(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 July 2015 (23.07.2015)

WIPO | PCT

(10) International Publication Number
WO 2015/108562 A1

(51) International Patent Classification:
F16H 63/36 (2006.01) *B60K 23/02* (2006.01)

(21) International Application Number:
PCT/US2014/045239

(22) International Filing Date:
2 July 2014 (02.07.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/927,656 15 January 2014 (15.01.2014) US
61/955,929 20 March 2014 (20.03.2014) US

(71) Applicants: **SZUBA CONSULTING, INC.** [US/US]; 701 South Waverly, Dearborn, Michigan 48124 (US). **VALUE EXTRACTION LLC** [US/US]; 21714 Garrison Street, Dearborn, Michigan 48124 (US).

(72) Inventor: **SZUBA, Joseph**; 701 South Waverly, Dearborn, Michigan 48124 (US).

(74) Agents: **PECK, Randall J.** et al.; Warner Norcross & Judd LLP, 900 Fifth Third Center, 111 Lyon Street NW, Grand Rapids, Michigan 49503-2487 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: METHOD OF FORMING JOINT FOR INTERCONNECTING ADJACENT ELEMENTS AND JOINT FORMED THEREBY

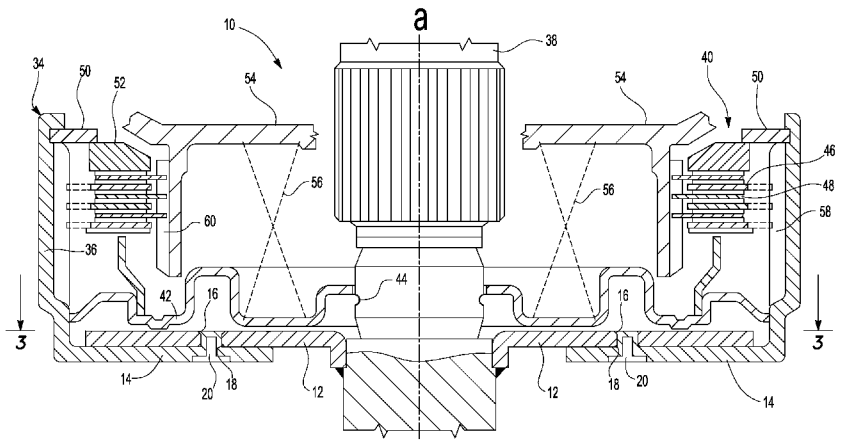

Fig-1

(57) Abstract: A method of forming a joint for interconnecting adjacent elements comprises providing a first element defining at least one aperture extending from a first edge to a second edge through a thickness of the first element. The method further comprises mating a second element to the first element with the second element overlaying the at least one aperture of the first element at the second edge thereof such that the second element extends through the at least one aperture perpendicular to the first element with an excess portion of the second element extending beyond the first edge of the first element. Finally, the method comprises compressing the excess portion of the second element such that the second element is continuous across the at least one aperture and adjacent the first and second edges of the first element, thereby interlocking the first and second elements and forming the joint.

WO 2015/108562 A1

METHOD OF FORMING JOINT FOR INTERCONNECTING ADJACENT ELEMENTS AND JOINT FORMED THEREBY

PRIOR APPLICATIONS

[0001] This Application claims priority to and all the advantages of United States Provisional Patent Application Serial No. 61/955,929, filed on March 20, 2014 and United States Provisional Patent Application Serial No. 61/927,656, filed on January 15, 2014.

FIELD OF THE INVENTION

[0002] The present invention generally relates to a method of forming a joint and, more specifically to a method of forming a joint for interconnecting adjacent elements and to the joint formed by the method.

DESCRIPTION OF THE RELATED ART

[0003] Joints and methods of forming joints are well known in the art and utilized in a variety of industries for adjoining adjacent elements or components in an assembly. Joints are commonly prepared based on the materials of the elements or components to be joined. For example, when the elements or components comprise a metal or alloy, one method of adjoining such elements or components is laser welding.

[0004] However, laser welding requires expensive equipment, additional processing steps, and deleteriously adds to an overall thickness of the assembly and adjacent elements by virtue of a contributing thickness of the joint itself. Further, laser welding may result in burrs and spatter being disadvantageously introduced to the elements or components, which can result in failure of mechanical assemblies, particularly where there are small tolerances and/or moving parts.

[0005] One specific example of a mechanical assembly including such joints is an automotive assembly, such as a transmission clutch housing. It is desirable to minimize weight of components in the transmission clutch housing to improve fuel economy and decrease material cost. However, to achieve a desired strength and longevity, housings are

generally required to have a certain minimum thickness, and additional joint layers associated with laser welding add to these minimum thicknesses while suffering from the additional drawbacks identified above. Thus, there remains an opportunity to provide improved methods of adjoining adjacent elements or components.

SUMMARY OF THE INVENTION

[0006] The present invention provides a method of forming a joint for interconnecting adjacent elements being subject to divergent forces. The method comprises the step of providing a first element defining at least one aperture extending from a first edge to a second edge through a thickness of the first element. The method further comprises mating a second element to the first element with the second element overlaying the at least one aperture of the first element at the second edge thereof such that the second element extends through the at least one aperture perpendicular to the first element with an excess portion of the second element extending beyond the first edge of the first element. Finally, the method comprises compressing the excess portion of the second element such that the second element is continuous across the at least one aperture and adjacent the first and second edges of the first element, thereby interlocking the first and second elements and forming the joint.

[0007] The present invention also provides the joint formed in accordance with the method.

[0008] The inventive method obviates the significant costs associated with conventional methods of joining elements, e.g. laser welding. Further, the inventive method provides joints that are free from spatter and burrs associated with such laser welding. Additionally, the inventive method may be utilized to form joints which do not provide any additional thickness to the adjacent elements that are interconnected via the joint, which is advantageous in many industries where thicknesses are of significant concern. Finally, the

inventive method forms joints having excellent strength and longevity that are not susceptible to failure, unlike many conventional joints.

[0009] The inventive method and resulting joints may be utilized in various diverse industries, such as residential and commercial construction, automotive housings, and in the construction and mating of train components, ship components, plane components, white goods and machines, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in light of accompanying drawings in which:

[0011] FIG. 1 shows a cross-sectional view of a clutch assembly including a joint according to the present invention;

[0012] FIG. 2 shows a fragmented, perspective view of the clutch housing of FIG. 1 prior to forming the joint of the present invention;

[0013] FIG. 3 shows a plan view of the clutch housing prior to forming the joint of the present invention;

[0014] FIG. 4A is a sectional view showing an initial step of one method of forming the joint of the present invention;

[0015] FIG. 4B is a sectional view showing another step of one method of forming the joint of the present invention;

[0016] FIG. 4C is a sectional view showing yet another step of one method of forming the joint of the present invention;

[0017] FIG. 4D is a sectional view showing the joint of the present invention formed in FIGS. **4A-4C**;

[0018] FIG. 5 is a sectional view showing a portion of the joint of the present invention during its formation;

[0019] FIG. 6 is a sectional view showing an aperture for forming the joint of the present invention;

[0020] FIG. 7A is a plan view of one embodiment of the joint of the present invention;

[0021] FIG. 7B is a sectional view of line **7B-7B** of FIG. 7A showing the joint of the present invention;

[0022] FIG. 7C is a sectional view of line **7C-7C** of FIG. 7A showing the joint of the present invention;

[0023] FIG. 8 is a plan view showing another embodiment of the joint of the present invention;

[0024] FIG. 9A is a plan view showing one embodiment of the joint of the present invention;

[0025] FIG. 9B is a sectional view of line **9B-9B** of FIG. 9A showing the joint of the present invention;

[0026] FIG. 10 is a sectional view showing the joint of FIG. 9B but with a strengthening agent;

[0027] FIG. 11 is a sectional view showing an alternative embodiment of the joint of the present invention including a passivating layer;

[0028] FIG. 12 shows a partial sectional view of a clutch assembly including a joint according to the present invention;

[0029] FIG. 13A is a sectional view showing an initial step of an alternative method of forming the joint of the present invention; and

[0030] FIG. 13B is a sectional view showing the alternative embodiment of the joint formed in FIG. 13A.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Referring to FIG. 1, a side sectional view of a clutch assembly including a joint according to the present invention is generally shown at **10,** with the joint interconnecting a first element **12** and a second element **14** within the assembly **10**. It is to be appreciated that the joint is not limited to use in such assemblies **10**. For example, the joint may be utilized in other applications, such as other automotive housings, e.g. differential housings, torque converter housings, catalytic converter housings, and brake housings, as well as in the construction and mating of train components, ship components, plane components, etc., as described below.

[0032] The assembly **10** of FIG. 1 including the joint is first described, following by a description of various methods of forming the joint. In the embodiment of FIG. 1, the assembly **10** includes a housing **34** defined by an annular wall **36**. The annular wall **36** circumscribes a transmission shaft **38** that defines a shaft axis A. In this embodiment, the annular wall **36** of the housing **34** extends axially between an open end **40** and the second element **14**, which serves as and may be referred to herein with respect to this embodiment as a floor. The second element **14** extends radially inwardly toward the transmission shaft **38**. A piston **42** circumscribes the transmission shaft **38** and is positioned adjacent the second element **14** of the housing **34**. The first element **12** in this embodiment seals the second element **14** of the housing **34** and the transmission shaft **38**. Transmission fluid pumps through the transmission shaft **38** through outlets **44** and to the space located between the piston **42** and the floor of the housing **34** to shift the clutch assembly **10** in a known manner. A fibrous plate **48** circumscribes the transmission shaft **38** and is positioned in an abutting relationship between the piston **42** and a plurality of clutch plates **46**. The clutch plates **46** are separated by fibrous plates **48**. Clutch plates **46** and the fibrous plates **48** circumscribe the transmission shaft **38** and are retained in the housing **34** by snap ring **50** as will be explained further herein below. A clutch pressure plate **52** is disposed between the plurality of clutch

plates **46**, the fibrous plates **48**, and the snap ring **50**. A shift member **54** overlies the open end **40** of the housing **34** and provides biasing support to biasing member **56** for biasing the piston **42** toward the floor of the housing **34**. For example, the joint may be utilized in the construction of the clutch assembly of U.S. Pat. No. 8,240,446, which is incorporated by reference herein in its entirety. Moreover, the joint may be utilized in other clutch assemblies, such as those not including the formed retention ring of U.S. Pat. No. 8,240,446.

[0033] The housing **34** defines a plurality of housing splines **58** spaced around a full 360° of the housing **34** as best shown in FIG. 2. The shift member **54** defines a plurality of member splines **40** as seen in FIG. 1 so that the housing splines **38** and the member splines **60** are opposed enabling positioning of the clutch plates **26** engage either the housing splines **38** or the member splines **40** as shown in FIG. 1. Therefore, it should be understood by those of ordinary skill in the art that the clutch plates **26** define a plurality of spaced teeth (not shown) that engage the housing splines **58** in a gear-like manner.

[0034] The present invention provides a method of forming the joint for interconnecting adjacent elements that are subject to divergent forces. The divergent forces may each independently be, for example, linear, angular, etc. The adjacent elements are referred to herein as the first element **12** and the second element **14**, and the first and second elements **12**, **14** may be various elements or components of various assemblies, as introduced above. Referring to the FIGS, the first element **12** defines at least one aperture **22** extending from a first edge **16** to a second edge **18** through a thickness of the first element **12**. Typically, the first element **12** defines a plurality of apertures **22**, as the apertures **22** are utilized to form the joint, and use of additional joints increases the strength and longevity of assemblies including such joints. For clarity, "the aperture," as used herein, may refer to but one aperture **22** defined by the first element **12** or the plurality of apertures **22**. The method further comprises mating the second element **14** to the first element **12** with the second element **14** overlaying the at least one aperture **22** of the first element **12** at the second edge

18 thereof such that the second element **14** extends through the at least one aperture **22** perpendicular to the first element **12** with an excess portion **19** of the second element **14** extending beyond the first edge **16** of the first element **12**. This mating step may be carried out in a variety of techniques, as set forth below. Finally, the method comprises compressing the excess portion **19** of the second element **14** such that the second element **14** is continuous across the at least one aperture **22** and adjacent the first and second edges **16**, **18** of the first element **12**, thereby interlocking the first and second elements **12**, **14** and forming the joint.

[0035] In various embodiments as shown throughout the FIGS., the first edge **16** of the first element **12** is further defined as a chamfered edge. Chamfering the first edge **16** of the first element **12** may be carried out via known methods. The chamfered edge **16** of the first element **12** typically presents an acute angle **Θ** relative to an axis b of the aperture **22** of the first element **12**, as shown in FIG. 6. The acute angle **Θ** is from greater than 0 to less than 90, alternatively from greater than 10 to less than 80, degrees. The acute angle **Θ** may be selected based on a desired surface area contact between the first and second elements **12**, **14**, as this surface area contact generally impacts the strength of the joint. In particular, the acute angle **Θ** and the surface area contact between the first and second elements **12**, **14** is directly proportional. The surface area contact may be modified based on the actuate angle **Θ** and a shape of the aperture **22**, which may be any conventional shape (e.g. circular, rectangular, etc.) or may be irregular, as shown in FIGS. 7A, 8, and 9A. Chamfering of the first edge **16** may be carried out at the same time the aperture **22** is formed, e.g. via the same machining equipment, or before or after formation of the aperture **22**.

[0036] In these or other embodiments, and as shown throughout the FIGS., the second edge **18** of the first element **12** is rounded. As known in the art, rounded edges are distinguished from chamfered edges, with rounded edges presenting a radius and chamfered edges presenting an angle. When the second edge **18** of the first element **12** is rounded, preparation of the joint, particularly with respect to mating the first and second elements **12**,

14 and disposing a portion of the second element **14** in the aperture **22** of the first element **12**, can be more easily accomplished.

[0037] FIG. 2 shows an exploded view associated with the formation of the joint via a first embodiment to form the clutch assembly **10** of FIG. 1. In the embodiment of FIG. 2, the second element **14** includes a plurality of preformed protuberances **24** corresponding to the shape and location of the plurality of apertures **22** of the first element **12**. The preformed protuberances **24** are referred to as being "preformed" because they are formed prior to mating the first and second elements **12**, **14**, in contrast to the second embodiment disclosed below. The preformed protuberances **24** may be formed via a variety of techniques, e.g. mechanical punching. The preformed protuberances **24** may have a variety of shapes, which may be regular or irregular, and which generally correspond to the shape of the aperture **22**. Further, the preformed protuberances **24** may optionally be dimpled or have other features at distal ends thereof for the subsequent compression step. In the embodiment of FIG. 2, the preformed protuberances **24** generally extend for a distance greater than the thickness of the first element **12**. As such, upon mating the first and second elements **12**, **14**, the preformed protuberances **24** form the excess portion (not shown) of the second element **14**. To form the joint in the embodiment of FIG. 2, after disposing the preformed protuberances **24** of the second element **14** in the apertures **22** defined by the first element **12**, the excess portions of the preformed protuberances **24**, i.e., the portions of the preformed protuberances that extend beyond the second edge **18** of the first element **12**, are compressed. The excess portions may be compressed via known mechanical pressing techniques. Typically, such compression deforms the preformed protuberances **24** to flatten the preformed protuberances **24** along the chamfered edge **16** of the first element **12**, while also increasing a strength of the material of the second element that is compressed and deformed. In this embodiment, the joint is flush and presents a substantially continuous surface across a side of the first element **12** opposite the second element **14**. Said differently, the second element **14** may be substantially

continuous across the aperture **22** defined by the first element **12**. If desired, however, the second element **14** may be raised slightly even after the step of compressing the excess portion of the second element **14**, e.g. in applications where thickness tolerances are not of concern.

[0038] FIGS. 13A and 13B show a sectional view of the formation of the joint in accordance with the first embodiment of FIG. 2, but with the preformed protuberance **24** characteristic of a cast housing. In particular, FIG. 13A illustrates the second element **14** including the preformed protuberance **22** and the first element **12** defining the aperture **22**, and FIG. 13B illustrates the formed joint after compressing the excess portion (not shown) of the second element **14** to flatten the excess portion about the chamfered edge **16** of the first element **12**, thus interlocking the first and second elements **12**, **14** and giving the joint.

[0039] FIG. 3 shows a top view of the first element **12** defining the apertures **22** associated with FIG. 2. As shown in FIG. 3 and introduced above, the apertures **22** may be, for example, circular, as illustrated at **22a**, or irregular, as illustrated at **22b**.

[0040] A second embodiment of the method to form the joint is shown in FIGS. 4A-4D. In this second embodiment, the excess portion **19** is not from a preformed protuberance, as in the first embodiment, but instead is formed by deforming the second element **14**. As shown in FIG. 4A, in this second embodiment, mating the first and second elements **12**, **14** merely comprises aligning the first and second elements **12**, **14** in a parallel and adjacent relationship. A forming tool **26**, which may alternatively be referred to as a die button, is aligned with the aperture **22** of the first element **12**. As shown in FIG. 4B, the forming tool **26** is pressed into the second element **14** in a direction toward the first edge **16** of the first element **12** for a distance less than the thickness of the first element **12** to partially dispose the forming tool **26** and the second element **14** in the aperture **22** of the first element **12**. In this embodiment, the second element **14** generally comprises a malleable and/or ductile material that is capable of such deformation, e.g. a metal or alloy. Similarly, the forming tool

26 typically comprises a sufficiently rigid material, e.g. a metal or alloy that is the same as or different from the second element **14**. Alternatively, the forming tool **26** may comprise a urethane or other rigid polymeric material. Although the forming tool **26** is disposed in the aperture **22** of the first element **12** for a distance less than the thickness of the first element **12**, the contributing thickness of the second element **14** results in the formation of the excess portion **19** of the second element **14** extending beyond the second edge **18** of the first element **12**. When the first element **12** defines a plurality of apertures **22**, deforming the second element **14** in the plurality of apertures **22** of the first element **12** may be carried out simultaneously via a single step, e.g. with a plate including a plurality of forming tools **26** extending therefrom, or in series.

[0041] FIG. 4B illustrates an optional step associated with this second embodiment of forming the joint. Specifically, FIG. 4B shows a press **28** with a rounded attachment imparting a dimple to the excess portion **19** of the second element **14**. This pressing step is typically carried out with the forming tool **26** and opposite press being flush with the first element **12** to prevent the second element **14** and forming tool **26** from being forced from the aperture **22**. Typically, use of this pressing step and the resulting dimple in the excess portion **19** makes compression of the excess portion **19**, particularly with regards to overlaying the excess portion **19** about the chamfered edge **18** of the first element **12**, much easier, although this step is not required. The rounded press **28** may comprise the same material or a different material as the forming tool **26**, although the rounded attachment of the press **28** similarly is capable of deforming the excess portion **19** of the second element **14**. FIG. 5 shows a sectional view of the second element **14** with the forming tool **26** disposed therein following this optional pressing step with the rounded attachment of the press **28**.

[0042] FIG. 4C shows the press **28** without the rounded attachment immediately prior to compressing the excess portion **19** of the second element **14**. As with the optional step described immediately above, this pressing step is typically carried out with the forming tool

26 and opposite press being flush with the first element **12** to prevent the second element **14** and forming tool **26** from being forced from the aperture **22** while compressing the excess portion **19** of the second element **14**. When the first element **12** defines a plurality of apertures, the press **28** may be utilized to simultaneously compress the excess portions **19** simultaneously.

[0043] FIG. 4D shows the joint upon compressing the excess portion **19** of the second element **14** such that the second element **14** is continuous across the aperture **22** and adjacent the first and second edges **16**, **18** of the first element **12**, thereby interlocking the first and second elements **12**, **14**. In FIG. 4D, the forming tool **26** is still disposed in the joint. If desired, the forming tool **26** may be left to remain in the joint. Alternatively, the forming tool **26** may be removed from the joint, which results in the joint defining a recess **20** associated with a shape and position of the forming tool **26**, as shown in FIG. 1. For example, the forming tool **26** may be integral with the plate such that separating the plate from the second element **14** removes the forming tool **26** from the joint and second element **14**. The recess **20** and resulting joint may alternatively be referred to as a tenon.

[0044] FIGS. 7A-9B show alternative embodiments of the joint when the aperture **22** is irregularly shaped. For example, in FIG. 7A, the aperture **22** is an elongated ellipse. FIGS. 7B and 7C show sectional views across lines 7B-7B and 7C-7C in FIG. 7A to show the different dimensions of the joint and associated recess **20** from removal of the forming tool **26**. FIG. 8 shows yet another joint when the aperture **22** and resulting joint is irregularly shaped. The aperture **22** and resulting joint of FIG. 8 is triangular in nature for maximizing surface area contact between the first and second elements **12**, **14** while decreasing volume of the aperture **22**, which provides joints having excellent strength and longevity. The aperture **22** and resulting joint of FIG. 9 is hexagonal in nature with rounded corners.

[0045] FIG. 10 shows a sectional view of an alternative embodiment of the joint of FIG. 9B. In particular, in FIG. 9A, the forming tool **26** is removed from the joint to define

the recess **20**. However, in FIG. 10, a strengthening agent **32** is disposed in the recess **20** of the joint to increase a strength thereof. The strengthening agent may be, for example, a cured composition, such as a urethane, an epoxy, etc. One of skill in the art readily understands that numerous different types of curable compositions may be cured to give cured products having excellent rigidity, and any of these curable compositions may be utilized to form the strengthening agent **32**. In embodiments including the strengthening agent **32**, the method typically further comprises disposing a curable composition in the recess **20** of the joint and curing the curable composition to give the strengthening agent **32**. The curable composition may be cured via a variety of techniques depending on the curable composition selected, e.g. heat, atmospheric moisture, irradiation, etc. Further, the strengthening agent **32** may be selected and utilized for minimizing noise, vibration, and harshness associated with certain mechanical assemblies including the joint.

[0046] The material of the first and second elements **12**, **14** may be independently selected and may vary based upon an application or end use of the joint. In various embodiments, the first element **12** comprises steel or a similar metal or alloy, and the second element **14** comprises aluminum. As understood in the art, contact between different types of metals or alloys, as in certain embodiments of the joint, results in galvanic corrosion, which is undesirable. To prevent such galvanic corrosion, the joint may include a passivating layer **62** between the first and second elements **12**, **14**, as shown in FIG. 11. The passivating layer **62** is disposed between the first and second elements **12**, **14**, to prevent direct contact therebetween and to minimize or prevent corrosion thereof. The passivating layer **62** may comprise any known material to prevent corrosion of metals. For example, the passivating layer **62** may be a protective coating formed from a coating composition. Alternatively, the passivating layer **62** may comprise an electroplated surface of the first and/or second elements **12**, **14**. The passivating layer **62** may be applied to one or both of the first and second elements **12**, **14** prior to forming the joint.

[0047] FIG. 12 shows an alternative embodiment of the clutch assembly of FIG. 1 where the first element **12** is a unitary piece with an exterior portion of the transmission shaft **38**. This alternative embodiment illustrates that the inventive method can be utilized in various housing assemblies.

[0048] As noted above and best shown in FIG. 1, the inventive method is particularly suitable for automotive housing assemblies. In fact, use of the inventive method provides increased strength and longevity as compared to conventional automotive housing assemblies assembled via laser welding. As such, use of the inventive method in assembling housings allows for decreased housing thicknesses, thus providing material cost savings and decreasing a weight of the housing assembly and improving a gas efficiency of an automobile including the same. In fact, it is believed that thicknesses of such housings may be reduced to 2.5, alternatively 2.0, alternatively 1.75, alternatively 1.5, millimeters, which is significantly less than the traditional 3.5 millimeter thicknesses of such housings. Further, the inventive method may be utilized in applications beyond transportation, such as consumer appliances, e.g. washing machines, dryers, and other white goods or major appliances, which also are commonly assembled via welding techniques.

[0049] However, as introduced above, the inventive method is not so limited. For example, the inventive method may be utilized to assemble airplanes, e.g. to attach metallic skin to an aircraft body in lieu of rivets. The inventive method may eliminate protrusions associated with rivets, which impact air resistance and fuel economy of airplanes. The inventive method may also be utilized in ships, trains, and other non-transportation applications where adjacent elements must be adjoined.

[0050] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular

situation while material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention but that the invention will include all embodiments falling within the scope of the appended claims.

What is claimed is:

1. A method of forming a joint for interconnecting adjacent elements being subject to divergent forces, said method comprising the steps of:

providing a first element defining at least one aperture extending from a first edge to a second edge through a thickness of the first element;

mating a second element to the first element with the second element overlaying the at least one aperture of the first element at the second edge thereof such that the second element extends through the at least one aperture perpendicular to the first element with an excess portion of the second element extending beyond the first edge of the first element; and

compressing the excess portion of the second element such that the second element is continuous across the at least one aperture and adjacent the first and second edges of the first element, thereby interlocking the first and second elements and forming the joint.

2. The method set forth in claim 1 further comprising the step of deforming the second element after mating the second element to the first element to form the excess portion.

3. The method set forth in claim 1 wherein providing the first element further comprises forming the at least one aperture into the first element.

4. The method set forth in claim 1 wherein the first edge of the first element is further defined as a chamfered edge.

5. The method as set forth in claim 4 wherein the chamfered edge presents an acute angle relative to an axis of the at least one aperture of the first element.

6. The method set forth in claim 4 wherein compressing the excess portion of the second element comprises compressing the excess portion of the second element over and adjacent the chamfered edge of the aperture.

7. The method set forth in claim 6 wherein the joint is flush with the chamfered edge of the first element.

8. The method set forth in claim 2 wherein deforming the second element comprises pressing a forming tool into the second element in a direction toward the first edge of the first element for a distance less than the thickness of the first element to partially dispose the forming tool and the second element in the at least one aperture.

9. The method set forth in claim 8 wherein compressing the excess portion is carried out with the forming tool partially disposed in the at least one aperture and wherein removing the forming tool after compressing the excess portion defines a recess in the joint.

10. The method set forth in claim 9 further comprising disposing a strengthening agent in the recess of the joint.

11. The method set forth in claim 1 wherein the at least one aperture is further defined as an irregularly shaped aperture.

12. The method set forth in claim 1 further comprising disposing a passivating layer between the second element and the first element.

13. The method set forth in claim 1 wherein the excess portion of the second portion is a protuberance formed prior to mating the second element to the first element.

14. A joint interconnecting adjacent elements formed in accordance with the method of claim 1.

15. A method of joining abutting elements being subject to divergent forces, comprising the steps of:

providing a first element and a second element;

forming a plurality of apertures into said first element, with said apertures defining a first aperture diameter and a second aperture diameter being greater than said first aperture diameter;

mating said second element to said first element with said second element overlaying said plurality of apertures disposed in said first element; and

forming protuberances into said second element extending into said apertures defined by said first element and counter-forming said protuberances from an opposite side of said first element from said second element thereby causing said protuberances to define a first protuberance diameter being substantially the same as said first aperture diameter and a second protuberance diameter being substantially the same as the second aperture diameter thereby interlocking said first element to said second element.

16. The method set forth in claim 15, wherein said step for forming protuberances into said second element is further defined by forming said protuberances into said second element prior to mating said second element to said first element.

17. The method set forth in claim 15, wherein said step for forming protuberances into said second element is further defined by forming said protuberances into said second element after mating said second element to said first element.

18. The method set forth in claim 15, wherein said step of forming said apertures into said first element is further defined by forming irregularly shaped aperture into said first element.

19. The method set forth in claim 18, wherein said step of forming said protuberances into said second element is further defined by forming irregularly shaped protuberances into said second element complimentary to said irregularly shaped apertures.

20. The method set forth in claim 15, wherein said first element and said second element are functional elements transferring forces therebetween.

21. The method set forth in claim 15, further including the step of providing an insulating member between said first element and said second element when said first element and said second element comprise incompatible materials.

22. The method set forth in claims 15, further including the step of filling said protuberance with a strengthening agent.

23. The method set forth in claim 15, wherein said step of forming a plurality of apertures into said first element is further defined by forming a plurality of apertures defining an inner surface, a portion of which defines and angle of between 25^{o} and 35^{o} with an axis defined by said aperture.

24. The method set forth in claim 15, wherein said step of providing said second element is further defined by said second element comprising cast aluminum or formed sheet metal.

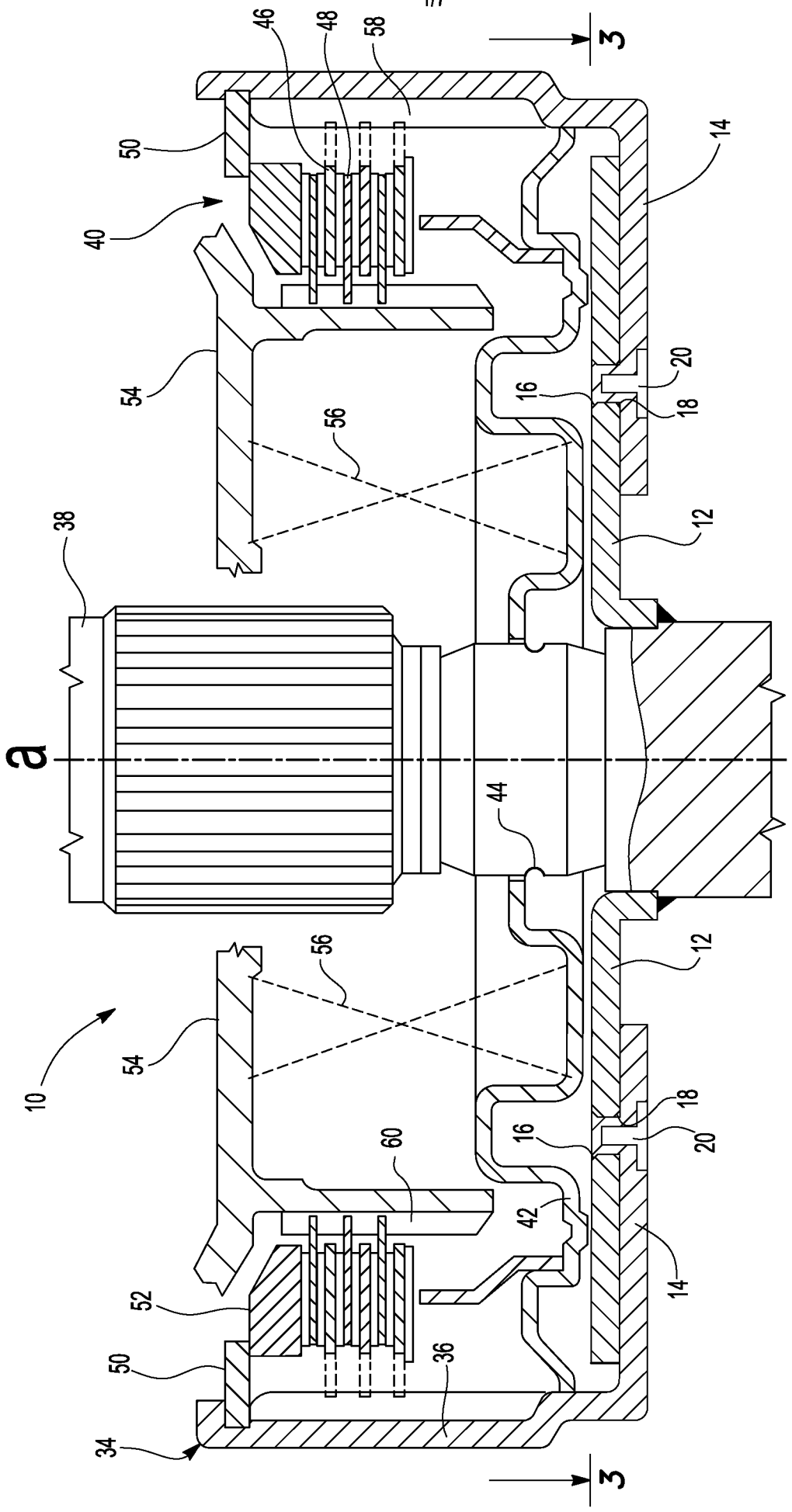
46
48
58
3
50
14
40
20
16
18
54
56
38
12
a
44
56
12
54
10
18
16
20
60
42
14
52
50
36
34
3

Fig-1

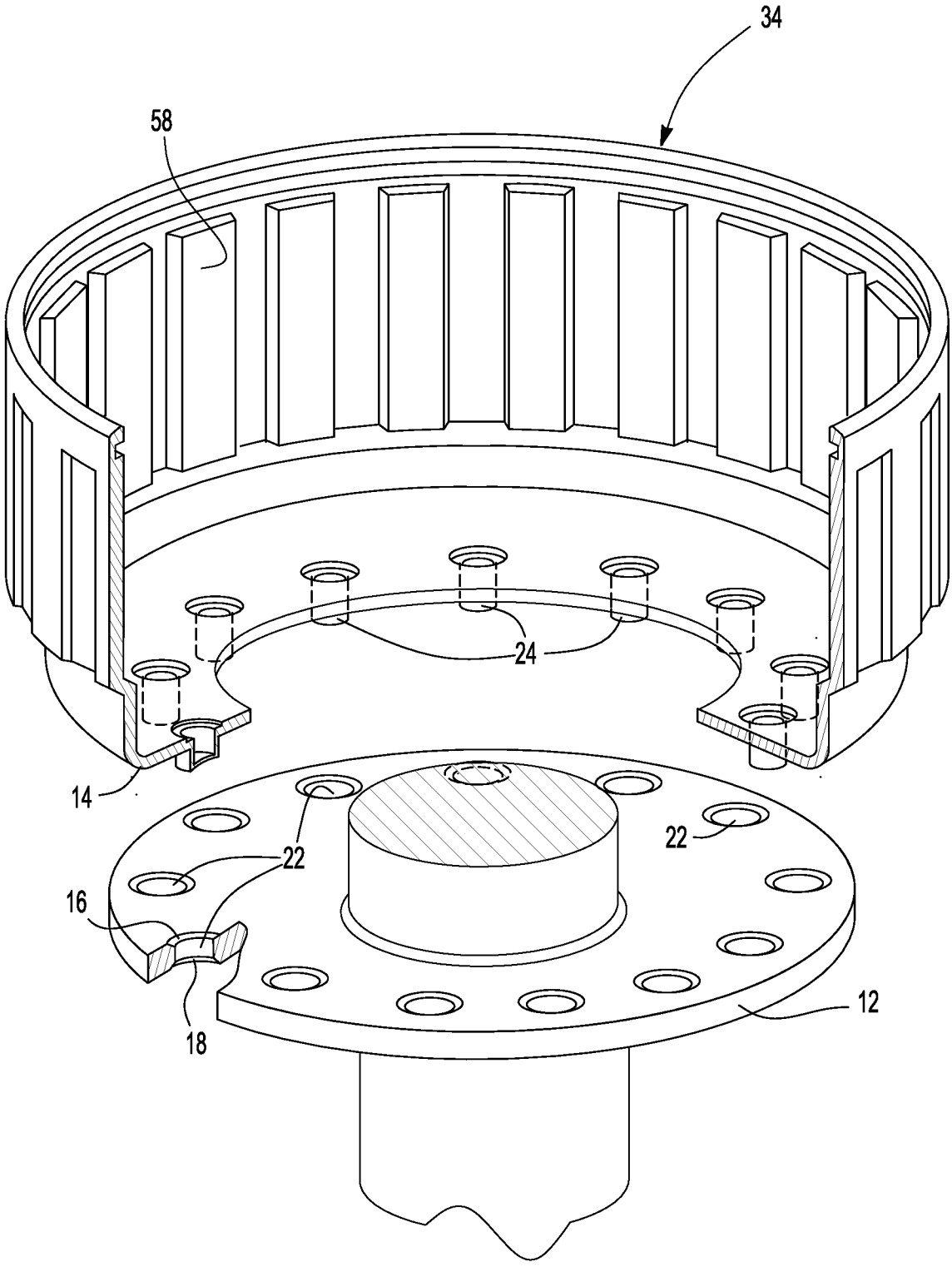

Fig-2

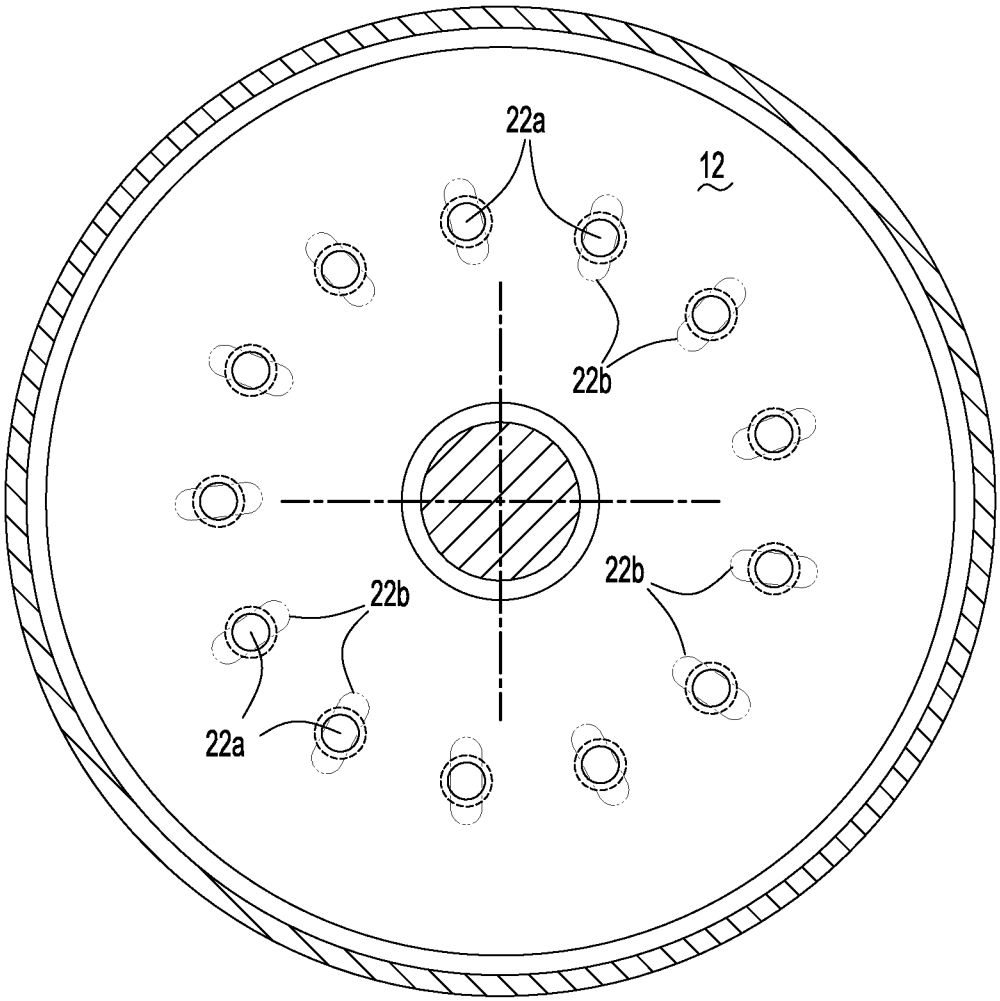

Fig-3

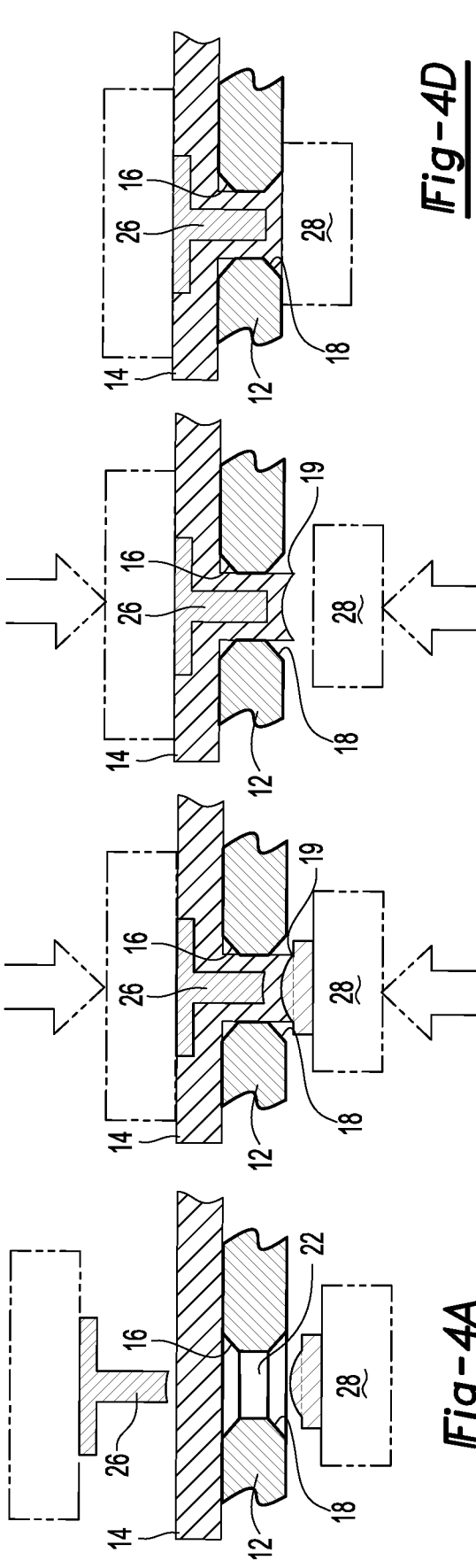

Fig-4A

Fig-4B

Fig-4C

Fig-4D

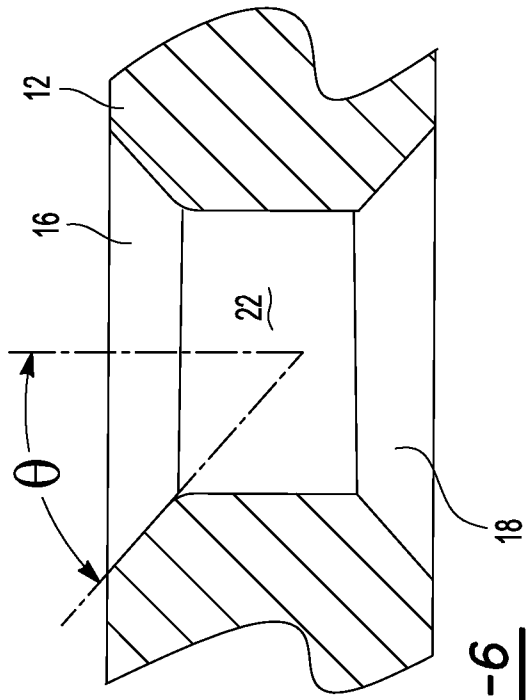

Fig-6

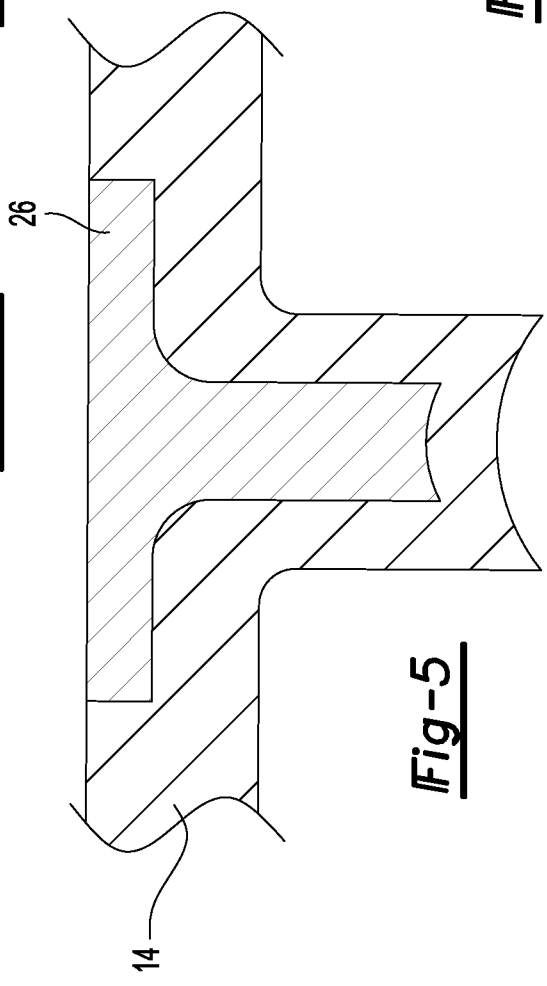

Fig-5

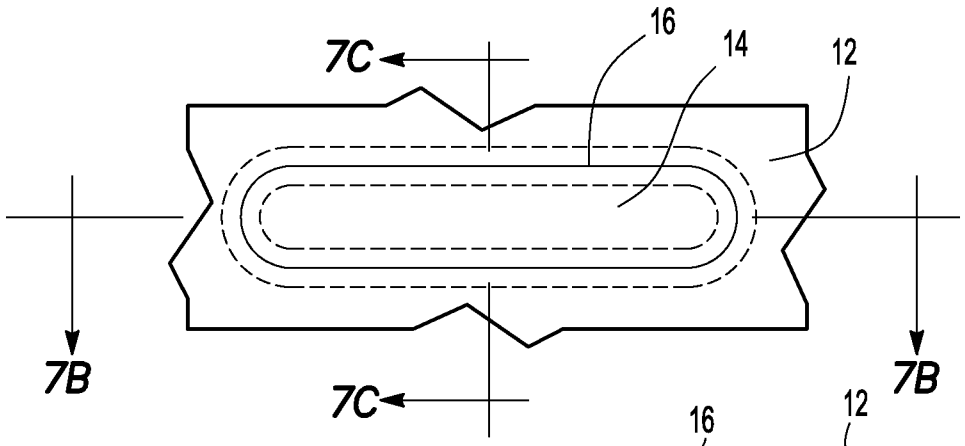

Fig-7A

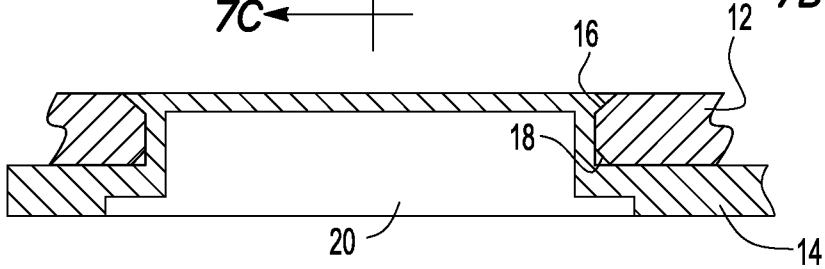

Fig-7B

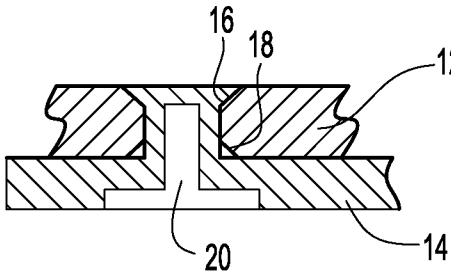

Fig-7C

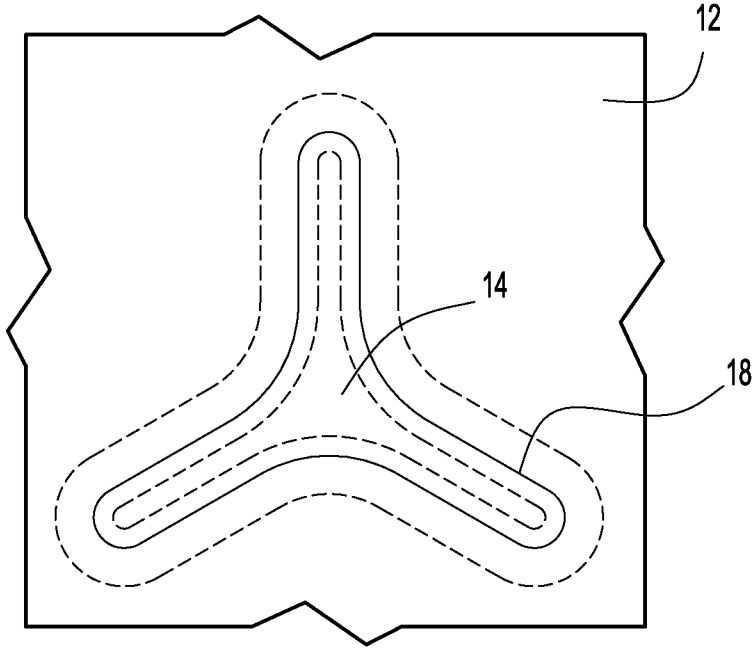

Fig-8

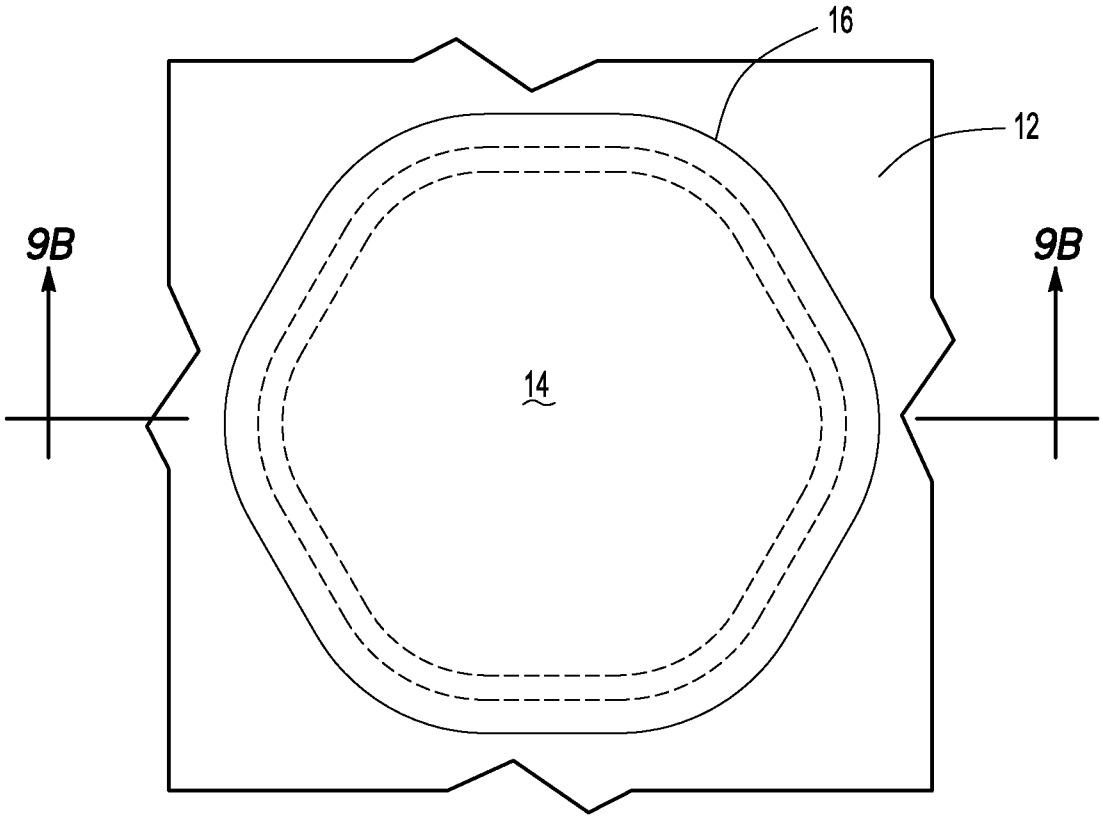

Fig-9A

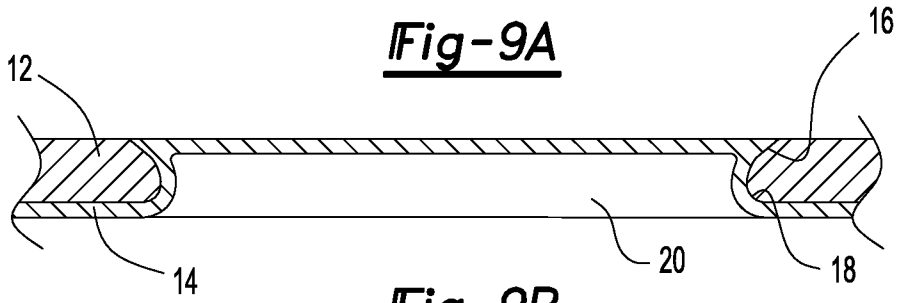

Fig-9B

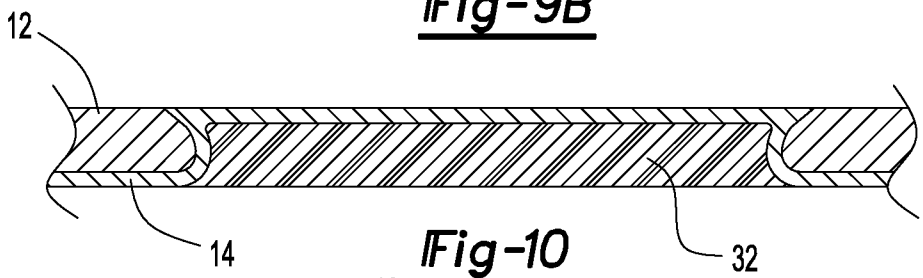

Fig-10

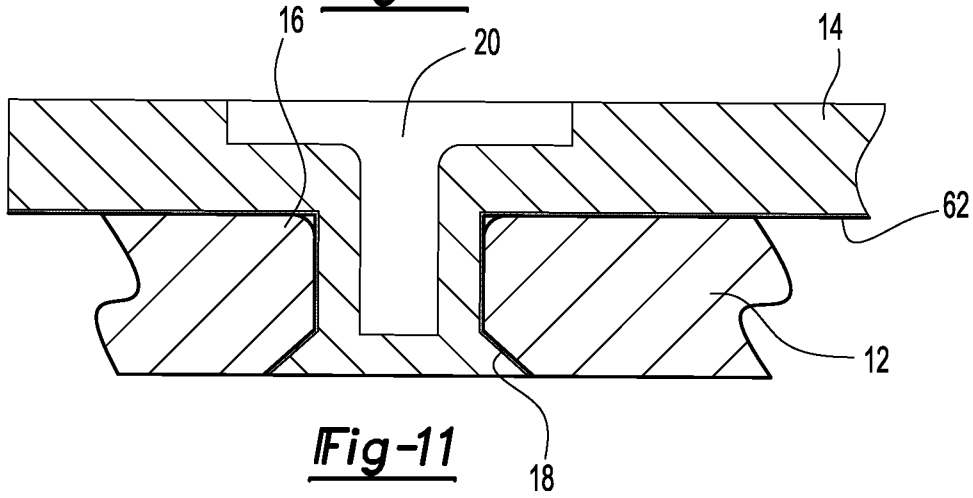

Fig-11

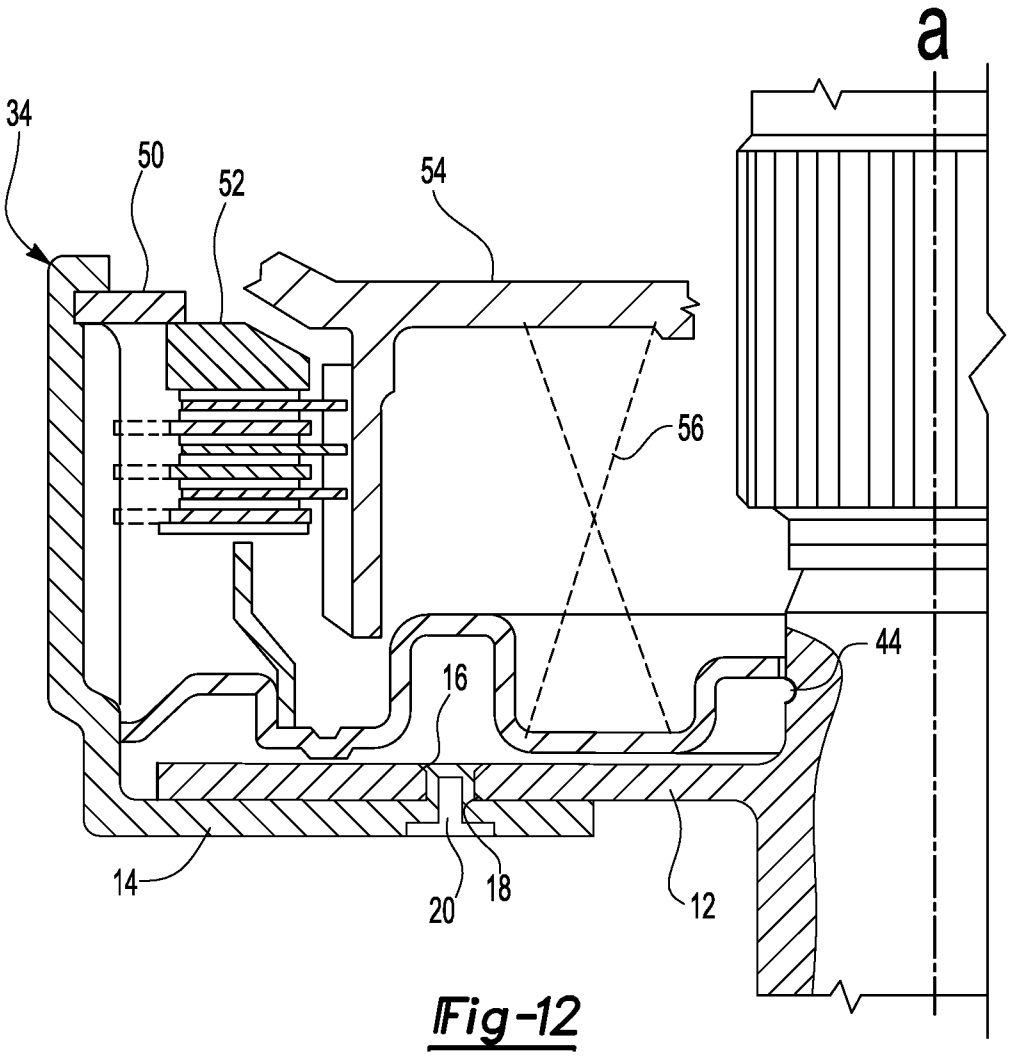

Fig-12

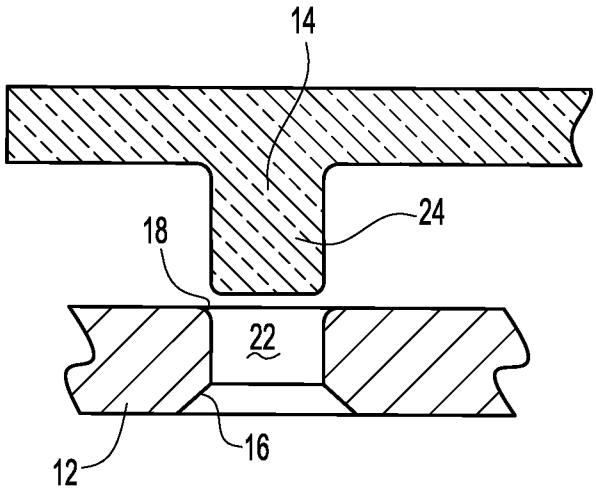

Fig-13A

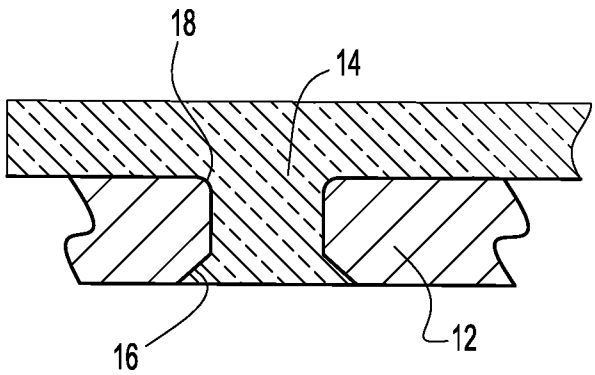

Fig-13B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/045239

A. CLASSIFICATION OF SUBJECT MATTER

F16H 63/36(2006.01)i, B60K 23/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F16H 63/36; B60K 17/34; F16D 3/14; B60K 23/08; F16H 3/44; F16H 37/04; F16H 1/32; B60L 15/20; B60K 23/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: transmission clutch, joint, interconnect, aperture, protuberance, compress and deform

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2010-128832 A2 (UNICK CORPORATION et al.) 11 November 2010 See abstract, paragraphs [40], [41], claim 1 and figures 5, 6, 8-10.	1-7,11-14
A		8-10,15-24
A	US 2010-0022344 A1 (HUANG, SHIH JYI) 28 January 2010 See abstract, paragraphs [0033], [0035], claim 12 and figures 3, 6.	1-24
A	US 2013-0053208 A1 (CHEN, TING-KUANG) 28 February 2013 See abstract, paragraphs [0020], [0029], claim 1 and figure 1.	1-24
A	US 2012-0244980 A1 (SU et al.) 27 September 2012 See abstract, paragraph [0022] and figures 1, 2.	1-24
A	US 5415261 A (FRIEDMANN, OSWALD) 16 May 1995 See abstract, column 5, lines 40-58 and figures 1, 5.	1-24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 October 2014 (30.10.2014)	**30 October 2014 (30.10.2014)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
CHOI, Sang Won
Telephone No. +82-42-481-8291

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/045239

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010-128832 A2	11/11/2010	KR 10-1091576 B1	13/12/2011
		KR 10-2010-0121353 A	17/11/2010
		WO 2010-128832 A3	14/04/2011
US 2010-0022344 A1	28/01/2010	US 7648125 B1	19/01/2010
US 2013-0053208 A1	28/02/2013	US 8517887 B2	27/08/2013
US 2012-0244980 A1	27/09/2012	US 8540041 B2	24/09/2013
US 5415261 A	16/05/1995	GB 2244541 A	04/12/1991
		GB 2244542 A	04/12/1991
		GB 2244543 A	04/12/1991
		GB 2244788 A	11/12/1991
		GB 2278652 A	07/12/1994
		GB 2279724 A	11/01/1995
		GB 2280726 A	08/02/1995
		GB 2280727 A	08/02/1995
		GB 2281767 A	15/03/1995
		JP 03455550 B2	14/10/2003
		JP 03457683 B2	20/10/2003
		JP 03522734 B2	26/04/2004
		JP 03616646 B2	02/02/2005
		JP 03660924 B2	15/06/2005
		JP 04-231753 A	20/08/1992
		JP 04-231754 A	20/08/1992
		JP 04-231755 A	20/08/1992
		JP 04-231757 A	20/08/1992
		JP 04-231758 A	20/08/1992
		JP 2003-035338 A	07/02/2003
		JP 2003-161335 A	06/06/2003
		KR 10-0219914 B1	01/09/1999
		KR 10-0239248 B1	15/01/2000
		KR 10-0241398 B1	02/03/2000
		KR 10-0248160 B1	01/04/2000
		US 5150777 A	29/09/1992
		US 5156249 A	20/10/1992
		US 5160007 A	03/11/1992
		US 5261516 A	16/11/1993
		US 5293977 A	15/03/1994
		US 5293978 A	15/03/1994
		US 5301780 A	12/04/1994
		US 5415261 A	16/05/1995