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SINTERED STEEL-BONDED HARD METAL ALLOY AND A METHOD OF PREPARING THE SAME

Fritz Frehn, Krefeld, Germany, assignor to Deutsche
Edelstahlwerke Aktiengesellschaft, Krefeld, Germany

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7 Claims

ABSTRACT OF THE DISCLOSURE

A sintered alloy of the type comprising a steel matrix and one or more metal carbides and which has high abrasion resistance, is characterized by the presence of free graphite in the steel matrix. Such sintered alloys are obtained by a method of sintering in which the sintered alloys are maintained for an extended period of time at sintering temperatures followed by controlled cooling.

This invention relates to sintered steel-bonded hard metal alloys, and particularly relates to such alloys containing primarily metal carbide e.g. titanium carbide, and to a method of producing such alloys.

Hard metal alloys in which one of the components is a hard metal, namely a metal carbide, boride, nitride or silicide, and the other component is steel, are well known. Due to the high content of hard metal amounting to between 10 and 75% by weight of the alloy, such hard metal alloys are extremely abrasion-resistant and are used for instance for making plastics-forming tools, such as draw plates.

For parts that are subject to abrasive wear conventional steel-bonded hard metal alloys have not hitherto proved entirely satisfactory. When two parts consisting of conventional hard metal alloys are in sliding contact, even slight surface roughness causes high rubbing friction immediately on failure of the lubricant film between the two surfaces, or its absence. In circumstances when one sliding part consists of a steel-bonded hard metal alloy and the other consists of another material, which for structural reasons frequently obtains, for instance when a steel shaft runs in steel-bonded hard metal alloy bearing bushes, then the part which does not consist of a steel-bonded hard metal alloy experiences very high abrasive wear by the rubbing action of the steel-bonded hard metal alloy part.

Materials that have so-called emergency running properties are also known, but these have little if any resistance to abrasive wear. Such materials may be porous sintered bearing materials, consisting for instance of iron, bronze, copper, German silver, plastics, carbon and other materials. Their lubricating properties derive from the fact that their pores are filled with oil, or materials such as copper, phosphor bronze and similar materials may have an inherent lubricity. Other materials that have self-lubricating properties are cast irons in which the presence of flaky or spheroidal graphite together with phosphides and sulphides is responsible for a self-lubricating effect. Other cast iron types contain minor proportions of chromium carbides and molybdenum carbides and possess a somewhat improved abrasion resistance. However, the wear-resistance of these materials likewise falls short of requirements.

The present invention provides a highly abrasion resistant hard alloy which has self-lubricating properties, and which is suitable for the fabrication of parts that in use will be exposed to considerable rubbing wear.

The invention provides a sintered steel-bonded hard metal alloy consisting essentially of 10 to 75% by weight of hard metal consisting substantially of one or more metal

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carbides, and from 25% to 90% by weight of a steel matrix containing free graphite.

The graphite content of alloys according to the invention is preferably between 0.8% and 3.9% by weight based on the total weight of the alloy.

Preferred hard metal alloys according to the invention consist essentially of

	Percent
Titanium carbide -----	10-75
Carbon -----	0.8-3.9
Silicon -----	0.5-6.0
Aluminium -----	0-7.0
Manganese -----	0-7.0
Nickel -----	0-36.0
Copper -----	0-8.0
Magnesium -----	0-0.1
Cerium -----	0-0.1
Boron -----	0-0.1
Total of chromium, molybdenum, vanadium, titanium -----	0-2.0
Iron -----	Balance

all percentages being by weight.

By the term "consisting essentially of" is meant that impurities and incidental ingredients which do not significantly affect the stated characteristics of the alloy may be present in small proportions.

The titanium carbide content in the said preferred hard metal alloys is preferably from 15 to 35%.

Up to 50% by weight of the titanium carbide in the said preferred alloys may be replaced by one or more other metal carbides.

Due to the presence of the graphite present in the steel matrix of the steel-bonded hard metal alloy according to the invention, the resultant structure resembles that of cast iron and has the self-lubricating properties of the latter. Tests have confirmed that the life of steel-bonded hard metal alloys that are known to be extremely abrasion-resistant is substantially prolonged by the addition of the graphite in the steel matrix whenever alloys according to the invention are subjected to rubbing wear. The wear-resistance to rubbing friction was also found to exist in situations when only one of the two frictionally co-operating parts consisted of the steel-bonded hard metal alloy according to the invention, and the other of another material.

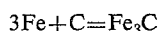
Due to the relatively high content of hard metal in the alloys according to the invention, such alloys can be produced only by conventional powder metallurgical techniques. A particular difficulty is the introduction of the free graphite into the steel matrix. The unusually high carbon content of the steel matrix in the alloys and the resultant low-melting eutectic in the stable system of the iron-carbon phase diagram (4.3% by weight C and 1153° C.) are responsible for major difficulties met in sintering, particularly since the proportion of this phase exceeds 50% by volume, and more particularly since completely dense, i.e. completely non-porous sinter bodies, are required. The solution of the carbon during sintering and its precipitation in the form of free graphite when cooling from sintering temperature give rise to complicated shrinkage conditions. The low density of the graphite compared with iron is a decisive factor in providing such difficulties.

The solubilities during sintering differ from those obtaining when a melt freezes, during which freezing carbon is primarily precipitated only from hypereutectic alloys (above 4.3% by weight of C), and continuing solidification causing graphite to attach itself to the carbon. By contrast, during sintering the formation of cementite must be prevented and the solution of the carbon in the iron assured. Consequently the manner in which the over-

all sintering treatment of hard metal alloys according to the invention is conducted is of primary importance.

A method according to the invention of sintering the said hard metal alloys is provided by forming a pressing of powdered starting materials (namely the elements forming the hard metal component and the steel matrix), and heating the pressing at the rate of from 80° to 100° C. per hour to a sintering temperature of from 1000° to 1200° C., maintaining the thus-heated pressing at the sintering temperature for at least 4, and preferably from 4 to 6 hours, cooling the sintered pressing at the rate of from 30° to 50° C. per hour to a temperature between 750° and 850° C., and then further cooling the pressing to room temperature at the rate of from 100° to 200° C. per hour.

The successful sintering of the process depends on the chemical composition, since during sintering the reaction



proceeds and a hard brittle material resembling white iron is produced having properties that are the exact reverse of those of the required material.

The addition of preferably at least 1% by weight of silicon, usually in the form of ferrosilicon, substantially inhibits the formation of cementite and promotes the formation of graphite. Aluminium and titanium have a similar effect. A particularly important step however is the method of sintering, i.e. a soaking time of at least 4, preferably 4 to 6 hours at sintering temperature and a cooling step that lasts for several hours as hereinbefore described to establish equilibrium between the alloy components, in order to precipitate the graphite in even distribution and to produce it in a desirable flaky form to provide the lubrication of the thus-produced material. The randomly-orientated graphite improves the resistance to temperature shock and the thermal conductivity of the material. The deliberately non-orientated, but finely and evenly distributed graphite flakes lead to a very low coefficient of friction and a high resistance to heat cracking which may occur when high and rapid surface friction arises, as when parts are inexpertly ground and the temperature is allowed to fluctuate by rapid heating and cooling.

A hard metal alloy according to the invention was prepared containing 20% by weight of titanium carbide, 2.5% by weight of carbon, 2.0% by weight of silicon, 1.5% by weight of nickel, balance iron. The steel matrix was purely ferritic and the graphite was present in spheroidal and flaky form. The titanium carbide was evenly distributed in grain sizes between 1 and 3 μm . The hardness of the said alloy was 33 to 36 HRC, corresponding to 321 to 353 HB. The proportion by volume of the graphite was in the range 35 to 40%, and provided the alloy with the desired self-lubricating property in addition to resistance to abrasive wear. This ferritic structure containing flaky graphite lamellae and having a titanium carbide content provides outstanding damping properties which improve even further with greater carbon contents, i.e. a pearlitic structure.

Additions of silicon in a quantity of from 0.5% to 6.0% by weight that are necessary for graphitisation improve the corrosion resistance.

An increase of the nickel content to 36.0% by weight leads to the production of an austenitic matrix having embedded therein titanium carbides and graphite, the content of carbon controlling the quantity of graphite present. Such austenitic alloys are corrosion resistant, non-magnetic, non-scaling, very tough and also satisfactorily machinable. The coefficient of thermal expansion of austenitic alloys is nearly twice that of ferritic or pearlitic alloys containing titanium carbide and graphite.

Manganese contents encourage the formation of austenite and may be as high as 7.0% by weight.

Aluminium in quantities up to 7.0% by weight in-

creases the volume of the liquid phase, which is desirable when the hard metal contents are high.

Copper up to 8.0% by weight has an aging effect and also improves the lubricity of the alloy.

Additions of magnesium and/or cerium cause the graphite to appear in the spheroidal form, as in the case of cast iron.

Boron up to 0.1% by weight has a deoxidant effect in the interior of the alloy and causes existing oxygen to be bound by forming B_2O_3 in the alloy, which easily volatilises at relatively low temperatures in a vacuum.

The elements, chromium, molybdenum, vanadium and titanium are not often required in hard metal alloys according to the invention, because they are strong carbide-formers that would at once react with the graphite. However, they may be incorporated in total quantities not exceeding 2.0% by weight, for hardening the alloy.

The production of hard metal alloys according to the invention utilizes the main constituents, namely hard metal, and the individual components of the steel matrix. The individual elements forming the hard metal component and the steel matrix, or key alloys containing the same such as carbonyl iron, graphite, silicon, for instance in the form of ferrosilicon, may be dry mixed, wet ground to a grain size of 1 to 3 μm , vacuum dried, pressed and sintered in a vacuum of 2×10^{-2} torr at about 1100° C.

Sintering proceeds in the manner hereinbefore described by slow heating, soaking for several hours at sintering temperature and gradual cooling in stages after sintering has taken place. A heat treatment of the sintered hard metal alloy may subsequently be carried out. This may comprise annealing to relieve internal stress without affecting the structure at a temperature between 550° and 650° C. For changing the streaky pearlite into a grainy pearlite a heat treatment may be performed between 650° and 800° C. For forming a ferritic matrix soft annealing between 800° and 925° C. is desirable. This causes the Fe_3C to decompose completely with an accompanying increase in volume. For pearlitic basic structures hardening in oil at 870° to 900° C. followed by drawing between 200° and 240° C. may be performed.

Steel-bonded hard metal alloys according to the invention are particularly suitable for providing parts that are subject to rubbing friction and that should therefore have self-lubricating properties to prevent the co-operating part from being excessively worn. Thus they may be used for a variety of specific applications, for instance for bearings which may work at temperatures rising up to 900° C. if the matrix is austenitic, for brake drums, brake shoes, brake blocks, clutch presser plates, valve tappets, liners, sealing rings, gaskets, piston rings, parts of machinery and pump parts. By associating parts made of the alloys according to the invention with steel or cast iron backing elements to which the alloy elements are soldered, welded or bolted, the cost of production thereof may be reduced.

What is claimed is:

1. A sintered steel-bonded hard metal alloy consisting essentially of 10 to 75% by weight of hard metal consisting substantially of one or more metal carbides and from 25% to 90% by weight of a steel matrix containing free graphite.

2. A hard metal alloy according to claim 1, wherein the said steel matrix contains from 0.8% to 3.9% by weight of free graphite based on the overall weight of the alloy.

3. A hard metal alloy according to claim 1, wherein the said metal-carbide is titanium carbide.

4. A hard metal alloy according to claim 1, having a composition (by weight):

	Percent
Carbide -----	10-75
Carbon (as free graphite) -----	0.8-3.0
Silicon -----	0.5-6.0
Aluminium -----	0-7.0

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	Percent	
Manganese -----	0-7.0	
Nickel -----	0-36.0	
Copper -----	0-8.0	
Magnesium -----	0-0.1	5
Cerium -----	0-0.1	
Boron -----	0-0.1	
Total of chromium, molybdenum, vanadium, titanium -----	0-2.0	
Iron with a content of combined carbon necessary for the hardening of the alloy -----	Balance	10

5. A hard metal alloy according to claim 4, containing from 15% to 35% of titanium carbide.

6. A hard metal alloy according to claim 4, in which up to 50% of the titanium carbide is replaced by one or more other metal carbides. 15

7. A method of producing a hard metal alloy consisting essentially of 10% to 75% by weight of hard metal consisting essentially of at least one metal carbide and from 25% to 90% by weight of a steel matrix containing free graphite, said method comprising: 20

mixing the at least one metal carbide and the components of the steel matrix together, forming pressings thereof, and

heating the pressings at the rate of 80° to 100° C. per hour to a sintering temperature of from 1000° to 1200° C., maintaining the thus-heated pressings at 25

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the sintering temperature for at least 4 hours, cooling the sintered pressings to between 750° and 850° C. at a rate of 30° to 50° C. per hour, and then further cooling the pressings to room temperature at the rate of 100° to 200° C. per hour.

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CARL D. QUARFORTH, Primary Examiner

B. HUNT, Assistant Examiner

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