Dec. 25, 1945. F. R. HENSEL 2,391,456

SPARK PLUG ELECTRODE

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Fig. 1

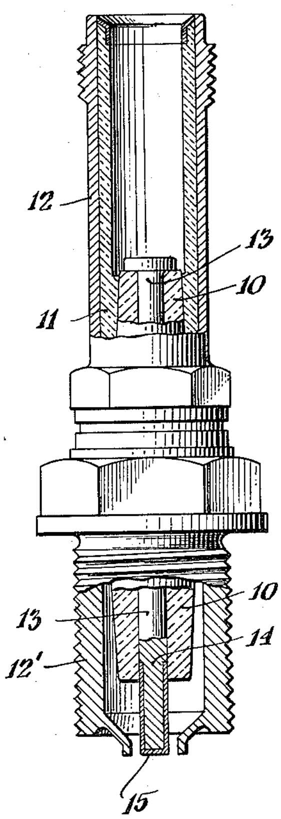


Fig. 2

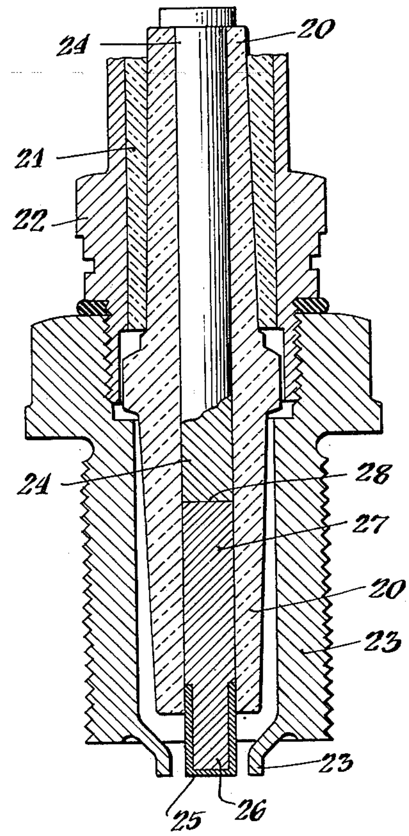
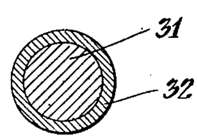


Fig. 3



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SPARK PLUG ELECTRODE

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8 Claims. (Cl. 123—169)

This invention relates to improvements in spark plugs, and more particularly to improved spark plug electrodes and improved methods of sealing such electrodes in a spark plug assembly.

With the use of increasing compression ratios and fuels of higher octane ratings in internal combustion engines such as aircraft engines, conventional spark plugs have not been entirely satisfactory. Due to the ever growing use of fuel-addition compounds such as degumming agents, anti-corrosion agents, and power-increasing agents, particularly those of the lead type, corrosion and erosion conditions occurring at the firing ends of spark plug electrodes are becoming increasingly severe.

Attempts have been made to reduce corrosion and erosion at the firing ends of spark plug electrodes by the use of corrosion resistant metals and alloys, but such attempts have not secured satisfactory results due in part to the poor thermal conductivity of these metals and alloys, and in part to the serious difference in thermal conductivity thereof with reference to the ceramic insulating or bonding material employed in the manufacture of the plug. It has also been proposed to reduce the operating temperature of the electrode, and thereby reduce corrosion and erosion of the metal in the sparking region, by employing a composite electrode having a metal core of very good heat conductivity such as copper, and a metal sheath composed of a metal resistant to heat and corrosion, such as stainless steel, nickel or nickel alloys. However, the elements of such a composite electrode possess unequal thermal expansion characteristics and as a consequence such electrodes have a tendency to warp or to change adjustment of the firing gap to a serious extent. Thus under modern conditions of varying load on the engine such spark plugs are apt to cease operation entirely and therefore are highly unsatisfactory.

Objects of the present invention are: to provide an improved spark plug and an electrode therefor having an exceptionally long life under severe heavy-duty conditions such as those encountered in modern aircraft engines; to provide a spark plug which will remain adequately cool in operation; and to provide a spark plug which will operate without leakage, corrosion or erosion and without alteration of the spark gap.

The above and other objects and advantages of the invention are attained by the provision of a spark plug electrode having a body of molybdenum or a molybdenum base metal composition integrally bonded to the ceramic insulator of the plug. In the preferred embodiment the molybdenum body is provided with an integrally bonded sheath of platinum or a platinum alloy at the sparking tip, and the coefficient of thermal expansion of the molybdenum base metal or metal composition closely matches the coefficients of expansion of both the ceramic material and the metallic sheathing material.

In the drawing:

Figure 1 is a view, partly in vertical section, of a spark plug having incorporated therein the improved electrode of the present invention;

Figure 2 depicts a view, in vertical section, of a modification of the invention; and

Figure 3 is a cross-sectional view of the improved electrode.

Referring to the embodiment illustrated in Figure 1, the spark plug shown comprises an insulating shell **10** which may be composed of porcelain or other insulating material. Sealing means **11**, such as mica, may be employed to seal the insulating shell **10** into the outer metal shell **12** which forms a part of the side electrode **12'** of the plug assembly. The central electrode, shown at **13**, comprises a core **14** composed of molybdenum or molybdenum composition having a high heat conductivity and a coefficient of thermal expansion substantially the same as, or less than, that of the cap or sheath **15** and of the insulator **10**. Sheath **15** is made of a material highly resistant to erosion and spark gap growth, preferably platinum or a platinum alloy, as described in more detail below. The entire central electrode **13** is hermetically fused, bonded, or otherwise integrally and securely sealed into the insulator **10**.

The present invention derives advantage from the combination of a high electrical conductivity and a low thermal coefficient of expansion of molybdenum and molybdenum base compositions, and from the fact that these values remain satisfactory at elevated temperatures. For example, the thermal coefficient of expansion of molybdenum over a temperature range of 25 to 100° C. is 4.9×10^{-6} per °C., and its electrical conductivity is about 34% I. A. C. S. Similarly, the thermal coefficient of expansion of platinum over the same temperature range is 8.9×10^{-6}. Spark plug insulators now in use have linear coefficients of thermal expansion between 3×10^{-6} and 9×10^{-6}. Most porcelains have a coefficient of expansion within the range 3 to 6×10^{-6}. Aluminum oxide has a coefficient of expansion of from 8 to 9×10^{-6}, and titania has a coefficient of expansion of from 5 to 8×10^{-6}. The figures are representative of permissible differences in the thermal coefficient of expansion of the materials which may be used according to this invention to yield a composite integrally bonded structure, the component elements of which are capable of expanding substantially uniformly under the influence of heat without distortion, warping leakage, or separation of the elements of such structure.

Figure 2 shows a longitudinal axial cross-section through the lower or inner half of a modified spark plug construction comprising an insulating shell or body **20** which may consist of porcelain, or aluminum oxide, or titanium oxide. Conventional sealing material **21** is provided to seal the insulating shell **20** into the outer metal shell **22** of the plug assembly. The side electrode is indicated at **23**. The central electrode consists of an upper section **24** and a lower section **27**, the two sections being united, as by butt-welding, for example as shown at **28**. Preferably, the upper section **24** consists of a rod of a material having satisfactory anti-corrosion, thermal and electrical properties, such as nickel or alloys thereof. The lower section **27** of the central electrode may consist of molybdenum and that portion thereof which is in close proximity to the sparking region preferably consists of a core **26** of either molybdenum or a sintered material comprising molybdenum, silver and copper. The sheath or cap **25** preferably consists of platinum or an alloy composed predominantly of platinum, the balance consisting of at least one of the following metals: tungsten, molybdenum, tantalum, rhenium, columbium, tin, beryllium, uranium, thorium, rhodium, palladium, osmium, iridium and ruthenium. Examples of preferred sheath compositions are: 96% platinum, 4% tungsten; 96% platinum, 4% molybdenum; 90% platinum, 10% rhodium; 88% platinum, 12% palladium. These materials are characterized by the combination of a high resistance to erosion, spark gap growth, and a coefficient of expansion close to the coefficient of expansion of molybdenum and molybdenum compositions.

Figure 3 illustrates a cross-sectional view of the sheathed portion of the improved electrode of this invention, the core of molybdenum or molybdenum composition being shown at **31**, and the sheathing of platinum or platinum alloy being shown at **32**.

A consideration of the difference in the coefficient of expansion between platinum and platinum alloys on the one hand, and metallic molybdenum on the other, indicates that there is a possibility of using central electrodes comprising sintered metal compositions containing molybdenum, instead of pure molybdenum. For example, sintered molybdenum-copper compositions are readily produced in ductile form. These compositions have the further advantage of higher thermal and electrical conductivities than those of pure molybdenum. Use may also be made of molybdenum-silver compositions. For example, the coefficient of expansion of a molybdenum-silver composition containing 60% molybdenum and 40% silver, varies as follows with temperature variations:

100 to 200° C.: 8×10^{-6}
200 to 300° C.: 9.5×10^{-6}
0 to 900° C.: 10.1×10^{-6}

Other examples of suitable molybdenum compositions are: 75% molybdenum, 25% copper; 50% molybdenum, 50% copper or silver; 65% molybdenum carbide, 35% silver.

In general, any metal alloy or metallic composition containing molybdenum may be used as a core material, provided it has good thermal and electrical conductivity, high strength, ductility, a low coefficient of thermal expansion, examples of such compositions being the carbides, nitrides and borides of molybdenum, sintered or otherwise compounded with the high conductivity metals such as silver and copper in the proportion of about 40% high conductivity metal and the balance the refractory metal or composition. By way of example, a composition containing about 60% molybdenum, and the balance silver has, in addition to the satisfactory coefficient of expansion set forth above, a thermal conductivity of about .45 to .5 gram calories per second per square centimeter per ° C. per centimeter.

A preferred method of producing the electrode core material consists in mixing the powdered ingredients in the desired proportion, pressing the mixture, and sintering the same, preferably in a reducing atmosphere. Optionally, powdered molybdenum alone is first pressed into the desired shape, then sintered in the usual manner, and during or after such sintering process, it is impregnated by heating in contact with one or more of the low melting point metals having high conductivities, such as copper or silver.

By way of illustration, the central electrode may have a diameter of about 0.06 inch and may comprise in the section thereof which is adjacent to the sparking tip, a core having a diameter of 0.04 inch and a sheath of platinum or platinum alloy having a wall thickness of 0.01 inch. This composite electrode may be formed by inserting a molybdenum wire into a seamless tube of platinum alloy and swaging the assembly to the desired final diameter.

If desired, the platinum or platinum alloy or composition cladding may be united with or otherwise integrally secured to the core by electro-deposition instead of by a swaging operation. Electro-deposition is preferable in some instances because electro-deposited platinum or platinum alloy is exceptionally resistant to spalling when a core metal of relatively high thermal expansive characteristics is used. Optionally an intermediate coating of nickel may be advantageously employed between the core and sheath. Such intermediate coating may be formed by a swaging or electro-deposition operation.

Since the electrical, thermal and expansion characteristics of tungsten are very similar to those of molybdenum, it is understood that tungsten may be substituted either wholly or in part for the molybdenum. In other words, instead of pure molybdenum, tungsten-molybdenum alloys may be used as core materials. In the case of molybdenum base composite materials such as molybdenum-copper or molybdenum-silver, it is possible to use a refractory base consisting either of mixtures of molybdenum and tungsten and their compounds or if desired, of pure tungsten and/or its compounds.

The above described examples are intended as illustrations and not as limitations of the invention, and it will be understood that numerous variations thereof may be practiced without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A spark plug comprising an electrode including a core and a sheath surrounding said core

with the entire inner surface of said sheath in direct electrically conductive relation with said core, said sheath comprising a material selected from the group consisting of platinum and platinum base alloys, and said core consisting of a material selected from the group consisting of molybdenum, molybdenum base sintered metal compositions, tungsten, tungsten base sintered metal compositions, and tungsten-molybdenum compositions.

2. Spark plug electrode as claimed in claim 1, wherein said sheath material consists of an alloy composed predominantly of platinum and the balance an alloying ingredient selected from the group consisting of platinum, rhenium, columbium, tin, beryllium, uranium, thorium, rhodium, palladium, osmium, iridium.

3. Spark plug electrode as claimed in claim 1, wherein said core material is a refractory material selected from the group consisting of molybdenum, the carbides, nitrides and borides of said metal, and compositions of these compounds with copper and silver.

4. A spark plug, comprising a composite electrode having a core and a sheath with the entire inner surface of said sheath in direct electrically conductive relation with said core integrally bonded in heat conductive relation to said core, said sheath comprising a platinum alloy, and said core comprising a material selected from the group consisting of compositions containing molybdenum and tungsten having a high thermal conductivity and a lower coefficient of linear expansion than said sheath.

5. A spark plug comprising an insulator of ceramic material having a passage therethrough, an electrode hermetically sealed into said passage, said electrode comprising a sheath of platinum and a core of molybdenum.

6. Spark plug as claimed in claim 5, in which the coefficient of linear expansion of said electrode is adapted to substantially match the coefficient of linear expansion of said insulator.

7. A spark plug comprising a ceramic insulator, a center electrode passing through said insulator and projecting to form a sparking point, and a side electrode cooperating therewith, at least a section of said center electrode being formed of molybdenum secured in and sealed to said insulator, said molybdenum portion also forming the core of said projecting sparking point, and a platinum sheath on said sparking point secured to said core with the entire inner surface of said sheath in direct electrically conductive relation with said core.

8. Spark plug as claimed in claim 7 in which at least a portion of said center electrode is formed of nickel.

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