosure relates to couplings. More particularly, the present disclosure relates to a thermal coupling which is suitable for coupling a structure having a high CTE (coefficient of thermal expansion) to a structure having a low CTE.

## BACKGROUND

[0002] In many applications, it is necessary to couple a structure having a high coefficient of thermal expansion (CTE) to a structure having a low CTE such as in the coupling of a metallic structure and a ceramic structure, for example. However, the thermal mismatch between such structures may induce high strains in the ceramic if the structures are rigidly joined when the structures are heated. These forces can easily influence the ceramic structure, precluding the coupling of ceramic and metallic structures to each other in elevated temperature applications.

## SUMMARY

[0003] The present disclosure is generally directed to a thermal coupling. An illustrative embodiment of the thermal coupling includes a first structure having a first coefficient of thermal expansion; a second structure having a second coefficient of thermal expansion lower than the first coefficient of thermal expansion; a plurality of thermal expansion fingers provided in the first structure; a plurality of thermal expansion flanges extending from the plurality of thermal expansion fingers, respectively; and a flange extending from the second structure and attached to the plurality of thermal expansion flanges.

[0004] Another illustrative embodiment of the thermal coupling includes an attachment frame; a plurality of frame ribs extending from the attachment frame; a plurality of fastener rings provided on the plurality of frame ribs, respectively; and a plurality of fastener ring openings provided in the plurality of fastener rings, respectively.

## BRIEF DESCRIPTION OF THE ILLUSTRATIONS

[0005] The disclosure will now be made, by way of example, with reference to the accompanying drawings, in which:

[0006] FIG. 1 is a partial sectional perspective view of an illustrative embodiment of the thermal coupling, attaching a structure having a high CTE to a structure having a low CTE.

[0007] FIG. 2 is an end view of the low CTE structure side of the thermal coupling.

[0008] FIG. 3 is an end view of the high CTE structure side of the thermal coupling.

[0009] FIG. 4 is a side view of an illustrative embodiment of the thermal coupling and the high CTE structure and the low CTE structure connected via the thermal coupling.

[0010] FIG. 5 is a perspective sectional view of an alternative illustrative embodiment of the thermal coupling, attached to an aircraft engine nozzle (partially in section).

[0011] FIG. 6 is a front view of the alternative illustrative embodiment of the thermal coupling illustrated in FIG. 5.

[0012] FIG. 7 is a flow diagram of an aircraft production and service methodology.

[0013] FIG. 8 is a block diagram of an aircraft.

## DETAILED DESCRIPTION

[0014] Referring to FIGS. 1-4 of the drawings, an illustrative embodiment of the thermal coupling is generally indicated by reference numeral 1. The thermal coupling 1 may couple a structure having a relatively high CTE (coefficient of thermal expansion) 2 to a structure having a relatively low CTE 14 and facilitate relative thermal expansion and retraction of the high CTE structure 2 with respect to the low CTE structure 14 during cyclic heating and cooling of the thermal coupling 1. The high CTE structure 2 may be a metal such as titanium, for example, and may include a high CTE wall 3 which defines a structure interior 4 (FIG. 3). The low CTE structure 14 may be ceramic and may include a low CTE wall 15 which defines a structure interior 16. The high CTE structure 2 has a coefficient of thermal expansion (CTE) which is higher than that of the low CTE structure 14.

[0015] As shown in FIGS. 1 and 4, the thermal coupling 1 may include multiple generally elongated, parallel thermal expansion slots 7 which extend through the high CTE wall 3 of the high CTE structure 2. The thermal expansion slots 7 may be disposed in generally parallel, spaced-apart relationship with respect to each other around the circumference of the high CTE structure 2. The longitudinal axis of each thermal expansion slot 7 may be oriented in generally parallel relationship with respect to a longitudinal axis of the high CTE structure 2. A thermal expansion finger 7a may be defined between each pair of adjacent thermal expansion slots 7.

[0016] Thermal expansion flanges 8 may extend from the respective thermal expansion fingers 7a. Each thermal expansion flange 8 may be oriented in generally perpendicular relationship with respect to the corresponding thermal expansion finger 7a from which the thermal expansion flange 8 extends. As shown in FIG. 3, each thermal expansion flange 8 may have a pair of scalloped or beveled flange edges 8a. A flange slot 9 may be defined between each adjacent pair of thermal expansion flanges 8. As further shown in FIG. 3, a fastener opening 10 may extend through each thermal expansion flange 8 for purposes which will be hereinafter described.

[0017] An annular flange 18 (FIG. 2), which may be continuous, may extend from the low CTE wall 15 of the low CTE structure 14. The flange 18 may be oriented in generally perpendicular relationship with respect to the longitudinal axis of the low CTE structure 14. Multiple, spaced-apart fastener openings 19 may extend through the flange 18. The fastener openings 19 may correspond in number and position to the fastener openings 10 provided in the respective thermal expansion flanges 8 on the high CTE structure 2. As shown in FIG. 4, flange fasteners 20 may extend through the fastener openings 19 in the flange 18 and the registering fastener openings 10 in the thermal expansion flanges 8, respectively, to attach the low CTE structure 14 to the high CTE structure 2.

[0018] In typical application, a fluid (not shown) having an elevated temperature flows through the high CTE structure 2 and the low CTE structure 14. Due to its higher CTE, the high CTE structure 2 may expand to a greater extent than the low CTE structure 14 upon heating due to flow of the typically hot fluid through the high CTE structure 2 and the low CTE structure 14. Accordingly, the thermal expansion slots 7 between the thermal expansion flanges 7a facilitate axial and

radial expansion of the high CTE wall **3** of the high CTE structure **2** relative to the low CTE wall **15** of the low CTE structure **14**. In like manner, the flange slots **9** between the thermal expansion flanges **8** facilitate radial expansion of the thermal expansion flanges **8** of the high CTE structure **2** relative to the flange **18** of the low CTE structure **14**. The thermal coupling **1** may be capable of withstanding shear forces directed tangentially to the circumference of the thermal coupling **1** as well as loads which are directed parallel to the central axis of the thermal coupling **1**. Therefore, thermal stresses between the high CTE structure **2** and the low CTE structure **14** during thermal cycling may be minimized, thus substantially preventing any possible change in the typically ceramic low CTE structure **14**.

[0019] Referring next to FIGS. 5 and 6 of the drawings, an alternative illustrative embodiment of the thermal coupling is generally indicated by reference numeral **21**. The thermal coupling **21** is a scalloped ring or spaceframe structure including an attachment frame **22** which may be a material having a relatively high CTE (coefficient of thermal expansion). In some embodiments, the attachment frame **22** is a metal such as titanium, for example. The attachment frame **22** may include an annular frame ring **23**. Multiple, spaced-apart fastener openings **24** (one of which is shown in FIG. 5) may extend through the frame ring **23**. An annular frame flange **26** may extend from the frame ring **23**, in generally perpendicular relationship with respect to the frame ring **23**. Multiple, spaced-apart fastener openings **27** may extend through the frame flange **26**.

[0020] As shown in FIGS. 5 and 6, multiple frame ribs **30** may extend from the attachment frame **22** in generally adjacent, spaced-apart relationship with respect to each other. Each frame rib **30** may include a pair of generally elongated rib members **33** which converge distally toward each other as they extend from the attachment frame **22**. Each rib member **33** of each frame rib **30** may be oriented in generally parallel relationship with respect to the frame ring **23** and in generally perpendicular relationship with respect to the frame flange **26** of the attachment frame **22**. A fastener ring **31** may be provided on the converging distal ends of the rib members **33**. As shown in FIG. 5, a fastener ring opening **32** may extend through each fastener ring **31**.

[0021] In typical application, the thermal coupling **21** connects a first structure (not shown) having a high CTE (coefficient of thermal expansion) to a second structure **44** having a relatively low CTE. The high CTE structure is attached to the high CTE attachment frame **22**, whereas the low CTE structure **44** is attached to the fastener rings **31** of the frame ribs **30**. The frame flange **26** on the high CTE attachment frame **22** may be attached to the high CTE structure by extending fasteners (not shown) through fastener openings (not shown) provided in the high CTE structure and through the registering fastener openings **27** provided in the frame flange **26**. The fastener ring **31** on each pair of converging rib members **33** may be attached to the low CTE structure **44** by extending a rib fastener **34** through a rib fastener opening **49** provided in the low CTE structure **44** and through a registering fastener ring opening **32** provided in the fastener ring **31**. As shown in FIG. 5, in some applications, a seal strip **36** may be provided between the frame ring **23** of the high CTE attachment frame **22** and the fastener rings **31** on the frame ribs **30**.

[0022] When exposed to high temperatures, the relatively high CTE structure thermally expands relative to the rela-

tively low CTE structure **44**. The frame ribs **30** of the thermal coupling **21** facilitate radial and axial expansion of the high CTE structure relative to the low CTE structure **44** without the application of thermally-induced stresses to the low CTE structure **44**. The thermal coupling **21** may be capable of withstanding shear loads directed at right angles with respect to the center axis of the thermal coupling **21** as well as fore and aft loads which are directed parallel to the central axis of the thermal coupling **21**. Therefore, thermal stresses between the high CTE structure and the low CTE structure **44** during thermal cycling is minimized, thus substantially preventing any possible change in the low CTE structure **44** in cases in which the low CTE structure **44** is ceramic.

[0023] Referring next to FIGS. 7 and 8, embodiments of the disclosure may be used in the context of an aircraft manufacturing and service method **78** as shown in FIG. 7 and an aircraft **94** as shown in FIG. 8. During pre-production, exemplary method **78** may include specification and design **80** of the aircraft **94** and material procurement **82**. During production, component and subassembly manufacturing **84** and system integration **86** of the aircraft **94** takes place. Thereafter, the aircraft **94** may go through certification and delivery **88** in order to be placed in service **90**. While in service by a customer, the aircraft **94** is scheduled for routine maintenance and service **90** (which may also include modification, reconfiguration, refurbishment, and so on).

[0024] Each of the processes of method **78** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include without limitation any number of aircraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military entity, service organization, and so on.

[0025] As shown in FIG. 8, the aircraft **94** produced by exemplary method **78** may include an airframe **98** with a plurality of systems **96** and an interior **100**. Examples of high-level systems **96** include one or more of a propulsion system **102**, an electrical system **104**, a hydraulic system **106**, and an environmental system **108**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the automotive industry.

[0026] The apparatus embodied herein may be employed during any one or more of the stages of the production and service method **78**. For example, components or subassemblies corresponding to production process **84** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **94** is in service. Also, one or more apparatus embodiments may be utilized during the production stages **84** and **86**, for example, by substantially expediting assembly of or reducing the cost of an aircraft **94**. Similarly, one or more apparatus embodiments may be utilized while the aircraft **94** is in service, for example and without limitation, to maintenance and service **92**.

[0027] Although this invention has been described with respect to certain exemplary embodiments, it is to be understood that the specific embodiments are for purposes of illustration and not limitation, as other variations will occur to those of ordinary skill in the art.

1. A thermal coupling, comprising:  
a first structure having a first coefficient of thermal expansion;

a second structure having a second coefficient of thermal expansion lower than said first coefficient of thermal expansion;  
a plurality of thermal expansion fingers provided in said first structure;  
a plurality of thermal expansion flanges extending from said plurality of thermal expansion fingers, respectively; and  
a flange extending from said second structure and attached to said plurality of thermal expansion flanges.

**2.** The thermal coupling of claim **1** wherein said plurality of thermal expansion flanges is disposed in generally perpendicular relationship with respect to said plurality of thermal expansion fingers, respectively.

**3.** The thermal coupling of claim **1** further comprising a plurality of thermal expansion slots provided in said first structure between said plurality of thermal expansion fingers.

**4.** The thermal coupling of claim **1** further comprising a plurality of fastener openings extending through said plurality of thermal expansion fingers, respectively, and said flange, and a plurality of flange fasteners extending through said plurality of fastener openings, respectively.

**5.** The thermal coupling of claim **1** wherein said first structure comprises metal.

**6.** The thermal coupling of claim **1** wherein said second structure comprises ceramic.

**7.** The thermal coupling of claim **1** wherein said first structure comprises a generally elongated, cylindrical first structure wall and further comprising a plurality of thermal expansion slots provided in said first structure wall between said plurality of thermal expansion fingers.

**8.** The thermal coupling of claim **1** wherein each of said plurality of thermal expansion flanges has beveled flange edges.

**9.** A thermal coupling, comprising:  
an attachment frame;  
a plurality of frame ribs extending from said attachment frame;  
a plurality of fastener rings provided on said plurality of frame ribs, respectively; and  
a plurality of fastener ring openings provided in said plurality of fastener rings, respectively.

**10.** The thermal coupling of claim **9** wherein said attachment frame comprises an annular frame ring and an annular frame flange extending from said frame ring.

**11.** The thermal coupling of claim **10** further comprising a plurality of spaced-apart fastener openings provided in said frame ring.

**12.** The thermal coupling of claim **10** further comprising a plurality of spaced-apart fastener openings provided in said frame flange.

**13.** The thermal coupling of claim **10** wherein said frame flange is disposed in generally perpendicular relationship with respect to said frame ring.

**14.** The thermal coupling of claim **9** wherein each of said plurality of frame ribs comprises a pair of generally elongated rib members extending from said attachment frame and converging on a corresponding one of said plurality of fastener rings.

**15.** A thermal coupling, comprising:  
an annular attachment frame;  
a plurality of generally elongated frame ribs extending from said attachment frame in angular relationship with respect to each other;  
a plurality of fastener rings provided on said plurality of frame ribs, respectively; and  
a plurality of fastener ring openings provided in said plurality of fastener rings, respectively.

**16.** The thermal coupling of claim **15** wherein said attachment frame comprises an annular frame ring and an annular frame flange extending from said frame ring.

**17.** The thermal coupling of claim **16** further comprising a plurality of spaced-apart fastener openings provided in said frame ring.

**18.** The thermal coupling of claim **16** further comprising a plurality of spaced-apart fastener openings provided in said frame flange.

**19.** The thermal coupling of claim **16** wherein said frame flange is disposed in generally perpendicular relationship with respect to said frame ring.

**20.** The thermal coupling of claim **15** wherein each of said plurality of frame ribs comprises a pair of generally elongated rib members extending from said attachment frame and converging on a corresponding one of said plurality of fastener rings.

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