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RINGS IN COMPACTING MILLS

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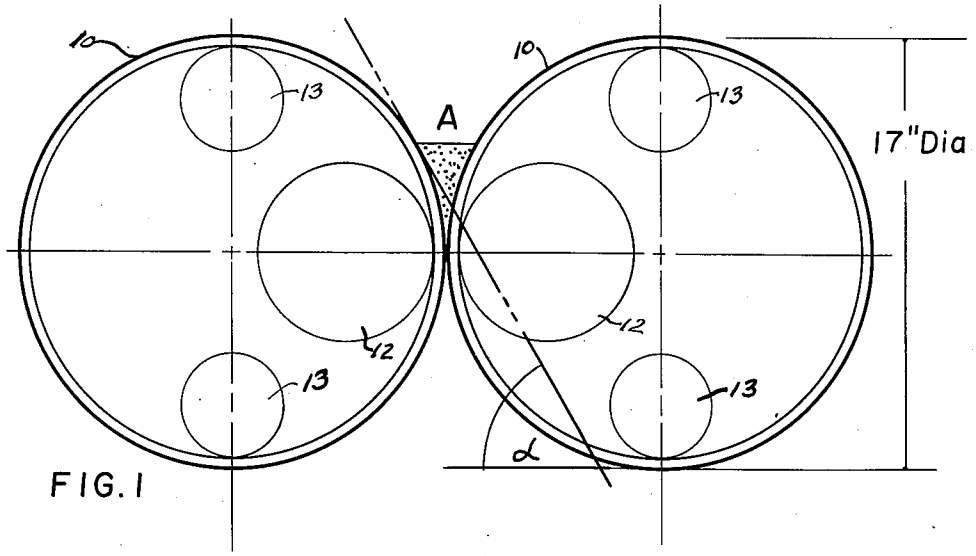


FIG. 1

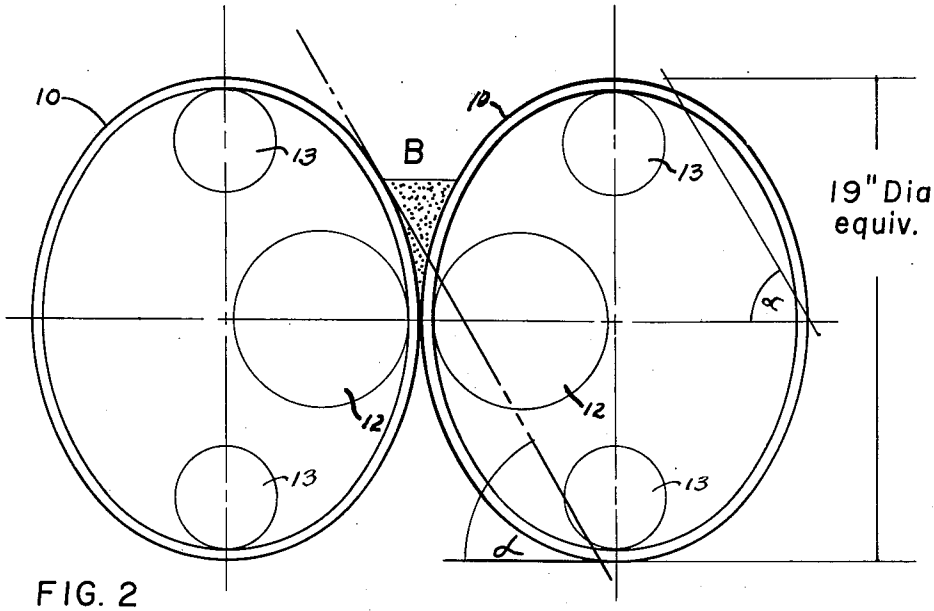


FIG. 2

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RINGS IN COMPACTING MILLS

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The present invention relates to the compacting of pulverulent material and more particularly to the compacting of pulverulent material to produce strip of varying thicknesses.

It is well known that powder or pulverulent material can be formed into strip by feeding the powdered material into the nip between oppositely, laterally disposed rolling surfaces. This direct rolling process is a versatile method for producing strip in a wide variety of materials that possesses certain advantages over the conventional method of producing strip, to wit, melting, casting and then rolling. For instance, certain brittle alloys cannot be made into strip by the ordinary methods. In addition, the direct rolling process has the advantage of being continuous as well as requiring a minimum of expensive equipment, e.g. melting furnaces, etc.

In this direct rolling powder process, the rate of production of the strip is dependent upon a number of variables such as morphology of the powders comprising the powder feed, rate of the feed of the powders to the rolling surface and the speed of the rolls. With regard to the morphology of the particles it has been found that irregularly shaped particles are the most advantageous, e.g., carbonyl nickel powder. With regard to the other listed variables, it is to be noted that an increase in the speed of the rolls does not necessarily cause an increase in the production rate of the strip. It has been proposed that a cause of this unfortunate development is the interference to the powder feed at the roll gap of escaping entrapped air. One method which has been found to mitigate the deleterious effects of the entrapped air during compacting is to replace the air by substituting a less viscous gas therefor, such as hydrogen and a full discussion of the advantages which accrue is to be found in application Serial No. 675,110, now U.S. Patent No. 2,987,778, issued June 13, 1961. However, limitations to the thickness of the strip obtainable are still existent and this is equated with the diameter of the rolls used to effect compaction. When metal powder, for instance, is formed into a continuous compacted strip by rolling, it is found that for a strip of given density the maximum thickness of the strip obtainable depends upon the diameter of the rolls which are used for compaction. Thus, for example, when carbonyl nickel powder is rolled into strip it is found that rolls having a diameter of 8" cannot produce a strip thicker than about 0.035", and further, that the maximum thicknesses of the strip produced by rolls having a diameter of 24" is of the order of 0.1". Now, in order to produce a strip of ¼" thickness by means of conventional rolls the diameter would need to be of the order of about 5 feet and the plant would necessarily be expensive and of great size. In addition, it is difficult and cumbersome to recove one set of rolls and substitute rolls of different diameter when the thickness of strip to be produced is changed substantially.

Although many attempts were made to overcome the foregoing difficulties and other disadvantages, none as far as we are aware was entirely successful when carried into practice on an industrial scale.

It has now been discovered that strip of varying thicknesses can now be produced by the direct rolling of particulate material from a single set of compacting surfaces having special characteristics and without the need for changing rolls.

It is an object of the present invention to provide a novel device for compacting pulverulent material to form strip in a wide range of thicknesses.

It is a further object of the present invention to provide compacting apparatus having a readily variable nip and/or gripping zone.

The invention also contemplates providing a new and novel method for producing strip from powdered ingredients in a number of thicknesses.

Other objects and advantages will become apparent from the following description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a diagrammatic cross sectional view of a compacting apparatus within the contemplation of this invention.

FIGURE 2 is a diagrammatic cross sectional view of identical compacting apparatus of FIG. 1 in which the flexible rolls are distorted from the free state.

Generally speaking, the present invention contemplates apparatus for compacting pulverulent material, such as powdered metals and/or alloys, non-metallics, refractory oxides, etc., comprising a unique pair of oppositely disposed members adapted to compact pulverulent material as the material is fed therebetween, as from a hopper. The apparatus also includes, in general, means for feeding powder to the compacting members and means for actuating the compacting members. At least one, and advantageously both, of said unique pair of members is substantially cylindrical in shape and is hollow but self-sustaining, i.e. it is capable of maintaining its shape without substantially bending due to its own weight. In addition, the hollow member is characterized by a continuous, flexible, resilient metal-compacting surface having a substantially regular, curvilinear cross-sectional shape, e.g., circular elliptical etc. A feature of the hollow member is that it is capable of having its radius of curvature varied by the application of force and yet is sufficiently resilient to return to its substantially cylindrical shape upon release of the force. This special feature of the hollow member, i.e. having a radius of curvature that may be varied, enables the production of strip of varying thicknesses without the need for changing and/or replacing the compacting members. At least one of the oppositely disposed members is provided with direct and/or indirect means for driving the member in frictional contact with the pulverulent feed to be compacted. In order to vary the radius of curvature of the hollow member, which in turn causes a change in the gripping zone, means are employed for distorting and/or deforming the hollow member within its elastic limit.

The gripping zone is the zone at which the compacting surfaces begin to positively drive the powder feed through the gap between the compacting surfaces. It can be determined physically by feeding the powder onto the compacting surfaces, then stopping the apparatus and gently blowing away the uncompacted powder. The angle of nip or the angle of friction hereinafter specified as the angle $90-\alpha$ is variable but has only one value for a given set of rolls and any particular pulverulent material.

The employment in the compacting apparatus of a hollow member having a metal compacting surface possessing in combination the properties of continuity, flexibility and resiliency and self-sustenance has numerous advantages. For example, a continuous metal compacting surface has the advantage of allowing a continuous compacting operation. Secondly, the flexibility of the compacting surface allows the surface to be distorted and/or deformed without cracking. This characteristic of being deformable is particularly advantageous as strip of varying thicknesses can then be produced with the same compacting member since its radius of curvature adjacent the roll gap is variable depending on the amount of distor-

tion. In addition to the foregoing, another important advantage of the hollow member in the rolling apparatus contemplated by this invention is its resiliency and self-sustenance since such a member is capable of constantly applying substantial compacting pressure to the gripped feed.

As was mentioned hereinbefore, the hollow member of this invention has a closed curvilinear cross-sectional shape deformed from the circular. The attendant advantage to this deformed curvilinear cross-sectional shape is that two of such compacting surfaces define a cusp-like contour between them and, thus, the surfaces remain in closer relationship for longer distances during compacting. In addition, when hollow members are deformed so that in operation the compacting surfaces follow an elliptical or quasi-elliptical path, for example, the longer axes of which are substantially parallel to the direction of flow of powder between the rolls, the effective volume of the gripping zone of the rolling members is increased as compared to the gripping zone of the undeformed rolling members.

In carrying the invention into practice it is advantageous to employ in a rolling mill as the compacting apparatus two mounted hollow rolls (which in their free state are cylindrical) having their axes parallel and so arranged to define a nip between them. The hollow rolls are flexible and resilient so that they can be distorted (without being substantially permanently deformed) from the cylindrical form to provide at the nip and the zone in which the compaction occurs a volume of acceptance, hereinafter defined, greater than that provided by the said hollow rolls in their free state. The outer surfaces of the hollow rolls comprise the powder compacting surface. The hollow rolls are advantageously loose, flexible, resilient metal rings frictionally driven by rolls or other suitable means and maintained in position by smaller load bearing rolls and/or idlers in rolling contact with them. The idlers can also have the function of the deforming means.

The preferred arrangement of the hollow and supporting rolls is shown diagrammatically in the accompanying drawings in which FIGURES 1 and 2 show the hollow rolls before and after distortion respectively.

In the drawing there are two flexible hollow rolls **10** surrounding the normal rolls **12** of a two-high mill and each engaged internally by two further rolls **13**, diametrically disposed in relation to the rolls **12**. Means are provided for forcing the bearings of the rolls **12** apart from one another. Initially the two rolls **12** of each pair are close enough to allow the corresponding roll **10** to be slid over them axially, while of course any obstructing parts are temporarily dismantled. When the bearings of the rolls **12** are urged apart, the rolls **10** are distorted into the substantially elliptical shape shown in FIGURE 2. Simultaneously the zone above the nip in which powder fed to the nip is effectively gripped and compacted is increased from that indicated at A in FIGURE 1 to that indicated at B in FIGURE 2.

It is to be appreciated that other arrangements of idler rolls and driving rolls for distorting the hollow rolls can be provided and that these will give a similar rolling and compacting action as that of the rings and/or the disposition of the internal rolls already referred to. Thus, the idler rolls can be moved in a direction toward or away from the roll gap as well as toward or away from each other.

The present invention also contemplates a process for producing strip in a variety of thicknesses by the direct rolling method. According to this process, particulate material is fed between rotating compacting rolls through a roll gap to produce strip. Thus particulate or pulverulent material, such as mentioned herein, is fed into a compacting zone defined by a pair of opposed and converging metal surfaces, at least one of the surfaces being a rotating, flexible but resilient, distorted hollow cylindrical surface such as described herein. Advantageously, both surfaces are thus characterized and rotate oppositely. In practice the process of the present invention to produce metal strip is carried out by feeding powder into the rolling zone of a roll mill having at least one flexible, resilient hollow roll while rotating the rolls of said rolling zone and while applying force to said hollow roll or rolls in order to elastically distort them so that the effective diameter (or radius of curvature) of said hollow roll or rolls is increased at or near the nip of the rolling zone. Thereafter, compacted green strip emerging from the mill is sintered and hot and/or cold rolled to reduce the porosity of the sintered product and to produce useful metal strip. In order to produce strips having different thicknesses, it is a simple task to vary the radius of curvature of the compacting surface. In this connection, an increase in the radius of curvature of the compacting surface causes an increase in the thickness of strip produced using such compacting surface during compacting, and conversely when the radius of curvature is decreased, the resultant strip is thinner. In addition, the present process is applicable to the production of strip having varying thicknesses by changing the radius of curvature of at least one of the compacting surfaces during the compacting operations.

For the purpose of giving those skilled in the art a better understanding of the invention the following illustrative example is given:

Example

In order to produce strip 0.1 inch thick (2.54 mm.), two hollow rolls of 17 inches (432 mm.) outside diameter having a wall thickness of 0.156 inch (395 mm.) and having a cylindrical form in their free state are provided. The hollow rolls are made from a steel containing about 1.8% nickel, about 1.3% chromium, about 1% molybdenum and 0.25% vanadium. The hollow rolls are characterized by having an elastic limit of about 60 to about 65 tons per square inch (t.s.i.), a maximum stress of about 100 tons per square inch and an elongation of 10%. The hollow rolls are arranged with their axes parallel to define a nip and are frictionally driven by a pair of solid rolls each of 8 inches diameter (203 mm.). A pair of idler rolls diametrically opposed are arranged internally of each of the hollow rolls as shown in FIG. 1. The idler rolls have a diameter of 2.5 inches (63.5 mm.). A force of 0.54 ton (548.6 kg.) was needed to move each pair of idler rolls apart to produce a long cross-sectional axis in each hollow roll of 19 inches (480 mm.). When elastically deformed (or flattened) in such fashion the hollow rings take up a geometrical configuration which is elliptical or quasi-elliptical. In the foregoing apparatus, carbonyl nickel powder having a particle size of about 3 microns and having a bulk density of about 1.0 gram per cubic centimeter (g./cc.) was introduced between the rolls. The rolls were rotated at about 1 revolution per minute (r.p.m.) to produce a peripheral speed on the rolling surface of about 4.5 feet per minute (f.p.m.) and strip was produced having a thickness of 0.1 inch and having a density of about 5 g./cc. Thus, the effective diameter of the distorted rolls was such as to give the aforementioned thickness of strip which would only be obtainable with rolls having a diameter of 24 inches (610 mm.). The strip was then placed in a furnace and sintered at a temperature of about 1150° C. for about 5 minutes. Subsequently, the sintered strip was cold rolled in the aforementioned apparatus in order to increase the density of the strip to 8.9 g./cc.

Analytically, it can be shown that the distortion of flexible rings arranged with internal driving rolls and idler rolls provide a compaction volume for the powder which is much increased from that which would be available if the rings were in their cylindrical free state. While the theory of the mechanism is not fully understood, a possible explanation may be had by reference

to both FIG. 1 and FIG. 2. In effect, there is provided a compacting zone before distortion having an area of acceptance A, delimited by the tangent to the roll making an angle α with the horizontal centre line of the rolls, the angle $90-\alpha$ being the angle of friction. The area of acceptance A multiplied by the face width of the roll, for the powder, provides a volume of acceptance having a movable hopper wall of sufficient rigidity to provide compaction in that it is not locally distorted by the pressure applied to the powder. By distorting the rolls **10** made of metal having a high fatigue limit, e.g. by moving idler rolls **13** outwardly until they take on a configuration shown in FIG. 2 there is provided a compacting zone of area of acceptance B which is larger than that of A.

The present invention is particularly applicable to the rolling of powdered materials directly into strip such as metals, alloys, non-metallics refractories, etc. In addition, the apparatus of the present invention can be used effectively in the rolling of solid materials. Mills according to this invention can also be used for the cold rolling of sintered strip in which rolls of larger diameter or effectively large diameter are advantageously used in order to eliminate porosity and reduce the tendency to surface cracking.

It is to be noted that the present invention is not to be confused with the endless belt rolling surface of the prior art in which the radius of curvature of the belt at the roll nip is substantially equivalent to the radius of a supporting and/or driving rolls plus the thickness of the belt. In addition, the endless belt arrangement is not self-sustaining and does not provide a smooth transition in the radius of curvature.

Although the present invention has been described in conjunction with preferred embodiments it is to be understood that modifications and variations may be resorted to without departing from the spirit and scope of the invention, as those skilled in the art will readily understand. Such modifications and variations are considered to be within the scope and purview of the invention and of the appended claims.

We claim:

1. Rolling apparatus for compacting pulverulent material fed thereto comprising a pair of oppositely disposed rolls adapted to compact pulverulent material when passing therebetween, at least one of said rolls being hollow and self-sustaining and characterized by a continuous, flexible, resilient metal compacting surface having a regular, enclosed curvilinear cross-sectional shape, means for driving at least one of said rolls and means positioned within at least one hollow roll for elastically adjusting the radius of curvature of said hollow roll.

2. Rolling apparatus for compacting pulverulent material as claimed in claim 1 wherein the means for adjusting the radius of curvature of at least one hollow roll of the pair of rolls comprises at least one positionally adjustable roll adapted to be positioned in rolling contact with the interior surface of a hollow roll of said pair of rolls.

3. Rolling apparatus for compacting pulverulent material fed thereto comprising a pair of parallel axially aligned, oppositely disposed members adapted to compact pulverulent material when passing therebetween, said members being hollow and self-sustaining and characterized by a continuous, flexible, resilient metal compacting surface having a regular, enclosed curvilinear cross-sectional shape, a driving roll in frictional contact with each of said members and a pair of idler rolls adjustably positioned within each of said hollow members and adapted to elastically distort said members.

4. Rolling apparatus for compacting pulverulent material fed thereto comprising a pair of parallel axially aligned, oppositely disposed members adapted to compact pulverulent material when passing therebetween, said members being hollow and self-sustaining and characterized by a continuous, flexible, resilient metal compacting surface having a regular, enclosed curvilinear cross-sectional shape, a driving roll in frictional contact with each of said members and means adjustably positioned within each of said hollow members and adapted to elastically distort said members.

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