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METHOD FOR ROLLING DISKS AND A DISK ROLLING MILL FOR THE PRACTICE OF THE METHOD

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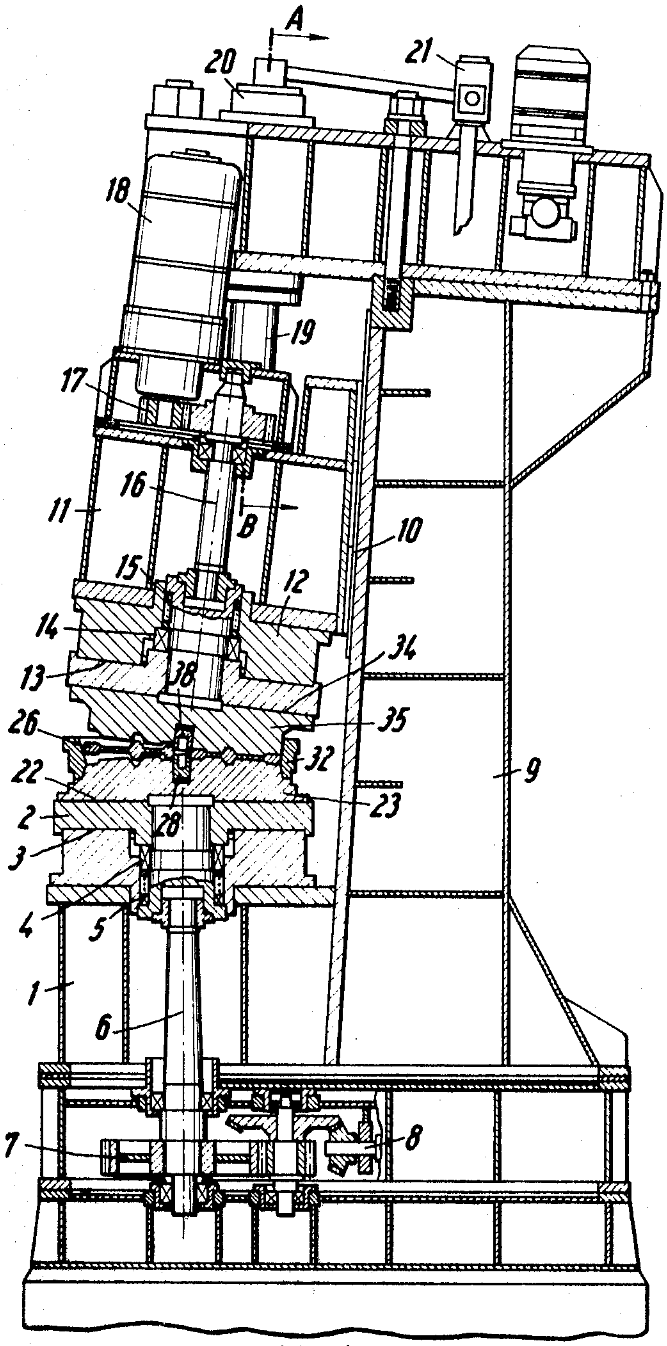


Fig. 1

Inventor:

Otto Ulrych

By Burgess, Dinklage & Sprung

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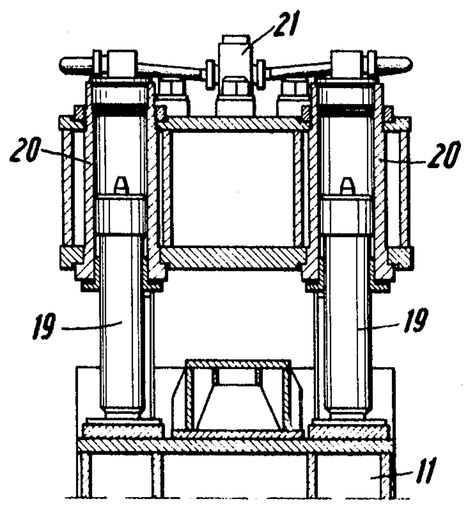


Fig. 2

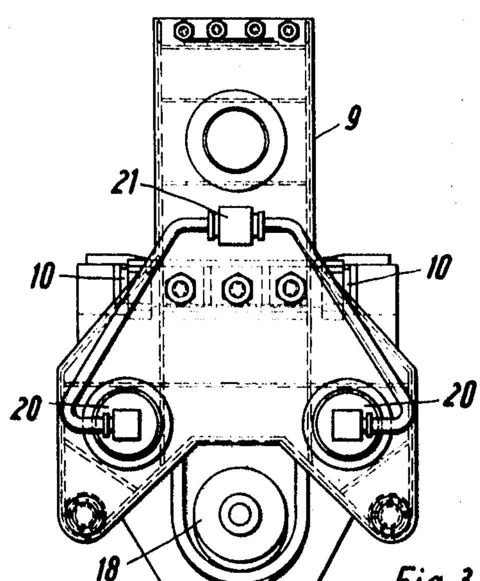


Fig. 3

Inventor:
Otto Ulrich
By Burgess, Dinklage & Sprung
ATTORNEYS

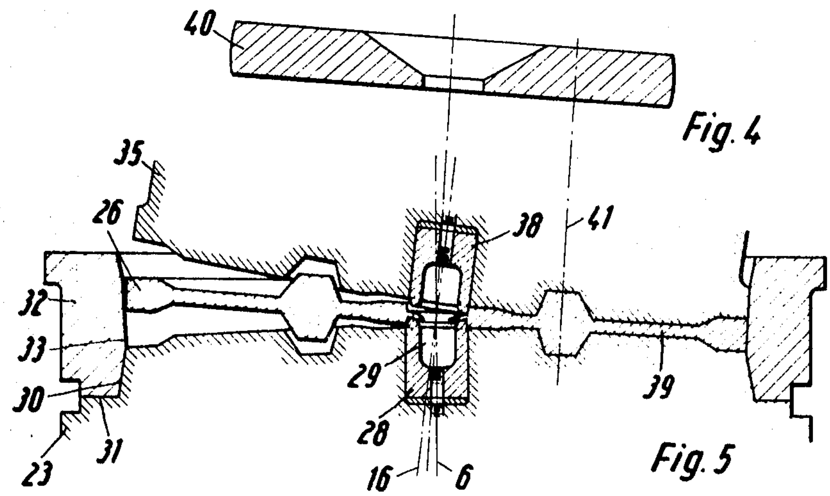


Fig. 4

Fig. 5

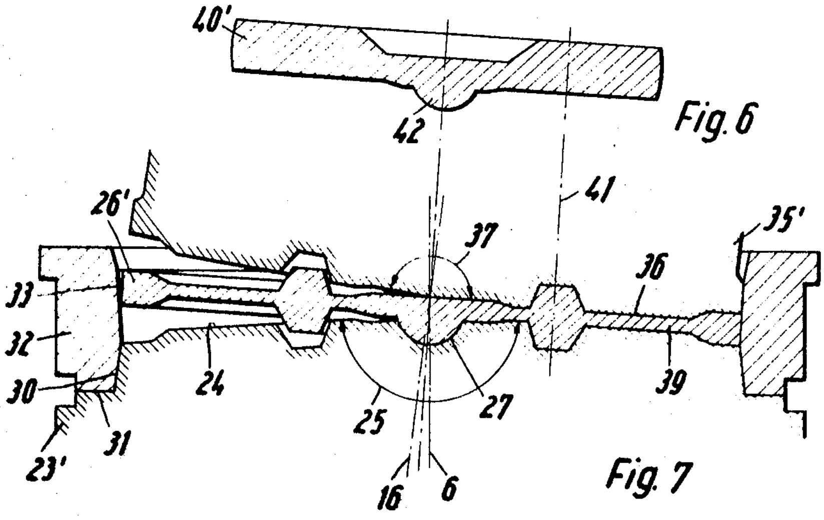


Fig. 6

Fig. 7

Inventor:
Otto Ulrich
BY: Burgess, Dinklage & Sprung
ATTORNEYS

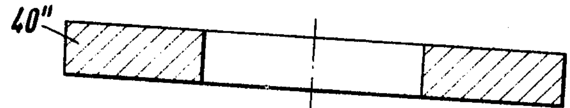


Fig. 8

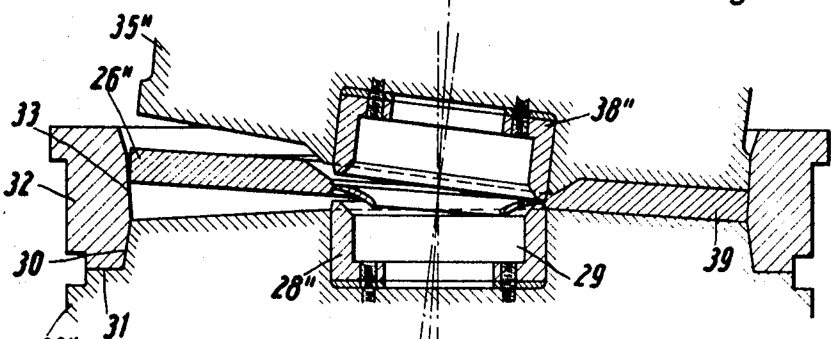


Fig. 9

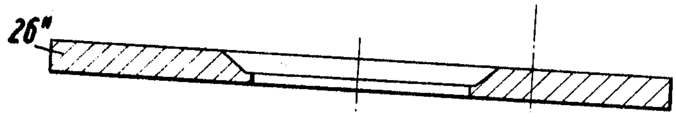


Fig. 10

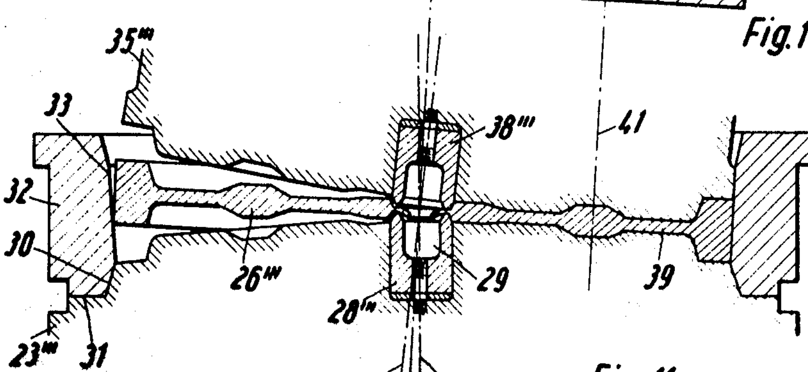


Fig. 11

Inventor:
Otto Ulrich
BY: Burgess, Dinklage & Sprung
ATTORNEYS

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# METHOD FOR ROLLING DISKS AND A DISK ROLLING MILL FOR THE PRACTICE OF THE METHOD

Otto Ulrych, Dortmund-Horde, Germany, assignor to Rheinstahl Wagner Werkzeugmaschinenfabrik m.b.H., Dortmund, Germany

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Int. Cl. B21h *1/02*

U.S. Cl. 72—84 19 Claims

## ABSTRACT OF THE DISCLOSURE

Apparatus for rolling stock into contoured disks including upper and lower rolls having desired contours negatively on the working surfaces thereof which surfaces are obtuse angle conical surfaces wherein the upper roll is tilted from the vertical an amount sufficient to provide engagement between the two working faces on one side of the cone only. Pressure exerting means is shown adapted to urge the working surfaces together. Method of using this apparatus is described.

The invention relates to a method of rolling disks that are to be shaped on both sides, especially thin-wall disks, and a disk rolling mill for the practice of the method.

In the manufacture of wheel bodies and other disk-shaped workpieces by the rolling method, one normally begins with a previously formed blank, especially a forged blank, which is given the desired final shape on a disk rolling mill by the action of a plurality of rolls which modify the diameter and thickness of the blank. One known design of disk rolling mills for rolling previously forged blanks has rollers which are short in proportion to the disk diameter, usually tapered, and arranged in pairs, and which are urged against one another during the rolling in order to reduce the thickness of the blank and increase its diameter. The rolls are first applied in the vicinity of the hub of the disk and, for the purpose of rolling the disk web, they are displaced radially outward and made to approach one another axially. Additional rolls or pairs of rolls are provided for the rolling and shaping of the rim and tread of the disk.

For the rolling of forged disks which undergo a relatively small diameter increase in the rolling process, as in the case of wheel disks and railroad car wheels, disk rolling mills are used in which the pair of rolls acting on the disk from both sides are short in proportion to the disk diameter and can be brought to bear against one another, and they can simultaneously apply pressure radially of the disk. In this rolling mill, the application of appropriately shaped tapered rolls in conjunction with a roll acting on the external periphery of the rim of the disk produces a reduction of the radial thickness of the rim and a reduction of the thickness of the web, while at the same time increasing the diameter of the disk. In this case, too, additional pairs of rolls can be provided for rolling down or maintaining the flanks of the rim of the disk.

The above mentioned disk rolling mills require preshaped blanks, and, on account of the nature of the rolling process which they permit, they can only make disks having a flat web. This is because of the fact that the gap formed between the rolls engages the disk along only a portion of its diameter, and shifts radially in relation to the center of the disk during the rolling process.

A disk rolling mill has become known in which the one roll contains a complete negative of the one side of the disk to be rolled, while the negative of the other side is created on the mantle surface of an obtuse-angle cone



forming the counter-roll. The axes of the two rolls are set at an angle to one another. One roll is freely rotatable and the other is driven and they can be brought to bear against one another. The rolling process is performed as follows: a socket punched in one face of the disk is placed on a stud in the non-conical roll; the rolls are then rotated and the gap between them is narrowed, increasing the diameter of the blank and rolling it into the negative of the non-conical roll. With rolling mills of this kind it is possible to roll disks having a web that is other than flat or one that has a special cross section. However, they have the disadvantage that the workpiece is lying fully on the non-conical roll and is considerably cooled thereby. Consequently, this method and therefore this apparatus are unsuitable for the rolling of thin disks, especially those made of materials having a narrow range of suitable rolling temperature, or those which require a long rolling time on account of their poor rolling characteristics.

It is an object of this invention to provide a novel means for rolling stock to a desired contoured shape.

Another object of this invention is to provide a novel rolling mill.

Other and additional objects of this invention will become apparent from a consideration of this entire specification including the claims and drawing hereof.

In accord with and fulfilling these objects, one aspect of this invention includes a novel rolling mill which has an upper and lower roll having a lower and an upper working face, respectively, which working faces are obtuse angle cones, and which rolls are angularly oriented with respect to each other so as to have an obtuse angle between the axes thereof, preferably such that only a small portion of the conical working faces are in working relation to each other at any given time.

The invention makes possible the economical manufacture of thin disks having special cross sections, the shape given to one face being able to differ from that given to the other. It offers special advantages in the production of axially symmetrical, discoidal bodies from highly heat-resistant, expensive materials that are difficult to shape, such as those used, for example, in engines for aircraft and spacecraft. The forming of such parts in presses would entail very great press forces and consequently high machine costs, and forming them by machining alone would be uneconomical on account of the poor machinability of the materials and the excessive waste.

The advantages of the invention are due to the fact that, on the one hand, the workpiece contacts the two forming rolls only in the area of a roll gap, so that the heat losses are slight, and, on the other hand, the roll gap extends over the entire disk radius, thereby eliminating the shifting of the roll gap radially with reference to the center of the disk, which renders any special fashioning of the disk impossible.

According to the invention, a discoidal blank heated to forging temperature is centered on one patterned roll, and is first partially gripped between this one roll, which bears on its obtusely conical mantle surface the pattern that is to be rolled into the one face of the disk, and the other roll, which bears on its obtusely conical surface the pattern that is to be rolled into the other face of the disk, the axis of the latter roll being at an angle to the axis of the former, while the rolls are rotated and the distance between them is reduced, and then the blank is shaped so as to fill the roll gap resulting from the pattern and the distance between the rolls. In order to achieve a specified outside diameter of the disk in the rolling process and thereby keep down the material losses in the later machining of the rolled disks, it is further proposed that the outside diameter of the disk be limited by a boundary surface or rim collar rising above the patterned mantle surface of the roll and flaring outward toward the other roll. For the rolling of disks whose outside diameter is greater than that of the disk blank and in which a central hub bore is ultimately to be made, the invention proposes that the discoidal blank have a center hole punched in it and that it be centered by the engagement of this hole with a centering stud provided on at least one of the rolls. If, however, unperforated disks are to be produced having an outside diameter larger than that of the blank, the discoidal blank is to have a central stud, according to the invention, and is to be centered by the engagement of this stud in a center recess in the roll. A simple blank manufacture and a reliable centering of the blank can be achieved by making the central stud of the blank and the recess in the roll cup-shaped. The use of punched or unpunched blanks having an outside diameter equal to that of the punched disk is made possible by the invention owing to the fact that the discoidal blank is centered by its outside diameter in the boundary surface of the roll.

In order to achieve the desired flow of material, especially in the case of hard-to-form materials and deep patterns to be rolled into the disks, and in order to keep the roll wear low, it is furthermore proposed that the rolling be performed successively between a series of pairs of rolls, each pair bringing the disk closer to the desired final shape, and the last pair having a pattern corresponding to the final shape.

For convenience in handling the workpieces, and to enable the equipment to be installed in a smaller amount of space, particularly for multi-stage rolling, the invention proposes, as a disk rolling mill for the practice of the method of the invention, a bottom roll having a perpendicular shaft and an upper roll having an axis at an angle to the perpendicular. An especially simple construction of the disk rolling mill can be achieved if, according to a further proposal, both rolls can be driven and the upper roll can be brought to bear against the lower one. To permit the achievement of optimum rolling conditions for various disk materials and diameters, it is desirable to provide for variation of the speed at which the rolls are driven. To enable equal rolling effects to be achieved on both sides of the disk, and to enable the distance between the unheld portion of the disk and the upper and lower rolls to be small and equal in the interest of a secure disk guidance, the apex angles of the patterned mantle surfaces of both rolls are to be equal and as large as possible, preferably about 170°. A roll gap that is parallel with reference to the theoretical, unpatterned mantle surfaces is produced by tilting the axis of the upper roll away from the perpendicular by an angle amounting to half of the difference between the sum of the apex angles of the mantle surface of both rolls and 360°. To permit an unstrained application of the upper roll to the lower, it is proposed that the direction of application of the upper roll against the lower be inclined from the perpendicular so that the angle of inclination amounts to half of the difference between the apex angle of the lower roll mantle surface and 180°, being thus perpendicular to the roll gap, and so that the intersection of the two roll axes lies always in the center plane of the rolled disk. In order to keep the force required for the application of the upper roll to the lower as small as possible, thereby minimizing its adverse effects, particularly on the mounting and guiding means of the upper roll, the force ("rolling force") by which the upper roll is applied to the lower roll (or the resultant force where more than one force is at work) and the resulting of the rolling resistance acting in the area of the roll gap do not produce any moment during the rolling process. This is achieved pursuant to the invention by the fact that the line of application of the force by which the upper roll is applied to the lower roll runs in the direction of application of the upper roll, and hence perpendicularly to the roll gap, and runs through or near the centroid of the rolling zone adjacent the roll gap formed by the upper roll and the lower roll.

The convenient internal centering of the pre-punched



disk on the lower roll with the production of only a small burr or fin in the area of the hole is achieved according to a further proposal by means of a tapered centering pin in each of the rolls, projecting from the center of each roll, the sum of the projecting lengths of the centering pins being smaller than the thickness of the rolled disk in the area of the centering pins.

Lastly, the rim collar mounted on the lower roll and forming the outside boundary of the roll gap is removable so as to permit the easy removal of the rolled disk by means of a fork lift truck or the like.

Understanding of this invention will be facilitated by reference to the drawing in which:

FIG. 1 shows a longitudinal section through a disk rolling mill with a disk in the final phase of the rolling;

FIG. 2 shows a partial section through the upper portion of the disk rolling mill on line A–B of FIG. 1;

FIG. 3 is a top view of the disk rolling mill;

FIG. 4 shows a forged and punched blank;

FIG. 5 shows tolls of the disk rolling mill in the rolling position with a disk rolled from the blank of FIG. 4;

FIG. 6 shows a forged, unperforated blank having a hemispherical centering boss;

FIG. 7 shows tools of the disk rolling mill in the rolling position with a disk rolled from the blank of FIG. 6;

FIG. 8 shows a forged and punched blank;

FIG. 9 shows tools of the disk rolling mill in the rolling position roughing the blank of FIG. 8;

FIG. 10 shows the roughed blank produced as shown in FIG. 9; and

FIG. 11 shows tools of the disk rolling mill in the rolling position with a disk rolled from the roughed blank of FIG. 10.

In a rolling mill frame **1**, a lower roll holder **2** is rotatably mounted on a hydrostatic thrust bearing **3** and two shaft bearings **4** and **5** with a vertical shaft **6**, and is driven through a gear transmission **7** and a partially shown drive shaft **8** by a variable-speed motor which is not represented. An upright **9** of the rolling mill frame **1** has guideways **10** which are inclined 3.5° from the vertical and on which a slide **11** is displaceably guided. An upper roll holder **12** is rotatably mounted on the slide **11** on a hydrostatic thrust bearing **13** and two shaft bearings **14**, **15**, with a shaft **16** inclined 7° from the vertical, and it can be driven through a gear transmission **17** by a variable-speed motor **18**. Motor **18** runs synchronously with the motor driving shaft **8**, as a result of being powered by a common Ward-Leonard system. Two plungers **19** are fastened to the top of the slide **11**. The plungers **19** are held in two double-acting hydraulic cylinders **20** fastened to the upright **9**. The large upper piston faces and the small lower piston faces of the plungers **19** can be driven by hydraulic fluid by means of a hydraulic control **21**, which is not shown in detail.

The plungers **19** and hydraulic cylinders **20** are so arranged that the line of application of their resultant force lies in the plane passing through the perpendicular shaft **6** and the inclined shaft **16**, is inclined 3.5° from the vertical, and runs approximately through the centroid of the rolling zone which is to be explained later.

A lower roll **23**, **23'**, **23''** and **23'''**, respectively, is fastened to a tool plate **22** of the bottom roll holder **2** by known means. Its top side **24** (FIG. 7) is of conical construction with an apex angle of 173° and bears the pattern that is to be rolled into the bottom side of a disk **26**, **26'**, **26''** and **26'''**, respectively. The bottom rolls **23**, **23'**, **23''** and **23'''** are each shaped according to the desired disk design. The bottom roll **23'** (FIG. 7) has a central hemispherical recess **27**. The bottom rolls **23**, **23''** and **23'''** (FIGS. 5, 9, 11) are each provided with a centering pin **23**, **28''**, **28'''** fastened, by means not shown, in a center bore. The centering pins have a central cup **29** and have a taper at the end that projects from the bottom roll. A rim collar **32** is removably mounted on a tapered portion **30** and a flange **31** on the outer periphery of the bottom rolls 23, 23′, 23″ and 23‴, and projects above the bottom roll. The inner surface 33 of the rim collar 32 flares conically in the portion that is free of the bottom roll, at an angle corresponding to the direction of the guideway 10.

A top roll 35, 35′, 35″, 35‴, respectively, is fastened removably to a tool plate 34 of the upper roll holder 12 by means which are not shown. A bottom face 36 (FIG. 7) of the top roll is of conical shape with an apex angle 37 of 173°, and it bears the pattern that is to be rolled into the top side of disk 26, 26′, 26″ and 26‴, respectively. The upper rolls 35, 35″ and 35‴ are provided with a center bore into which a centering pin 38, 38″ and 38‴, respectively, of the same design as the centering pin 28, 28″ and 28‴, respectively, is inserted and fastened. At the point of the shortest distance between the bottom roll and the top roll is a roll gap 39. When both rolls are in contact with the disk 26, 26′, 26″ and 26‴, respectively, a rolling zone is formed here, which in the peripheral direction of the roll has the shape of a narrow segment or sector of a circle. Approximately through the centroid of this rolling zone runs the line of the application of the resultant force of the plunger 19 driven by hydraulic fluid, as already mentioned above.

A forged and punched blank 40 from which disk 26 is made is shown in FIG. 4. By rolling the blank between rolls 23 and 35 a disk is produced bearing the pattern shown in FIG. 5. The point of division of flow in this disk, i.e., the point at which the zone in which the material flows radially inward during the rolling meets the zone in which the material flows radially outward during the rolling, is identified by a line 41. The forged blank 40′, which is provided with a hemispherical boss 42 in the center as shown in FIG. 6, will be made into the disk 26′ by rolling between the rolls 23′ and 35′ bearing the pattern shown in FIG. 7. The forged and punched blank 40″ of FIG. 8 is roughed between the rolls 23″ and 35″ of FIG. 9 to a disk 26″ which is finish-rolled between the rolls 23‴ and 35‴ of FIG. 11 to form a disk 26‴.

The procedure is as follows:

In order to produce a disk 26 according to FIG. 5, one starts with a forged and punched blank 40. This blank is of such dimensions and shape that, on the one hand, a minimum of forming under the forging press is required, and on the other hand the distribution of material in it comes as close as possible to the material distribution in the rolled disk 26, taking into consideration the point of division of flow 41 established by the area of maximum material accumulation in the rolled disk. The blank 40 is punched to fit the centering pin 28. The slide 11 of the rolling mill is in its upper end position. Rolls 23 and 35 are standing still. The blank 40, heated to forging temperature, is laid on the lower roll 23 and centered by its hole on the centering pin 28. The blank lies horizontally. When the hydraulic control 21 is set to "Advance," slide 11 is lowered until the upper roll 35 settles on blank 40 and brings it into a tilted position in a one-sided contact between rolls 35 and 23, this tilt being determined by the apex angles 25 and 37 of the rolls and the tilt of the upper roll axis 16. When the hydraulic control 21 is then set to "Roll," the hydraulic pressure required for the predetermined rolling force is applied to the upper surfaces of plunger 19, and the motors driving rolls 23 and 35 are energized, thereby accelerating rolls and blank to the selected speed. The rotation of the rolls and the blank, with the simultaneous diminution of the distance between the rolls under the influence of the rolling force brings about the gradual forming of blank 40 to disk 26 which has a shape conforming to the roll pattern. In this process the material outside of the line of division of flow flows substantially outward, where it is limited by the inside surface 33 of the rim collar 32. The material inside of the line of division of flow is displaced substantially inward, its flow being limited by the centering pns 28 and 38.



Owing to the tilted position of the disk during the rolling process, only a very small fraction of the disk surfaces are in contact with the rolls. Most of the disk surfaces are free of the rolls, so that the loss of heat from the disk to the rolls is slight, even when the rolls are internally cooled. As soon as the outside diameter of the disk encounters the rim collar 32, diameter increases ceases, because despite the fact that most of the disk is unsupported, approximately two-thirds of its exterior periphery remains within the inside surface 33 of the rim ring 32. The continued downward feed of the upper roll in this phase of the process merely produces a complete filling out of the pattern determined by the roll gap 39 formed by lower roll 23, upper roll 35, centering pins 28 and 38 and rim ring 32. Any excess material penetrates into the gap between the two centering pins and collects in cups 29 in these pins.

The rolling speed, i.e., the rotatory speed of the rolls, and the rolling force, i.e., the force applied to plunger 19, are selected on the basis of the working characteristics of the material being rolled. In the case of hard-to-work, highly heat-resistant materials, for which the method and apparatus are particularly well suited, a very slight reduction per revolution is made, at correspondingly high rolling speed. After completion of the rolling process the rolls are stopped, and slide 11 is raised back to its upper terminal position by applying hydraulic power to the lower piston faces of plunger 19. Rim ring 32 is lifted from the bottom roll 23, whereupon the entire periphery of the rolled disk 26 will be caught in the rim ring and the disk will be lifted with the ring out of the rolling mill. The disk can be removed from the rim ring for further transportation, merely by inverting the ring or by some other such operation.

Depending on the final pattern desired in the disk, it can then be further worked, or, if desired, it can be reheated, if necessary, and rolled in stages in additional rolling mills. It is also possible to perform multi-stage rolling using only a single rolling mill by first rolling a suitable number of disks, and then replacing the rolls with others having the pattern required for the next rolling stage.

An example of two-stage rolling is shown in FIGS. 8 to 11. In this case one starts out with a forged, punched blank 40″. This cylindrical perforation in blank 40″ has a relatively large diameter to correspond to the material distribution in the finished disk 26‴. The blank is laid on the lower roll 23″ and centered thereon by a centering pin 28″. In the first rolling stage blank 40″ is rolled between rolls 23″ and 35″ in the manner described previously, to form a disk 26″. Since disk 26″ at the end of the rolling already has the outside diameter of the finished-rolled disk 26‴, the centering of disk 26″ on bottom roll 23‴ in the second rolling stage is performed by means of the inside surface 33 of the rim ring 32. The rolling process in the second stage reduces the inside diameter of the disk to the size determined by centering pins 28‴ and 38‴.

If an unpunched disk is to be rolled whose blank diameter is smaller than the diameter of the rolled disk, in the interest of reducing the forged work, a blank 40′ is used which has a hemispherical centering boss 42, as shown in FIG. 6. When this blank is laid on the bottom roll 23′ it is centered in the hemispherical recess 27 in the bottom roll. Otherwise the rolling process is the same as described before.

It is preferred in the practice of this invention to produce titanium products in disk form. In this regard it has been found that titanium is perculiarly well-adapted to use and to shaping using the device and method of this invention. The disk should be rolled at a temperature of about 900 to 1040° C., preferably at least about 950° C. since it is only between these temperatures that titanium can be economically rolled. Further it is preferred that the roll gap widen in a radially outward direction, whereby to ensure the flow of material radially outward during rolling of the titanium disks.

What is claimed is:

**1.** Method of producing contoured disks which comprises heating a titanium disk blank to 900 to 1,040° C.; inserting such hot disk blank between two contoured rolls, which rolls have disk directed contoured conical surfaces with axes disposed at an angle to each other; and turning said rolls for a time sufficient and with a force sufficient to impart said contour to said disk blank.

**2.** A roll mill comprising two oppositely disposed contour faced rolls having a centering pin projecting from the center of each adapted to contour a workpiece therebetween wherein each of said rolls has a workpiece directed working face which is itself an obtuse angle conical surface having substantially the same apex angle and which face has a negative of the contour intended to be imparted to said workpiece, and wherein the axes of said rolls diverge from each other by an obtuse angle; which mill contains means to rotate both of said rolls about its axis, means to urge said working faces toward each other and means defining a peripheral boundary about said workpiece.

**3.** Mill as claimed in claim **1**, wherein said rotation means is a variable speed drive.

**4.** Mill as claimed in claim **1**, wherein the apex angle $\gamma$ of the conical surfaces is about 170°.

**5.** Mill as claimed in claim **1**, wherein said roller axes divergence obtuse angle is about twice the cone apex angle minus 180°.

**6.** Mill as claimed in claim **1**, wherein said means to urge said working faces together is applied along a line which diverges from the divider of the angle $\gamma$ by about 90°.

**7.** Mill as claimed in claim **6**, wherein a roll gap exists between adjacent portions of said working faces and wherein said line of applied urging is directed toward the center of said roll gap.

**8.** Mill as claimed in claim **7**, wherein said roll gap widens in a radial direction.

**9.** Mill as claimed in claim **7**, wherein said line of urging is substantially perpendicular to said roll gap.



**10.** Mill as claimed in claim **1**, wherein the combined length of said centering pins is less than the desired thickness of the workpiece adjacent thereto.

**11.** Mill as claimed in claim **1**, wherein each working face has a different contour.

**12.** Mill as claimed in claim **1**, wherein said boundary surface flares from one of said working faces to the other of said working faces.

**13.** Method as claimed in claim **1**, including centrally prepunching said disk blank.

**14.** Method as claimed in claim **1**, including forming a centrally disposed recess in said disk blank and mounting said disk blank in said mill such that said recess mates with a projection from said working face.

**15.** Method as claimed in claim **1**, including forming a centrally disposed projection on said disk blank and mounting said disk blank in said mill such that said projection mates with a recess in said working face.

**16.** Method as claimed in claim **1**, carried out successively with a plurality of roll pairs.

**17.** Method as claimed in claim **1**, including urging said working faces together during operation of said rolls.

**18.** Method as claimed in claim **1**, wherein said disk is at about 900 to 950° C. during rolling.

**19.** Method as claimed in claim **1**, including forcing said disk material in an outward radial direction during said rolling.


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LOWELL A. LARSON, Primary Examiner

U.S. Cl. X.R.

72—86