

Sept. 22, 1970

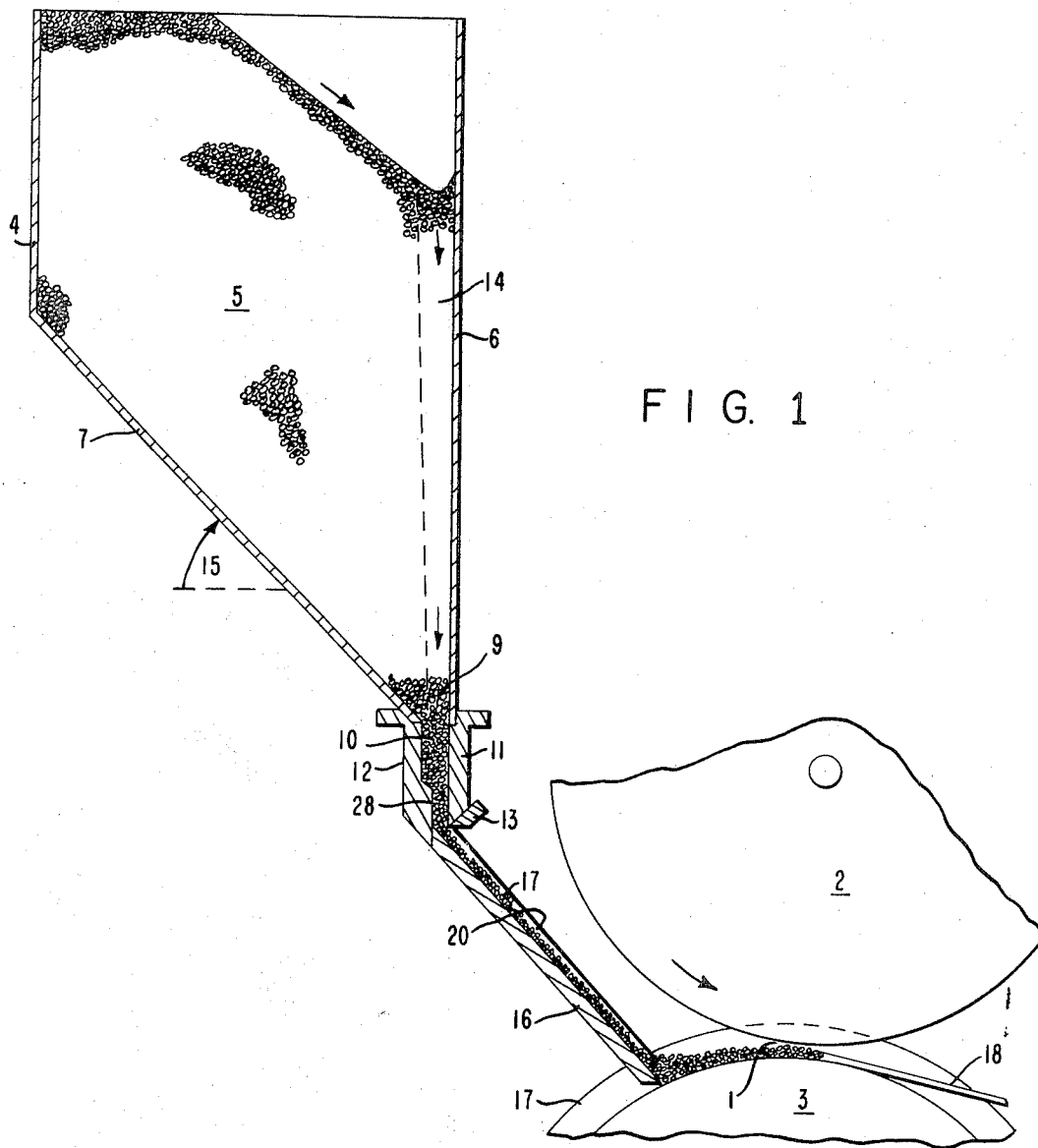
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3,530,210

METAL POWDER ROLLING PROCESS

Filed April 10, 1968

3 Sheets-Sheet 1



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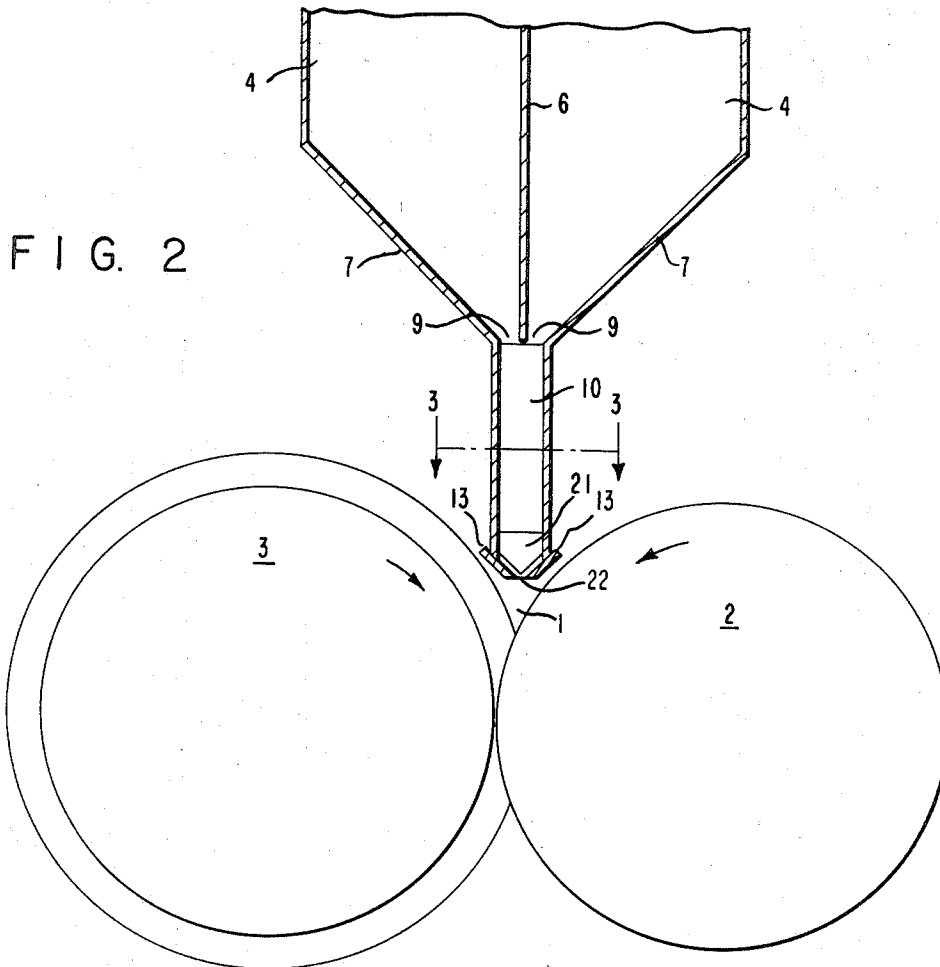
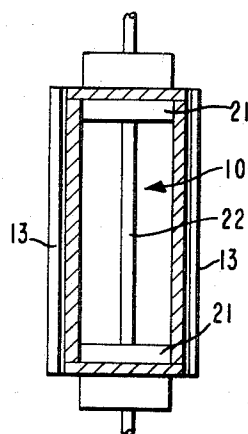


FIG. 3



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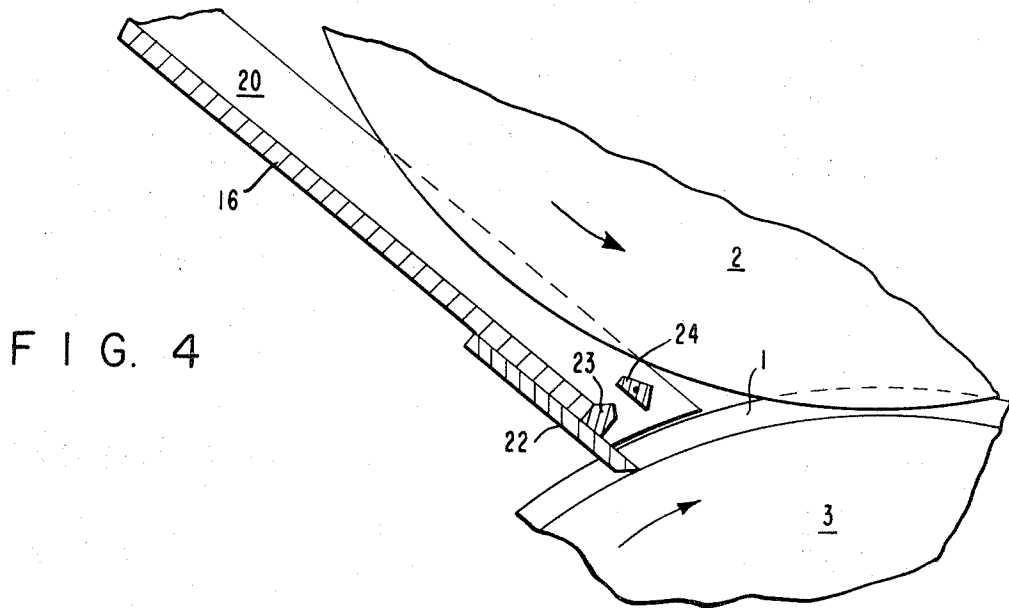
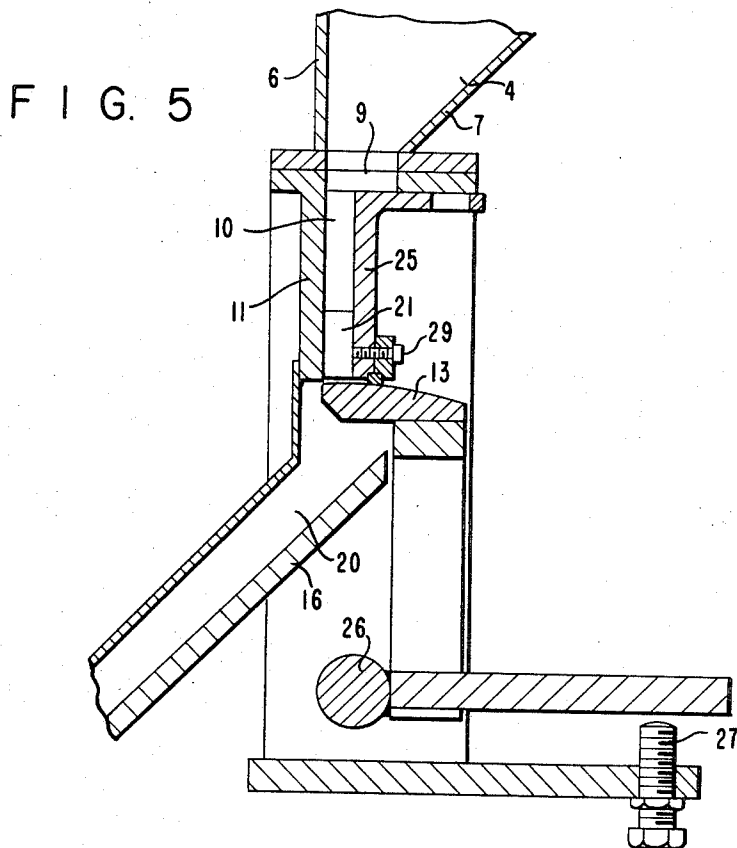


FIG. 4



F I G. 5

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1

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METAL POWDER ROLLING PROCESS

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5 Claims

ABSTRACT OF THE DISCLOSURE

Metal powder is rolled directly to sheet with at least 75% theoretical density by flowing the metal powder to the rolling nip in a rectangular profile as it enters the roll nip, the powder longitudinally tumbling just in advance of the rolling nip to aid in avoiding particle size segregation.

BACKGROUND OF THE INVENTION

Field of the invention

The invention is in the field of powder metallurgy and more particularly the compaction of metal powders, by rolling, to form metal sheet.

Description of the prior art

When metal powder is compacted to sheet between opposing rolls, there is a tendency for it to spill out at the ends of the roll gap, thus giving a sheet which is not compacted to the same density, coherence or thickness at the edges as in the middle. This leakage has been minimized by using a pair of rolls, one of which is recessed by providing it with a flange at each end and the other of which is unflanged and mated to the first roll. The use of such flanged rolls gives rise to another problem—namely, that there is a tendency for the sheet to become wedged between the flanges, with the attendant difficulty of discharging it from the rolls.

In Lund et al. U.S. Pat. 3,162,708, a method is described for solving the above-mentioned problems by mounting a flange, of greater diameter than the roll, at each end of one of the rolls but spaced a short distance from each opposing end of the roll so that there are relatively narrow spaces between the roll ends and the opposing flanges. The rolled sheet still requires superficial trimming along its edges during subsequent operations, and, of course, the described edge control has little effect on the uniformity of the properties of the center of the sheet, especially when relatively wide sheet is being rolled.

In Lenel U.S. Pat. 2,937,942, a contoured gate in a powder supply hopper is used to control the feed, to the nip of a pair of unflanged rolls, of a continuous layer of loose metal powder of predetermined, progressively increasing thickness laterally from the center of the layer. Only a "green strip" is thus produced, however, and normally this is sintered to develop strength and finally the strip is usually rerolled to meet surface and thickness specifications. Contouring the powder supply in the manner described can result in particle segregation in powders wherein the particles vary in size and density; moreover, the contour specified is directly opposite to that required for high density compaction with edge restrictions.

SUMMARY OF THE INVENTION

Now according to the present invention the foregoing and related problems of the prior art are avoided and metal powders are advantageously fed to a nip between a pair of aligned, male and female rolls in a rolling mill and are directly rolled to sheet having a uniform density of at least 75% of theoretical by the described processes, in which (1) a supply of the powder is provided in con-

2

tact with, and laterally contained by, a low-friction, vertical wall in a plane parallel to the roll nip; (2) a powder mass having a substantially rectangular cross section is withdrawn from said supply by gravitational fall along said wall; (3) the larger dimension of said cross section is controlled at about the width of the male roll and the lesser dimension at a magnitude sufficient to provide withdrawal, in a given time interval, of the requisite amount of metal to form the desired amount of rolled sheet in that interval; (4) said powder mass is passed gravitationally without sidewise distortion, to the roll nip; and (5) the powder mass is rolled to strip between the rolls. In the special case where the powdered metal entering the roll nip comprises metal particles of non-uniform particle size, the powder is preferably mixed in the nip by tumbling it longitudinally but not laterally.

Useful in carrying out the claimed processes is a mill of the invention in which there is (A) a hopper for holding a supply of the powder, said hopper having (1) a low-friction, vertical front wall in a plane parallel to the roll nip, (2) a sloping bottom downwardly inclined toward the front wall at or slightly more than the slide angle, i.e. the angle at which a thin layer of the powder will slide down such sloping bottom, and (3) an outlet slot located at the bottom of the hopper between its front wall and bottom at their closest convergence, said slot having a substantially rectangular opening and being in open communication with (B) a metering section having (4) a throat defined by parallel vertical front and rear walls spaced apart a distance substantially equal to the front-to-rear dimension of the slot, said front wall being in the same plane as the hopper front wall and, in a preferred embodiment, contiguous therewith, and vertical side walls spaced apart about the width of the male roll, and (5) a gate at the bottom of the throat, closable to close the opening between the front and rear walls and openable to form an opening of predetermined front-to-rear dimension, and (C) when the rolls are vertically disposed, conveying means, connecting said metering section below the gate, to the roll nip. In one specific embodiment the vertical side walls of the throat are defined by moveable edge control stops, operable to regulate the width of the powder stream leaving the gate. In another specific embodiment a mechanism for remixing the powder is provided in the form of a pair of bars located across the bottom of the conveying means, C, the first bar being a deflector so positioned as to direct, in an upwardly direction toward the upper roll, powder sliding down the conveying means, and the second bar being a reflector located in the path of such upwardly directed powder and so positioned as to intercept such powder and redirect it into the roll nip.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a diagrammatic sketch, not to scale, showing a metal powder rolling mill of the invention, including the supply hopper, metering section, and discharge means, feeding powder to the nip of a pair of vertically disposed mating rolls, and

FIG. 2 is a similar sketch showing the feeding means as applied to mated, horizontally disposed rolls, and

FIG. 3 is a view looking down from a cross section, taken on line 3—3 of FIG. 2, showing the throat-width control mechanism, and

FIG. 4 is a cutaway view showing a mixing mechanism in the discharge means, adapted to mix a non-uniform powder as it enters the roll nip, and

FIG. 5 shows, in cross section, a powder metering section with adjustable rear wall and a gate mechanism adapted to limit the flow of powder therethrough to a predetermined limit.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides improvements in processes for roll-compacting metal powders to sheet, the improvements consisting of a sequence of cooperative steps for delivering non-segregated powder to the roll nip at a constant, controllable rate in equilibrium with the nip requirements, whereby uniform, high density compacts are produced and improved control of the sheet thickness and edge characteristics are achieved. The methods comprise withdrawing representative feed metal powder from a supply hopper in a relatively thin vertical section adjacent to a low-friction vertical wall downward by the main powder mass in the hopper, thereby supplying representative powder to a communicating metering zone situated below the hopper and confined between opposing vertical walls lying in planes substantially parallel to the roll nip, controlling the gravity flow of powder from the metering zone by a gate to maintain in the metering zone the zone in which dilation of the powder occurs, delivering the powder from the gate to the roll nip, and coordinating roll speed, roll opening and the mill load, relative to the flow of metal from the metering zone, to preserve a balanced flow of metal powder through the system and produce metal strip in a continuous manner.

A powder rolling mill of this invention, useful in carrying out the above-described processes, is illustrated in FIG. 1 wherein a roll nip 1 is formed by alignment of male roll 2 and female roll 3 having flange or shoulder 17. A hopper 4 holds a supply of powder 5, said hopper having a low-friction, vertical front wall 6, a bottom 7 downwardly inclined toward the front wall at an angle 15 very slightly more than the slide angle of the powder, and an outlet slot 9 forming, with said front wall, bottom, and with side walls not shown, a substantially rectangular opening. This slot is in open communication with a metering section having a throat 10 defined by parallel, vertical front wall 11 and rear wall 12 and vertical, parallel side walls, not shown, spaced apart about the width of the male roll. At the bottom of the throat there is a gate 13, shown in FIG. 1 in open position, but closable to close the opening between the front and rear walls to any predetermined degree. In the preferred embodiment shown by FIG. 1, there is also a constriction 28 which effects a reduction in the front-to-rear dimension of the throat, this constriction running downwardly from about midway of the vertical dimension of the throat to below the line at which the gate, when closed, meets the rear wall of the throat and forming a vertical face parallel to the front wall of the throat. Discharge means, in the form of a chute 16, are shown connecting the bottom of the metering section to the roll nip at a steeper angle than the slide angle for the powder. The sheet 18 leaves the roll nip in compacted condition.

In one preferred embodiment of the invention, illustrated in FIGS. 2 and 3, the width of the powder stream through the gate is partially restricted by movable edge control stops 21 which regulate the width of the stream leaving the gate and consequently the width of the powder stream entering the roll nip. These edge stops, in zero position, are set apart about the width of the male roll and are adjustable, by means not shown, to increase or decrease the width of the stream leaving the gate.

FIG. 2 shows an apparatus of the invention in which the rolls are in horizontal arrangement—that is, their axes of rotation are in a horizontal plane. In this embodiment the powder discharges directly to the roll nip, the dual gates 13 directing the powder to the desired location. A dual hopper 4 is shown, in which the low-friction, vertical wall 6 functions also as a divider between the two sections of the hopper. There are also dual slots 9, discharging into a common throat 10 in the metering section.

The vertical arrangement of rolls shown in FIG. 1 is preferred, but when it is used with metal powders having a wide variety of particle sizes there tends to be some segregation of particles according to size during passage of the powder from the metering section to the roll nip, even though the chute is polished so the powder slides generally in a mass. This is corrected, in the embodiment illustrated in FIG. 4, by remixing the powder just before it enters the nip.

In FIG. 4, the upper roll 2 is shown engaging the lower, flanged roll 3. The chute 16 with side walls 20 is set to deliver the powder as near as possible to the roll nip 1, while an extension 22 is positioned to have close clearance with the roll face to prevent downward loss of powder. At the end of the main chute is mounted a first remixing element in the form of beveled bar 23 and a second element 24 which is a rotatably adjustable bar for providing optimum remixing. The chute side wall 20 preferably forms a close clearance with the periphery of the roll flange 19. In a preferred arrangement, used for continuous rolling of the same or similar powders, the roll flange is just about high enough to retain that depth of loose powder which is passing through the roll nip.

In operation, remixing of the powder is effected by causing it to cascade over and against horizontal bars 23 and 24, parallel to the roll nip. Preferably, the downward-flowing powder is deflected upwardly by bar 23 against overhanging bar 24 and rebounds downwardly into the roll nip. The double deflection causes the powder particles to remix in such fashion that any size segregation present is effectively erased. The clearance between the operative surfaces of the mixing bars is preferably small but not small enough to cause restriction or choking of the powder flow. Alternatively, the overhanging surface can be the upper roll. This manner of mixing the powder tumbles it longitudinally, i.e. in the direction of general flow, but not laterally, so that the powder stream entering the roll nip remains uniformly thick and evenly distributed across the width of the nip.

FIG. 5 illustrates a particularly practicable embodiment of the metering section, wherein the throat opening is adjustable and the gate opening is preset. The throat 10 is situated between the hopper discharge slot 9 and the discharge chute 16, and is defined by front wall 11, rear wall 25, and end stops 21. The front-to-rear dimension of the throat can be varied by a corresponding movement of rear wall 25. A sealing mechanism, held in place by screw 29, is movable with the rear wall and acts to prevent powder leakage between said wall and gate 13. This gate, shown in closed position, is mounted on gate pivot 26 in a manner such that it can be opened, as by power-actuated means not shown, to a predetermined degree limited by the setting of stop 27.

In processes for roll compaction of metal powders one of the chief problems is to obtain a uniform discharge of a representative feed from the powder storage hopper, i.e., a feed which is non-segregated as to particle size or density. The mere dumping of a batch of powder into the hopper can cause such segregation, the finer particles usually working downward. According to the present invention, it has been found that withdrawal from the hopper of a powder of substantially non-segregated state can be accomplished by limiting such withdrawal to a relatively thin vertical section of the main mass, shown in FIG. 1 as 14, along a low-friction, vertical wall of the hopper, the bulk of the powder remaining at rest with its upper surface at its angle of repose. This vertical section moves downward as a mass and does not experience appreciable segregation. It is fed by thin layers sliding down the free surface which recombine at the top of the moving column. Concentrations of any additives in the discharge stream are similar to concentrations of a mixed powder charge, provided precautions are taken to eliminate segregation while charging the hopper. This is in contrast to the changes in concentration encountered in

the discharge stream from a normal hopper, where differential motion exists and bridging causes powder to dump in non-representative masses.

The vertical low-friction hopper wall should be smooth enough that the metal powder does not cling or anchor to it. It may be polished on its inner surface to reduce friction. A smoothness of RMS 15 or better is desired, and the smoothness should not vary more than about 20% over the operative surface. The sloped hopper bottom, on the other hand, is made rough, if necessary, to fix the slide angle of the powder, i.e., the smallest angle from the horizontal at which the powder slides down the sloped bottom. The slope of the bottom is usually set at the slide angle, and the pressure of the powder prevents the sliding of a bottom layer into the outlet and yet provides for the desired representative emptying of the hopper without retaining a bed of powder. The side walls are of less importance in determining the nature of the hopper discharge; they merely contain the powder. Preferably they are vertical or slightly sloped and conveniently they are spaced apart a distance about the same as the width of the following metering zone. To promote further the laminar flow of powder under low friction conditions a strip of the side wall adjacent to the vertical front wall can be polished, or a polished insert can be mounted on the side wall.

Controlling the metal powder discharge from the supply hopper in the manner just indicated does not alone suffice to establish the powder supply to the roll nip; the rate of powder flow to the nip must also be controlled. If one seeks to do this by a gate mounted on the hopper discharge slot one finds that there is a variation in the flow rate, even for a given gate setting, as the level of powder in the hopper changes. This is due to the change of head and consequent change in pressure at the hopper discharge slot, the changes being viewed as analogous to relationships between liquid flow and pressure except that wall friction limits the flow variation with height of powder. To establish a constant pressure, and therefore a constant flow for a given gate setting, the metering section described above in reference to FIGS. 1 and 5 has been provided according to the present invention. The powder-handling capacity of the system is set by the hopper slot, which is normally large enough that the discharge pressure is not constant, and the metering section is added to provide additional wall friction. The wall friction can be further increased, and a horizontal pressure component added, by using a step or slope, shown as constriction 28 in FIG. 1.

The metering section throat is a relatively thin rectangular space located under, and communicating with, the hopper discharge slot. Its width is normally the same as that of the hopper discharge slot. Its height and thickness is determined from the flow characteristics of the particular powder being rolled, and the desired rate of flow, shorter heights and greater thicknesses making for higher flow rates. The thickness is set, by experiment or from previous experience, to be greater than the static bridging distance for the powder, and to provide for the maintaining of the essential powder dilation zone within the metering section.

The metering zone may be multiple in nature, thus comprising two or more stepped sections. The vertical front and rear walls are kept vertical and parallel, but by a step or series of steps in one or both of these walls the throat can be made successively thinner toward the bottom gate. Stepped metering zones provide increased control and are used when a wider range of flow rates is desired.

In general, the throat of the metering section is sized by experiment to provide a desired rate of flow of a given powder. The throat height and front-to-rear thickness dimensions to be used can be determined roughly by preliminary tests in a flow tester simulating the throat and lower part of the hopper of the metering section, and

more precisely by means of an adjustable wall in the metering section itself as illustrated in FIG. 5. In operation, the metering section dimensions are adjusted until the powder flow is constant during changing levels in the feed hopper. Flow rates can then be adjusted with the gate and balanced with roll speeds and settings to maintain continuous production of quality strip. These variables can be manipulated within reasonable ranges by adjustments to the feed stream width. The width restriction required is gauged by the appearance of the sheet. To facilitate this adjustment a constant flow rate of preset magnitude is desired. This can be accomplished by providing higher single metering zones or by means of a series of stepped zones as just described.

An explanation of the action in the metering section is that an expansion of the powder takes place as the lower part of it flows through the gate. The point at which this expansion occurs is called the dilation point. The flow rate is constant when the dilation point is stabilized at a given level within the throat. This level is established by the gate opening. At this point, the dilating powder falls away from the overlying powder (which acts as though it were momentarily attempting to bridge across between the parallel vertical walls), producing a density gradient reaching in a restricted area to the top of the powder mass, leaving a zone of powder just below which has a lower bulk density than the adjacent powder above it. It is a condition of constant pressure at the dilation point that results in constant rate of flow. As the flow is increased by opening the gate, the dilation point rises; and, to give a wider range of controlled constant rates, the stepped sections are used so that as higher rates are wanted, to meet increased roll demands, the dilation point rises into larger sections.

To establish the desired stable dilation point each metering zone should be at least twice as high as its thickness. The steps in multiple metering zones may be horizontal, in which case a heel of powder is retained, thus introducing a horizontal pressure component, and the flow characteristics are satisfactory; conversely, the steps can be sloped at or just steeper than the slide angle of the powder contemplated for use; maximum effectiveness is achieved at an angle of about 45° with normal metal powders.

In addition to eliminating segregation in the powder feed and establishing the desired rate of flow of powder to the nip as already described above, it is important in processes of this invention to control the edges of the powder stream so that the thickness and density of metal across the rolled sheet is held uniform. If this is not done, and insufficient powder is supplied at the edge of the rolls, the edges of the sheet are irregular and cracked, requiring deep shearing with an attendant loss of prime yield. The use of roll flanges, as proposed in U.S. Pat. 3,162,708 discussed above, to retain the powder and mold the edge of the sheet, is helpful, but gives rise to new problems. The shoulder friction pulls in excess powder at the edges. Compacting pressure is applied to the edges of the sheet being formed and the center portion of the sheet is not subjected to full compacting pressures. The center then cracks because it cannot elongate at the same rate as the compacted edges.

According to the present invention it has been found that by suitably controlling the width of the metering zone just above the discharge gate the powder stream can be tailored to give sound edges and uniform strip. Such control is accomplished by means of the edge control stops 21 discussed above with respect to FIGS. 2 and 3. These control stops are movable plungers entering the metering section at each end of the throat at the bottom to restrict the width of the powder stream. This controlling effect persists even along a chute to the rolls. The edge controls are provided with reasonably accurate positioning means such as slide supports and screw adjustments. Their location must be above the gate, but otherwise is not

critical as long as they exert the desired control on the width of the powder stream flowing through the gate. They may vary in size, shape and position as will be indicated by experimentation with a given powder. They are preferably shaped to fit the gate closures well enough to stop entirely or almost eliminate the powder flow at the ends of the gate. Their inward end surfaces are preferably vertical and smooth.

The final adjustment of the edge controls is made in view of an inspection of the metal strip coming from the rolls. If one edge is "starved," i.e. less dense than the main portion of the strip, the corresponding end stop is withdrawn enough to effect the correction. When an edge of the strip is being overfed, as indicated by increased thickness and/or density relative to that of the main part of the sheet or by excessive powder spillover at the roll flange, the corresponding stop is moved inward to make the correction. The extent of movement of these edge stops needed to control the edge thickness is usually less than 10% of the width of the strip being formed; however, a greater movement may be provided to permit manufacture of various widths of strip by feeding powder from the same hopper assembly. Thus, to change to a different width of product, it is necessary to change only the rolls and the chute. Conversely, for continuous operation on the same powder to produce a product of predetermined width and thickness at an established mill load, the throat can be designed to optimum dimensions on the basis of previous experience, and the use of variable end stops dispensed with. In this event, of course, the sidewalls of the hopper and throat will be spaced no further apart than the width of the roll work surface.

As already noted, in a preferred arrangement of the powder-rolling mill the flange of the female roll is just about high enough to retain that depth of loose powder contained in the powder bed entering the roll nip. Thus, the vertical height of the flange at the top of the chute side wall (20 of FIG. 1) is $R \times T$ where R is the compaction ratio from loose powder to full density strip and T is the thickness of the strip. The arrangement minimizes the loss of metal powder due to extrusion between the flange and upper roll. It also improves the effectiveness of the edge control stops 21 just described. This is because any excess of powder at the edge spills over the flange and is recovered for reuse as such. With a higher flange the width of the feed stream must be decreased. The preferred clearance between the top roll end and the base of the flange is, for example, up to about 0.5 times the green strip thickness when rolling titanium powder.

In the processes of this invention the various control means hereinabove described are coordinated with the usual roll characteristics. The conventional characteristics so controlled include mill roll gap, roll speed, and load on rolls. These are coordinated with the edge control stop settings and the overall rate of powder flow, the latter being controlled by the proper setting of the powder gate and the proper design and size of the metering section. The variables must be brought into cooperation with the flow rate in the range which has the effect of stabilizing the powder dilation zone within the metering zone. The dimensions of the metering zone may be selected on the basis of knowledge of the other variables; alternatively, this zone may be made variable by providing a movable rear wall which can change the front-to-rear dimension.

The dynamic balancing of the system is facilitated by experience attained through experimentation. The order of adjusting the variables may be varied.

The apparatus and processes of this invention have been successfully applied to the rolling of strip from powders of various metals, including titanium, aluminum, zinc, lead, stainless steel, tool steel, copper, and metals of the group consisting of iron, cobalt and nickel in which there is dispersed a particulate refractory oxide, such as thorium,

having an average particle size in the range of about 5 to 120 millimicrons.

The invention will be better understood by reference to the following illustrative examples.

EXAMPLE 1

This example illustrates the use of a Fenn Mill adapted to the conditions of this invention for rolling titanium metal powder.

The mill was of 2 high design with rolls 12" in diameter with ten-inch face widths. The lower roll carried at its ends integral $\frac{1}{4}$ " high flanges which cleared the upper roll by 0.040". The rolls were flat, i.e. not crowned, and were set in the light of trial runs at -10 mils to give a green strip 24 mils thick. The feeder was of the type shown in FIG. 1 with step 28 omitted. The metering section walls were polished to RMS 15-16. The single metering zone was 4 inches high, 10 inches wide inside, and $\frac{3}{4}$ inch thick. The edge control stops were $\frac{3}{16}$ inch diameter rods initially set in 0.3 inch and in sliding contact with the chute surface and the feed gate. The chute was set at 45° from horizontal with the first re-mix bar face $\frac{3}{16}$ inch wide and set at the end of the chute in a horizontal position, as shown in FIG. 4. The second re-mix baffle had a $\frac{3}{16}$ inch impact surface facing the first element and set at 75° from horizontal.

The titanium powder used was substantially all between 60 and 200 mesh (U.S. Standard Sieve). The charge was cone blended with 2% of isopropanol added just prior to discharge into the feed hopper. The isopropanol helped minimize segregation of fines during filling of the hopper. The isopropanol was evaporated by a stream of dry nitrogen passing slowly through the hopper aided by infrared radiation on the hopper walls.

An expedient mill load was chosen at 400,000 lbs. The mill was started at 10 ft. of strip per minute and the powder gate opened to give, on the basis of previous calibration, 5.6 lbs. of powder per minute. The mill speed was then adjusted to produce a mill load of 400,000 lbs. Inspection of the resulting green strip showed weak edges that lacked metal. The edge control stops were then backed out to remedy this condition. When the edges appeared to be as dense as the main strip the stops were at 0.2" at the drive side and 0.1" at the outboard side. The strip was then 91% dense with only the outer $\frac{1}{16}$ inch edges of lower density. It had less than 1 mil crown and was readily sintered and rolled to fully dense sheet without trimming.

Inspection of the strip with a low power microscope showed that it was sufficiently dense and uniform to be rerolled to thinner gauge if desired. The density and thickness of the strip sample inside one-inch edge margins did not vary more than 3% over the length of the sheet. Previous efforts not employing the stated features of this invention resulted in poor edges necessitating trimming of 2 to 4 inches from the 10-inch strip.

EXAMPLE 2

This example illustrates the use of rolls set in horizontal opposition for rolling nickel powder containing dispersed thorium without the use of re-mixing baffles.

A so-called "TD Nickel powder," all -30 mesh, and containing nominally, by weight, 97.5% Ni and 2.5% ThO_2 in the form of uniformly dispersed particles having an average size less than 250 millimicrons, was loaded into the hopper of a mill such as shown in FIG. 2 except that the feed hopper was single rather than duplex. The low-friction wall of the hopper was polished and was essentially vertical. The metering zone was 4 inches high, $1\frac{1}{4}$ inches thick and 10 inches wide to match the width of the rolls. One roll was flanged as indicated. The edge control stops were placed in contact with the single gate which permitted the powder to drop directly into the roll nip.

Prior to start-up the mill load was selected at 360,000 lbs. The mill speed was set initially at 20 ft./min., the roll gap setting at .025 inch, and the feed rate at 34 lbs. min. The edge control stops were set at 1 3/16 inch inside the roll flange on the basis of previous experience with this set-up using the same kind of powder. The mill was started and the feed gate opened. The mill load was watched and the mill speed adjusted to arrive at the desired mill load of 360,000 lbs. at which condition the mill speed was 17 ft./min. The product strip was .067 inch thick with a uniform density to within 1/8 inch of the flange face.

I claim:

1. In a process for rolling a metal powder directly to sheet having a uniform density of at least 75% of theoretical by feeding said powder to a nip between a pair aligned male and female rolls and pressing said powder to sheet between said rolls, the steps comprising (1) providing a supply of the powder in contact with, and laterally contained by, a low friction, vertical wall in a plane parallel to the roll nip; (2) withdrawing from said supply, by gravitational fall along said wall thence between two opposite vertical walls, a mass of said metal powder having a substantially rectangular cross section; (3) controlling the larger dimension of said cross section at a magnitude no greater than the width of the male roll and the lesser dimension at a magnitude sufficient to provide withdrawal in a given time interval of the requisite amount of metal to form the desired amount of rolled sheet in said time interval and to maintain a dilation point of said powder mass between said two opposite vertical walls; (4) passing said mass of metal powder over mixing elements just prior to said metal mass entering said nip to cause longitudinal tumbling of said powder and thereby mix

non-uniform sized particles thereof while avoiding side-wise distortion of said mass entering said roll nip; and (5) rolling said powder mass between said rolls to form said sheet.

2. A process of claim 1 wherein the metal powder comprises aluminum.

3. A process of claim 1 wherein the metal powder comprises titanium.

4. A process of claim 1 wherein the speed of rolling is controlled, relative to the rate of feeding powder to the nip, so that the amount of powder in said nip area remains substantially constant.

5. A process of claim 1 wherein the larger dimension of a cross section of said powder mass passing to the roll nip is controlled by increasing said larger dimension when the edges of the rolled sheet are less dense than the main portion of said sheet and decreasing said larger dimension when the edges are more dense than said main portion.

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U.S. Cl. X.R.

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