ABSTRACT: The disclosure relates to utilization of metallic shavings, usually regarded as waste. The shavings are compressed to billets and extruded. Prior to extrusion the shavings and/or the billets may be annealed. To control composition the shavings may be mixed with particular powder at selected ratios prior to compression.
METHOD FOR MANUFACTURING COMPACTED TUBES AND RODS

The present invention relates to a method for manufacturing elongated workpieces such as pipes, tubes, rods, wire, at nonporous consistency but having relatively high density, utilizing metallic particles such as flaky and coarsely fibrous raw material.

In this specification the term "flake" refers to particles having a width which is larger than the thickness and an extension at least as large as the width. Usually, however, the length of such a particle is considerably larger than the width. An example of flakes within this definition is, for example, metallic cuttings as they are produced during operations such as boring, drilling, planing, lathing, sawing or the like. Such flakes are created as a waste, particularly when compact or porous objects made of metal powder are worked in that matter.

The term "fiber" is used here to denote particles having a length which is large in relation to its cross-sectional dimensions, whereby the cross section may be round, oval, square shaped, or the like. Examples of fibers within that definition are, for example, fine sawdust, sawmill waste, filings, or the like. Also, within the definition "fibers" powder particles of elongated grain shape or wire cuttings are included.

The surfaces of the flakes and fibers can be rough and cracked, i.e., smoothness is not a prerequisite for practicing the invention. All these types of particles together will, in the following, be collectively called "shavings."

During cutting operations such as lathing, sawing, drilling, of high alloy steel blocks large quantities of shavings are produced. The economic value of the thus subdivided material, on a unit weight basis, is considerably lower than the value of a compact piece. Steel mills usually do not like to process loosely packed shavings because of comparatively large volume requirements and because a considerable amount will be lost through burning. In other words, the value of such shavings as raw material for a melting process is quite low.

There, therefore, a need to prepare such shavings prior to further utilization, and in particular, the shavings should be presented in a more suitable overall configuration prior to being fed to smelting equipment. It has been suggested, for example, to simply compress the shavings so as to form blocks, briquettes, or the like, and to charge the melting furnace with such blocks or briquettes or to burn them. Of course, the volume of such compressed and compacted shavings as compared with loose piling thereof, is considerably lower.

In accordance with other suggestions, the shavings are compressed, sintered and hot pressed. However, manufacturing of higher grade products such as rods, or pipes at nonporous compacted consistency has not been tried successfully prior to the present invention. Particularly shavings which contain chromium have been regarded as being essentially useless and impossible to be recompacted to form any high-grade nonporous workpieces.

It is an object of the present invention to manufacture articles which have compact density and are essentially nonporous, using such shavings as the raw material. It is a particular object of the invention to manufacture high-grade products using the rather economically available shavings. It is another object of the invention to control the composition of the manufactured product so that the composition of the shavings used may differ from the composition of the final product. Upon practicing the invention it was found that frequently the resulting product had properties which were superior to comparable properties of the material from which the shavings were gained originally through working thereof.

In accordance with the present invention a method which includes the following steps is suggested. At first the shavings are compressed to form blocks or billets, preferably cylindrical billets, and the density of the material of the resulting product should be superior to the relative density is about 60 to 80 percent of the solid material. Subsequently, the billets are heated and extruded at a temperature above the recrystallization temperature, whereby workpieces at the desired profiles are obtained. For example, rods, tubes or the like can be extruded, whereby the final cross section should be not more than one-third of the original cross section. Heating and extrusion is carried out in an environment free from oxygen and the influx of oxygen is to be avoided. The products resulting from the extrusion are subsequently worked in a manner known, per se, to obtain, for example, wire or tubes having smaller dimensions.

The steps outlined in the previous paragraph constitutes the basic method, however, in cases the following steps should be included. The compressed, but still porous billets, are heat treated prior to extrusion. In case the particular material has oxides which are easily reducible, such as nickel, copper or soft iron; the billets are preferably annealed just in the presence of a reducing gas such as hydrogen. However, if the shavings consist of or include a material the oxide of which is rather difficult to reduce, such as chromium, then the annealing is carried out essentially in a vacuum but in the presence of a reducing medium. The reducing medium is usually carbon and should be present in sufficient quantities in the compressed porous billets. After reduction has been completed, it may be desirable to provide further reaction particularly by exposing the billets to an all-enveloping and penetrating gas. Thus, the blocks can, for example, be recarbonized or nitrided.

In preparation for carrying out the principal steps in accordance with the invention, it is preferred to collect the different shavings separately as to quality. In case the collected shavings include nonmetallic impurities, such as sand, a cleaning process should precede the compounding steps. The shavings are preferably cleaned in a liquid which also desorbs them. Impurities and dirt particles sticking to the surface of the shavings are dissolved and/or separated and drop to the bottom of the tank containing the cleaning liquid. This cleaning process, however, can be dispensed with if the impurities consist exclusively of substances which will vaporize or decompose at elevated temperatures within the range used for subsequent processing. This holds true particularly for grease and oil.

Still prior to compressing the shavings it may be advisable, but not always absolutely necessary, to anneal them in air so that they oxidize. For example, steel shavings known as 18/8 chromium nickel steel, are preferably annealed for 10 minutes in a temperature of 800 to 1,000 °C. It must be observed that during the work process, as the shavings were produced, the substance constituting the shavings was considerably hardened. This annealing step reverses, so to speak, that hardening, and thus facilitates further processing. The surface oxidation resulting from annealing the shavings in air has the following purpose. Subsequently, as the oxide layer is reduced, the shavings obtain smooth surface contours which are highly susceptible to reaction and sintering.

In accordance with another feature of the invention the composition of the final product can be controlled in that the shavings are mixed with a metal powder, whereby the relative powder content may go up to 80 percent, preferably, however, a range of 20 to 60 percent is used. The powder should have a grain size smaller than 2 mm. Shavings and metal powder are preferably mixed by including a substance which inhibits separation. The substance should have a certain stickiness to provide some bonding between powder particles and shavings. For example, stearic acid, molasses, or the like, can be used.

In principle, the powder may consist of the same material as the shavings, for example, copper, nickel, soft iron, or the like. However, the composition of the added powder may well be quite different from the composition of the shavings. These differences may relate to the material in its entirety or merely as to alloying components and/or the relative content thereof. Thus, the powder may serve to establish particular proportional ratios of the various components in the final product. This is particularly desirable if the final product is to consist of high-alloy steel. Wire cuttings could be added to the shavings in lieu of powder but for the same purpose.

The adding of powder generally opens numerous possibilities for controlling the relative content of the various com-
components in the final product. As stated, shavings and powder may differ as to the proportion of the element components, whereby, for example, even minor relative differences in the proportion of various alloying components in shavings and powder permit rather accurate adjustment of the composition of the final product. It was in shavings powder permit that, for example, high-alloy tubes or welding rods could be produced in this manner as very accurate metering of the constituents is permitted.

The invention is not limited to making this type of product. Moreover, shavings and powder may have quite different composition. In the following, several different examples are outlined with particularity to show versatility of the principles of the invention.

**EXAMPLE 1**

Flaky shavings were collected after rods had been sawed; the rods in particular consisted of 18/8 chromium nickel steel. The shavings were cleaned in a degreasing liquid and subsequently compressed to cylindrical billets of 58 mm. diameter and approximately 100 mm. in height. The billets were pressed in a steel mold. After compression the billets had a specific weight of 5.3 grams per cubic cm. and a relative density of 67 percent. These billets were lined and welded in a soft iron coating. The clad billets were extruded at 1,200° C. to produce rods with substantially no porosity.

**EXAMPLE 2**

This example includes essentially all steps outlined above. Shavings resulting from lathing of 18/8 chromium nickel steel billets were collected and cleaned in a degreasing liquid. The shavings were subsequently annealed in air for 10 minutes at 900° C. to form an oxide coating. Independently therefrom a powder was produced by atomizing steel having 18 percent chromium and 8 percent nickel. The oxidized shavings and the powder were mixed at a ratio of 70 percent shavings to 30 percent powder. The carbon and oxygen contents of the mixture had a ratio of approximately 1 to 1.3. Next, this mixture was compressed in a steel form to produce cylindrical billets of 58 mm. diameter and approximately 100 mm. height.

The billets had a specific weight of approximately 5.6 grams per cubic cm. and a relative density of approximately 31 percent. These billets were annealed in a vacuum furnace for about 10 hours at 1,250° C. at a pressure of approximately 10⁻⁴ torr. (mm. mercury). In order to protect the billets from oxidation, they were lined with a soft iron coating and welded. Finally, tubes were extruded from the billets at 1,200° C. The tubes had essentially no porosity and a carbon content of approximately 0.04 percent.

In the following examples the method steps are the same as in **EXAMPLE 2**, but the components differ.

**EXAMPLE 3**

The mixture employed consisted of 20 percent shavings of soft iron; 30 percent shavings of steel having 25 percent chromium and 20 percent nickel; 20 percent shavings of steel having 8 percent chromium, 23 percent steel powder with 36 percent chromium and 5 percent nickel powder. Extruded rods had a chromium content of approximately 18 percent and a nickel content of approximately 11 percent; the rods had heticogen grain structure.

Of course, the invention can also be employed by using shavings of nonferrous metal, for example, copper or nickel, or nonferrous alloys. The invention also permits production of products with uniformly distributed inclusions, for example, carbides, oxides, and nitrides. The invention is furthermore amenable to employment of those types of materials which include small portions of rather easily oxidizing metal such as aluminum. For example, the inventive method can be used to extrude rods of a chromium-aluminum steel to be used as heating element having 5 to 6 percent aluminum. The finely distributed aluminum oxide improves heat resistance and creep strength. Moreover, aluminum oxide inhibits formation of coarse grains.

The invention is not limited to the embodiments described above, but all changes and modifications thereof not constituting departures from the spirit and scope of the invention are intended to be included.

1. Method of making compacted, essentially nonporous workpieces such as rods or pipes of high density, comprising the steps of:

   1. Providing metal powder, including shavings containing a substantial amount of chromium;
   2. Compressing said shavings into form billets at a relative density of 60 to 85 percent; and
   3. Annealing the billets essentially in a vacuum and in the presence of a reducing medium such as carbon;

   4. Extruding workpieces from the annealed billets at a temperature above the recrystallizing temperature of the shavings while protecting the billets against oxidation.

2. The method as set forth in claim 1, including the steps of providing a metal powder having composition different from the shavings, and mixing powder and shavings at a particular selected ratio to control composition of the extruded workpiece.

3. A method as set forth in claim 1, and including the step, preceding the compressing of the shavings, of cleaning the shavings.

4. A method as set forth in claim 3, the cleaning step including subjecting the shavings to a degreasing liquid.

5. A method as set forth in claim 1, the shavings being provided from materials of different composition.

6. A method as set forth in claim 1, and including the step of mixing different metal powders with the shavings.

7. A method as set forth in claim 1, and including the step of mixing the shavings with wire cuttings.

8. A method as set forth in claim 7, the wire cuttings originating from wires of different material.

9. The method as set forth in claim 1, and including the step of mixing the shavings with a metal powder, the metal powder constituting up to 80 percent of the mixture.

10. The method as set forth in claim 9, and including the step of heat treating the shavings while exposed to air prior to mixing with powder.

11. A method as set forth in claim 1, and including the additional step of oxidizingly annealing the shavings prior to compressing.

12. A method as set forth in claim 1, and including the step of mixing the shavings prior to compressing with metal powder in a relationship of 20 to 60 percent metal powder.

13. Method as in claim 1, the providing step comprising the providing of chromium-aluminum steel shavings, and annealing.

**EXAMPLE 4**

The shavings-powder mixture consists of 50 percent shavings of an unalloyed soft iron and 50 percent steel powder with 36 percent chromium and 16 percent nickel. Rods extruded from billets of such mixture exhibit heterogeneous structure of highly stretched ferrite and austenite grains, they are also quite ductile.
the shavings at a temperature of about 800° to 1,000° C. prior to compression, to obtain oxide coating on the shavings.

14. Method as in claim 13, including mixing the annealed shavings with a steel powder of differing chromium nickel content.