



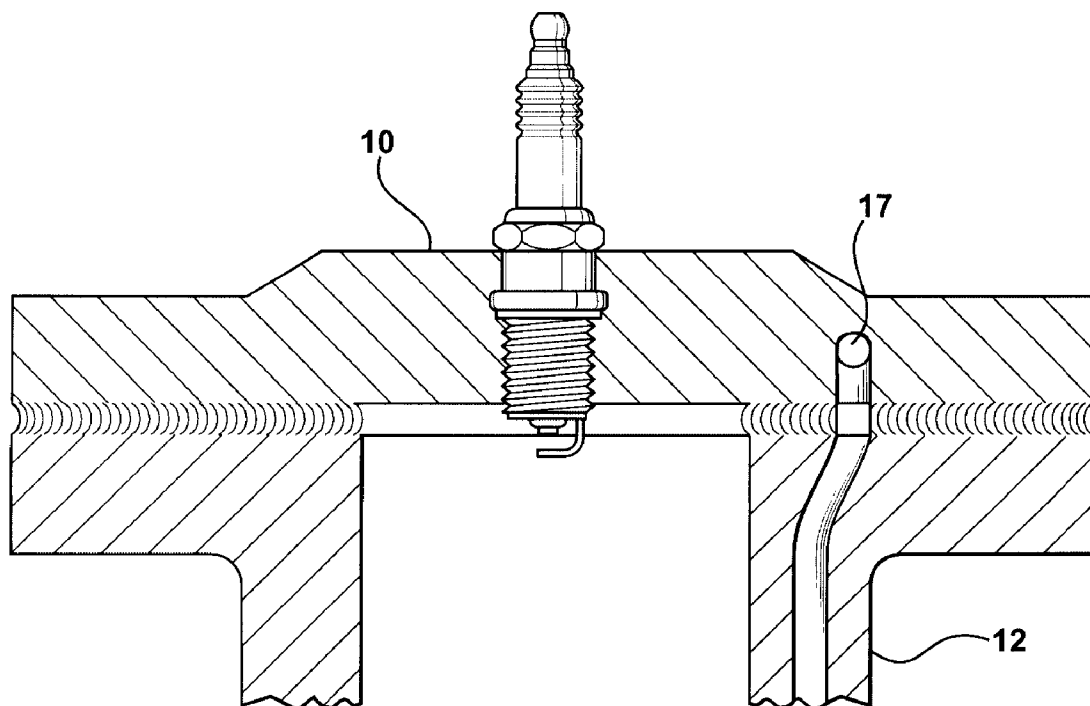
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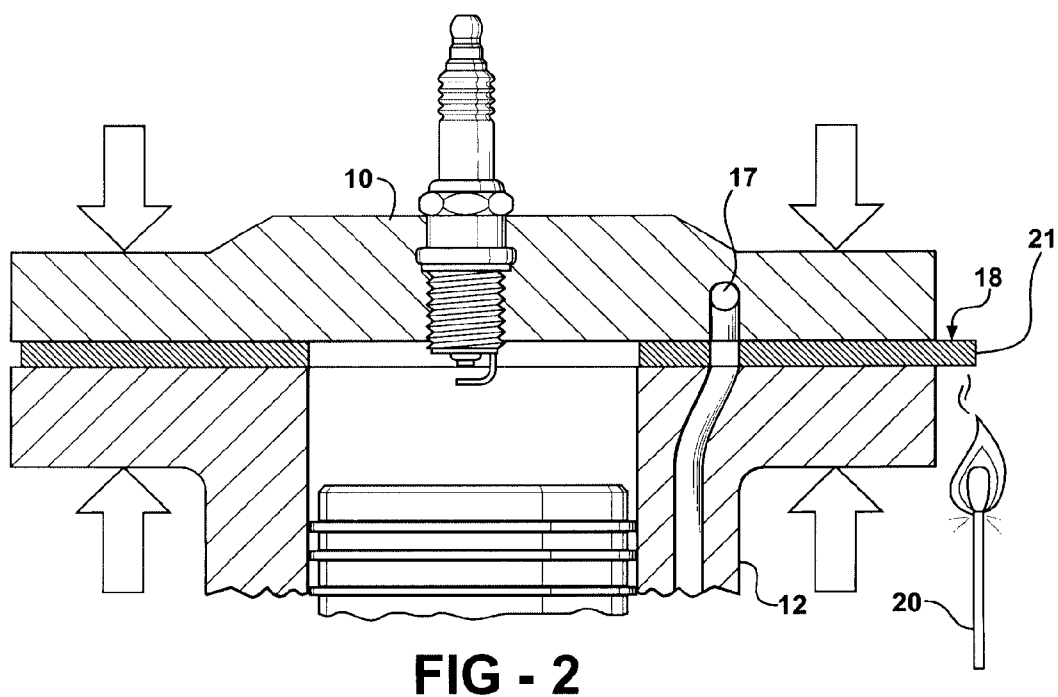
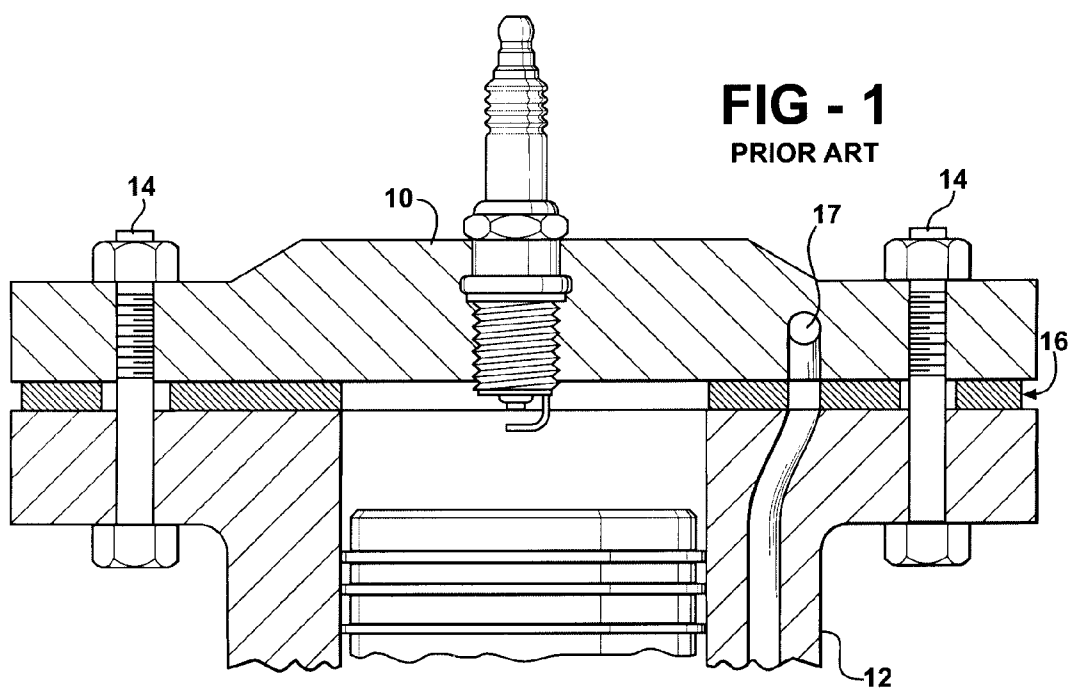
(19) **United States**(12) **Patent Application Publication****Kinney et al.**(10) **Pub. No.: US 2006/0219331 A1**(43) **Pub. Date: Oct. 5, 2006**(54) **EXOTHERMIC WIRE FOR BONDING
SUBSTRATES****Publication Classification**(51) **Int. Cl.**
C22F 1/00 (2006.01)(52) **U.S. Cl.** **148/527**(75) Inventors: **Philip Kinney**, Royal Oak, MI (US);
Myron Schmenk, Lambertville, MI
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MI (US)(57) **ABSTRACT**

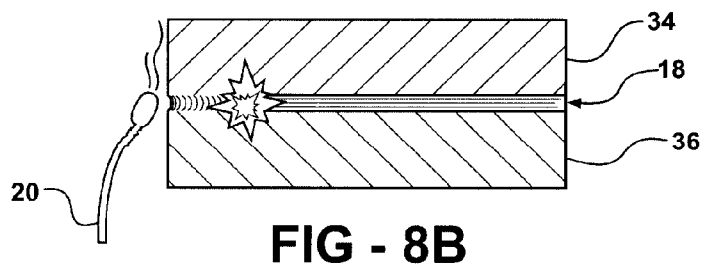
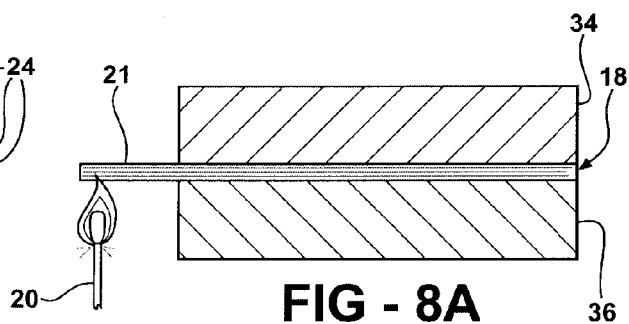
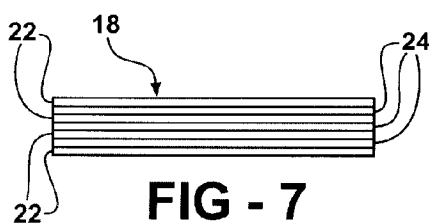
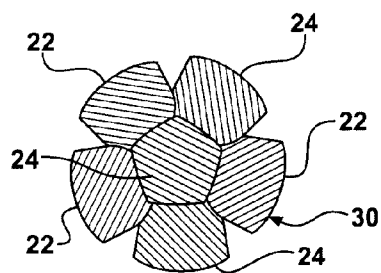
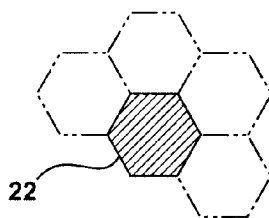
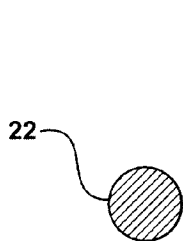
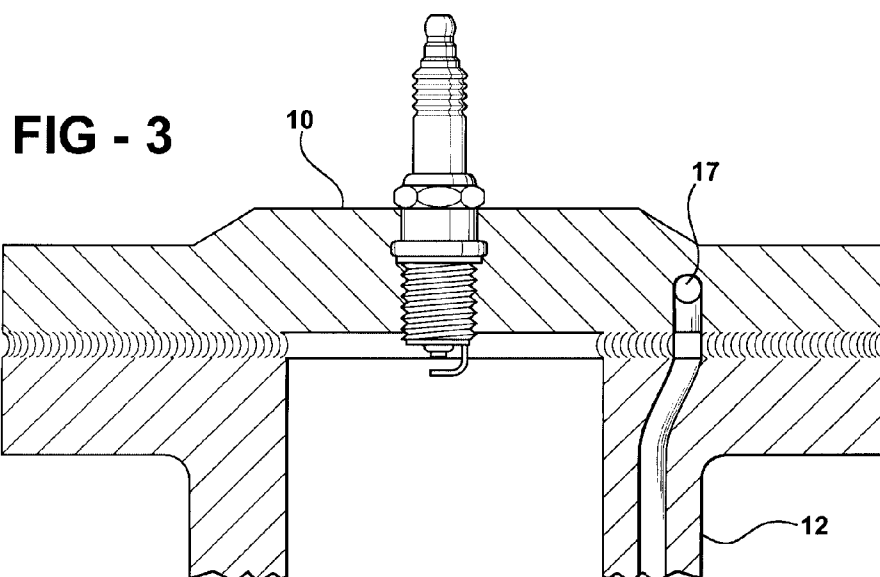
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BLOOMFIELD HILLS, MI 48304-2970 (US)(73) Assignee: **Federal Mogul World-Wide, Inc.**,
Southfield, MI (US)(21) Appl. No.: **11/278,449**(22) Filed: **Apr. 3, 2006****Related U.S. Application Data**(60) Provisional application No. 60/667,999, filed on Apr.
4, 2005.

An exothermic cord, foil, or ribbon is produced by first cold drawing individual round wires of the constituent materials under a cover gas. The cold drawing operation yields a clean surface that is free of oxidation and other contaminants. Next, the constituent wires are brought together and twisted, cold drawn, swaged, and/or friction welded to create a unitary cord exhibiting intimate contact between the constituent materials. The unitary cord may then be used directly or further shaped to a desired form and/or thickness. By controlling the size ratio between the cross-sections of the constituents, a degree of control can be exercised over the exothermic reaction characteristics. The unitary cord, once formed, can be coated with braze and/or flux materials to aid in a subsequent joining operation. Multiple cords can be woven together to form a cloth structure. The exothermic assembly can be applied in the field of gaskets to permanently affix opposing surfaces together, such as affixing a cylinder head in an operative position over a cylinder block.







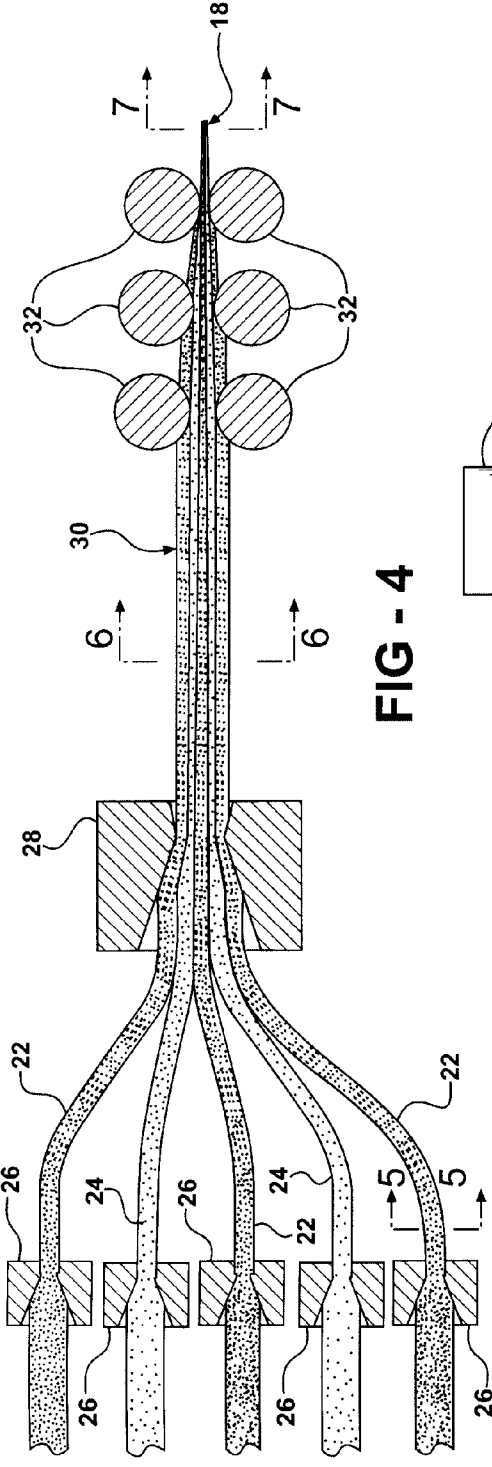


FIG - 4

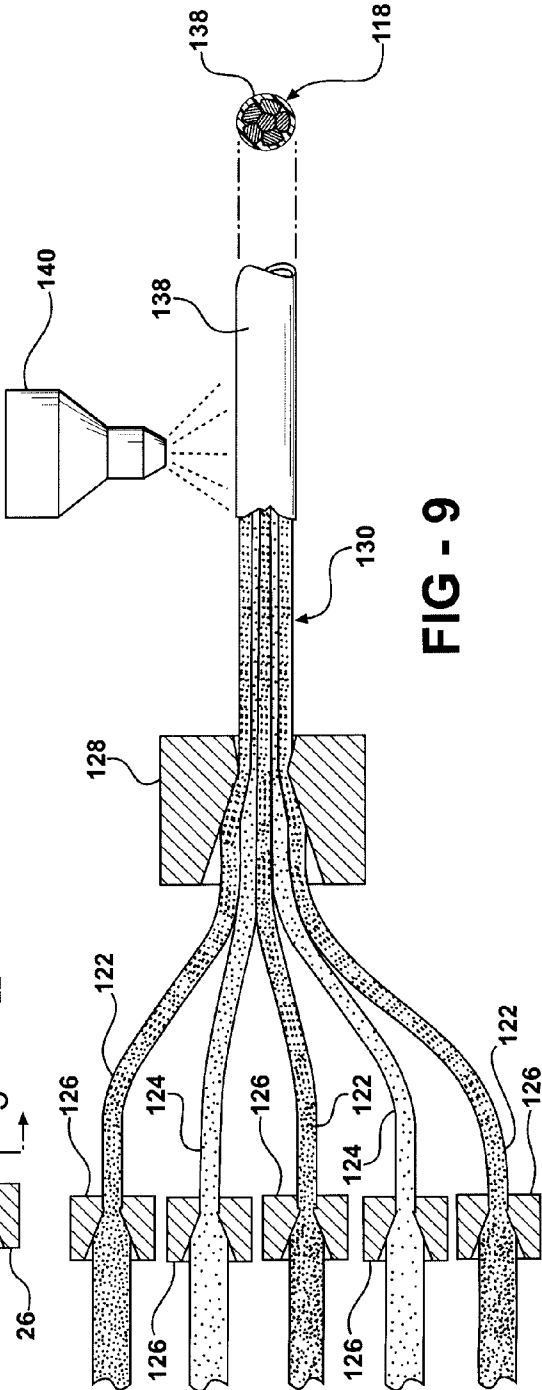
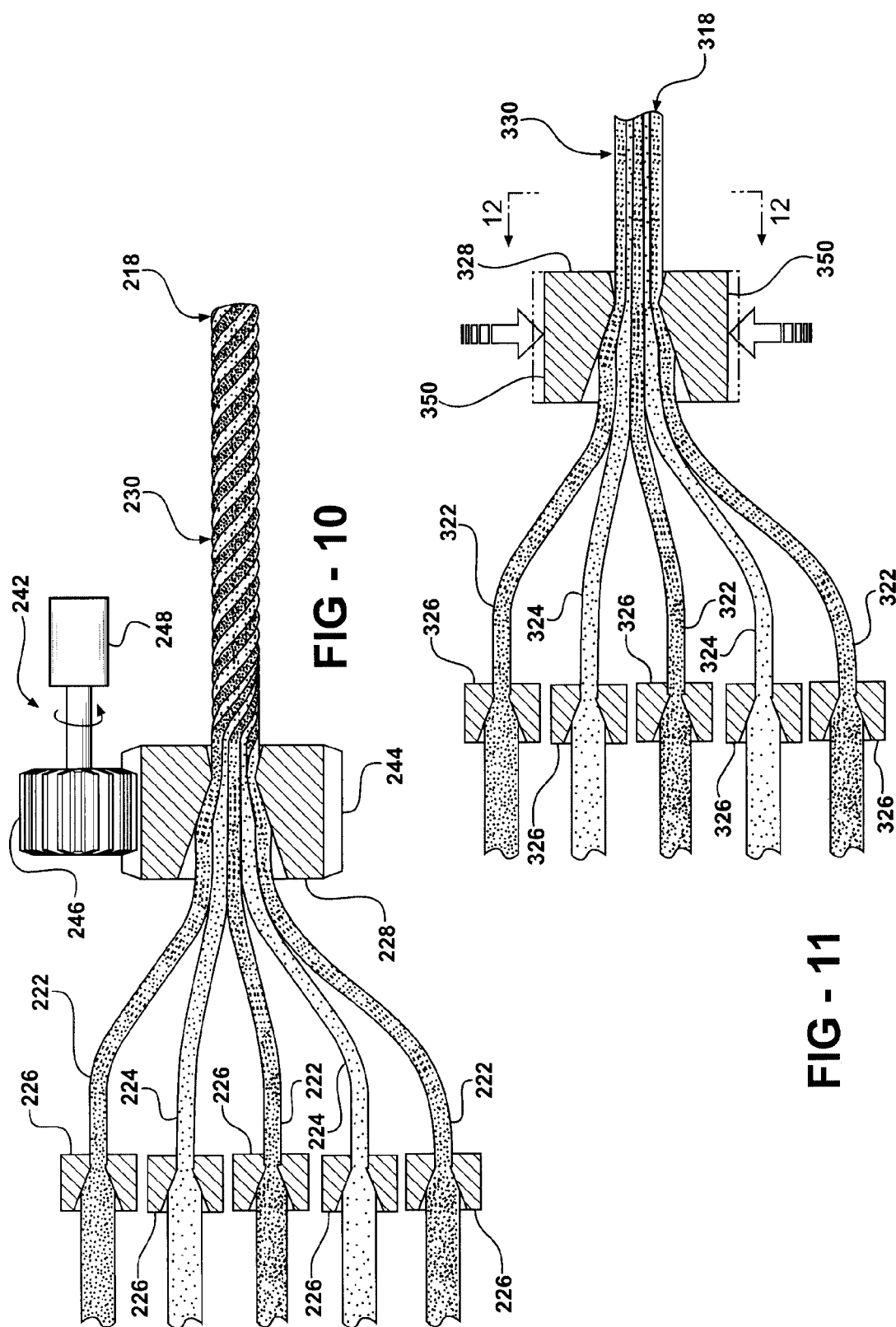


FIG - 9



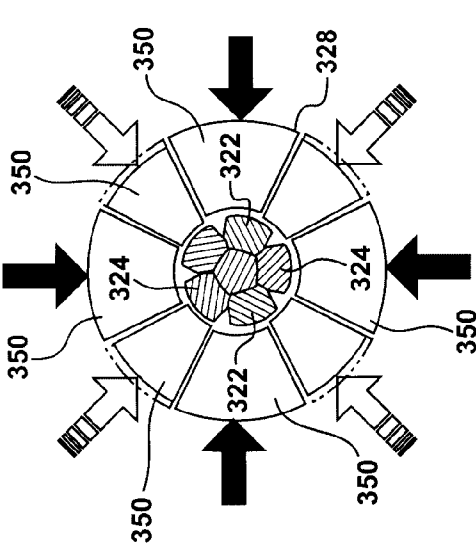


FIG - 12

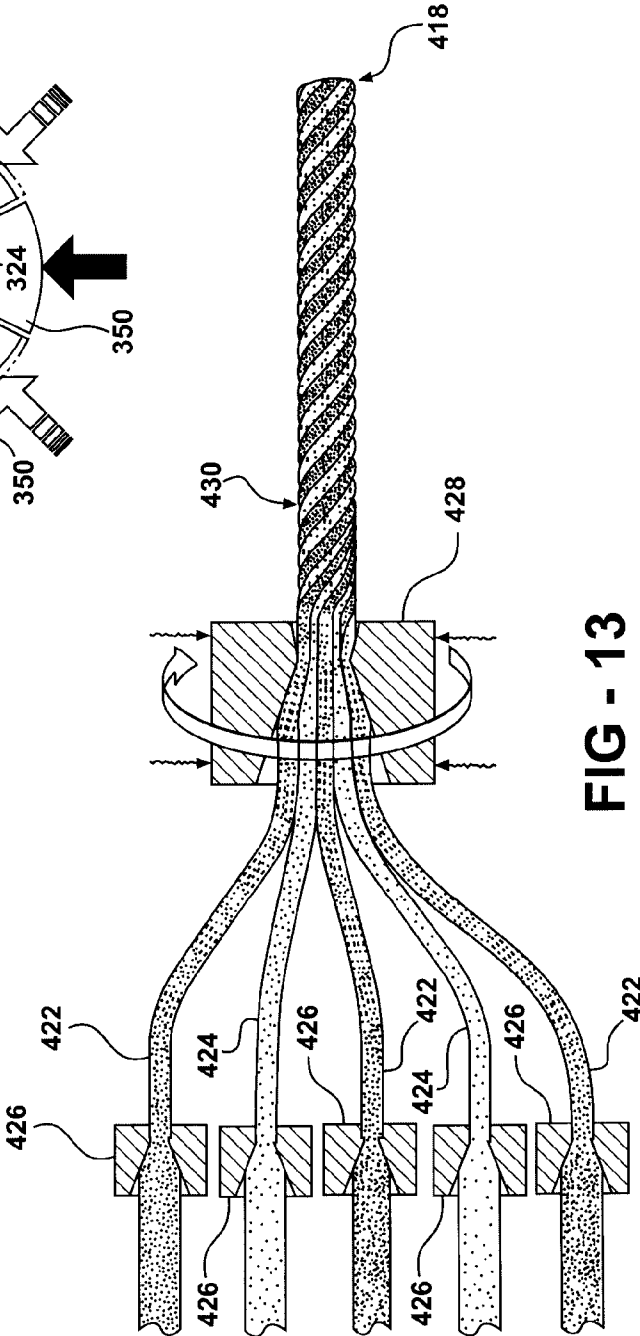


FIG - 13

EXOTHERMIC WIRE FOR BONDING SUBSTRATES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This invention claims priority to U.S. Provisional Application No. 60/667,999 filed Apr. 4, 2005.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates to an improved method of forming exothermic materials for various applications, and for use of exothermic material to permanently seal a cylinder head to a block in an internal combustion engine.

[0004] 2. Related Art

[0005] Reactive multilayer foils and coatings are used in a wide variety of applications requiring the generation of intense, controlled amounts of heat in a planar region. Such structures conventionally comprise a succession of substrate-supported layers that, upon appropriate excitation, undergo an exothermic chemical reaction that spreads across the area covered by the layers and thus generate precisely controlled amounts of heat. Such exothermic chemical materials are particularly useful as sources of heat for specialized welding, soldering, and brazing operations. However, they can also be used in other applications requiring controlled local generation of heat, such as primers for incendiary devices.

[0006] Reactive multilayer materials permit exothermic reactions with controlled and consistent heat generation. The basic driving force behind such reactions is a reduction in atomic bond energy. When the reactive materials are ignited, the distinct layers mix atomically, generating heat locally. This heat ignites adjacent regions of the structure, thereby permitting the reaction to travel the entire length of the structure, generating heat until all the material is reacted.

[0007] In addition to reactive coatings, efforts have been made to develop free-standing reactive layers by cold rolling. Nickel-Aluminum multilayer reactive foils have been formed by cold-rolling bi-layer sheets of Ni and Al, followed by repeated manual folding and repeated cold rolling. After the first bi-layer strip is rolled to half its original thickness, it is folded once again to regain its original thickness and to double the number of layers. This process is repeated many times.

[0008] The fabrication of rolled foils is time consuming and difficult. The rolling passes introduce lubricating oil and other contaminants, such that the surfaces of the rolled materials must be cleaned after every pass. In addition, the manual folding of sheet stock does not easily lend itself to large-scaled production. When many metal layers are rolled at once, these layers can spring back, causing separation of the layers and degradation of the resulting foil. Such separations also permit undesirable oxidation of interlayer surfaces and impedes unification of the layers by cold welding.

[0009] Accordingly, there is a need for improved methods of fabricating reactive multilayer structures, particularly for large-scale production applications.

SUMMARY OF THE INVENTION AND ADVANTAGES

[0010] The invention comprises a method for producing a multi-stranded exothermic assembly of the type for propa-

gating an exothermic reaction between the strands in response to an initial thermal impulse. The method comprises the steps of providing elongated first and second wires of respective constituent metallic materials each having a generally round cross-section, cold drawing the first and second wires through respective reduction dies in a non-oxidizing atmosphere, bringing the first and second wires into contact with one another in a non-oxidizing atmosphere, and simultaneously plastically deforming the first and second wires together into a unitary cord so that the surfaces of the first and second wires are pressed into contact to facilitate a sustained propagating exothermic reaction in response to an initiating thermal impulse.

[0011] According to another aspect of this invention, a one-time use gasket is provided of the type for sealing a cylinder head to a cylinder block in an internal combustion engine. The one-time use gasket comprises a sheet-like body, at least one cylinder bore opening formed in the body, and at least one fluid flow passage formed in the body. The fluid passage is isolated from the cylinder bore opening. The body is fabricated from a reactive multi-stranded exothermic assembly of the type for propagating an exothermic reaction in response to an initiating thermal impulse. The heat produced during the exothermic reaction is sufficient to metallurgically fuse the cylinder head to the cylinder block while maintaining fluidic isolation between the cylinder bore opening and the fluid flow passage.

[0012] According to yet another aspect of this invention, a method for establishing a fluid-tight seal between opposing surfaces having formed therebetween at least two discrete flow passages, is provided. The method comprises the steps of forming a gasket from a reactive multi-stranded exothermic assembly of the type for propagating an exothermic reaction in response to an initiating thermal impulse, forming at least two spaced and isolated flow passages in the gasket for conducting fluid material between the two opposing surfaces, aligning the openings in the gasket with the flow passages in the opposing surfaces, compressing the gasket between the opposing surfaces, initiating a propagating exothermic reaction in the gasket body, melting the opposing surfaces in response to the heat generated during the exothermic reaction, and metallurgically fusing the opposing surfaces together while permitting fluid exchange between the isolated flow passages.

[0013] The subject invention, as expressed through these various methods and apparatus, provides an exothermic cord, foil, ribbon or cloth produced in a manner that is particularly conducive for large-scale production applications. Utilizing commercially available wire products, the subject invention allows an exothermic assembly to be produced at lower cost as compared with prior art exothermic foils and the like. The subject methods enable substantially faster throughput of finished product. By controlling the size ratio between the cross-sections of the constituents, a degree of control can be exercised over the exothermic reaction characteristics and, therefore, tuned to particular applications. Accordingly, the subject invention provides a lower cost, higher production rate technique for creating reactive multi-layer assemblies for use in any of the known applications, including welding, soldering, brazing, and as primers for incendiary devices.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] These and other features and advantages and applications of the present invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0015] **FIG. 1** is a simplified cross-sectional view of a prior art internal combustion engine having a traditional gasket positioned in the interface between the cylinder head and cylinder block;

[0016] **FIG. 2** is a cross-sectional view as in **FIG. 1**, but showing an exothermic gasket assembly disposed in the region once occupied by the prior art gasket in preparation for an exothermic reaction which will result in permanent attachment of the cylinder head to the cylinder block;

[0017] **FIG. 3** is a view as in **FIG. 2**, but showing the cylinder head permanently affixed to the cylinder block following the exothermic reaction;

[0018] **FIG. 4** is a simplified schematic view showing the formation of the subject exothermic assembly in a cold-drawing operation on bulk wires;

[0019] **FIG. 5** is a cross-sectional view of a single wire taken generally along lines 5-5 of **FIG. 4**;

[0020] **FIG. 5A** is a cross-sectional view of an alternative cross-section of a single wire, with representative bundled wires shown in phantom;

[0021] **FIG. 6** is a cross-section of the cord taken along lines 6-6 of **FIG. 4**;

[0022] **FIG. 7** is an end view of a completed exothermic ribbon as taken along lines 7-7 of **FIG. 4**;

[0023] **FIGS. 8A and 8B** are simplified views showing an exothermic assembly disposed between two substrates in the sequence of before and then during a welding or joining operation;

[0024] **FIG. 9** is a simplified schematic view as in **FIG. 4** but showing an optional application of a braze or other coating material applied to the cord and beneficial in a later joining application;

[0025] **FIG. 10** is a schematic view as in **FIG. 4** yet showing another method of tightly bundling the wires through a twisting operation to form the exothermic cord;

[0026] **FIG. 11** is yet another alternative method of tightly packing the wires by rotary swaging;

[0027] **FIG. 12** is an illustrative cross-sectional view of the swaging die taken generally along lines 12-12 of **FIG. 11**; and

[0028] **FIG. 13** is still another alternative method of tightly combining the wires using an ultrasonic friction welding technique.

DETAILED DESCRIPTION OF THE
PREFERRED EMBODIMENT

[0029] Referring to the Figures, wherein like numerals indicate like or corresponding parts throughout the several views, a prior art engine assembly is shown in **FIG. 1**

including a cylinder head **10** affixed to a cylinder block **12** via head bolts **14**. A gasket **16** is disposed between the head **10** and block **12**, clamped under pressure from the head bolts **14**. The gasket **16** seals the internal pressure and fluids cycling within the cylinder bore to prevent leakage and maximize combustion efficiency.

[0030] In some engine applications, it may be desirable to permanently seal the cylinder head **10** to the cylinder block **12** without the aid of a gasket **16**. Reminiscent of prior art fixed head engines, in which the cylinder head and cylinder block form one inseparable unit, an engine assembly thus formed has the advantage of eliminating the expense of a gasket **16** and its vulnerability as a leak path over time. However, sealing a cylinder head **10** to a cylinder block **12** without the aid of a gasket **16** is a very difficult undertaking because there are many flow passages **17** which must be sealed. For example, liquid coolant and liquid oil are routed in respective passages **17** between the cylinder head **10** and the cylinder block **12** for proper lubrication and cooling. There are also sometimes passages provided for valve train components. The cylinder bore itself can even be considered a flow passage. If these passages are not independently sealed in isolation from one another, then the engine will leak fluids and there can be contamination between the various fluids and passages.

[0031] The subject invention overcomes these issues in the manner shown in **FIGS. 2 and 3** in which an exothermic assembly, generally indicated at **18**, is strategically routed around all of the various passages, as well as the combustion chambers. The strategically routed exothermic assembly **18** can be in the form of a continuous, snake-like ribbon of material laid in a course, or formed into a sheet-like or cloth-like body member similar in appearance to modern gasket bodies. With the cylinder head **10** firmly held in compression as suggested by the force arrows, the exothermic assembly **18** is ignited to accomplish a weld of the cylinder head **10** to the cylinder block **12** and thus form a fully sealed, integral engine assembly without the use of a gasket **16**. Although **FIG. 2** does not show continued use of the head bolts **14**, it may be desirable to retain use of some or all of the head bolts **14** for added integrity.

[0032] An energy source, such as the representative match **20** shown in **FIG. 2**, ignites an exposed wick portion **21** of the exothermic assembly **18**, thus initiating a propagating exothermic reaction between its interstitial layers. As an alternative to the match **20**, an electric sparking device, laser beam, or other device capable of producing the requisite thermal impulse can be used. Because the exothermic assembly **18** has such large interfacial areas between alternating layers of the constituent materials (typically Ni and Al), ignition from the flame source **20** causes the atoms or molecules of the constituent materials to rapidly mix and combine in a highly exothermic reaction. Once the heat is generated locally at the ignition point, it is conducted along the assembly **18** and initiates additional mixing, thereby sustaining the reaction. The speed at which the reaction front proceeds depends upon the physical properties of the constituent materials and how they are arranged. The reaction front causes atoms to diffuse normal to the layers themselves, with heat being conducted parallel to the layers.

[0033] In addition to joining a cylinder head **10** to a block **12** using the exothermic assembly **18**, it is possible to

permanently seal other components in an internal combustion engine using these techniques. For example, the engine exhaust ports can be permanently sealed to the exhaust manifold, the intake ports can be permanently sealed to the intake manifold, or any of the various covers or housings can be fixed in a permanently sealed condition. Anywhere a gasket has been used in the past, and even in non-automotive applications, the component parts can instead be permanently fixed and sealed using the exothermic assembly 18 and techniques here described.

[0034] The exothermic assembly 18 thus applied to permanently seal engine components can be accomplished using prior art type exothermic materials. However, the invention also contemplates a novel technique for producing an exothermic assembly 18 using bulk wires of constituent materials, as shown in FIG. 4. As mentioned above, the constituent materials can be Ni and Al or alloys thereof, but other materials can be used as well, including titanium-aluminides and the like. In fact, any of the currently known and available materials used in reactive multilayer foil applications may be used in the context of this invention.

[0035] In FIG. 4, bulk wires of commercial grade Ni 22 and Al 24, for example, are readily available from numerous commercial sources. These bulk wires 22, 24 are typically formed with a generally round cross-section. These commercially available wires 22, 24 are first cold-drawn (below 100° C.) through respective reducing dies 26. The bulk wires 22, 24 may be of any effective size, but diameters in the range of 50 microns have proven satisfactory. This first drawing operation, conducted under a cover gas (such as nitrogen or argon), removes all oxides and other contaminants from the wires 22, 24, thus providing clean surfaces that are suited for an exothermic reaction.

[0036] As shown in FIG. 5, the first draw dies 26 may simply reduce the original diameter of the bulk wires, thus resulting in a smaller circular cross-section. However, the dies 26 can alternatively impart a full or partial geometric shape to the wires 22, 24, such as shown in FIG. 5A. In this example, the first dies 26 impart a hexagonal cross-section to the wires 22, 24 which may aid in better nesting and increased surface contact as represented by the phantom adjacent wires. Of course, other wire shapes are possible.

[0037] Once drawn through the first dies 26, the wires 22, 24 are merged and drawn as a bundle through a second die 28 which squeezes the wires 22, 24 into a cord 30. A representative cross-section of the cord 30 is shown in FIG. 6 to illustrate that the surfaces of the wires 22, 24 have been brought into substantial contact with one another through plastic deformation so that a large interfacial surface area is established between the respective wires 22, 24. Those skilled in the art will readily appreciate that the number of strands of wires 22, 24 can be varied substantially, and that the five strands shown in the figures are merely illustrative. On the minimum side, there must be at least two such wires 22, 24, whereas there is not an effective maximum limit. Wire bundles with strand numbers in the 10's or 100's may be used.

[0038] The cord 30 exiting the second draw die 28 can be used immediately in an exothermic reaction in the form thus created, or can be further shaped by progressive rolling dies 32 to create a ribbon similar to the configuration illustrated in FIG. 7. Alternatively, the cord 30 can be shaped into other

designs or configurations and is not limited to the flat ribbon shape shown in FIG. 7. Likewise, it is not necessary that the resulting cross-section be continuous. Thus, the cord 30 can be shaped by any other means known to those skilled in the art, including stamping, further drawing, forging, and the like.

[0039] FIGS. 8A and 8B illustrate, in simplified terms, the sequence of welding upper 34 and lower 36 substrates using the exothermic assembly 18 ignited by a flame source 20. Once ignited at the wick 21, the exothermic reaction propagates along the assembly 18, fusing together the opposing surfaces along the way.

[0040] FIG. 9 illustrates a supplemental application technique of the subject forming process. The result is a slightly modified exothermic assembly 118. Here, the constituent bulk wires 122, 124 are pulled through the first draw dies 126 as in the preceding embodiment, and then merged and pulled through the second drawing die 128 as in FIG. 4. The cord 130 emerging from the second draw die 128 is then directed to a coating operation where a braze material 138, contained as a suspension or powder in a hopper 140, is applied to the exterior surface of the cord 130 to thus encase the exothermic assembly 11' for benefit in a later joining operation. Instead of the braze material 138, other coatings can be applied, such as solder, flux, or other beneficial treatments. Once the sprayed material 138 is sufficiently solidified or dried, the exothermic assembly 118 is ready for use in any conceivable application (i.e., not limited to internal combustion engines).

[0041] FIG. 10 illustrates yet another alternative forming technique for the exothermic assembly 218. In this situation, the bulk wires 222, 224 are drawn through the first set of dies 226 and then brought together in a twisting device, generally shown at 242. The twisting device 242 includes a collar 244 driven by a gear wheel 246 via a motor 248. The twisting operation takes the place of the second draw die 228 as in FIGS. 4 and 9, to effectively bring the wires 222, 224 tightly together to form a bulk exotherm with good interfacial contact between the constituent wires 222, 224. The resulting cord 230 of twisted construction is ready for use in an exothermic reaction, or can be coated with a braze material as described in the preceding example. Alternatively, the resulting cord 230 of twisted construction can be rolled or shaped using progressive rollers like that shown in FIG. 4, or other post-forming techniques, to achieve a desired shape in the resulting exothermic assembly 218. In situations where it would be advantages to work with a sheet of exothermic material, a cloth may be readily formed by weaving or felting a number of exothermic cords.

[0042] FIG. 11 illustrates the use of rotary swaging to assemble the reactants. In this example, the second die 328 is formed in sections 350 that can be separately actuated to "hammer" the bundle of wires 322, 324 into a tightly packed condition, as shown in FIG. 12. The swaging die 328 can be simultaneously rotated to impart a twist to the emerging cord 330 or simply allow the wires to remain parallel.

[0043] FIG. 13 illustrates the use of ultrasonic welding for joining the reactants. Here, the second die 428 is vibrated at high frequency to surface weld the individual wires 422, 424 together. The die 428 may also be rotated to introduce a twist in the resulting cord 430 as in preceding examples.

[0044] It will be appreciated that all of the various assembly techniques can be blended to form additional hybrid

variations with the resulting exothermic assembly useful in any application in which prior art reactive multilayer foils and coatings have been used. Thus, while the invention has been described in an illustrative manner, it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

[0045] Obviously, many modifications and variations of the invention are possible in light of the above teachings. It is, therefore, to be understood that the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A method for producing a multi-stranded exothermic assembly of the type for propagating an exothermic reaction between the strands in response to an initiating thermal impulse, said method comprising the steps of:

providing an elongated first wire of a constituent metallic material having a generally round cross-section;

providing an elongated second wire of a constituent metallic material dissimilar from that of the first wire and having a generally round cross-section;

cold drawing the first wire through a reduction die in a non-oxidating atmosphere;

cold drawing the second wire through a reduction die in a non-oxidating atmosphere;

bringing the first and second wires into contact with one another in a non-oxidizing atmosphere; and

simultaneously plastically deforming the first and second wires together into a unitary cord so that the surfaces of the first and second wires are pressed into contact to facilitate a sustained propagating exothermic reaction in response to an initiating thermal impulse.

2. The method of claim 1, wherein said step of plastically deforming the first and second wires includes cold drawing the first and second wires through a reducing die.

3. The method of claim 1, wherein said step of simultaneously plastically deforming the first and second wires includes twisting the first and second wires together in a generally helical pattern.

4. The method of claim 1, wherein said step of simultaneously plastically deforming the first and second wires includes simultaneously cold drawing and twisting the first and second wires together.

5. The method of claim 1, wherein said step of simultaneously plastically deforming the first and second wires includes swaging.

6. The method of claim 5, wherein said step of simultaneously plastically deforming the first and second wires further includes twisting the wires into a generally helical configuration.

7. The method of claim 1, wherein said step of simultaneously plastically deforming the first and second wires includes ultrasonically welding the first and second wires to one another.

8. The method of claim 7, wherein said step of simultaneously plastically deforming the first and second wires further includes twisting the wires in a helical configuration.

9. The method of claim 1, further including the step of applying a material coating to the unitary cord following said step of simultaneously plastically deforming the first and second wires.

10. The method of claim 9, wherein said step of applying a material coating includes coating the unitary cord.

11. The method of claim 1, further including the step of weaving a plurality of the cords into a cloth.

12. The method of claim 1, further including the step of flattening the unitary cord following said step of simultaneously plastically deforming the first and second wires.

13. The method of claim 12, wherein said flattening step further includes passing the unitary cord through a rolling mill.

14. A one-time use gasket of the type for sealing a cylinder head to a cylinder block in an internal combustion engine, said gasket comprising:

a sheet-like body;

at least one cylinder bore opening formed in said body;

at least one fluid flow passage formed in said body, said fluid flow passage isolated from said cylinder bore opening; and

said body being fabricated from a reactive multi-stranded exothermic assembly of the type for propagating an exothermic reaction in response to an initiating thermal impulse, whereby the heat produced during the exothermic reaction is sufficient to metallurgically fuse the cylinder head to the cylinder block while maintaining fluidic isolation between said cylinder bore opening and said fluid flow passage.

15. The assembly of claim 14, wherein said body includes a protruding wick.

16. The assembly of claim 14, wherein said multi-stranded exothermic assembly consists essentially of alternating wires of a first constituent metallic material and a second constituent metallic material, said second constituent metallic material being dissimilar to said first constituent metallic material.

17. The assembly of claim 16, wherein said first constituent metallic material consists essentially of an aluminum-based alloy.

18. The assembly of claim 16, wherein said second constituent metallic material consists essentially of a nickel-based alloy.

19. A method for establishing a fluid-tight seal between opposing surfaces having formed therebetween at least two discrete flow passages, said method comprising the steps of:

forming a gasket from a reactive multi-stranded exothermic assembly of the type for propagating an exothermic reaction in response to an initiating thermal impulse;

forming at least two spaced and isolated flow passages in the gasket for conducting a fluid material between the two opposing surfaces;

aligning the openings in the gasket with the flow passages in the opposing surfaces;

compressing the gasket between the opposing surfaces;

initiating a propagating exothermic reaction in the gasket body;

melting the opposing surfaces in response to the heat generated during the exothermic reaction; and

metallurgically fusing the opposing surfaces together in regions around the flow passages to permanently seal the opposing surfaces together while permitting fluid exchange between the isolated flow passages.

20. The method of claim 19, wherein said step of forming a gasket includes providing an elongated first wire of a constituent metallic material having a generally round cross-section, providing an elongated second wire of a constituent

metallic material dissimilar from that of the first wire and also having a generally round cross-section, cold drawing the first wire through a reduction die in a non-oxidizing atmosphere, cold drawing the second wire through a reduction die in a non-oxidizing atmosphere, bringing the first and second wires into contact with one another in a non-oxidizing atmosphere, and simultaneously plastically deforming the first and second wires together into a unitary cord.

* * * * *