June 30, 1970 D. B. COFER 3,517,537

METHOD OF HOT-FORMING CONTINUOUSLY CAST ALUMINUM

Filed Sept. 15, 1967

Fig. 1

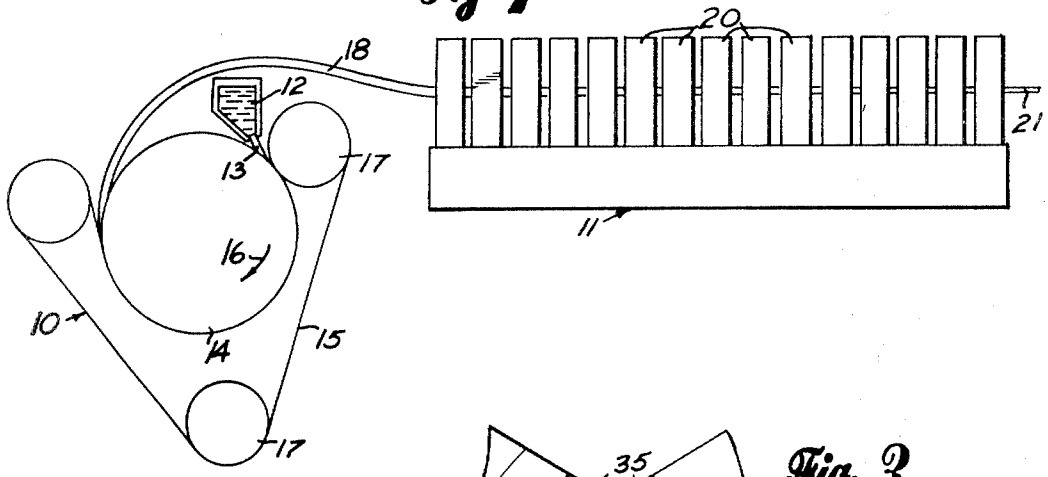


Fig. 3

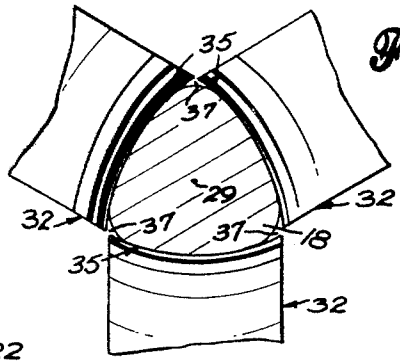


Fig. 2

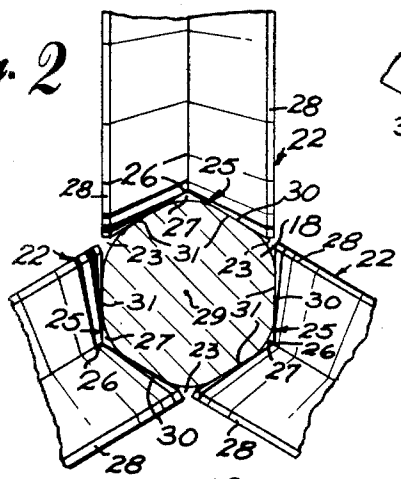


Fig. 8

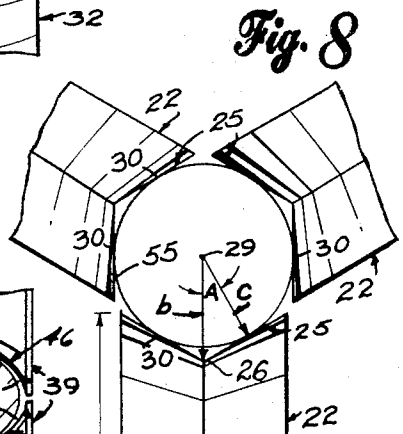


Fig. 5

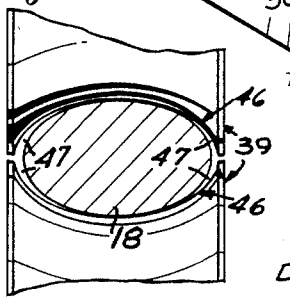
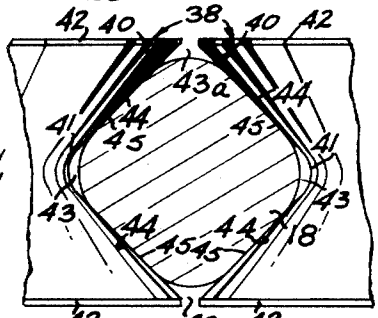


Fig. 4



D

Fig. 7

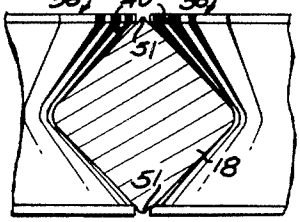
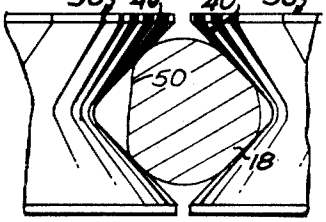


Fig. 6



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METHOD OF HOT-FORMING CONTINUOUSLY CAST ALUMINUM

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ABSTRACT OF THE DISCLOSURE

What is disclosed herein is a method of hot-forming continuously cast aluminum or a similar cast metal comprising feeding the cast metal from a continuous casting machine through a series of roll stands with the cast metal always subjected to a lengthwise compressive force between adjacent roll stands in spite of variations in the volume per unit of time of the cast metal resulting from the operating characteristics of the continuous casting machine. In each roll stand the cast metal is compressed to a smaller cross-sectional area and the lengthwise compressive force to which the cast metal is subjected between all roll stands is achieved by always feeding the cast metal toward a roll stand at a greater volume per unit of time than is required to adequately fill the space defined by the rolls of the roll stand but at not so great a volume per unit of time as to cause fins or cobbles.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to hot-forming a cast metal and more particularly, to a method of hot-rolling a cast metal passed to a rolling mill from a continuous casting machine by using a plurality of roll stands and in which the cast metal is always subjected to a limited lengthwise compressive force between adjacent roll stands.

Prior art

In the manufacture of metal rod from molten metal, a cast metal from a continuous casting machine is characteristically processed through a series of roll stands which progressively reduce the cross-sectional area of the cast metal until the desired rod configuration is obtained. Each roll stand is constructed so that the concave peripheries of two or more rolls are disposed about the path of the cast metal as the cast metal is passed through the roll stand, and the area defined by the peripheries of the rolls is smaller than the cross-sectional area of the cast metal as it enters the roll stand. The rolls of each roll stand are driven by a driving means at a predetermined speed, but because of the reduction in cross-sectional area of the cast metal in the roll stand, the linear velocity of the cast metal is higher when the cast metal leaves the roll stand than when the cast metal enters the roll stand. Thus, the rolls of each successive roll stand are driven at a higher speed than the rolls of the preceding roll stand.

As the cast metal from a continuous casting machine is processed through the roll stands of a rolling mill as generally described above, lengthwise tensive or compressive forces may be applied to those portions of the cast metal extending between adjacent roll stands. When one roll stand feeds the cast metal toward a subsequent roll stand at a volume per unit of time which tends to be greater than the subsequent roll stand is able to accept, a lengthwise compressive force is applied to the cast metal. When this lengthwise compressive force exceeds acceptable limits, it causes the subsequent roll stand to be excessively overfilled with cast metal so that the cast metal in passing through the subsequent roll stand is urged into gaps between adjacent rolls of the roll stand to form undesirable ribs or fins on the cast metal. When this lengthwise compressive force is excessive, the subsequent roll stand does not accept all of the cast metal being urged into it and a cobble is formed in the cast metal. This requires that the mill be shut down until the cobble is removed.

A lengthwise tensive force is applied to the cast metal extending between adjacent roll stands when one roll stand feeds the cast metal at a volume per unit of time insufficient to adequately fill the space defined by the rolls in a subsequent roll stand so that the subsequent roll stand tends to pull the cast metal toward it. A lengthwise tensive force applied to the cast metal extending between adjacent roll stands may result in stretching the cast metal so that it breaks or in improperly reducing the cross-sectional area of the cast metal.

These problems resulting from lengthwise tensive and compressive forces are particularly significant where the cast metal is a non-ferrous metal such as aluminum that is passed directly from a continuous casting machine to a rolling mill since the cast metal is relatively easy to cobble with a lengthwise compressive force or break with a lengthwise tensive force and since a continuous casting machine characteristically feeds cast metal to a rolling mill at various volumes per unit of time which tend to cause overfilling or underfilling of the roll stands and resulting compressive and tensive forces. Moreover, regardless of the particular cast metal, another result of inadequately filling the space defined by the rolls of a roll stand in addition to a tensive force is that the cast metal is processed with a flat side; that is, the cast metal will not be formed with a shape corresponding to that defined by the rolls of the roll stand.

SUMMARY OF THE INVENTION

The invention disclosed herein comprises a method of hot-forming a cast metal fed from a continuous casting machine through a series of roll stands in which the cast metal between adjacent roll stands is always subjected to a limited lengthwise compressive force, the compressive force being applied to the cast metal regardless of variations in the volume per unit of time of the cast metal. Specifically, the invention includes feeding a cast metal in a predetermined range of volumes per unit of time from one roll stand to a subsequent roll stand so that the space defined by the rolls of the subsequent roll stand is always sufficiently filled to subject the cast metal to a lengthwise compressive force but never becomes so excessively filled as to cause ribs or fins on the cast metal or the cobbling of the cast metal.

Accordingly, it is an object of this invention to provide a method of hot-forming cast aluminum, or a similar metal without creating flats, fins or cobbles.

Another object of this invention is to provide a method of hot-forming a cast metal through a plurality of roll stands wherein the cast metal is not subjected to a tensive force.

Another object of this invention is to provide a method of hot-forming a cast metal wherein the spaces defined by the rolls of the roll stands of a rolling mill are set prior to operating the rolling mill so that when the rolling mill is subsequently operated, only lengthwise compressive forces within an acceptable range are applied to the cast metal between the roll stands.

Another object of this invention is to provide a method of hot-forming a cast metal through a plurality of roll stands, wherein the cast metal is worked to an optimum extent by the rolls of each roll stand.

Another object of this invention is to provide a method of hot-forming a cast metal to achieve the foregoing and other objects where the cast metal is cast in a continuous

casting machine and is fed directly to a rolling mill at a hot-forming temperature and at various volumes per unit of time within the range of volumes.

Other objects, features and advantages of the present invention will become apparent upon reading the following specification, when taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of a continuous casting apparatus with which the method disclosed herein may be used, showing a cast bar as it is passed from a continuous casting machine through a series of roll stands in a rolling mill;

FIG. 2 is a cross-sectional view of a cast bar as it is being hot-formed by the rolls of a roll stand having three rolls;

FIG. 3 is a cross-sectional view of a cast bar after it has passed from the roll stand of FIG. 2 and is being hot-formed by a subsequent roll stand;

FIG. 4 is a cross-sectional view of a cast bar as it is being hot-formed by the rolls of a roll stand having two rolls;

FIG. 5 is a cross-sectional view of a cast bar after it has passed from the roll stand of FIG. 4 and is being hot-formed by a subsequent roll stand;

FIG. 6 is a cross-sectional view of a cast bar as it is being hot-formed in a roll stand, the cast bar being of smaller volume than that required to adequately fill the space defined by the rolls of the roll stand;

FIG. 7 is a cross-sectional view of a cast bar as it is being hot-formed in a roll stand, the cast bar being of a volume so large as to excessively overfill the space defined by the rolls of the roll stand;

FIG. 8 is a partial side elevational view of the rolls of a roll stand, showing the manner in which the working diameter of a roll is determined.

DESCRIPTION OF THE EMBODIMENTS

Referring now more particularly to the drawing, in which like numerals indicate like parts throughout the several views, FIG. 1 shows a continuous casting machine **10** and a rolling mill **11**. The continuous casting machine **10** serves as a casting means for solidifying a molten metal **12**, such as molten aluminum poured from a pouring spout **13** into the mold formed between a casting wheel **14** and an endless band **15** extending along the periphery of the casting wheel **14**. As the casting wheel **14** and endless band **15** move in the direction indicated by arrow **16** to carry the molten metal through the lower segment of casting wheel **14**, the molten metal **12** is cooled and solidified into a cast bar **18**. The endless band **15** is positioned against the lower segment of casting wheel **14** by a plurality of idler wheels **17**. After solidification in the annular groove in the periphery of casting wheel **14**, the cast bar **18** is directed away from the periphery of casting wheel **14** and passed directly to the rolling mill **11** at a hot-forming temperature.

The rolling mill **11** comprises a plurality of roll stands **20** disposed in alignment with one another. Roll stands **20** each include a plurality of rolls which engage the cast bar **18**. As is shown in FIGS. 2–5, the rolls of each roll stand **20** may be two or more in number and arranged diametrically opposite from one another (FIGS. 4 and 5) or arranged at equally spaced positions about the axis of movement of the cast bar **18** through the rolling mill **11**. The rolls of each roll stand **20** of the rolling mill **11** are rotated at a predetermined speed by a power means such as one or more electric motors (not shown) and the casting wheel **14** is rotated at a speed generally determined by its operating characteristics. The rolling mill **11** serves to hot-form the cast bar **18** into a rod **21** of a cross-sectional area substantially less than that of the cast bar **18** as it enters the rolling mill **11**.

As is shown in FIGS. 2 and 3, and in FIGS. 4 and 5, the peripheral surfaces of the rolls of adjacent roll stands in the rolling mill **11** change in configuration; that is, the cast bar **18** is engaged by the rolls of successive roll stands **20** with surfaces of varying configuration, and from different directions. This varying surface engagement of the cast bar **18** in the roll stands **20** functions to knead or shape the metal in the cast bar **18** in such a manner that it is worked at each roll stand and also to simultaneously reduce and change the cross-sectional area of the cast bar **18** into that of the rod **21**.

As each roll stand **20** engages the cast bar **18**, it is desirable that the cast bar **18** be received with sufficient volume per unit of time at the roll stand **20** for the cast bar **18** to generally fill the space defined by the rolls of the roll stand so that the rolls will be effective to work the metal in the cast bar **18**. However, it is also desirable that the space defined by the rolls of each roll stand **20** not be overfilled so that the cast bar **18** will not be forced into the gaps between the rolls. Thus, it is desirable that the rod be fed toward each roll stand **20** at a volume per unit of time which is sufficient to fill, but not overfill, the space defined by the rolls of the roll stand **20**.

As the cast bar **18** is received from the continuous casting machine **10**, it usually has one large flat surface corresponding to the surface of endless band **15** and inwardly tapered side surfaces corresponding with the shape of the groove (not shown) in casting wheel **14**. As cast bar **18** is compressed by the rolls **22** such as those shown in FIG. 2, the cast bar **18** is deformed so that it generally takes the cross-sectional shape defined by the adjacent peripheries of the rolls as shown in FIG. 2. The cast bar **18** will be kneaded or worked and its surfaces will conform to the surfaces **30** of V-shaped grooves **25**. If the volume of the cast bar **18** fed to the roll stand is adequate generally to fill the space defined by the rolls **22**, voids **27** will be defined between the cast bar **18** and the central recesses **26** of each roll **22**, and voids **23** will be defined between the cast bar **18** and the portions of the surfaces **30** adjacent the flat peripheral surfaces **28** of the rolls. Generally, the voids **27** defined at the central recesses **26** of the rolls **22** will be approximately equal in volume to the voids **23** defined adjacent the flat peripheral surfaces **28** between the surfaces **30** of the rolls and the cast bar **18**. Thus, each surface **30** of each roll generally has an area of contact **31** with the cast bar **18** extending only over a central portion of each surface **30** when the space defined by the rolls has been adequately filled with the cast bar **18**.

As is shown in FIG. 3, the roll stand subsequent to the roll stand of FIG. 2 generally has rolls **32** disposed at 120 degree intervals about the axis of movement **29** of the cast bar **18**, but oriented 60 degrees around the axis **29** from the rolls **22** of FIG. 2. Also, rolls **32** are formed with concave surfaces **35** which change the cross-sectional shape of the cast bar **18** into the shape of a triangle with convex sides. While rolls **32** of FIG. 3 do not define a central recess such as central recess **26** of the rolls **22** of FIG. 2, small voids **37** are defined between adjacent rolls **32**, similar to the voids **23** defined by rolls **22** of FIG. 2.

If the rolling mill **11** utilizes only two rolls at each roll stand **20**, as shown in FIGS. 4 and 5, the peripheral surfaces of the rolls are constructed usually with alternately V-shaped and concave grooves. As is shown in FIG. 4, rolls **38** define V-shaped grooves **40**, the legs of the V being angled at approximately 90 degrees. Each roll **38** defines a central recess **41** at the center of its V and flat peripheral surfaces **42** on each side of its groove **40**. When a cast bar **18** of a volume adequate to fill the space defined by the rolls **38** is received by the roll stand, small voids **43** and **43***a* are defined between the cast bar **18** and those portions of the working surfaces **44** of the rolls **38** which are adjacent the central recesses **41** and the flat peripheral surfaces **42**. Thus, the working sur-

faces **44** of each V-shaped groove **40** provide areas of contact **45** with the cast bar **18** which are bounded by voids **43** and **43***a*. As is shown in FIG. 5, the roll stand which is usually subsequent to the roll stand shown in FIG. 4 works the cast bar **18** from sides opposite to the sides of the cast bar **18** engaged by the roll stand of FIG. 4 with rolls **39** disposed 90 degrees about the cast bar **18** from the rolls **38** of the previous roll stand. The concave surfaces **46** of the rolls **39** generally engage the cast bar **18** throughout their center areas, while voids **47** are defined toward the sides of rolls **39**.

As is shown in FIG. 6, when the space defined by the rolls of a roll stand is not adequately filled with a cast bar **18** the cast bar **18** is reshaped by compression only to conform with the limited portions of the rolls which engage the cast bar **18**; that is, a portion of the cast bar **18** received by a roll stand **20** will not be compressed and a flat **50** or other flaw will be created in the cast bar **18**. Moreover, a roll stand **20** which is not adequately filled with a cast bar **18** is not effective to properly work the cast bar **18**. Furthermore, the rolls of a roll stand **20** are driven at a speed to hot-form a particular volume per unit of time and an inadequately filled roll stand such as that shown in FIG. 6 will tend to pull additional cast bar **18** into the roll stand, thus applying a tensive force to the cast bar **18** between the inadequately filled roll stand and the preceding roll stand.

As is shown in FIG. 7, when the space defined by the rolls of a roll stand **20** is excessively overfilled with a cast bar **18**, the cast bar **18** will entirely fill the space in the roll stand, including voids **23**, **27**, **37**, **43** or **43***a* described above and fins or ribs **51** will be formed on the cast bar **18** in the voids. Of course, further overfilling the space defined by the rolls may result in an excessive compressive force being applied to the cast bar **18** and in a cobble requiring the shut-down of the rolling mill **11**.

In order to avoid the situations shown in FIGS. 6 and 7 with roll stands **20** such as those shown in FIGS. 2–5, it is necessary to provide an acceptable range of volumes per unit of time of the cast bar **18** to each roll stand **20** of a rolling mill **11**. This acceptable range should serve to apply a lengthwise compressive force to the cast bar **18** as it passes between adjacent roll stands; however, the amount of compressive force should be limited so as never to be so great as to cause the cast bar **18** to excessively overfill the space defined by the rolls of a roll stand **20** and create fins or cobbles.

In providing an acceptable range of volumes per unit of time of the cast bar **18**, it is desirable to control the volume per unit of time of the cast bar **18** passing between adjacent roll stands **20** in terms of the ratio of the bar volume of the cast bar **18** leaving a roll stand per unit of time to a stand volume that expresses the volume of the cast bar **18** which will pass through the roll stand per the same unit of time without a tensive or compressive force being applied to cast bar **18** between the roll stand and the preceding roll stand. This ratio multiplied by 100 from convenience of expression relative to 100 provides a mill constant by which bar volume and stand volume are related and with which an acceptable range of volumes per unit of time of the cast bar **18** to be fed to each roll stand **20** of a rolling mill **11** is conveniently defined.

The stand volume indicative of the cast bar **18** which can be hot-formed by a roll stand while applying no tensive or compression forces to the cast bar **18** as it is fed from the preceding roll stand can be computed by the following formula:

$$SV=r.p.m.\times WC\times SA \quad (1)$$

where SV equals stand volume, r.p.m. equals revolutions per minute of the rolls of the roll stand, WC equals working circumference of the rolls of the roll stand, and SA is the stand area or the minimum cross-sectional area of the cast bar **18** required to adequately fill the space defined by the rolls of the roll stand as measured by the area of a circle **55** perpendicular to the axis **29** and inscribed within and engaging the rolls of the roll stand. The stand volume is conveniently computed in cubic feet per minute. The working circumference is the circumference of a roll where the circle **55** touches the roll and is estimated for rolls in each roll stand **20** by the following formula, and as illustrated in FIG. 8:

$$WC=\pi\times D-2(b-c\cos A) \quad (2)$$

where WC equals working circumference of a roll, D equals the outside diameter of the roll, *b* equals the distance from the center of the central recess **26** of the roll to the center of the circle **55** inscribed within the rolls of the roll stand, *c* equals the radius of the circle **55** extending to the point of contact of the circle **55** with the roll, and A equals the angle in degrees inscribed between *b* and *c*. When rolls of the type shown in FIG. 2 are utilized in a roll stand **20**, each of the rolls has a V-shaped groove with 120 degrees inscribed between the sides of the groove and A equals 30 degrees.

The bar volume of the cast bar **18** leaving a roll stand **20** per unit of time is computed by the following bar volume formula:

$$BV=LF\times BA \quad (3)$$

where BV equals bar volume, LF equals linear feet of the cast bar **18** per minute leaving the roll stand, and BA equals the cross-sectional area of the cast bar **18** as it leaves the roll stand.

It will be understood that the mill constant of a roll stand resulting from the ratio of the bar volume as defined by Equation 3 to the stand volume as defined by Equation 1 indicates whether the space defined by the rolls of the roll stand is underfilled, overfilled, or excessively overfilled with the cast bar **18** relative to that filling of the roll stand corresponding to SA at which no tensive or compressive forces are applied to the cast bar **18** as it passes to the roll stand from the preceding roll stand. This is because a mill constant greater than 100 indicates overfilling and a mill constant less than 100 indicates underfilling relative to that filling of the space defined by the rolls of the roll stand corresponding to SA at which no tensive or compressive forces are applied to the cast bar **18** between the roll stand and the preceding roll stand.

As previously explained, it is desirable to have a compressive force applied to the cast bar **18** as it passes between adjacent roll stands **20**. If the cast bar **18** is fed to a roll stand at a volume per unit of time in excess of the stand volume, the mill constant will be in excess of 100 and, a compressive force will be applied to the cast bar **18** extending between that roll stand and the one preceding it. Thus, the situation of underfilling illustrated in FIG. 6, which creates a flat or flattened area on the cast bar **18**, or which applies a tensive force to the cast bar **18**, is avoided.

In providing a mill constant in excess of 100 at each roll stand in a rolling mill, the volume of the cast bar **18** to be fed from the continuous casting machine **10** to the rolling mill **11** must be initially considered. This is because both the speed of the continuous casting machine **10** and the cross-sectional area of the cast bar **18** as it passes from the continuous casting machine **10** vary within ranges characteristic of the particular casting machine **10** so that the volume of the cast bar **18** per unit of time entering the first roll stand of a rolling mill **11** varies within a predetermined range of volumes. Thus, the stand area (SA) of the first roll stand must be selected so that the stand volume SV of the first roll stand is less than the volume of the cast bar **18** per unit of time entering the roll stand throughout the range of volumes of the cast bar **18** provided by the operating characteristics of the casting machine **10**. This results in the first roll stand always having a mill constant great-

er than 100 regardless of variations in the cast bar **18** entering the roll stand.

Once the stand area (SA) is established for the first roll stand, the range of bar volumes (BV) leaving the first roll stand is known and the stand area (SA) for the next roll stand is selected to provide a mill constant which is always greater than 100 as the volumes per unit of time of the cast bar **18** from the first roll stand vary. The stand areas (SA) for subsequent roll stands are similarly selected to insure a mill constant for each roll stand which is always in excess of 100 regardless of variations in the volume of the cast bar **18** fed to each roll stand.

Thus, at the particular predetermined r.p.m. of each roll stand, each roll stand receives a volume of the cast bar **18** which is in excess of that required to adequately fill the roll stand as defined by SV. In terms of roll stand constants, each roll stand has a mill constant which is always in excess of 100 regardless of the variations in the volume of the cast bar **18** which result from operating characteristics of the continuous casting machine **10**. Since the r.p.m. of each preceding roll stand is less than the r.p.m. of a subsequent roll stand, the stand area (SA) defined by the rolls of successive roll stands progressively decreases and the required mill constants are readily achieved with stand areas (SA) which provide a specific size of the rod **21** from the last roll stand.

In selecting mill constants for the roll stands of a rolling mill **11**, each roll stand may be regarded as having a nominal mill constant corresponding to a particular volume of the cast bar **18** from which the actual mill constant varies as the volume of the cast bar **18** varies. Although the nominal mill constants of the roll stands are selected in accordance with the specific characteristics of a particular continuous casting machine **10**, the nominal mill constant for each roll stand will in most rolling mills **11** be substantially higher than 100 to provide for maximum variation in volume of the cast bar **18** fed to the rolling mill **11** from a continuous casting machine **10**. However, a practical upper limit of the actual mill constant is established by the danger of cobbles and of fins or ribs as shown in FIG. 7 so the nominal mill constant must not be so high as to result in variations in the volume of the cast bar **18** causing the upper limit of the actual mill constants to be too high.

When hot-forming continuously cast aluminum, it has been found that limiting the actual mill constants to 125 or lower will not result in a compressive force which causes the forming of cobbles. Moreover, in order to avoid fins or ribs in the cast bar **18**, it has been found desirable to limit the upper limit of the actual mill constants in each roll stand below about 115. However, it has been found, through experimentation, that with most continuous casting machines **10** used for casting aluminum, a nominal mill constant of 106 is adequate to prevent variations in the volume of a cast bar **18** from causing an actual mill constant greater than 115 and less than 100 with the result that a compressive force is always applied to the cast bar **18** between roll stands but the compressive forces are never so large as to cause fins, ribs, or cobbles.

A rolling mill **11** having a nominal mill constant of 106 at each roll stand has been successively operated with a continuous casting machine **10** operating at substantially constant speed but with the cross-sectional area of the cast bar **18** as it passes from the continuous casting machine varying between 3.08 and 3.24 square inches. The rolling mill **11** was shut-down several times and fish poles were extracted and measured to determine that the rolling mill **11** was operating in accordance with the invention. The following table shows the results of the various measurements made at each of fifteen roll stands for each of five cast bars **18**:

		Cast bar				
		1	2	3	4	5
Area of cast bar (sq. in.)		3.24	3.14	3.19	3.08	3.19
Roll #1, 21.438 r.p.m., WD=8.923 in. Vel=50.08 f.p.m.	Bar area in.^{2}	2.72	2.70	2.78	2.76	2.76
	MC	103.88	103.28	106.13	105.44	105.40
Roll #2, 26.787 r.p.m.; WD=9.1795 in.; Vel=64.38 f.p.m.	Bar area in.^{2}	2.15	2.15	2.19	2.17	2.16
	MC	105.57	105.69	107.40	106.31	106.30
Roll #3, 33.47 r.p.m.; WD=9.292 in.; Vel=81.42 f.p.m.	Bar area in.^{2}	1.68	1.68	1.70	1.70	1.69
	MC	104.31	104.38	105.77	105.74	105.10
Roll #4, 41.817 r.p.m.; WD=9.4866 in.; Vel=103.83 f.p.m.	Bar area in.^{2}	1.35	1.33	1.35	1.35	1.34
	MC	106.89	105.31	106.73	106.90	106.10
Roll #5, 52.34 r.p.m.; WD=9.5756 in.; Vel=131.25 f.p.m.	Bar area in.^{2}	1.05	1.04	1.04	1.05	1.04
	MC	105.09	103.84	104.52	104.68	103.89
Roll #6, 65.41 r.p.m.; WD=9.7525 in.; Vel=166.5 f.p.m.	Bar area in.^{2}	.830	.833	.834	.836	.834
	MC	105.39	105.78	105.89	106.18	105.89
Roll #7, 81.73 r.p.m.; WD=9.9126 in.; Vel=209.58 f.p.m.	Bar area in.^{2}	.653	.650	.653	.650	.652
	MC	104.37	103.87	104.29	103.87	104.20
Roll #8, 102.125 r.p.m.; WD=9.9126 in.; Vel=265.0 f.p.m.	Bar area in.^{2}	.526	.525	.521	.520	.524
	MC	106.30	106.18	105.27	105.01	105.89
Roll #9, 128.19 r.p.m.; WD=9.9683 in.; Vel=334.5 f.p.m.	Bar area in.^{2}	.403	.413	.409	.407	.414
	MC	102.80	105.25	104.41	103.77	105.60
Roll #10, 160.17 r.p.m.; WD=10.0598 in.; Vel=421.8 f.p.m.	Bar area in.^{2}	.329	.334	.337	.332	.336
	MC	105.83	107.14	108.24	106.66	108.08
Roll #11, 200.13 r.p.m.; WD=10.176 in.; Vel=666.2 f.p.m.	Bar area in.^{2}	.259	.265	.265	.257	.265
	MC	104.41	106.66	106.70	103.52	106.82
Roll #12, 250.07 r.p.m.; WD=12.1997 in.; Vel=832.8 f.p.m.	Bar area in.^{2}	.206	.212	.213	.210	.212
	MC	104.66	107.81	108.11	106.54	107.71
Roll #13, 311.9 r.p.m.; WD=10.1997 in.; Vel=832.8 f.p.m.	Bar area in.^{2}	.1670	.1667	.1672	.1662	.1668
	MC	106.06	105.87	106.19	105.55	105.93
Roll #14, 389.72 r.p.m.; WD=10.268 in.; Vel=1047.7 f.p.m.	Bar area in.^{2}	.1330	.1365	.1321	.1354	.1358
	MC	106.26	109.06	105.55	108.18	108.50
Roll #15, 486.96 r.p.m.; WD=10.2861 in.; Vel=1311.3 f.p.m.	Bar area in.^{2}	.1090	.1114	.1119	.1115	.1112
	MC	109.0	111.4	111.9	111.5	111.2

It is believed that the figures presented in the above table illustrate the effectiveness of a nominal mill constant of 106 since it will be apparent that regardless of variations in the volume of the cast bar **18** resulting from the operating characteristics of the continuous casting machine **10**, the actual mill constant at each of the fifteen roll stands was always in excess of 100 but less than 115. Thus, a limited compressive force was applied to the cast bar **18** between adjacent roll stands and upon examining a rod **21** after processing through the rolling mill **11**, it was found that virtually no flats, ribs, or fins were present on the rod **21**. Moreover, no cobbles occurred during rolling and generally speaking, a superior product was produced.

It will be obvious to those skilled in the art that many variations may be made in the embodiments chosen for the purpose of illustrating the present invention without departing from the scope thereof as defined by the appended claims.

I claim:

1. In a method of hot-forming a cast metal bar from a continuous casting machine, the step of passing the cast metal bar through a series of roll stands and applying a lengthwise force to the cast metal bar as it passes simultaneously from a first roll stand and into a second roll stand.

2. In a method of hot-forming a cast metal bar, the steps of

feeding a cast metal bar from a continuous casting machine to a series of roll stands, and

compressing the cast metal bar at each successive roll stand to a smaller cross-sectional area while simultaneously feeding the cast metal bar into a successive roll stand with a preceding roll stand at a volume per unit of time which is other than that required to adequately fill a space defined by the rolls of said successive roll stand.

3. In a method of hot-forming a solid metal shape from a continuous casting machine, the step of applying a compressive force to said solid metal shape by feeding the solid metal shape simultaneously from a first roll stand and into a succeeding roll stand at a volume per unit of time greater than the minimum capacity of said succeeding roll stand.

4. In a method of hot-forming a solid metal shape from a continuous casting machine, the step of feeding the solid metal shape through a series of roll stands at a volume rate higher than each roll stand operates to normally accept, said solid metal shape being in at least two of said roll stands simultaneously.

5. In a method of hot-forming a cast metal bar from a continuous casting machine, the step of passing the cast metal bar through a series of roll stands and maintaining the metal volume of the cast metal bar leaving each roll stand per unit of time above that predetermined minimum volume which will neither overfill nor underfill the next roll stand.

6. The invention of claim 5 wherein the ratio of the metal volume to the minimum volume multiplied by 100 is in a range between 100 and 125.

7. The invention of claim 5 wherein the ratio of the metal volume to the minimum volume multiplied by 100 is approximately 106.

8. In a method of hot-forming a cast metal which is solidified in a casting means and which is subsequently passed to a hot-forming means at a hot-forming temperature and at a volume per unit of time that varies within a range of volumes, said hot-forming means including a plurality of roll stands each having a plurality of driven rolls defining a roll pass through which a particular volume per unit of time of said cast metal will pass without substantial tensive or compressive forces being applied to the said cast metal as said cast metal is fed to said roll pass, and said method including the step of feeding said cast metal from one roll stand to a subsequent roll stand at a volume per unit of time which is always greater than said particular volume per unit of time.

9. The method of claim 8 in which said particular volume per unit of time for each of said plurality of roll stands is defined by the formula:

$$SV=\text{r.p.m.}\times WC\times SA$$

where SV is said particular volume per unit of time, r.p.m. is the revolutions per minute of said driven rolls, SA is the area of a circle inscribed within said driven rolls perpendicular to the axis of movement of said cast metal through said roll pass, and WC is the circumference of a driven roll where said circle contacts a surface of said driven roll.

10. In a method of rolling a cast metal in a plurality of roll stands each having a roll pass defined by a plurality of driven rolls and through which said cast metal passes along an axis of movement, the step of adjusting the area of each roll pass transverse to said axis so that the volume of cast metal per unit of time passing through said each roll pass as defined by the formula:

$$SV=\text{r.p.m.}\times WC\times SA$$

is less than the volume of said cast metal leaving said roll pass as defined by the formula:

$$BV=LF\times BA$$

where SV is said volume of cast metal per unit of time passing through said roll pass, r.p.m. is the revolutions per minute of said driven rolls, SA is the area of a circle inscribed within and touching said plurality of driven rolls perpendicular to said axis, WC is the circumference of a driven roll where said circle touches to a surface of said driven roll, BV is the volume of said cast metal leaving said roll pass, LF is the velocity in linear feet per minute of said cast metal leaving said roll pass, and BA is the cross-sectional area of said cast metal leaving said roll pass.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,517,537 Dated June 30, 1970

Inventor(s) D. B. Cofer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The title of the invention is changed from "METHOD OF HOT-FORMING CONTINUOUSLY CAST ALUMINUM" to read--METHOD OF HOT-FORMING CONTINUOUSLY CAST METAL--.

Signed and sealed this 28th day of December 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Patents