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Clavin et al.

[11] 3,780,591

[45] Dec. 25, 1973

[54] **PIPE BENDING DIE**

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[52] **U.S. Cl.** **72/465,** 72/318, 72/701
[51] **Int. Cl.** **B21d 11/04**
[58] **Field of Search** 72/466, 469, 465, 72/701, 369, 318, 154, 159

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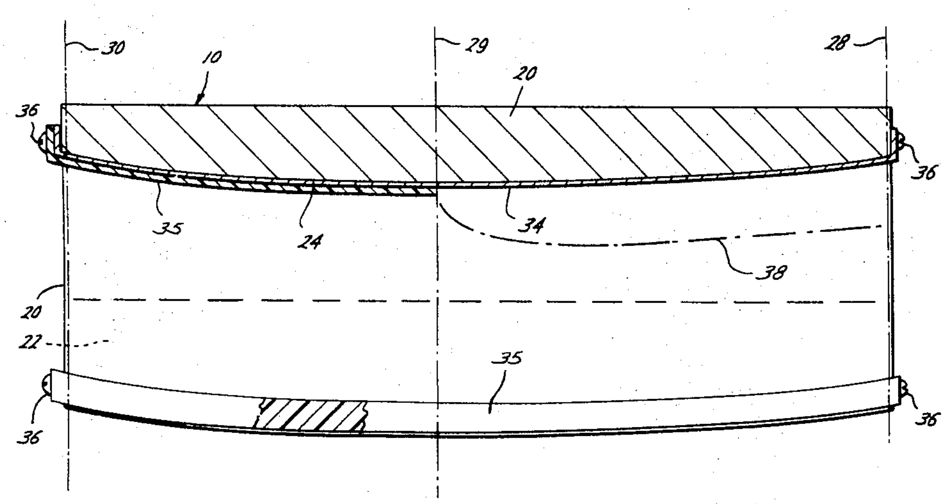
Assistant Examiner—M. J. Keenan
Attorney—J. Vincent Martin et al.

[57] **ABSTRACT**

An improved pipe bending die presenting a transversely concave and longitudinally convex bearing surface to the pipe. The bearing surface is comprised of a first longitudinal bearing surface which is hard and which provides substantially all of the external support for the pipe in the direction of the bend, and a second longitudinal bearing surface which is on either side transversely of the first bearing surface, which is compressible to a preselected degree and which provides support for the pipe to prevent bulging without damaging the external coating of the pipe. This abstract is neither intended to define this invention, which of course, is measured by the claims, nor is it intended to be limiting as to the scope of this invention in any way.

8 Claims, 9 Drawing Figures



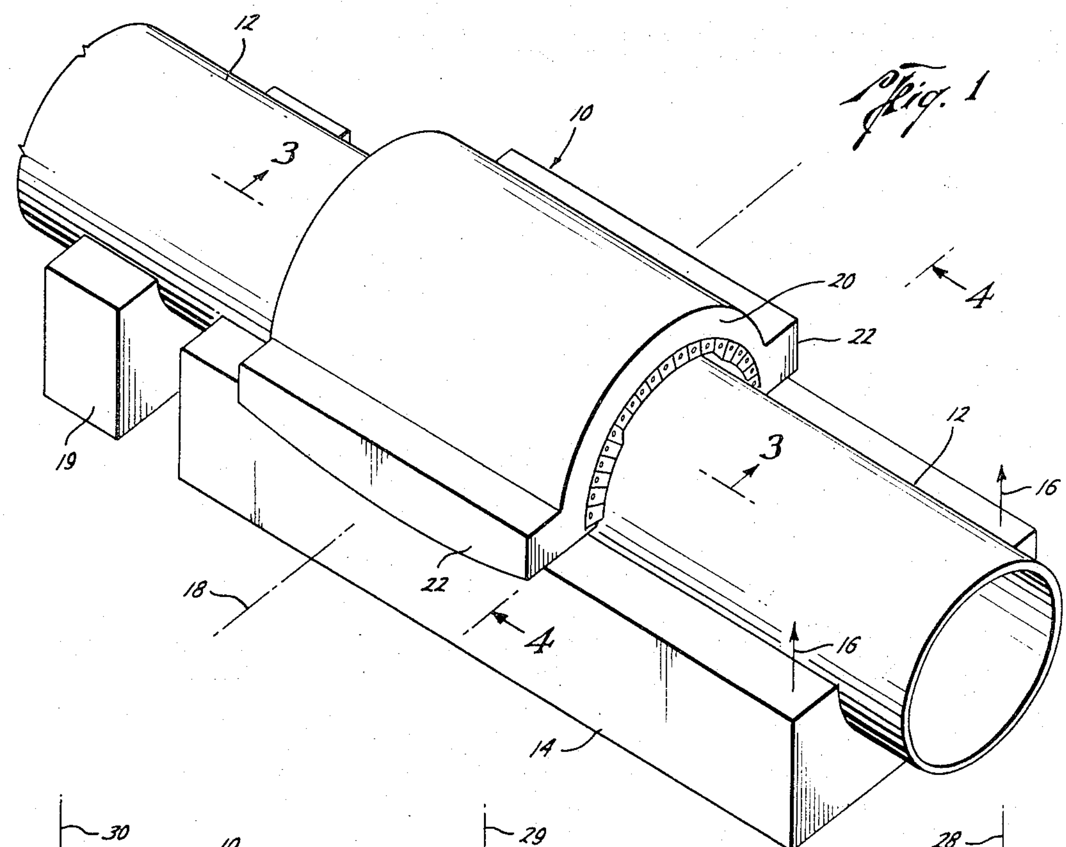

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Fig. 1

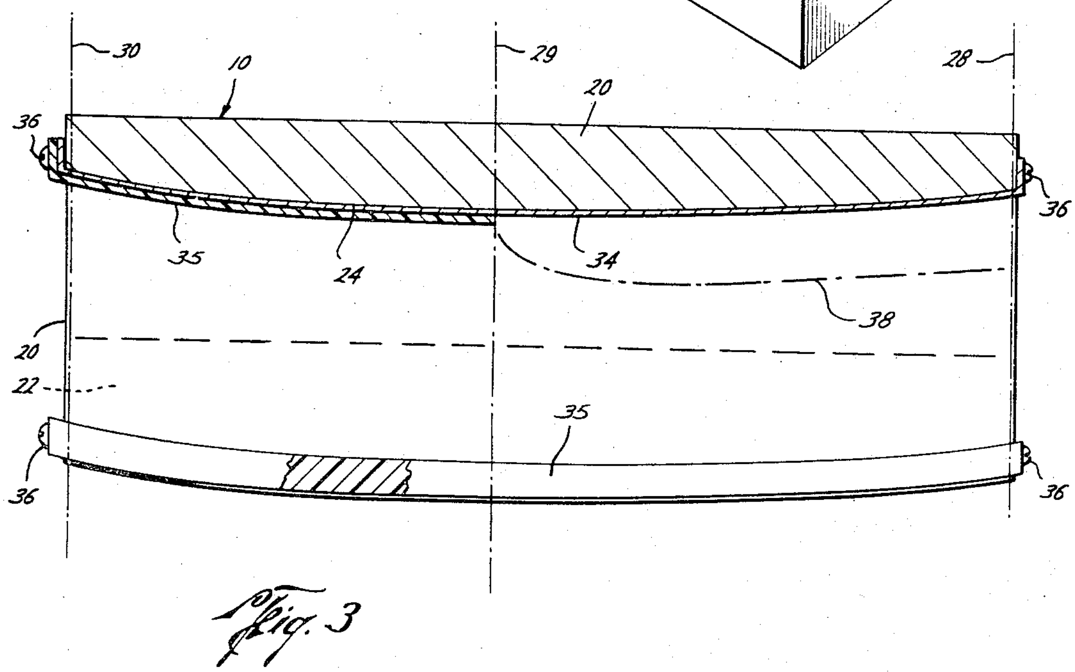
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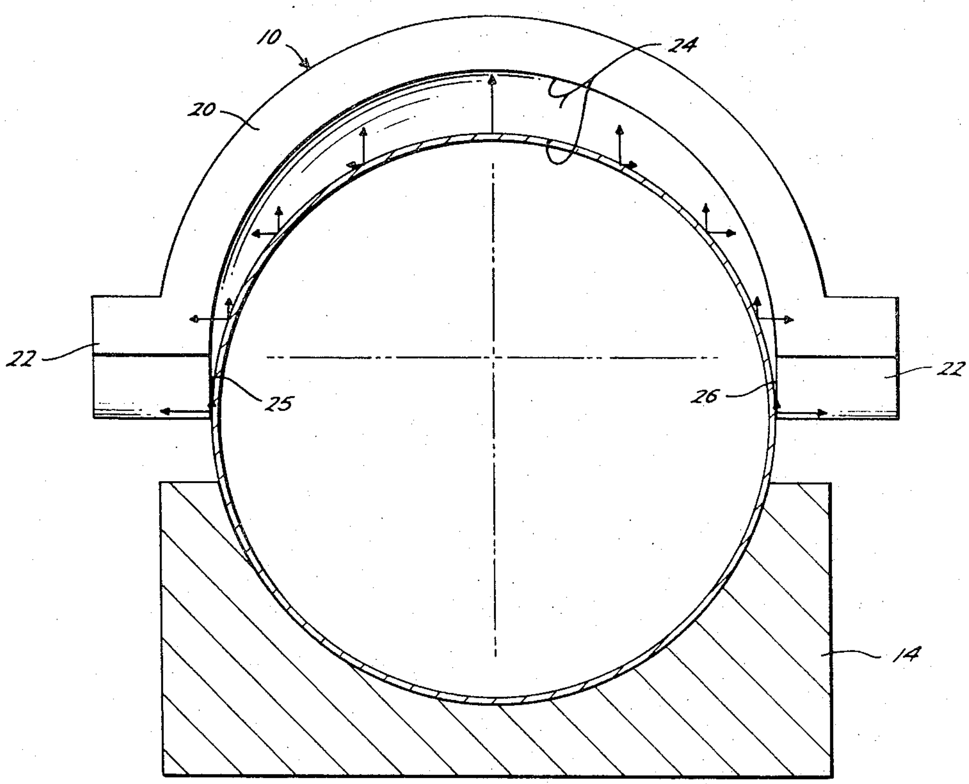
Fig. 3



PRIOR ART

Fig. 2

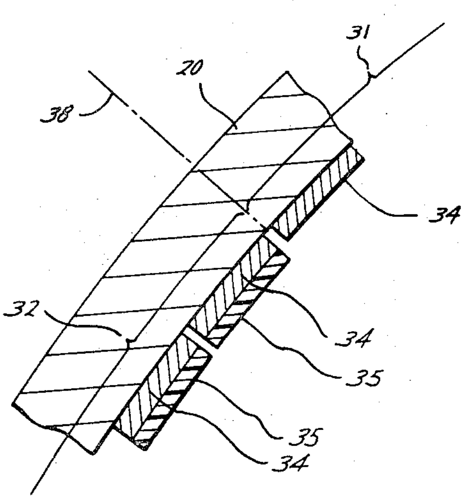


Fig. 6

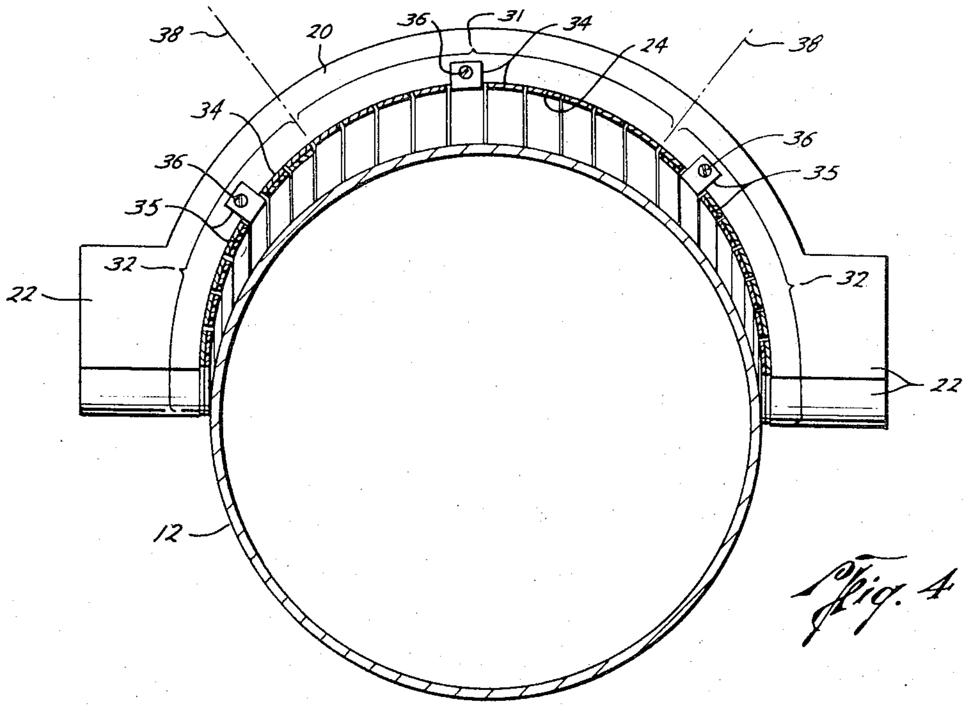

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Fig. 4

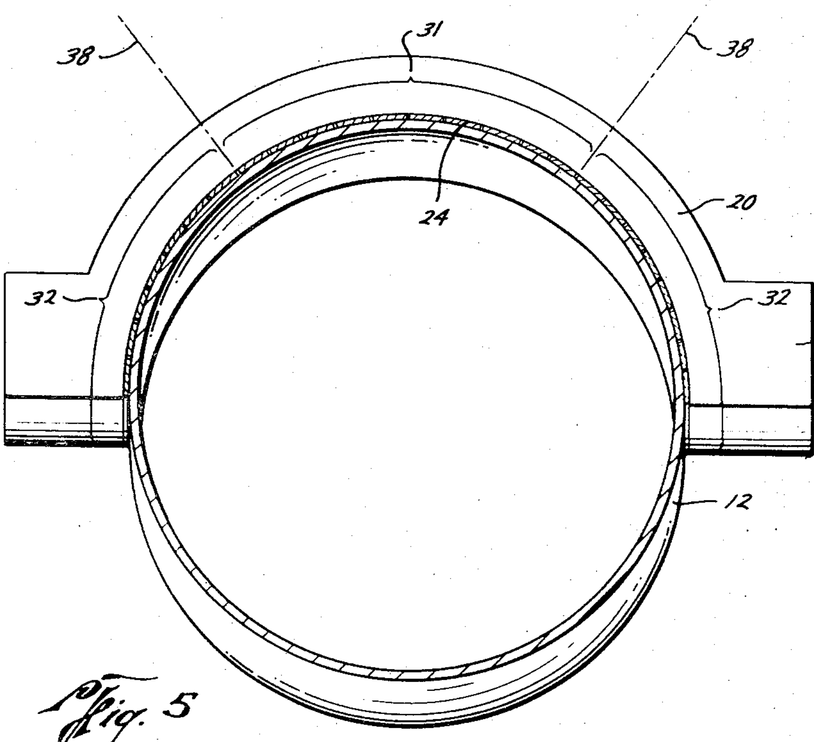
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Fig. 5

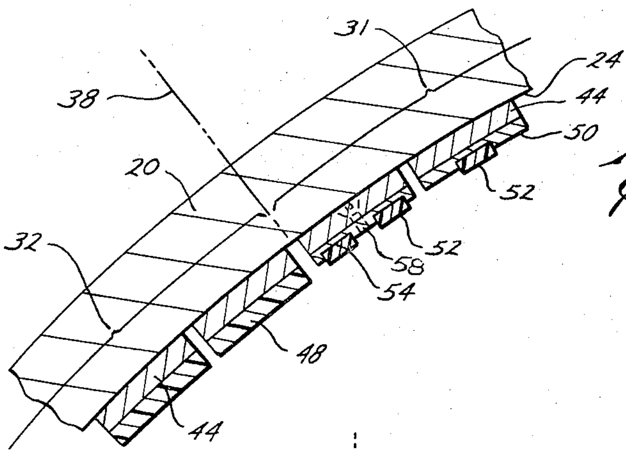


Fig. 7

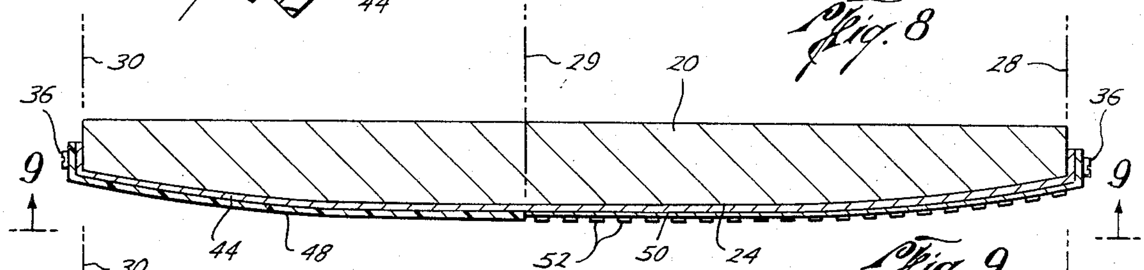
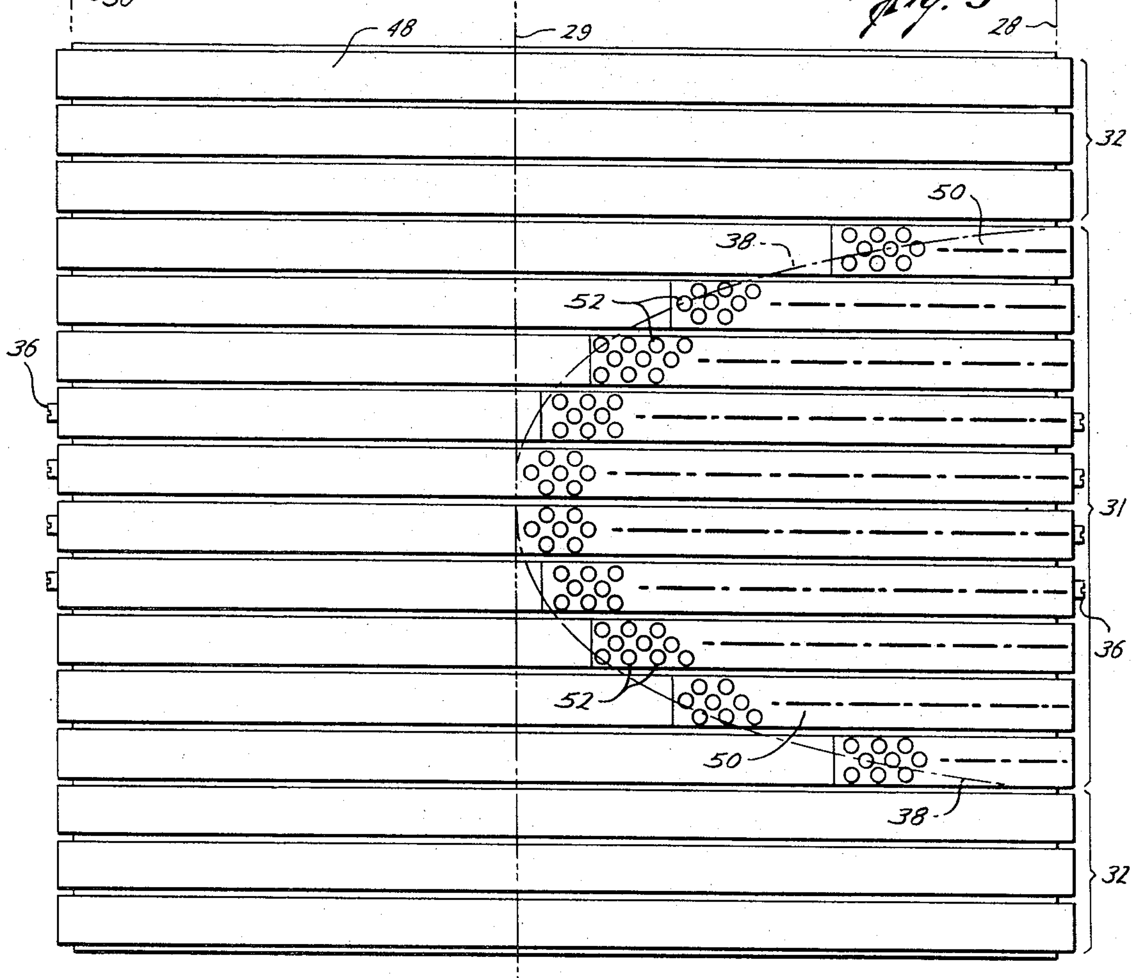


Fig. 8

Fig. 9



PIPE BENDING DIE

BACKGROUND AND OBJECTS OF THE INVENTION

This invention relates to an improved bending die and has particular application in a pipe bending machine utilized to bend large diameter pipes.

There exist numerous devices for bending large diameter pipe, such as the machines disclosed in the following U.S. Pat. Nos.: 2,347,593; 2,428,764; 2,500,980; 2,589,651; 2,708,471; 2,740,452; 2,740,453; 2,771,116; 2,970,633; 3,014,518; and 3,335,588. These devices generally accomplish the bending of large diameter pipe by engaging the pipe against a transversely concave and longitudinally convex bending die and utilizing some means to bend the pipe longitudinally against such die. It has been found, however, that pipe having a large diameter, such as 16, 20 and 24 inches, particularly thin-walled pipe, tends to wrinkle at the point of bend and to bend "out of round." Thus, means for internally supporting the pipe during bending have been developed, such as the pipe supporting mandrels disclosed in the following U.S. Pat. Nos.: 2,401,052; 2,984,284; 3,014,518; 3,043,361; 3,109,477; and 3,180,130. These internally supporting mandrels have proven excellent in operation and have solved most of the wrinkling problems, for instance, the wrinkling problem with which the bending machine disclosed in U.S. Pat. No. 2,428,764 was concerned.

However, the bending die itself has remained relatively unimproved. The need for an improved bending die is accutely silhouetted by the modern requirements of the pipeline industry wherein pipes having very large diameters (such as 48 inches) and having protective exterior coatings (such as epoxy) are bent by bending machines which apply enormous forces (such as 1 million pounds) to the pipe. It is a characteristic of large diameter pipe that when it is being bent its sides tend to bulge outward in planes normal to the direction of bend, and thus direct a portion of this enormous bending force outward normal to the direction of bend. In existing bending dies, the coaction of these outward forces and the movement of the pipe against the sides of the die causes the protective exterior coating of the pipe to be sheared away or otherwise damaged. Since these large diameter pipes are being used to contain fluids under high pressures, it is unacceptable to have any defects or irregularities (such as wrinkles in the pipe, damage to the protective exterior coating or the pipe becoming "out of round") produced in the pipe by the bending process.

This invention provides an improved bending die, particularly useful in bending machines and with internally supporting mandrels, for bending large diameter pipes. The improved bending die according to this invention presents to the pipe a hard, substantially unyielding, longitudinal bearing surface from the apex of the concave arc of the die to preselected points along the concave arc on either side of the apex. From these points outward on either side of the concave arc of the die, the improved bending die according to this invention presents to the pipe a longitudinal bearing surface which is compressible to a selected degree and which has a low coefficient of friction.

It is therefore, an object of this invention to provide an improved bending die against which a large diameter pipe may be bent with substantially fewer defects and irregularities being produced in the pipe than produced by dies presently used in the art.

More particularly, it is an object of this invention to provide an improved bending die around which a large diameter pipe may be bent that provides adequate support to the sides of the pipe during bending so that the pipe does not become "out of round," and protects the exterior coating of such pipe against damage.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention are hereinafter set forth and explained with reference to the drawings wherein like reference numbers indicate like parts:

FIG. 1 is an isometric view, schematically showing a typical bending die and its relationship to a large diameter pipe and a strongback.

FIG. 2 is an end elevational view of a typical bending die presently used in the art.

FIG. 3 is a sectional view of the improved bending die taken at line 3—3 in FIG. 1 with the pipe being omitted and only a portion of the strips comprising the bearing surfaces according to this invention being shown.

FIG. 4 is an end, elevational view of the improved bending die taken at line 4—4 in FIG. 1, with a pipe in the die but no pressure applied to the pipe.

FIG. 5 is an additional end elevational view of the improved bending die taken at line 4—4 in FIG. 1, with bending pressure having been applied to the pipe and the pipe bent against the die, but with the strongback being omitted.

FIG. 6 is a partial detail sectional view taken perpendicular to the longitudinal axis of the die showing portions of the strips comprising the first and second bearing surfaces.

FIG. 7 is a partial detail sectional view taken perpendicular to the longitudinal axis of the die showing an alternate construction of the strips comprising the first and second bearing surfaces.

FIG. 8 is a side view taken at line 8—8 in FIG. 7.

FIG. 9 is a developed view of the inside of the alternate construction of the bending die according to this invention.

DESCRIPTION OF THE INVENTION

FIG. 1 illustrates schematically the usual and preferred relationship between a bending die **10** and a large diameter pipe **12.** The pipe is cradled in a strongback **14** in a manner taught in the art described above. A suitable mandrel (not shown), such as taught in the art described above, is situated inside the pipe to support the pipe internally during bending. Means well known in the art described above are utilized to hold the bending die **10** stationary and apply necessary force to the strongback **14** to rotate it in the direction denoted by the arrows **16** about a preselected axis **18.** A holding shoe **19** prevents the opposite end of the pipe from being pivoted downward. The pipe **12** is bent by the strongback facing it against and into engagement with the internal bearing surfaces of the bending die **10.**

The body of the bending die **10** according to this invention may be constructed in any of numerous ways known to the art. Preferably, it is constructed so as to provide a support member **20** with outwardly extending flanges or shoulders **22.** The mode of construction of the support member **20** is not critical to this invention, so long as it is capable of being held stationary and is constructed of some hard, substantially unyieldable substance. The outwardly extending flanges or shoulders 22 extend along the longitudinal length of the support member 20 and the upper portion thereof engages with the means (not shown) for holding the bending die 10 stationary.

The inward facing bearing surface of support member 20 has a preselected shape depending upon the diameter of the pipe and the bend to be imparted to the pipe. As best illustrated in FIG. 2, for any vertical plane taken through the support member 20 perpendicular to its longitudinal axis, the inward facing surface 24 thereof is transversely concave —the concave arc preferably being generally semicircular with a very slight (in the order of 1 percent of the diameter) outward bulge in its sides. As best illustrated in FIG. 3, for any vertical plane taken through the support member 20 parallel to its longitudinal axis, the inward facing surface 24 thereof is longitudinally convex. As viewed in FIG. 3, the bending portion of the longitudinal bearing surface of support member 20 is between vertical planes 28 and 29 (shown as dashed lines). Although the portion of the longitudinal surface of support member 20 between vertical planes 29 and 30 does not support the pipe externally during bending, it is also convex so that after the pipe has been bent it does not interfere with the pipe when strongback 14 is lowered and the end of the pipe formerly resting on holding shoe 19 is raised.

For purposes of explanation of this invention, the line on the inward facing bearing surface 24 formed by a vertical plane through the longitudinal axis of the support member intersecting with the bearing surface, is referred to as the apex line of the bearing surface. The concave arc on the inward facing bearing surface of support member 20 formed by a vertical plane (plane 29 in FIG. 3) through the support member perpendicular to its longitudinal axis passing through the lowest point of the apex line and intersecting with the bearing surface, is referred to as the nadir concave arc.

As previously mentioned, when a large diameter pipe is bent longitudinally against a bending die, the sides of the pipe tend to bulge outward. The standard internal supporting mandrel used in the industry today is of little help in preventing this bulge because the sides of the pipe simply pull away from the mandrel. Thus, the burden rests on the bending die to prevent the pipe from bulging into an "out of round" disfigurement. It has been found, however, in the bending dies presently being used, that when the bending die is constructed so that it restrains bulging of the pipe, the exterior of the pipe is often scored or damaged during the bending process by the pipe sliding along the sides of the bending die. This phenomenom is illustrated in FIG. 2, which shows an end elevational view of a bending die, such as is presently used in the art, with a large diameter pipe therein. When there is no pressure on the strongback 14, as illustrated in FIG. 2, pipe 12 is in contact with the inward facing bearing surface of support member 20 only along its nadir concave arc. As upward force is applied to the pipe by the strongback 14, the pipe is bent longitudinally against the bending portion of the bearing surface of the die and the sides of the pipe attempt to bulge outward against the sides of the concave support member 20. Force vectors are shown in FIG. 2 at various points around the outer circumference of the pipe denoting the forces of the pipe against the bearing surface 24. Along the apex line of support member 20, there is only a force exerted in the upward direction, that is, the direction of the bend. Outward along the transverse concave arc in either direction from the apex line, the forces of the pipe perpendicular to the direction of bend increases as the result of the pipe attempting to bulge. The vector sum of the vertical and horizontal forces at each point yields the force at that point normal to the inward facing bearing surface 24. As the pipe slides upward against the bearing surface of support member 20, the force of friction will be equal to the normal force between the pipe and the inward facing bearing surface times the coefficient of friction of the materials. Due to this force of friction, the exterior of the pipe is often damaged.

In the improved bending die according to this invention, there is provided a first bearing surface longitudinally along the inward facing surface of the support member from the apex line thereof to preselected points outward along the concave arc on either side of the apex line. The concave shape of this first bearing surface should correspond to the outer shape of the pipe to be bent and, accordingly, is preferably circular with the same outside radius as the pipe. This first bearing surface is constructed of a very hard, durable material, and functions as the main external support for the pipe in the direction of the bend. From the preselected points outward along both directions of the transverse concave arc and longitudinally along the length of the support member there is provided an additional bearing surface, referred to herein as the second bearing surface. The second bearing surface presents to the pipe at all times a semicircular concave arc having a radius equal to the outside radius of the pipe and functions to provide support to the pipe to prevent it from bulging outward while being bent. However, the second bearing surface preferably is compressible to a selected degree and presents a low coefficient of friction to the pipe whereby the exterior coating of the pipe is not damaged as it slides against these bearing surfaces.

In the embodiment of this invention illustrated in FIGS. 3, 4, 5 and 6, the first bearing surface 31 is comprised of a plurality of strips 34 of hard material, such as brass or steel. The second bearing surface 32 is constructed of a plurality of said strips 34 of hard material, such as brass or steel, having bonded thereto a thin band 35 of material which is compressible to a preselected degree and which has a low coefficient of friction. It is preferable that these compressible bands 35 be constructed of polyurethane solid elastomer having a hardness in the durometer ranges of 60–95 on the Shore A scale or 50–65 on the Shore D scale. Each strip 34 preferably is removably secured to support member 20 by lapping the strip over each end of the support member and attaching the strip, as well as any polyurethane band 35 bonded thereto, to the end of support member 20 by bolts 36, welds or otherwise. Slight gaps preferably are left between the strips to allow them to expand slightly due to the pressure of the pipe against them and to receive dirt build-up carried by the pipe.

The pipe-contacting surfaces of the portions of the strips 34 having no bands 35 bonded thereto conjunctively form the transversely concave and longitudinally convex first bearing surface 31. The semi-circular concave shape of the first bearing surface 31 at any plane therethrough perpendicular to the longitudinal axis preferably has a radius equal to the desired outside radius of the pipe. It is important to note the manner in which this first bearing surface is constructed is not limited. Indeed, it could be constructed of a plurality of hard metallic strips welded to the support member, or a solid, hard metallic plate secured to the support member, or even be formed by the support member itself. It is preferable to utilize strips as illustrated in order that any defective strip may be easily and quickly replaced.

The portions of the strips **34** having no bands **35** bonded thereto and forming the first bearing surface **31** extend outwardly from the apex line of the concave arc of support member **20** to preselected points along the concave arc. From these preselected points outward along the concave arc of the die, the strips **34** have the compressible bands **35** bonded thereto. The combined strips **34** and bands **35** comprising the second bearing surface **32** preferably are slightly thicker than the strips **34** without the bands **35** comprising the first bearing surface **31.** The material chosen for the compressible band **35,** such as polyurethane solid elastomer, has a preselected degree of compressibility such that when the bands **35** are fully compressed by the pipe their pipe-contacting surfaces function conjunctively with the pipe-contacting surfaces of the uncovered strips **34** comprising the first bearing surface **31** to provide a firm, continuous, semi-circular bearing surface, having a radius equal to the desired outside radius of the pipe.

It is again important to note that the construction of the second bearing surface is not limited to the mode illustrated in this embodiment of the invention. Indeed, the compressible bands of material could be bonded directly to support member **20,** or solid sheets of such compressible, low coefficient of friction, material could be utilized in place of strips. However, it is preferable to utilize bands of the compressible material bonded to metallic backings and the combined strips secured to the support member in order that a defective strip may be replaced easily and quickly.

In FIG. **4,** for clarity in illustrating the invention, only certain of the strips forming the first and second bearing surfaces are shown to overlap the end of support member **20,** In FIG. **5** none of the strips is shown to overlap. However, it is understood that each of the strips in both FIGS. **4** and **5** is bolted to the end of the support member. In FIG. **3,** only certain of the strips forming the first and second bearing surfaces are illustrated. However, it is understood that the entire inward facing surface of support member **20** is covered with such strips.

For any transverse plane through the die along the portion of its length in which bending occurs (between planes **29** and **28**), the points along each side of the transverse concave arc where the sliding movement of the pipe becomes negligible, and thus no damage is done to the pipe due to the bulging force against the bearing surface and coefficient of friction of the materials, are referred to as the transition points. The transition line is the line comprised of the assemblage of all transition points in all transverse planes through the bending portion of the die. The second bearing surface should extend upwardly and inwardly toward the apex of the die at all points along the bending portion of the die at least as far as the transition line. The transition line may of course vary from one die to another depending on, among other factors, the shape of the die and the portion of the die against which the pipe will be bent. And the second bearing surface may project upwardly and inwardly toward the apex line past the transition line at certin points so long as the first bearing surface covers at least the portion of the die against which the main bending forces are applied. FIG. **3** illustrates with dotted line **38** a representative transition line along one side of the die The portion of the die from the apex line outwardly along the concave arc in both directions to the transition line **38** constitutes the first bearing surface **31** and provides the main external support for the pipe in the direction of the bend. The rest of the die from the transition line **38** outwardly constitutes the second bearing surface **32.** The entire portion of the die (between planes **29** and **30**) which does not support the pipe externally during bending preferably is constructed similarly to the described second bearing surface **32** in order to protect the exterior of the pipe against damage during movement into and out of position. Thus the strip **34** illustrated along the apex of the die has a compressible band **35** bonded thereto between planes **29** and **30.**

In operation (referring to FIGS. **4** and **5**), as pipe **12** is brought into contact with the bending die, it first contacts the second bearing surface **32.** As it is forced upward by strongback **14** and is bent against bending die **10,** the pipe is supported against sideward bulging by the second bearing surface **32** which, although slightly yieldable, provides a semicircular, firm bearing surface. The low coefficient of friction of the second bearing surface **32** insures that the outside protective coating of the pipe is not damaged while sliding upward into the die. As illustrated in FIG. **5,** when the pipe is fully engaged with bending die **10,** the second bearing surface has been compressed so that it functions in conjunction with the first bearing surface to provide a smooth, uniform bearing surface having a radius equal to the outside radius of the pipe being bent.

FIGS. **7, 8** and **9** illustrate an alternate construction of the first and second bearing surfaces **31** and **32,** respectively, according to this invention. Similarly to the previously described embodiment, a plurality of strips secured longitudinally along the inward surface **24** of the support member **20** are utilized to form the first and second bearing surfaces. Each strip, whether in the first or second bearing surface, is comprised of an underlying ribbon **44** of hard material, such as brass or steel, which traverses the entire longitudinal length of the die. This underlying ribbon **44** is typically one-eighth inch thick. Bonded to these underlying ribbons **44** throughout the area comprising the second bearing surface **32** are bands **48** of compressible material having a low coefficient of friction, such as the previously described polyurethane solid elastomer. For instance, along the apex of the die, the compressible band **48** would be employed from the end of the die (vertical plane **30**) which is not in contact with the pipe during bending to the portion of the die (vertical plane **29**) which first contacts the pipe during bending. The compressible bands **48** are also typically one-eighth inch thick.

Secured to the underlying ribbons **44** throughout the area comprising the first bearing surface **31** are second metallic ribbons **50** of hard material, such as brass or steel. The thickness of each of these second metallic ribbons **50** typically is three thirty-seconds inch so the combined thicknesses of the underlying ribbons **44** and the second ribbons **50** are slightly less than the combined thicknesses of the underlying ribbons **44** and the compressible bands **48** comprising the second bearing surface **32.**

Secured in the second metallic ribbons **50** of the first bearing surface **31** are a plurality of compressible inserts **52,** each of which is constructed of a material which is compressible to a preselected degree and which has a low coefficient of friction, such as the previously described polyurethane solid elastomer. Each insert **52** is secured, such as by bonding, in a cavity **54** formed in the second metallic ribbon. Each insert **52** protrudes from the surface of the second ribbons **50** a distance typically one thirty-second inch so the combined thickness of the materials comprising the first bearing surface is approximately equal to the combined thickness of the materials comprising the second bearing surface. The second ribbons **50** preferably are secured to the underlying ribbons **44** by bolts **58** countersunk in the bottom of the cavities **54** and in the underlying ribbons **44.** Each insert, when fully compressed, has its inward facing surface flush with the inward facing surface of the second metallic ribbon **50** in which it is secured. The entire strips are secured to support member **20** by bolts **36,** welds or otherwise.

The manner of constructing the first bearing surface with inserts therein is not limited to that described in the alternate embodiment of the invention. Indeed, rather than the unyielding portion of the first bearing surface comprising an underlying metallic ribbon and a second metallic ribbon, the unyielding portion could comprise simply a strip of hard material — as described in the previous embodiment —having cavities therein to receive the inserts.

The bending operation utilizing the alternate first bearing surface is as previously described. However, as the pipe is brought into contact with the first bearing surface, the pipe first engages the compressible inserts **52.** If the pipe should slide or move a small amount as it is engaging the first bearing surface, these inserts protect it against scratching another damage. As the strongback **14** bends the pipe against the die, the inserts compress until they are flush with the metallic surface of the first bearing surface so that there is presented to the pipe a bearing surface which is substantially unyielding to the pressures imposed thereon by the pipe.

From the foregoing it will be understood that the present invention provides an improved bending die for the bending of large diameter pipes wherein the pipe is adequately supported during bending so that it does not become "out of round" and wherein the outer protective coating of the pipe is not damaged during bending. It will now be apparent to those skilled in the art that the foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes may be made in the construction of the improved bending die within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. An improved pipe bending die comprising:

a transversely concave and longitudinally convex support member;

a first bearing surface which is substantially unyielding to the pressures imposed thereon by the pipe; and

a second bearing surface which is resiliently yieldable to a preselected degree to the pressures imposed thereon by the pipe and which presents a low coefficient of friction to the pipe;

said second bearing surface extending upwardly and inwardly along said support member at least to a preselected transition line and said first bearing surface extending over the remainder of said support member;

said preselected transition line being comprised of the various transverse points longitudinally along the die where the pipe ceases to slide appreciably against the bearing surfaces during bending;

said first and second bearing surfaces functioning conjunctively, when the pipe is bent around the die, to present a smooth, continuous bearing surface to the pipe.

2. An improved pipe bending die according to claim **1,** wherein:

said first and second bearing surfaces are each comprised of a plurality of strips positioned on and removably secured to the inwardly facing surface of said support member.

3. An improved pipe bending die according to claim **1,** wherein:

said first bearing surface includes slightly protruding surface areas which present a low coefficient of friction to the pipe and which are resiliently yieldable to a preselected degree to the pressures imposed thereon whereby when fully compressed by said pipe during bending they become flush with the rest of said first bearing surface.

4. A pipe bending machine having an improved bending die which has a support member with a transversely concave and longitudinally convex inwardly facing surface, and having means for bending a pipe longitudinally around said die with the direction of bend being toward the apex of the support member and having means for supporting the pipe internally during bending, wherein the improved bending die comprises:

a plurality of hard strips removably secured longitudinally along said inwardly facing surface; and

a plurality of bands resiliently compressible to a preselected degree and having a low coefficient of friction secured longitudinally along preselected portions of said strips;

said bands being secured at least to the ones of said strips and the portions of said strips located outwardly and downwardly from the apex of said support member beyond a preselected transition line;

said transition line being comprised of the assemblage of all of the points where the pipe ceases to slide appreciably against the die during the bending process.

5. A pipe bending machine having an improved bending die according to claim **4,** wherein:

each of said strips is constructed of a hard metallic material; and

each of said bands is of polyurethane solid elastomer.

6. A pipe bending machine having an improved die according to claim **4** wherein:

at least some of the ones of said strips and the portions of said strips not having said compressible bands secured thereto have a plurality of cavities therein, each cavity having secured therein an insert which presents a low coefficient of friction to the pipe and which is compressible to a preselected degree so that when the pipe is being bent, its pipe-contacting surface is flush with the strip in which it is secured.

7. An improved pipe bending die to be used in the bending of thin-walled pipe having a protective, external coating, comprising:

a first bearing surface for providing the main external support for the pipe in the direction of the bend; and

a second bearing surface for supporting externally the sides of the pipe against outward bulging during bending and for preventing the external coating of the pipe from being damaged during bending, the second bearing surface extending upwardly and inwardly toward the apex of the die in the direction of the bend at least as far as a preselected transition line, the transition line being comprised of the assemblage of all the points along the die on both sides of the apex thereof where the forces of friction between the pipe and the bearing surface against which it is moved are not of sufficient magnitude to damage the coating of the pipe;

the first and second bearing surfaces conjunctively presenting to the pipe a continuous external support of preselected shape.

8. An improved pipe bending die according to claim 7, wherein the first bearing surface includes at least some slightly protruding areas which present a low coefficient friction to the pipe and which are compressible to a preselected degree whereby during bending the areas are fully compressed by the pipe and are flush with the rest of the first bearing surface.

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