

COMPOSITION OF PARTICULATE MATERIALS FOR FORMING SELF-LUBRICATING PRODUCTS IN SINTERED STEEL, PRODUCT IN SELF-LUBRICATING SINTERED STEEL AND PROCESS FOR OBTAINING SELF-LUBRICATING PRODUCTS IN SINTERED STEEL

5 Field of the Invention

The present invention refers to specific techniques for manufacturing finished products (pieces) and semi-finished products (several articles), conformed from a composition of particulate materials (in the form of
10 metallic and non-metallic powders) and which are designed to be sintered, said products comprising, besides the elements constitutive of the metallic structural matrix of the product to be formed during the sintering step, a precursor phase of a solid lubricant, in the particulate
15 form and which, by dissociation during the sintering step, generates precipitates of the solid lubricant in the volume of the metallic matrix, leading to the formation of the micro-structure of a self-lubricating product presenting a continuous metallic matrix and which
20 is capable of imparting, to the sintered products, a low coefficient of friction allied to high mechanical strength and high hardness of the sintered piece or product. The invention refers to said metallurgical composition for forming the self-lubricating material "in
25 situ" during the sintering, to the pieces or products in sintered steel obtained from said composition, as well as to the specific alternative techniques or processes for obtaining said pieces or products by powder metallurgy.

Background of the Invention

30 Given the advanced stage of technological development, there is a need for developing functional materials with high performance, which are specifically designed for each particular group of applications. In several mechanical engineering applications, a need exists for
35 materials that have, at the same time, high mechanical strength and high wear strength allied to a low coefficient of friction.

It is estimated that about 35% of the whole mechanical energy produced in the planet is lost by lubrication deficiency and is converted in heat by friction. Apart from the energy loss, the generated heat impairs the performance of the mechanical system due to the heating. Thus, maintaining a low coefficient of friction in mechanical pieces under friction is highly important, not only for energy economy, but also to increase the durability of said pieces and of the mechanical systems in which they operate, besides contributing to environment preservation due to decrease of discarding material.

The way being used to reduce wear and friction between surfaces in relative movement is to maintain these surfaces separated, interleaving a lubricating layer therebetween. Among possible lubricating ways, the hydrodynamic (fluid lubricants) is the most used. In the hydrodynamic lubrication there is formed an oil film which separates completely the surface in relative movement. However, it should be pointed out that the use of fluid lubricants is usually problematic, as in applications at very high or very low temperatures, in applications in which the fluid lubricant may chemically react and when the fluid lubricant may act as a contaminant. Besides, in situations of limit lubrication resulting from cycle stops, or in situations in which it is impossible to form a continuous oil film, there occurs the contact between the pieces, consequently causing wear to the latter.

The dry lubrication, that is, the one using solid lubricants, is an alternative to the traditional lubrication, since it acts by the presence of a solid lubricant layer, which prevents the contact between the component surfaces, but without presenting rupture of the formed layer.

The solid lubricants have been well accepted in problematic lubrication areas. They can be used in

extreme temperatures, under high-load conditions and in chemically reactive environments, where conventional lubricants cannot be used. Moreover, dry lubrication (solid lubricants) is an environmentally cleaner
5 alternative.

The solid lubricant may be applied to the components of a tribological pair, in the form of films (or layers) that are deposited or generated on the surface of the components or incorporated to the volume of the material
10 of said components, in the form of second-phase particles. When specific films or layers are applied and in case they suffer wear, there occurs the metal-metal contact and the consequent and rapid wear of the unprotected confronting surfaces and of the relatively
15 movable components. In these solutions in which films or layers are applied, it should be further considered the difficulty in replacing the lubricant, as well as the oxidation and degradation of the latter.

Thus, a more adequate solution which allows increasing
20 the lifetime of the material, that is, of the components, is to incorporate the solid lubricant into the volume of the material constitutive of the component, so as to form the structure of the component in a composite material of low coefficient of friction. This is possible through the
25 powder metallurgy techniques, that is, by the conformation of a powder mixture by compaction, including pressing, rolling, extrusion and injection molding, followed by sintering, in order to obtain a continuous composite material, usually already in the final geometry and dimensions (finished product) or in geometry and
30 dimensions close to the final ones (semi-finished product).

Self-lubricating mechanical components presenting low coefficient of friction, such as self-lubricating
35 bushings, are produced by powder metallurgy techniques from metallic powders which form the metallic structural matrix of the sintered piece and which are mixed with

solid-lubricant powders. Said components have been used in diverse household appliances and small equipment, such as: printers, electric shavers, drills, blenders, and the like. Most of the well-known prior art solutions for the structural matrix use bronze, copper, silver, and pure iron. There are used as solid lubricant: molybdenum disulfide (MoS_2), silver (Ag), polytetrafluoroethylene (PTFE) and molybdenum diselenide (MoSe_2). Bushings with these types of self-lubricating materials, mainly with bronze and copper matrix containing, such as solid lubricant particles, graphite powder, selenium and molybdenum disulfide and low melting point metals, have been produced and used for decades in several engineering applications.

However, these pieces do not present high mechanical strength, as a function of its high volumetric content (from 25% to 40%) of solid lubricant particles, which results in a low degree of continuity of the matrix phase, which is the micro-structural element responsible for the mechanical strength of the piece. This high content of solid lubricant has been considered necessary for obtaining a low coefficient of friction in a situation in which both the mechanical properties of the metallic matrix (strength and hardness) and the micro-structure parameters, such as the size of the solid lubricant particles dispersed in the matrix and the average free path between these particles in the formed composite material, are not optimized for applications in which the piece is required to have high mechanical strength. The high volumetric percentage of solid lubricant, which has an intrinsic low strength to shearing, does not contribute to the mechanical strength of the metallic matrix. Furthermore, the solid lubricant particles shear easily and alter their shape, as a function of shearing forces that occur during the steps of mechanically homogenizing the powder mixture (carried out in mixers) and compacting the mixture, reducing even

more the degree of continuity of the metallic structural matrix of the formed self-lubricating composite.

Moreover, the low hardness of the metallic matrix allows a gradual obstruction of the solid lubricant particles to occur on the contact surface of the sintered material or product. Thus, in order to maintain a sufficiently low coefficient of friction, there has been traditionally used a high volumetric percentage of solid lubricant in the composition of dry self-lubricating composite materials.

A partially differentiated and more developed scenario, as compared with that previously described, is disclosed in US6890368A, which proposes a self-lubricating composite material to be used at temperatures in the range between 300°C and 600°C, with a sufficient traction resistance ($R_m \geq 400\text{MPa}$) and a coefficient of friction lower than 0,3. This document presents a solution for obtaining pieces or products of low coefficient of friction, sintered from a mixture of particulate material which forms a metallic structural matrix and including, as solid lubricant particles in its volume, mainly hexagonal boron nitride, graphite or a mixture thereof, and states that said material is adequate to be used at temperatures in the range between 300°C and 600°C, with a sufficient traction resistance ($R_m \geq 400\text{MPa}$) and a coefficient of friction smaller than 0,3.

As described in the Brazilian patent application (provisional number 018080057518) filed on September 12, 2008, in the name of the same applicants of the present invention, pieces or products obtained from the consolidation of a powder mixture simultaneously presenting the structural matrix powders and the solid lubricant powders, such as for example, hexagonal boron nitride and graphite, have low mechanical strength and structural fragility after sintering.

The deficiency cited above results from the inadequate spread (dispersion), by shearing, of the solid-lubricant

phase between the powder particles of the structural matrix during the steps of mixing and conforming (densification) the pieces or products to be produced. The solid lubricant spreads, by shearing, between the

5 particles of the structural matrix phase, and tends to surround said particles during the mixing and conforming steps, which submit said solid lubricant to stresses which surpass its low shearing stress.

On the other hand, the presence of the solid lubricant

10 layer between the particles (of the powder) of the structural matrix, formed by shearing, impairs the formation of metallic contacts between these particles which form the structural matrix of the composite during the sintering; this contributes to a reduction of the

15 degree of continuity of the structural matrix phase of the composite material, structurally fragilizing the material and the obtained products.

Such problems can be mostly solved through solutions proposed in the prior Brazilian patent application

20 mentioned above, resulting in obtaining composite materials with mechanical strength greater than that of the prior art solutions.

However, in the solution proposed in said prior patent application of the same applicants of the present

25 invention, the non-metallic particulate solid lubricant, for example hexagonal boron nitride, graphite or both, has to be mixed to the metallic materials which form the structural matrix of the composite product to be sintered, further requiring the addition of at least one

30 particulate alloy element, so as to form, during the sintering step of the conformed metallurgical composition, a liquid phase between the particulate material which forms the structural matrix and the non-metallic particulate solid lubricant, in order to

35 agglomerate the latter in discrete particles and prevent the non-metallic particulate solid lubricant from spreading, by shearing, between the particles of the

structural matrix phase, tending to surround them during the steps of mixing and conforming (densification) the pieces or products to be produced, fragilizing the latter.

5 In face of the drawbacks cited above, it is desirable to provide a solution which does not require the previous mixing of the solid lubricant particles in the metallurgical composition to be sintered, nor the addition of an alloy element in the metallurgical
10 composition to form a liquid phase in the latter during its sintering.

Summary of the Invention

It is, therefore, an object of the present invention to provide a composition of particulate materials for
15 forming sintered steels, comprising a metallic structural matrix which permits, per se and during sintering thereof, forming a finished or semi-finished product in self-lubricating sintered steels with a high degree of continuity of the structural matrix and presenting high
20 mechanical strength and high hardness, with a fine distribution of a solid lubricant phase generated in the sintering.

It is likewise an object of the present invention to provide a product in self-lubricating sintered steel,
25 obtained from a conformation by powder compaction via pressing, rolling and others or by injection molding, followed by sintering the composition defined above, and which presents a high degree of continuity of the metallic structural matrix, a low coefficient of friction
30 and high mechanical strength and high hardness, with a fine distribution of a solid lubricant phase of graphite generated in the sintering.

It is also another object of the present invention to provide a process for obtaining products in self-
35 lubricating sintered steel, such as defined above, from said composition of particulate materials, said process including neither the previous mixture of solid lubricant

particles in the metallurgical composition to be sintered, nor the addition of an alloy element in the metallurgical composition to form a liquid phase in the latter during its sintering.

5 In a first aspect of the present invention, the objects cited above are attained through a composition of particulate materials for the manufacture of products in self-lubricating sintered steel, previously conformed by one of the operations of compacting and injection molding
10 said composition which comprises: the iron as the main particulate metallic material; at least one particulate alloy element, with the function of hardening the iron, forming therewith a ferrous structural matrix; and a non-metallic compound, precursor of a solid lubricant phase
15 of graphite to be formed in the product during the sintering.

In a way of carrying out the invention, the non-metallic particulate compound is a compound of the carbide or carbonate type including a chemical element which
20 stabilizes the iron alpha phase of the ferrous structural matrix. In another way of carrying out the present invention, the non-metallic particulate compound is deprived of any chemical element which stabilizes the iron alpha phase, thus being necessary to include, in the
25 metallurgical composition, an additional particulate alloy element which has the function of stabilizing the iron alpha phase.

In the present invention, there occurs the formation of graphite particles by dissociation of a precursor phase
30 during the sintering step of the pieces or products. As examples of precursor phases for carrying out the invention, it can be cited: silicon carbide (SiC), molybdenum carbide (Mo_2C), chromium carbide (Cr_3C_2), and the like. In the step of preparing the powder mixture
35 which will constitute the new composite material, carbides in the form of fine powder particles (preferably from 5 to 25 μm) are mixed to the iron powder (major

component) and other powders of alloy elements that are present in the powder mixture. The most indicated carbides to cause precipitation of graphite nodules in ferrous matrix, forming a self-lubricating sintered steel, are those which have in their formula a chemical element which can strongly stabilize the iron alpha phase, as for example, the element Si present in the silicon carbide (SiC). During the sintering step, that is, at the sintering temperature of the pieces or products, the silicon carbide (SiC) dissociates and the chemical element silicon becomes a solid solution in the iron, that is, in the ferrous structural matrix. As the dissociation of the SiC progresses, the amount of solubilized Si increases in the ferrous matrix in the surroundings of the SiC particles which are in dissociation. As can be verified in the iron-silicon equilibrium diagram, the chemical element silicon strongly stabilizes the iron alpha phase; the vertex of the loop $\alpha \longleftrightarrow (\alpha + \gamma)$ in Fe-Si diagram occurs for values of 2.15% by weight (4,2%at) of Si. Thus, during the sintering of the sintered steel, carried out typically between 1125°C and 1250°C, when the concentration of silicon solubilized in iron, around the SiC particle in dissociation, reaches the solubility limit of the gamma-phase, there occurs a transformation of the gamma-iron into alpha-iron. In the first instants of the SiC dissociation process, while the Si concentration does not reach the value required to stabilize the alpha-phase around the SiC particle in dissociation, the carbon resulting from the dissociation also becomes a solid solution and spreads to the interior of the matrix, but as soon as the ferrous matrix around the SiC particulate in dissociation is transformed into alpha-phase, the process for solubilizing carbon is interrupted because the solubility of carbon in the iron alpha phase is very low (maximum value is of 0.022% by weight at 727°C). Thus, the carbon released, as a

consequence of the carbide dissociation, forms graphite nodules, which are surrounded by a layer of alpha-iron, although the remainder of the matrix can continue presenting the gamma phase.

5 Brief Description of the Drawings

The invention will be described below, with reference to the enclosed drawings, given by way of example of embodiments of the invention and in which:

10 Figures 1A, 1B and 1C represent, sequentially and schematically, the evolution of the micro-structure during the sintering step, resulting from the dissociation of the carbide particles mixed with the iron powder (matrix), figure 1A representing the two-phase micro-structure of the material in the initial phase of
15 the process, in which the carbide particles are still intact, that is, the reaction has not yet initiated, whilst figure 1B represents the situation in which there has already occurred partial dissociation of the carbides and figure 1C shows the situation in which the
20 dissociation has already been completed;

Figure 2 shows, schematically, the desired ideal situation (microstructural model) for the distribution of the solid lubricant particles or nodules in the volume of a composite material, in steel, with low coefficient of
25 friction, allowing maintaining a high degree of continuity of the matrix of the composite material; in an ideal situation, the solid lubricant must be in the form of discrete particles or nodules uniformly distributed in the volume of the material, with a regular average free
30 path " λ " between the particles or nodules;

Figure 3 is a picture of the micro-structure of the material of the present invention in the already sintered state, after the dissociation of the carbide particles, showing the graphite nodules surrounded by a clear layer
35 which is formed by the alpha-phase, and the matrix of the composite material;

Figure 4 shows a detail of the graphite structure in the

interior of the nodule generated during the sintering, through a picture obtained with a high increase (of 20,000 X) in the scanning electron microscope with field emission gun (FEG-SEM), which evidences the structure in the form of graphite skins or flakes of nanometric thickness;

Figure 5 represents, schematically and in a simplified diagram, an example of compaction in the formation of a piece or product to be posteriorly sintered, said compaction being made so as to provide a self-lubricating layer in two opposite faces of the product to be sintered; this process should be used when it is desired only one self-lubricating layer in one or more faces of the sintered piece;

Figures 6A, 6B and 6C represent examples of products whose conformation is obtained by compaction carried out by extrusion, respectively, of a bar in a self-lubricating composite material, of a tube in a self-lubricating composite material, and of a bar with a core in metallic alloy coated with an outer layer with a self-lubricating material; and

Figure 7 represents, schematically and in a simplified diagram, an example of compaction in the formation of a piece or product to be posteriorly sintered, said compaction being made by rolling a self-lubricating composite material on the opposite faces of a plate or strip in metallic alloy.

Description of the Invention

As already previously mentioned, one of the objects of the invention is to provide a composition of particulate materials, which can be homogeneously mixed and conformed (densified) by compaction (pressing, rolling) or by extrusion or injection molding of powders, so that it may assume a defined geometry (piece) to be submitted to a sintering operation, in order to obtain a product which presents high hardness, mechanical strength and reduced coefficient of friction in relation to the products

obtained by the prior art teachings. The present composition comprises: a main particulate metallic material which is preponderant in the formation of the composition, and at least one particulate alloy element
5 with the function of hardening the preponderant material, these components being responsible for the formation of a structural matrix in the composite product, in steel, to be sintered; and a precursor particulate material which allows obtaining solid lubricant nodules upon its
10 dissociation during the sintering.

According to the invention and as illustrated in figure 2, the main particulate metallic material is iron, defining a ferrous structural matrix 10, and the precursor phases for generation of nodules 20 of solid
15 lubricant by dissociation during the sintering are compounds based on carbides or carbonates, preferably formed with chemical elements which stabilize the iron alpha phase in the ferrous structural matrix 10. When the precursor phase used does not have, in its composition, a
20 chemical element capable of stabilizing the iron alpha phase in the ferrous matrix 10, a specific additional alloy element in a sufficient amount to stabilize the iron alpha phase should also be added to the composition of the material of the present invention.

25 The alloy element with the function of hardening the ferrous structural matrix is defined, for example, by one of the elements selected from chrome, molybdenum, carbon, silicon, phosphorus, manganese and nickel, but it should be understood that one can use other elements, such as
30 vanadium and copper, which carry out the same function in the structural matrix, as well as more than one alloy element at the same time. It should be noted that the invention requires the provision of an alloy hardening element which may carry out the function of hardening the
35 ferrous structural matrix to be formed during the sintering, by interdiffusion of the components (chemical homogenization), but this aspect should not be limited to

the alloy elements exemplified herein.

Figures 1A, 1B, 1C and 2 show, schematically, several steps of the evolution of the micro-structure of the composite as a function of the dissociation of the carbide (SiC) during the sintering. Figure 3 shows a picture, obtained by optical microscopy, of the micro-structure of the composite material formed after its sintering, and figure 4 shows the structure of the precipitate graphite presenting, in the interior of the nodules, the form of "skins or leaves" of nanometric thickness. This structure favors the formation of a tribological layer on the interface of the relative moving surfaces of the tribological pair, increasing the efficiency of the solid lubrication.

The parallel addition of other alloy elements, which stabilize the iron alpha phase in the powder mixture which will form the composite, accelerates the rising of the alpha phase in the matrix during the sintering operation, increases the tendency to generate graphite nodules 20 by dissociation of carbide particles mixed in the volume of the material.

The alloy elements which stabilize the iron alpha phase and coming from the carbide dissociation, besides preventing the carbon from solubilizing in the matrix, since they form a layer of alpha phase 12 around the particle 11 in dissociation, they also contribute to increase the hardness of the matrix when in solid solution; nevertheless, if the hardness increase reached by the presence of these alloy elements in solid solution in the iron is not sufficient, other alloy elements should be additionally added to the powder mixture, so as to be solubilized in the matrix during the sintering operation, aiming at achieving the hardness and mechanical strength necessary for the application.

Thus, in the present invention, the metallic structural matrix of the material is formed by iron automatically hardened by a solid solution with the alloy elements

which stabilize the iron alpha phase, as for example, silicon and molybdenum dissolved in the ferrous matrix as a consequence of the dissociation of the carbides mixed to the iron powder in the processing of the material by powder metallurgy.

Besides these necessarily present stabilizing alloy elements, other alloy elements might be added to the powder mixture with the function of adjusting the mechanical strength and the hardness of the matrix, allowing reaching a high performance in relation to the tribological and mechanical behavior of the dry self-lubricating composite material generated during the sintering. As examples of other alloy elements, advantageously used in the present invention, to increase the mechanical strength and the hardness of the matrix, besides the Si, Mo, and P elements, which are strong stabilizers of the iron alpha phase, there can be cited the elements Cr, Ni, Mn, W, V, and C.

As to the types of carbides used, the powder mixture composition, which is formulated for the production of products by powder metallurgy in the present invention, is formed by two distinct alternatives:

Alternative 1: Iron powder + particles of carbide powder which are formed by chemical elements which stabilize the iron alpha phase (mixed in a volumetric percentage $\leq 10\%$), which, at the sintering temperature, generate graphite nodules upon dissociation thereof, + powder particles of other chemical elements called alloy elements, which have the function of increasing the hardness and the strength of the ferrous structural matrix;

Alternative 2: Iron powder + carbide powder particles which are not formed by chemical elements which stabilize the iron alpha phase (mixed in a volumetric percentage $\leq 10\%$), + powder of alloy elements which stabilize the iron alpha phase which has the function of stabilizing the alpha phase of the ferrous matrix, in order to prevent

the carbon coming from the carbide dissociation from being dissolved by the ferrous matrix, + other alloy elements which are present for adjusting the mechanical properties of the structural matrix of the composite.

5 Since the metallic ferrous structural matrix 10 is the sole micro-structural element of the composition that confers mechanical strength to the composite material to be formed, the higher the degree of continuity of the matrix of said composite, the higher will be the
10 mechanical strength of the sintered article or piece produced with the material. The maintenance of the high degree of continuity of the metallic structural matrix of the dry self-lubricating sintered composite material requires, besides a low porosity, a low volumetric
15 percentage of the solid lubricant phase, since the latter does not contribute to the mechanical strength of the material and, consequently, does not contribute to the mechanical strength of the sintered products. Besides, the solid lubricant which is present in the volume of the
20 material should be dispersed in the form of discrete particles or nodules 20, uniformly distributed in the volume, that is, with a regular average free path " λ " in the interior of the ferrous structural matrix 10 (see figure 2). This permits generating greater lubrication
25 efficiency and, at the same time, guarantees a higher degree of continuity of the matrix, which on its turn guarantees a higher mechanical strength to the composite material.

The metallic matrix of the material is required to be
30 highly resistant to plastic deformation, in order to operate not only as a mechanical support with the necessary load capacity, but also to prevent the solid lubricant particles from being covered by plastic deformation of the structural matrix, upon operation of
35 the piece (when frictioned in relative movement), preventing the solid lubricant from spreading in the interface where it should form a layer of solid

lubricant.

According to the invention, the additional alloy component, which stabilizes the iron alpha phase, is defined by at least one of the elements selected from
5 phosphorus, silicon, cobalt, chrome and molybdenum. Although these elements are considered the most adequate to separately or jointly act in stabilizing the iron alpha phase at sintering temperatures (about 1125°C to about 1250°C), it should be understood that the invention
10 resides in the concept of stabilizing the iron alpha phase, in order to impair the carbon dissolution, and not in the fact that the alloy component(s) used are necessarily the ones exemplified herein.

When the composition of the invention is conformed by
15 compaction, the main particulate metallic material (iron) presents, preferably, an average particle size lying between about 5 μm and about 90 μm . On its turn, the hardening element, with the function of hardening the structural matrix, and the precursor component of the
20 solid lubricant phase (compound) should present a particle size preferably smaller than about 45 μm ; it should be further understood that the average particle size of the main particulate metallic material, that is, of the iron, should be always larger than the average
25 particle size of the alloy elements and the precursor components (compounds) of the solid lubricant phase.

When the composition of the invention is conformed by injection molding, the main particulate metallic material (iron) presents, preferably, a particle size lying
30 between about 5 μm and about 25 μm . In the same way, the alloy elements and the precursor components (compounds) of the solid lubricant phase present, preferably, a particle size also between about 5 μm and about 25 μm .

When the conformation of the composition, previous to the
35 sintering, is carried out by extrusion or by injection molding, the composition should further comprise at least one organic binder selected preferably from the group

- consisting of paraffin and other waxes, EVA, and low melting point polymers in a proportion generally ranging from about 15% to about 45% of the total volume of the metallurgical composition, upon the conformation by extrusion, and from about 40% to 45%, upon the conformation by injection molding. The organic binder is extracted from the composition after the conformation step, for example by evaporation, before the conformed product is conducted to the sintering step.
- 10 The compositions described above are obtained by mixing, in any adequate mixers, predetermined quantities of the particulate materials selected for the formation of the composition and for the subsequent obtention of a self-lubricating sintered product.
- 15 The mixture of the different particulate materials is homogenized and submitted to a densification operation by compaction, that is, by pressing or rolling, or also by molding by extrusion or injection of powders, obtaining in this operation, not only the densification of the powder mass, but also the desired shape for the product to be obtained by sintering.
- 20 In case of conformation by powder molding by extrusion or injection, the mixture of the components containing the organic binder is homogenized at temperatures not inferior to the melting temperature of the organic binder, the thus homogenized mixture being granulated to facilitate its handling, storage and supply to an injection machine.
- 25 After conformation of the piece, this is submitted to the extraction of the organic binders, generally carried out in two steps, the first step being a chemical extraction process in solvents (for example, hexane) and the second step being an extraction process by thermal degradation, or a CD plasma assisted thermal process.
- 30 With the composition proposed herein, it is possible to obtain self-lubricating sintered pieces or products with hardness from 230 HV to 700 HV, a coefficient of friction

$\mu \leq 0.15$, a mechanical traction resistance from 350 to 750 MPa (depending on the alloy elements which are present and on the processing parameters used) and also with a dispersion of amorphous carbon nodules with the inner structure in the form of skins with nanometric thickness, which facilitates the spreading of the graphite in the interface of the movable surfaces, forming a solid lubricant layer.

Figures 5, 6A, 6B, 6C and 7 of the enclosed drawings have the purpose of exemplifying different possibilities of conforming the present composition, by compacting a certain predetermined quantity of the composition to any desired shape, which can be that of the self-lubricating sintered final piece or product desired to be obtained, or a shape close to that desired final one.

However, in a large number of applications, the self-lubricating characteristic is necessary only in one or more surface regions of a mechanical component or piece to be submitted to a friction contact with other relatively movable element.

Thus, the desired self-lubricating product can be constituted, as illustrated in figure 5, by a structural substrate 30 preferably conformed in a particulate material and receiving, in one or two opposite faces 31, a surface layer 41 of the composition 40 of the present invention. In the illustrated example, the structural substrate 30 and the two opposite surface layers of the composition 40 are compacted in the interior of any adequate mold M, by two opposite punches P, forming a compacted and conformed composite product 1, which is posteriorly submitted to a sintering step. In this example, only the two opposite faces 31 of the structural substrate 30 will present the desirable self-lubricating properties.

Figures 6A and 6B exemplify products in the form of a bar 2 and a tube 3, respectively, obtained by extrusion of the composition 40 in an adequate extrusion matrix (not

illustrated). In this case, the conformation by compaction of the composition 40 is carried out in the extrusion step of the latter. The bar 2 or tube 3 can then be submitted to the sintering step, for the formation of the iron-based structural matrix 10 and incorporating discrete dispersed and particles of the particulate solid lubricant 20.

Figure 6C illustrates another example of product formed by a composite bar 4, comprising a structural core 35, in a particulate material and which is circumferentially and externally surrounded by a surface layer 41 formed from the composition 40 of the invention. Likewise in this case, the conformation and the compaction (densification) of the structural core 35 and of the outer layer 41 in the composition 40 are obtained by co-extrusion of the two parts of the composite bar 4, which is then submitted to the sintering step.

When the compaction of the composition 40 is carried out by extrusion, as it occurs, for example, in the formation of the bars 2, 3 and 4 of figures 6A, 6B and 6C, said composition can further comprise an organic binder which is thermally removed from the composition, after the conformation of the latter and before the sintering step, by any of the known techniques for said removal.

The organic binder may be, for example, any one selected from the group consisting of paraffin and other waxes, EVA, and low melting point polymers.

Figure 7 represents, also schematically, another way to obtain a composite product in sintered steel presenting one or more surface regions having self-lubricating characteristics. In this example, the product 5 to be obtained presents a structural substrate 30 formed in a particulate material, previously conformed in the form of a strip, it being noted that, on at least one of the opposite faces of the structural substrate 30, in a continuous strip, there is rolled a surface layer 41 of the composition 40 of the present invention. The

composite product 5 is then submitted to a sintering step.

While the invention has been presented herein by means of some examples of possible compositions and associations with different structural substrates, it should be understood that such compositions and associations can suffer alterations that will become evident to those skilled in the art, without departing from the inventive concept of controlling the distribution, in discrete particles, of the solid lubricant in the structural matrix, and also of the eventual tendency of said solid lubricant to dissolve in said matrix, during the sintering step, as defined in the claims that accompany the present specification.

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CLAIMS

1. A composition of particulate materials for forming self-lubricating products in sintered steel, conformed by powder compaction or injection molding, characterized in that it comprises: iron as a main particulate metallic material; at least one particulate alloy element, with the function of hardening the iron, forming therewith a ferrous structural matrix; a non-metallic particulate compound, precursor of a solid lubricant phase of graphite to be formed in the composite product during the sintering, wherein the non-metallic particulate compound is a compound of the carbide or carbonate type; and an additional particulate alloy element, which stabilizes the iron alpha phase of the ferrous structural matrix, defined by at least one of the elements selected from silicon, phosphorus, cobalt, molybdenum and chrome, wherein, when the composition being conformed by powder compaction (pressing, rolling, double pressing or compaction), the particles of the main particulate metallic material (iron powder) present an average size lying between 5 μm and 90 μm , the particles of the particulate alloy element with the function of hardening the iron, and the particles of the non-metallic particulate compound present a size smaller than 45 μm , and when the composition being conformed by injection molding, the main particulate metallic material (iron powder) as well as the particulate alloy element and the non-metallic particulate compound present a particle size lying between 5 μm and 25 μm .

2. The composition, as set forth in claim 1, characterized in that the non-metallic particulate compound, includes, in its composition, a chemical element which stabilizes the iron alpha phase of the ferrous structural matrix.

3. The composition, as set forth in claim 2, characterized in that the chemical element which stabilizes the iron alpha phase is selected between silicon carbide, molybdenum carbide and chromium carbide.

5

4. The composition as set forth in claim 1, characterized in that, when the composition is conformed by injection molding, the composition comprises at least one organic binder.

10

5. A product in self-lubricating sintered steel, obtained from a composition of particulate materials, as defined in any of claims 1-4 and submitted to a conformation previous to the sintering, characterized in that it presents a hardness between 230 HV and 700 HV, a coefficient of friction $\mu \leq 0.15$ and a traction resistance between 350 and 900 MPa.

6. A process for obtaining self-lubricating products in sintered steel, from the composition of particulate materials as defined in claim 1, characterized in that it comprises the steps of:

- mixing, in predetermined quantities, the particulate materials which define the metallurgical composition;
- homogenizing the particulate material mixture;
- compacting the particulate material mixture, so as to provide the mixture with the shape of the product to be sintered;
- sintering the compacted and conformed mixture, at temperatures from 1125°C to 1250°C, forming, during the sintering, graphite nodules by the dissociation of the precursor compound in the volume of the structural matrix.

7. The process, as set forth in claim 6, characterized in that the step of compacting the particulate material mixture, which defines the composition, comprises

rolling the latter in a plate or strip to be subsequently sintered.

8. The process, as set forth in claim 6, characterized in
5 that the step of compacting the particulate material
mixture, which defines the composition, comprises
rolling the latter on at least one of the opposite faces
of a structural substrate in the form of a plate or
strip of particulate material compatible with the main
10 particulate metallic material which forms the structural
matrix.

9. The process, as set forth in any of claims 7 or 8,
characterized in that it comprises, after the sintering
15 of the particulate materials, the additional step of cold
rolling the plate or strip for reducing the residual
porosity, followed by an eventual annealing.

10. The process, as set forth in any of claims 7 or 8,
20 characterized in that the step of compacting the
particulate material mixture, which defines the
composition, comprises the extrusion in one of the
shapes defined by a bar and a tube.

25 11. The process, as set forth in claim 6, characterized
in that the step of compacting the particulate material
mixture, which defines the composition, comprises
the extrusion of the latter in the form of a tubular
sleeve around a structural core in the form of
30 a bar of particulate material compatible with the main
particulate metallic material which forms the structural
matrix, so as to form a composite bar.

12. A process for obtaining self-lubricating products in
35 sintered steel, from the composition of particulate
materials, as defined in claim 4, and characterized in
that it comprises the steps of:

- mixing, in predetermined quantities, the particulate materials which define the metallurgical composition;
- homogenizing the particulate material mixture, at a temperature not inferior to that of melting the organic
5 binder;
- granulating the composition to facilitate its handling, storage and supply into an injection machine;
- injection molding the particulate material mixture, so as to provide the mixture with the shape of the product
10 to be sintered;
- extracting the organic binder from the molded piece; and
- sintering the pieces obtained by conformation of the powders, at temperatures from 1125°C to 1250°C.