Nov. 28, 1961 J. DASHER 3,010,148

ROLLING MILL

Filed Jan. 13, 1958

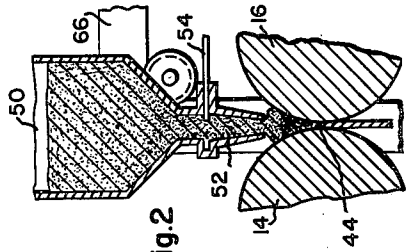


Fig.2

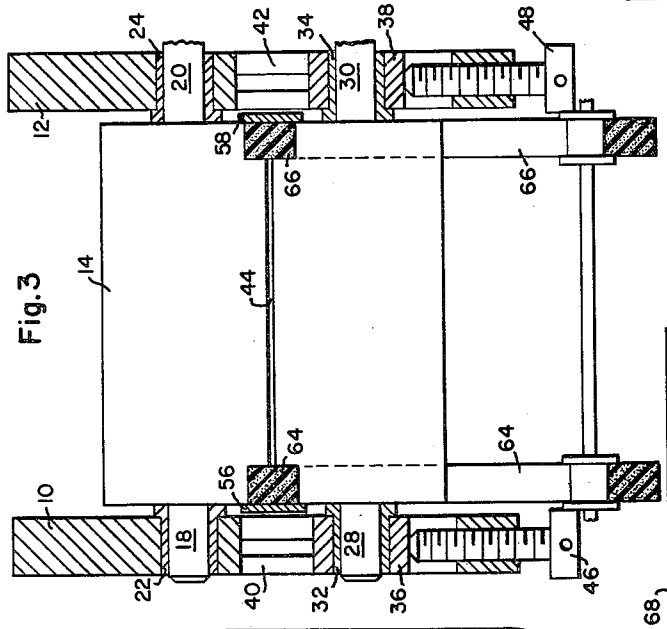


Fig.3

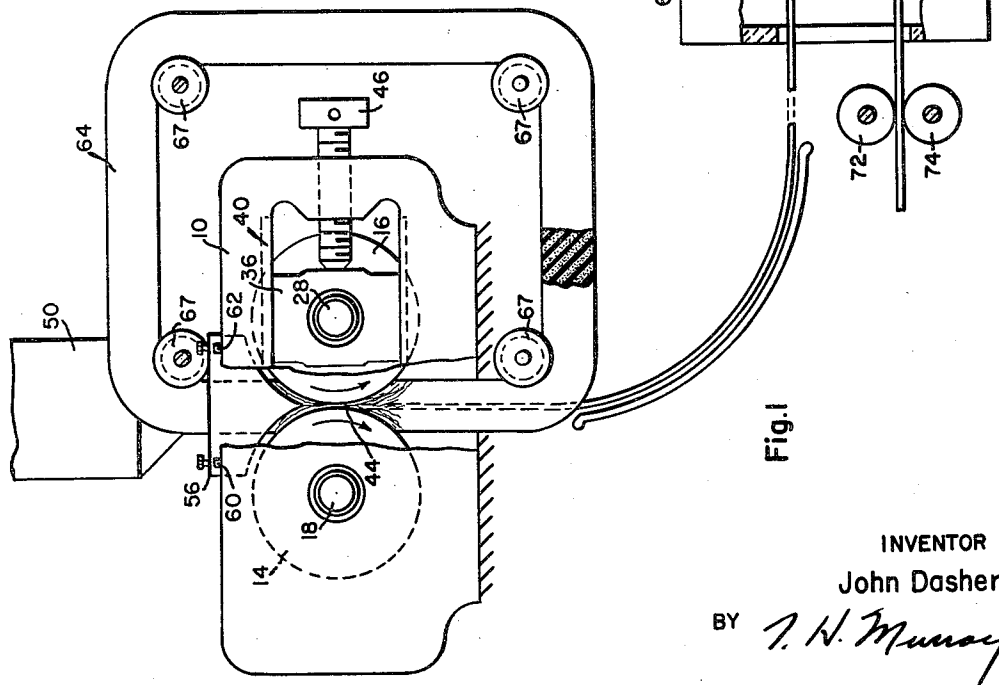


Fig.1

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ROLLING MILL

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This invention relates to apparatus for compacting metal powders into wrought metal sheets and more particularly to apparatus for rolling metal powders into metal sheet having a uniform density and compactness across the entirety of its width.

In rolling metal powder into wrought shapes, fine dustline particles are introduced into a roll gap formed between horizontally spaced rolls. As the metal powder passes through the gap, it is subjected to a rolling pressure sufficient to cause the metal powder particles to cohere. Thereafter, the resulting wrought metal article is subjected to a sintering treatment in order to increase the strength and ductility of the compacted article; and, finaly, the wrought metal article is further rolled, either hot or cold, to effect a further compacting thereof.

The edges of a sheet produced in a conventional powder rolling process of the type described above are generally wavy and rough. When the metal powder is compressed between the rolls, a green or unsintered strip is obtained which has a uniform density across the center area, but a low density at the edges where the powder is free to be pressed sideways and even to fall through the rolls uncompressed. When such a strip is sintered and re-rolled, the dense center elongates while the porous edges compact but do not elongate, thereby resulting in numerous edge cracks.

It is an object of this invention to provide a novel metal powder rolling mill which will produce green sheet or strip having a uniform density across its width. As will become apparent from the following description, the foregoing object is achieved by running rubber or plastic foam material between the rolls at the opposite ends thereof. Such materials have captive bubbles or closed pores which allow the material to be compressed under high pressure without incurring permanent deformation, and are characterized by an inflexible rigidity when compressed. Thus, when the resilient foam runs through the gap between the rolls, it becomes rigid and forms a positive stop for metal powder fed into the roll gap. In this manner, sideways movement of the metal powder is limited at the edges of the rolls so that the density of the sheet or strip is the same across its entire width.

Another object of the invention is to provide a metal powder rolling mill which will produce metal strip or sheet in various widths without changing the length of the rolls. This is accomplished by varying the spacing between two lengths of resilient foam which run through the roll gap, and is a distinct advantage over other powder rolling mill arrangements for obtaining dense sheet edges wherein the rolls must be changed for each sheet width desired.

A still further object of the invention is to provide a novel sintering furnace arrangement for green strip produced in a metal powder rolling mill, said sintering furnace being substantially shorter in length and proportionately less expensive than conventional sintering furnaces.

The above and other objects and features of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings which form a part of this specification and in which:

FIGURE 1 is a side view of one embodiment of the invention;

FIG. 2 is a cut-away view of FIG. 1 showing the details of the hopper mechanism for feeding metal powder into the gap between the rolls of the mill; and

FIG. 3 is a top view of the embodiment of the invention shown in FIGS. 1 and 2.

Referring to FIGS. 1 and 3, the embodiment of the invention shown includes a pair of roll housings **10** and **12** which carry two horizontally spaced rolls **14** and **16**. Roll **14** has two neck portions **18** and **20** at its opposite ends which extend into journal bearings **22** and **24** carried in housings **10** and **12**. In a similar manner, roll **16** has two neck portions **28** and **30** at its opposite ends which extend into journal bearings **32** and **34** which are carried on two bearing chocks **36** and **38**. The chocks, in turn, may be adjustably positioned on guideways **40** and **42** formed in the housing **10** and **12**. As will be understood, the roll gap **44** between rolls **14** and **16** may be varied in width by adjusting two screwdowns **46** and **48** which force chocks **36** and **38** to move along guideways **40** and **42**, respectively. A motor and gear reducer arrangement, not shown, is connected to the right neck portions **20** and **30** for rotating rolls **14** and **16** at the same speed, but in opposite directions.

Mounted in housings **10** and **12**, as shown in FIG. 2, is a hopper **50** having a downwardly extending tapered discharge spout **52** adapted to direct metal powder from the hopper into the roll pass **44**. A shutter **54** is provided in the spout **52** to control the flow of metal powder in an obvious manner.

As shown in FIGS. 1 and 3, the mill is provided with two endless belts **64** and **66** of rubber or plastic foam material which are guided in closed paths by a series of rollers **67**. The foam material may be made from rubber, polyurethane or any other plastic material which can be processed to contain captive bubbles or closed pores which permit the material to e compressed under high pressure without incurring permanent deformation. In this connection it is important to note that a truly compressible substance must be used for the belts **64** and **66**. Liquids and solids are obviously not compressible; and although solid rubber and some plastics may appear compressible, they merely deform when placed under pressure and would spread out over the roll surfaces when passed through a roll gap without becoming rigid. Thus, the necessity for a truly compressible substance becomes apparent. When the rubber or plastic foam of the present invention is compressed, it becomes essentially incompressible and sufficiently rigid to act as a positive stop for metal powder fed into the roll gap. Materials of this type can be compressed to as little as $\frac{1}{20}$ of their original size; and, accordingly, a belt one inch thick could be used for green strip having a thickness of 0.05 inch. Before compression, the captive air within the closed pores of the foam constitutes up to 95% of the volume of the belts. When the belts pass between the rolls, however, the compressed air constitutes a very small percentage of the total volume (i.e., less than 2%). Metal powder fed into gap **44** will tend to move sideways toward the edges of the rolls. The compressed foam be-

tween the rolls, however, provides a positive stop for this metal powder; and, thus, the powder must pass through the roll pass **44** at its edges rather than being spread out over the edges of the rolls. This results in a green strip having a uniform density across its entire width such that the edge cracks referred to above do not appear in the finished product. It should be noted that the sponge belts are nipped by the rolls and begin to compress before their actual passage through the roll gap. Thus, as shown in FIG. 3, a pile of powder can be carried on the rolls without spilling out over their edges, the opposite foam belts forming walls for this pile.

It will be apparent that the spacing between belts **64** and **66** may be varied at will whereby the width of the strip produced in the mill may be varied without changing rolls. During rolling, there may be a tendency for the belts to move outwardly under the compacting pressure; and, accordingly, two guide plates **56** and **58** are provided for resisting any outward movement of the belts. As shown in FIG. 1, each guide plate is carried on two spaced bars **60** and **62** which extend between the housings **10** and **12**. The plates may be adjustably positioned on the bars **60** and **62** to suit various belt spacings and sheet widths.

In operation, rolls **14** and **16** will rotate in the direction shown by the arrows in FIG. 1. At the same time, hopper **50** will forward measured quantities of metal powder to the roll gap **44**. In this process, metal powder will tend to move sideways toward the edges of the rolls. If positive stops, such as the compressed belts **64** and **66** are not provided to limit this sideways movement, metal powder will be effectively squeezed out at the ends of the roll pass **44**; and, consequently, the density of the sheet at its edges will be less than in the center. However, by providing the belts **64** and **66**, such sideways movement is limited or stopped, and the metal powder must pass through the roll gap **44** between these stops rather than being spread out at the edges of the roll.

As shown in FIG. 1, the resulting green or unsintered sheets pass from the rolls **14** and **16** to a sintering furnace **68** where the continuous sheet is heated under a controlled atmosphere to prevent oxidation of the same. Sintering involves both time and temperature; and for any given temperature, the length of the furnace is inversely proportional to the speed of the sheet. That is, longer sintering furnaces are required for higher rolling speeds. Furthermore, the cost of the furnace is, of course, increased as its length increases; and for any given length, the height of the furnace must be great enough to allow for the sintering process. If the green sheet is passed through the furnace only once, there is necessarily a relatively large amount of waste space above and below the sheet. In the present invention, the length of the furnace **68** may be materially reduced for a given sintering temperature and rolling speed without materially increasing its height. This is accomplished by effectively passing the sheet through furnace **68** at least twice instead of once as in conventional furnaces. In FIG. 1, it can be seen that the sheet first passes through the furnace, moves around roll **70**, and then passes out of the same end of the furnace at which it entered. Thereafter, the sintered sheet from furnace **68** is again rolled by rolls **72** and **74** to further densify the wrought metal article. The diameter of roll **70** should be something in excess of two feet.

In passing from rolls **14** and **16** to the furnace **68**, the green sheet is relatively fragile. Accordingly, it is important that the sheet be passed over the top of roll **70** at the entrance end rather than the bottom of the roll. The point of maximum strain on the sheet is at **76**. If the green sheet were fed into the bottom of the furnace and the direction of rotation of roll **70** reversed, the degree of sintering and the strength of the sheet would not be as great at point **76** as it would be if the reverse were true since, in the latter case, the sheet is sintered by an

added amount of time equal to the period required to pass between points **78** and **76**.

Obviously, two or more rolls could be used in furnace **68**, depending upon space requirements, in order to pass the sheet through the furnace three or more times. Generally speaking, the percentage increase required in the height of the furnace decreases with each time the sheet is passed through. In addition, two or more rolling mills could feed green sheet to a single sintering furnace having a plurality of lines for passing the green sheet through the furnace one or more times to fully utilize the available space in the furnace.

Although the invention has been shown in connection with a certain specific embodiment, it will be readily apparent to those skilled in the art that various changes in form and arrangement of parts may be made to suit requirements without departing from the spirit and scope of the invention.

I claim as my invention:

1. A powder rolling mill comprising, in combination, first and second axially aligned compacting rolls, the axes of said rolls being spaced to form a roll gap therebetween, and a pair of endless belts of resilient foam material containing captive air bubbles and arranged to pass through the ends of said roll gap as the rolls rotate whereby the belts provide rigid positive stops for metal powder fed into the gap at their points of maximum compression, the thickness of said foam belts when uncompressed being many times greater than the width of said roll gap.

2. A powder rolling mill having first and second axially aligned compacting rolls with their axes spaced to form a roll gap therebetween spaced belts of resilient foam material containing captive air bubbles and arranged to pass through said roll gap as the rolls rotate whereby the foam material becomes compressed in passing through said roll gap providing a rigid positive stop for metal powder fed into the gap between said belts, the thickness of said foam material when uncompressed being many times greater than the width of said gap.

3. In a powder rolling mill having first and second axially aligned compacting rolls, the axes of said rolls being spaced to form a roll gap therebetween, spaced endless belts of resilient foam material containing captive air bubbles and arranged to pass through said roll gap as the rolls rotate whereby the foam material becomes compressed in passing through said roll gap forming a rigid positive stop for metal powder fed into the gap between said belts.

4. In a powder rolling mill having first and second axially aligned compacting rolls spaced to form a roll gap therebetween, spaced lengths of resilient foam material arranged to pass through said roll gap as the rolls rotate whereby the foam material becomes compressed in passing through said roll gap providing a rigid positive stop for metal powder fed into the gap between said lengths, said foam material containing captive air bubbles which constitute up to 90% of the volume of said material when uncompressed and from zero to 2% of the volume when compressed by said rolls.

5. Apparatus to continuously form strip of predeterminable width from powdered material comprising a frame, a pair of horizontally spaced apart cylindrical compacting rolls mounted on said frame and defining therebetween an open-ended roll gap and an open-ended powder reservoir thereabove, and means adjustable longitudinally of said rolls to seal the ends of said roll gap and of said reservoir at predetermined positions to determine the width of strip formed, the sealing means comprising a plurality of endless belts of resiliently compressible material rotatably mounted upon said frame and movable in paths passing through said roll gap at said predetermined positions.

6. The apparatus of claim 5 wherein the resiliently compressible material is susceptible of resilient compression to at least about $\frac{1}{20}$ of its uncompressed thickness,

7. Apparatus to continuously form strip of predeterminable width from powdered material comprising a frame, a pair of horizontally spaced apart cylindrical compacting rolls mounted on said frame and defining therebetween an open-ended roll gap and an open-ended powder reservoir thereabove, means adjustable longitudinally of said rolls to seal the ends of said roll gap and of said reservoir at predetermined positions to determine the width of strip formed, the sealing means comprising a plurality of endless belts of resiliently compressible material rotatably mounted upon said frame and movable in paths passing through said roll gap at said predetermined positions, and means to adjust the positions of said belts.

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