United States Patent [19]

Whalen et al.

[11] **3,909,909**

[45] **Oct. 7, 1975**

[54] **HARMONIC PRESS AND METHOD OF FORGING**

[75] Inventors: **Mark E. Whalen,** Pepper Pike; **Joseph W. Malleck,** Chagrin Falls, both of Ohio

[73] Assignee: **Republic Steel Corporation,** Cleveland, Ohio

[22] Filed: **Oct. 4, 1973**

[21] Appl. No.: **403,422**

Related U.S. Application Data

[62] Division of Ser. No. 164,788, July 21, 1971, Pat. No. 3,783,494.

[52] **U.S. Cl.** **29/420.5;** 72/190; 72/406

[51] **Int. Cl.²** **B21B 13/18**

[58] **Field of Search** 72/189, 190, 270, 250, 72/406; 29/420.5; 100/41

[56] **References Cited**

UNITED STATES PATENTS

2,252,697	8/1941	Brassert	29/420.5
2,290,734	7/1942	Brassert	29/420.5
3,374,654	3/1968	Uebing	72/189
3,475,807	11/1969	Wise	72/270
3,583,192	6/1971	Kocks	72/189

Primary Examiner—Lowell A. Larson

Attorney, Agent, or Firm—Watts, Hoffmann, Fisher & Heinke Co.

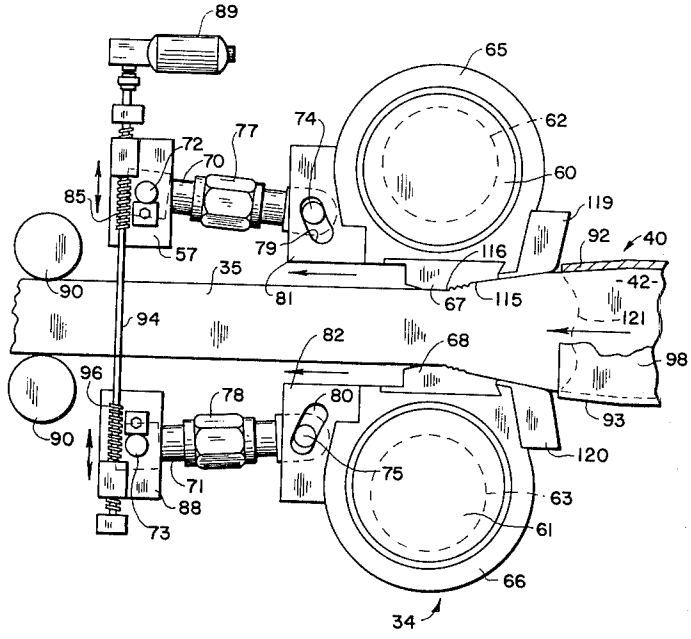
[57] **ABSTRACT**

Disclosure of a method and apparatus for forming metal products from scrap or other small pieces. Pieces of scrap metal are bonded together by baling into bales of from 20% to 50% metal by volume. The bales are then heated from 1200°F. to 2350°F. and fed through a feed magazine into a harmonic impacting press.

Deformation of bales prior to reaching the impacting station in the harmonic press is controlled by control of the press and by peripheral confinement of the bales prior to being fed into the impacting station in the press.

There is also a disclosure of a means to fuse bales together through use of a thermal powder.

16 Claims, 13 Drawing Figures



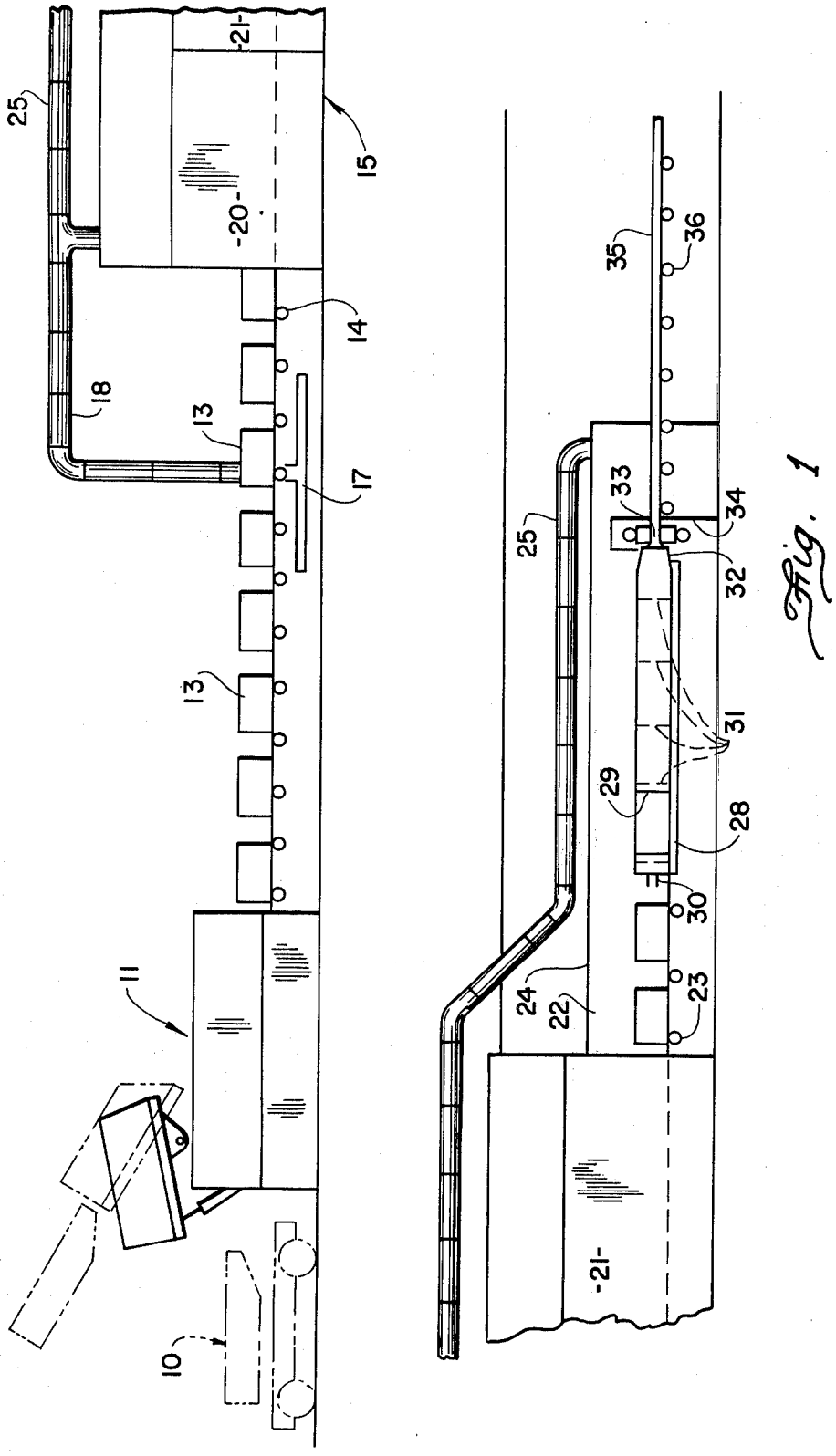

25
21
15
20
14
18
13
17
13
11
10
35
36
33
34
25
32
31
29
28
30
24
22
23
21

Fig. 1

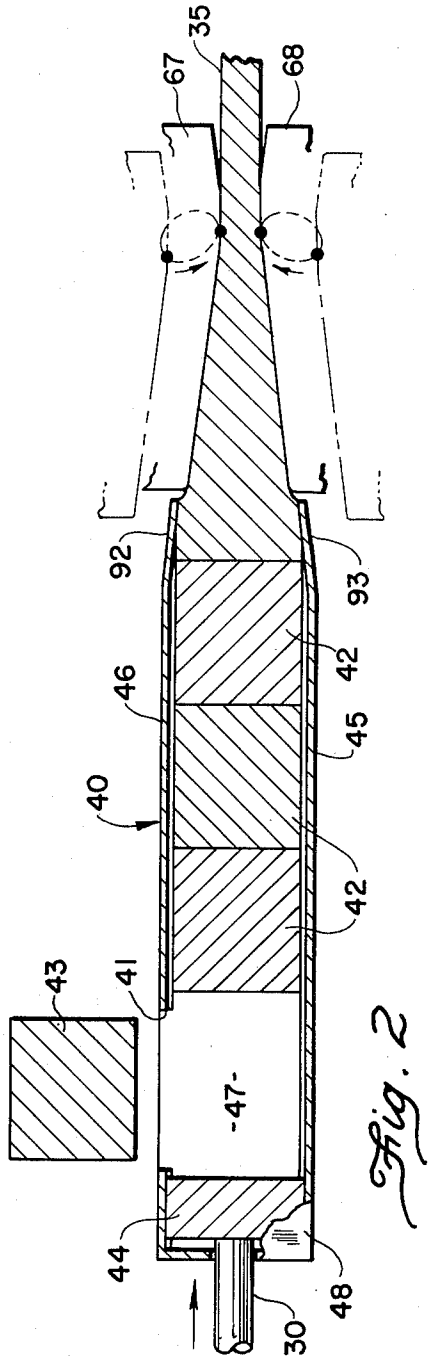

35
67
68
92
93
46
42
45
40
42
43
41
-47-
44
48
30

Fig. 2

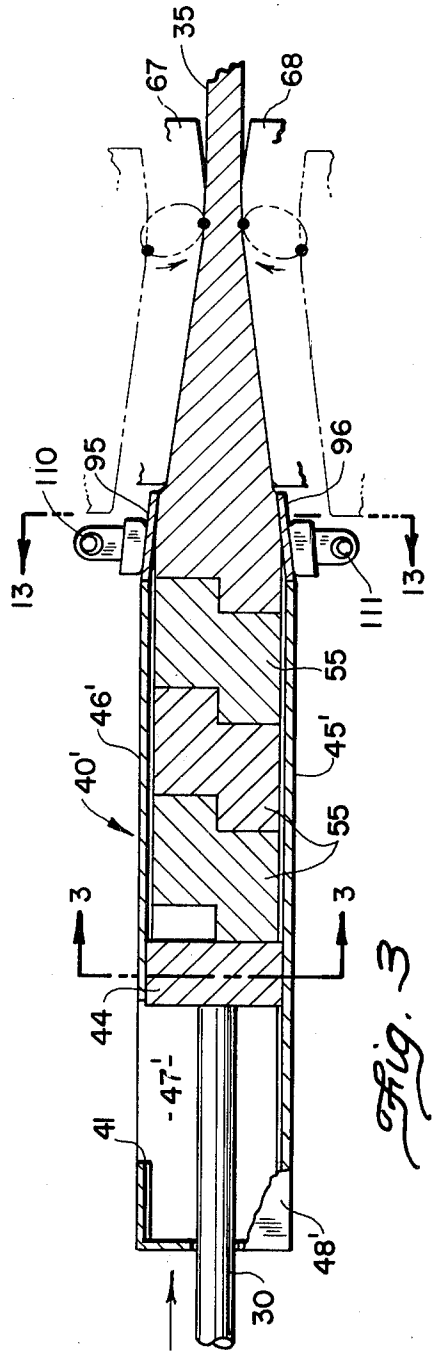

35
67
68
110
95
96
13
13
111
55
46'
45'
40'
55
3
3
44
-47'-
41
48'
30

Fig. 3

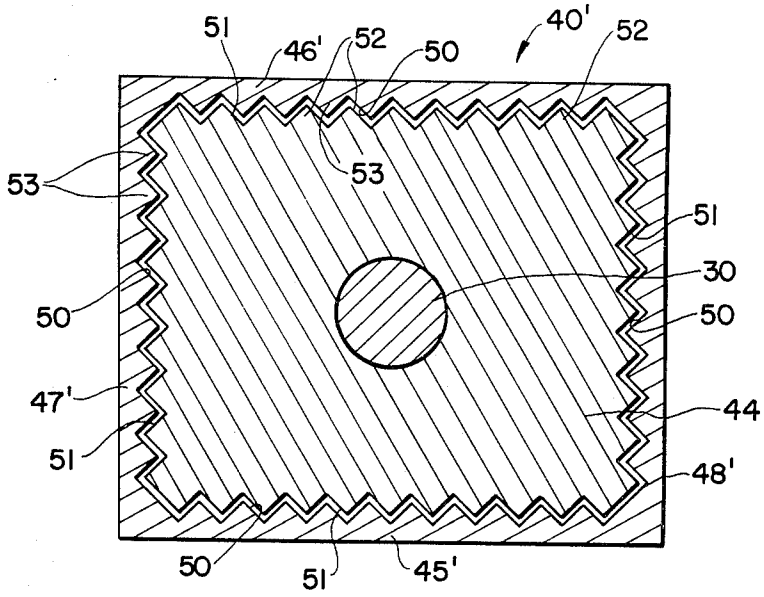


Fig. 4

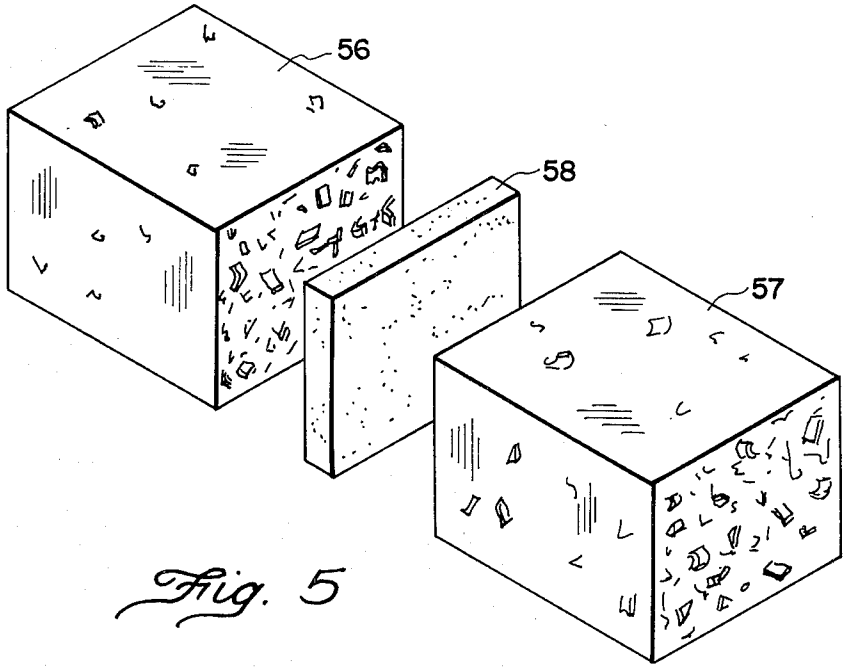


Fig. 5

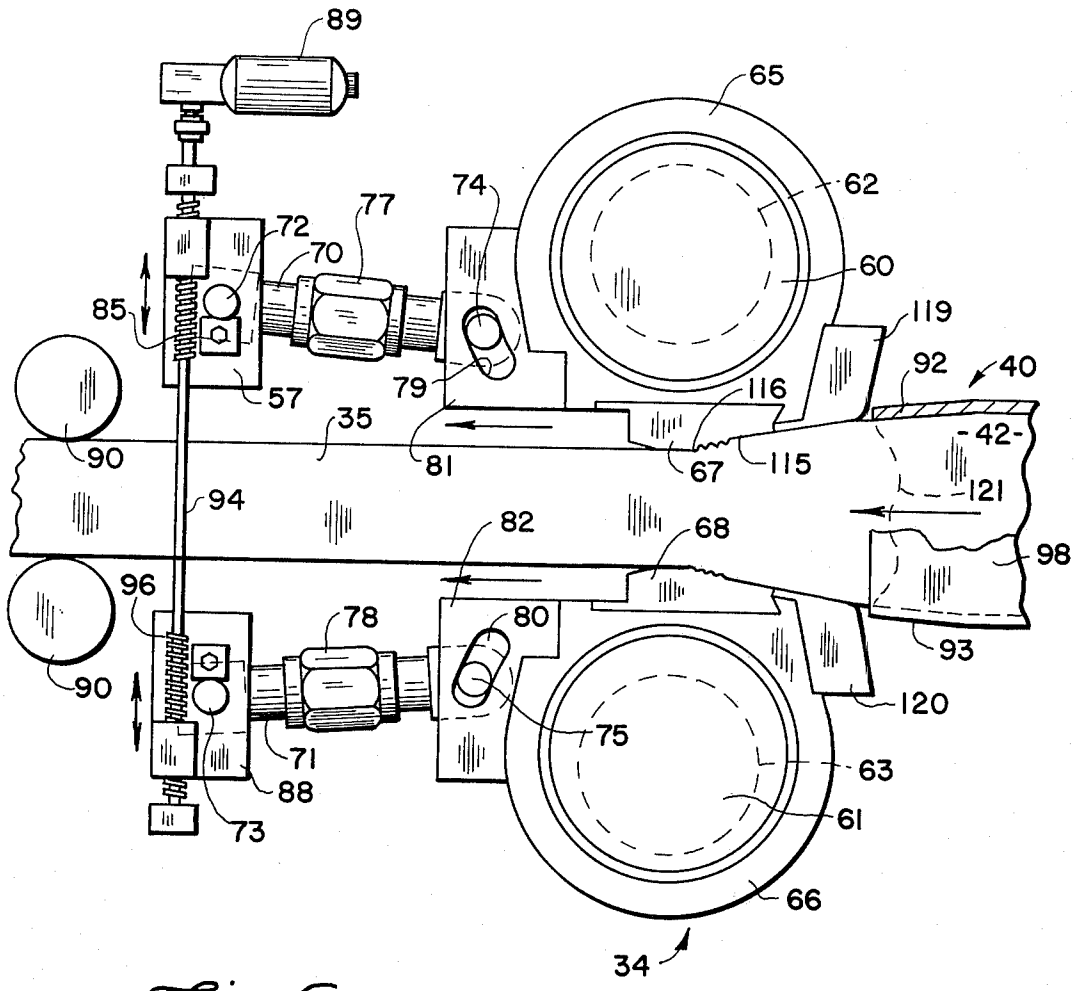

89
65
62
74
77
72
70
60
85
119
92
40
116
57
79
35
42
90
81
67
115
121
94
82
68
98
96
78
80
93
90
120
75
71
63
88
61
73
66
34

Fig. 6

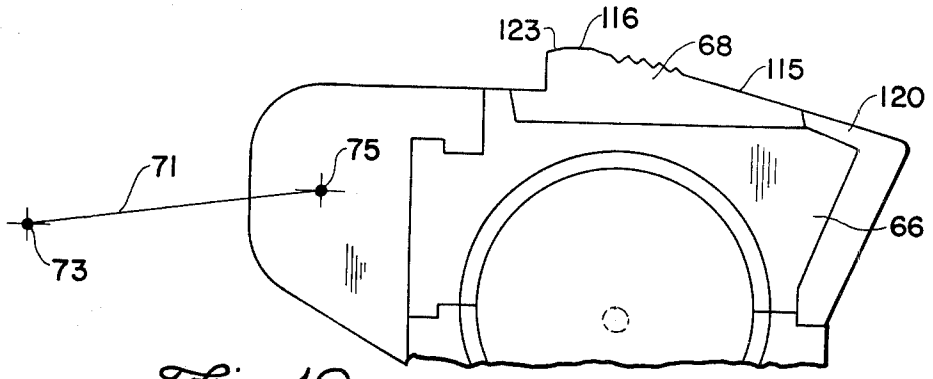


Fig. 10

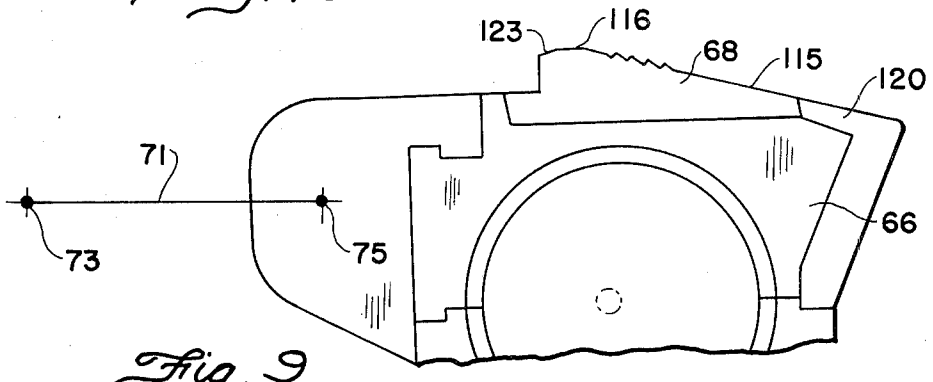


Fig. 9

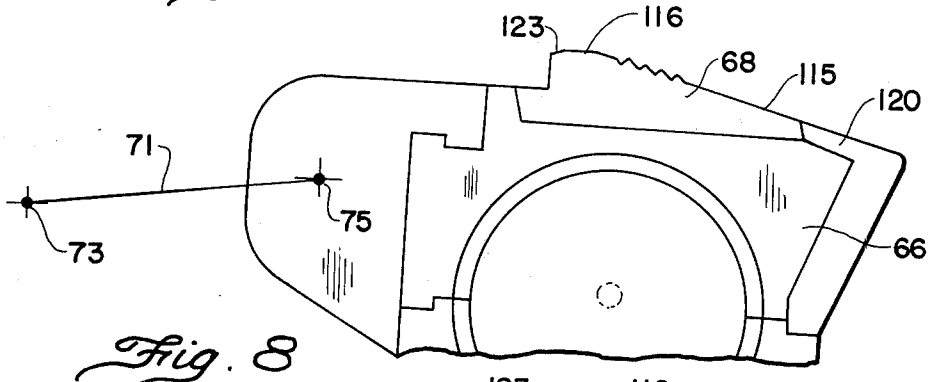


Fig. 8

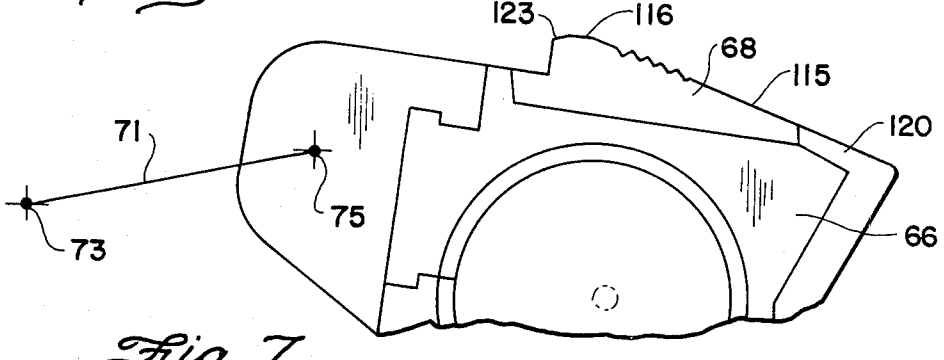


Fig. 7

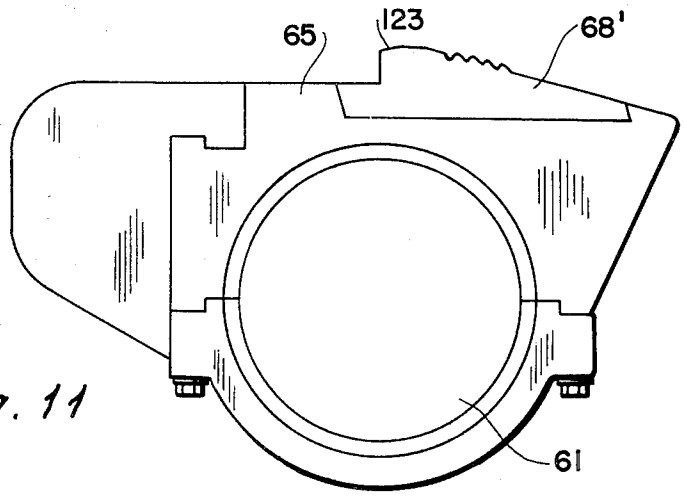


Fig. 11

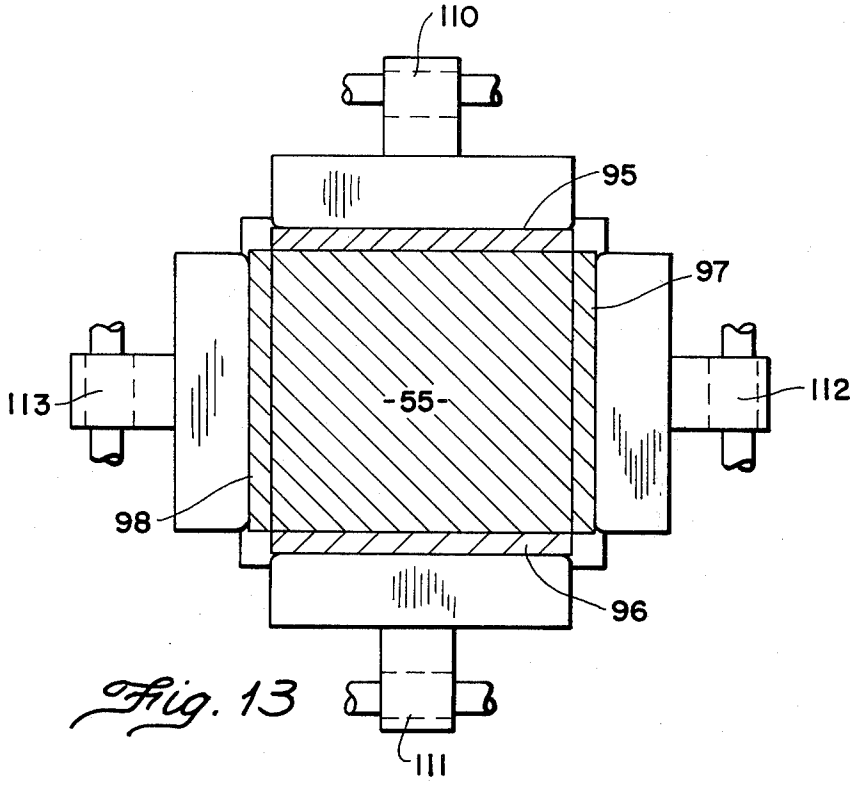


Fig. 13

TEMPERATURE & RATE OF STRAIN EFFECT
ON STEEL COMPRESSION STRESS

TEMP. °F	RATE OF STRAIN SEC.$^{-1}$	AVERAGE STRESS (10^3LB/IN^2) TO COMPRESS				
		10%	20%	30%	40%	50%
65	SLOW	78	93	99	103	106
1700	4.00	18.5	22.25	23.25	23.6	23.75
	8.00	19.1	23.0	25.1	26.5	26.25
	12.00	20.09	23.8	25.7	26.85	26.9
	24.00	21.65	25.4	27.7	28.75	29.6
1850	4.00	14.35	18.05	19.8	20.55	20.0
	8.00	16.1	19.0	21.0	22.1	22.1
	12.00	16.8	19.6	21.3	22.65	22.7
	24.00	18.7	21.75	23.15	24.65	24.6
1950	4.00	12.65	15.0	16.3	16.8	16.0
	8.00	13.75	16.1	18.1	18.75	18.65
	12.00	14.4	16.8	18.45	19.4	19.9
	24.00	15.45	18.5	20.40	21.85	22.25
2075	4.00	10.9	12.8	13.65	13.65	12.9
	8.00	11.75	13.65	14.9	15.4	14.95
	12.00	12.35	14.3	15.65	16.5	16.6
	24.00	13.65	16.0	17.5	18.5	18.75
2200	4.00	8.85	10.5	10.8	10.8	9.9
	8.00	9.6	11.0	11.75	11.9	11.3
	12.00	10.05	11.4	12.35	12.5	12.25
	24.00	11.00	12.7	13.75	14.4	14.2

Fig. 12

HARMONIC PRESS AND METHOD OF FORGING

This is a division of Application Ser. No. **164,788,** filed July **21, 1971,** now issued as U.S. Pat. No. **3,783,494.**

CROSS REFERENCE TO RELATED APPLICATIONS

1. U.S. Application for Letters Patent Ser. No. **121,861** filed Mar. **8, 1971** by Mark E. Whalen et al. entitled "Apparatus and Solid State Method for Converting Small Pieces of Metal to a Workpiece " now issued as U.S. Pat. No. **3,744,118.**

2. U.S. Application for Letters Patent Ser. No. **122,110** filed Mar. **8, 1971** by Mark E. Whalen et al. entitled "Novel Apparatus and Solid State Method for Converting Small Pieces of Metal to a Workpiece" now issued as U.S. Pat. No. **3,768,139.**

3. U.S. Application for Letters Patent Ser. No. **164,789** filed July **21, 1971** by Mark E. Whalen et al. entitled "Apparatus and Solid State Method for Converting Small Pieces of Steel to a Workpiece", now issued as U.S. Pat. No. **3,802,932.**

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a novel and improved method of converting scrap metal pieces to a body of solid metal useful in manufacturing operations and, additionally, to an improved apparatus for carrying out the conversion.

2. Description of the Prior Art

In conventional commercial processes for conversion of the scrap steel to commercial steel, the scrap metal is melted and then processed with conventional steel-making techniques. Other than the melting step, the scrap conversion does not involve any process which is uniquely demanded by the presence of scrap.

The referenced prior applications disclose a method and apparatus for converting steel scrap to useful commercial products such as coils of steel strip. With the process of the invention, relatively large slabs are made, but, as in conventional manufacture of strip steel from billets, the finished strip has spaced seams where the slabs are joined together.

According to the teachings of the referenced prior applications, the scrap is baled. When the bales are small they are joined together to form "jumbo bales" and then further processed. The further processing includes heating the bales to from **1200°F.** to **2350°F.** and then forging in a harmonic press to produce a unitary, cohesive, and solid one-piece slab.

While the referenced prior applications suggest formation of slabs with impaction of the bales while hot with a single pass through a harmonic press, the referenced applications also teach the use of a second press to cold compress the bales prior to heating. Alternatively, the prior applications teach multiple stages of hot compression, either by multiple passes through a single hot harmonic press, or the utilization of a plurality of hot presses.

SUMMARY OF THE INVENTION

It has now been discovered that by appropriate control of forces transmitted into portions of the bale which have not yet entered the compaction station, and by appropriate control of the forging platens, a high-quality steel slab can be manufactured from a hot, relatively porous, bale in a single pass through a compaction or forging station in the harmonic press under a greatly increased range of conditions. In addition, in accordance with this invention, it is now possible to manufacture a continuous steel slab so that a finished coil of steel strip can be free of any seams where strips from different slabs have been joined together; or, as is the case with some conventional steel-making techniques, where strips from billets have been joined together.

In operation of a harmonic press which is forging a bale into a steel slab, some of the impacting forces are transmitted longitudinally of the bale in directions generally opposed to the path of bale feed travel. If properly constrained and controlled, these forces precompress the portions of the bale immediately upstream along the feed path from the compression station to reduce the compaction subsequently necessary in the forging station. Moreover, with proper constraint and control a "pool" of precompressed bale pieces is developed. The pool is developed as feeding commences and after a brief period of time the pool reaches a relatively stable size. Once the pool has reached a stable size, it provides a quantity of relatively dense scrap material which resists the longitudinal dissipation of the compaction forces and thus assists in developing a highly efficient application of compaction forces in the forging press. If the impacting forces are not constrained and controlled, they cause the bale to bulge and these forces are uselessly dissipated.

The force control and confinement is accomplished by: (**1**) perimetrally constraining the portions of the bale in the feed path adjacent the compression station; (**2**) by controlling the rate of feed of the workpiece, which control is also a function of the adjustment of the path of travel of the press anvils; and (**3**) further control of the path of travel of the anvil to achieve what is here referred to as "rate of strain". Rate of strain is analogous to, but different from, conventional "strain rate".

In the preferred embodiment, bales while hot are fed to a feed magazine. The feed magazine delineates an elongated bale feed path along which a plurality of bales are positioned in juxtaposed relationship.

The magazine is equipped with a reciprocal ram which is hydraulically or screw driven to force bales in the magazine into engagement with one another and thence along the feed path into the compression station. The ram is retractable and once retracted further bales may be fed through a suitable feed opening into the magazine.

The magazine is constructed so that rupture and distension of the bales due to the forces applied by the ram are prevented. In addition, portions of the magazine adjacent the outlet end and near the press compaction station are tapered to provide a funneling portion which precompresses the bale somewhat as it is fed to the compaction station. This precompression by funneling, coupled with the forces transmitted along the workpiece path from the forging station, produces the pool referred to above. Thus, there is a precompression zone where the pool of relatively dense material is developed.

The magazine walls in the funnel portion are preferably tapered at **5°** to **15°** with the path of bale travel. This taper contributes to the development of the pool of precompressed material.

To facilitate the incremental movement of the bales during a feed portion of an impacting cycle of the forging press, these tapered walls of the funnel portion can be made to reciprocate in synchronism with the anvils of the forging press during the feed portion of the cycle. Thus, the funnel portion is out of engagement with the bale during the feed portion of a cycle.

To assure that bales to not separate one from the other as one is fed through the compaction station, either or both of two procedures are followed. The first procedure is to maintain pressure on bales in the feed magazine with a ram at times when the lead edge of the bale is approaching and then being fed into the compaction station. Thus, loading of additional bales is accomplished in coordination after the commencement of self-feed of a bale through the forging press. The second technique is to weld bales together while in the magazine.

This welding of the bales while in the magazine is accomplished by placing a cake or package between the bales which are to be welded. The cake is composed of a mixture of steel powder and thermite. The thermite is a mixture of finely granulated aluminum with an oxide of iron or other metal interspersed through it. In the preferred arrangement, the ignition of the thermite is achieved by simply compressing the bales in the magazine, which compression, coupled with the heat of the bales, is sufficient to ignite the thermite and effect welding of scrap pieces in one bale to the scrap pieces in the adjacent bale.

The inner walls of the magazine are serrated and the perimeter of the ram has complemental serrations. If pieces of scrap tend to project from the bale, the crests of the magazine serrations will engage the pieces of scrap and maintain the scrap in spaced relationship with the base of the magazine serrations. As the ram advances, projections of its serration will then extend laterally outwardly beyond any scrap and tend to roll any projecting scrap inwardly. In the absence of the serrations, there would be a tendency for such projecting pieces of scrap to become wedged between the ram and the walls of the magazine, jamming the ram.

Accordingly, the objects of the invention are to provide novel and improved methods and apparatus for joining metal particles together into a useful product while maintaining the metal in its solid state.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims taken in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic flow diagram showing the process of steel formation of this invention;

FIG. **2** is a cross-sectional view of a schematic drawing showing the feed magazine and harmonic press of the invention;

FIG. **3** shows a slightly-modified form of the feed magazine and bale configuration as compared with FIG. **2**;

FIG. **4** is a cross-sectional view of the magazine and ram on an enlarged scale and as seen from the plane indicated by the line **3—3** of FIG. **3**;

FIG. **5** is an exploded, perspective view showing the orientation of two bales and a cake of thermite material prior to welding the two bales together with the thermite material;

FIG. **6** is a somewhat schematic view of the forging press utilized in this invention;

FIGS. **7–10** are diagrammatic views showing the path of anvil travel during the forging cycle of this invention;

FIG. **11** is a modified form of anvil support for achieving the rates of strain utilized in this invention;

FIG. **12** is a rate of strain table; and,

FIG. **13** is a cross-sectional view of the funnel portion of the magazine of FIG. **3** as seen from the plane indicated by the line **13—13** of FIG. **3.**

THE OVERALL PROCESS

FIG. **1** is a flow diagram of the process of solid state steel conversion. A transport car is shown schematically at **10.** The transport car **10** is used to deliver scrap to and then charge it into a baler **11.** In the baler **11,** the scrap, which is an admixture of random sizes, is compressed by a pressure of the order of **1000** to **7500** pounds per square inch until it is from **20%** to **65%** densified and preferably approximately **35%** dense when the bales are to be joined by welding. By these percentages, it is meant that scrap is typically formed into a bale in the shape of a rectangular solid with a preferred **35%** of the volume of that solid being steel. Thus, the bales are compressed to a condition for transport from the baler when they weigh from **100** to **300** pounds per cubic foot.

The baling of an admixture of randomly oriented scrap of random sizes is highly important to the performance of the process of this invention. As will become more apparent presently, the baling causes the scrap pieces to become physically intertwined and interlocked to provide a bale having an inherent strength and rigidity. The strength and rigidity not only serves a more conventional function of facilitating the transport of the scrap in a condensed way, but also, more importantly, is a major factor in inhibiting longitudinal dissipation of impact forces during a subsequent forging operation.

Bales **13** are discharged from the baler **11** onto a conveyor **14.** The conveyor **14** transports the bales **13** to a two-zone furnace shown generally at **15.** As the bales **13** pass along the conveyor **14,** they are preheated by exhaust gases emanating from a plenum **17** fed by exhaust gases from the furnace through a conduit **18.** Preheated bales are fed into a first furnace zone **20** where they are heated from **1000°F.** to **1200°F.** in an inert atmosphere. Heated bales are then transported to a second zone **21** where they are heated to from **1200°F.** to **2000°F.** in a reducing atmosphere. The advantages of these atmospheres are described in greater detail in the referenced concurrently filed application.

Hot bales, identified by the numeral **22,** are fed along another conveyor **23** under a hood **24** supplied by escaping oven gases. The hot bales **22** are maintained in the oven atmosphere until condensed to a solid slab. A stack **25** is provided to deliver furnace gases from the hood **24** to the furnace near its inlet or feed end and to the plenum **17** used for preheating the slab.

A magazine is shown generally at **28.** The magazine **28** has a side load opening **29.** When the heated bales **22** traveling along a conveyor **23** are aligned with the load opening **29,** a transfer mechanism (not shown) is used to shift the heated bale **23** laterally off the conveyor **23,** through the load opening **29** and into the magazine **28.** As will be described in greater detail presently, the magazine is equipped with a ram (not

shown) that is actuated by a ramrod, a portion of which is shown at **30.**

A plurality of heated bales are fed into the magazine as indicated by the dashed lines **31.** The ram forces the bales along a feed path to the right as seen in FIG. **1.** The bales are forced through a funnel portion **32** of the magazine and thence into a forging station **33** of a hot forming harmonic forging press **34.**

The hot press **34** is used to reduce the bale until it is a solid mass of steel and thereafter to continue the reduction until it has been reduced by about **30%** from its thickness when it becomes solid. As is described in greater detail in the referenced prior applications, the hot press **34** has side restraints of a width equal to the width of the original bale dimension. Accordingly, in compressing the bale until it is a thin solid slab, the thinning results in compaction and elongation, not widening.

Because of the operation of the magazine **28** which will be described presently, the finished slab coming out of the harmonic press **34** is a continuous slab indicated at **35.** This continuous slab is shown being transported along a roller table **36** for further processing into strip steel or other finished product.

FEED MAGAZINE

Referring now to FIG. **2,** a feed magazine is shown generally at **40.** The feed magazine **40** corresponds to the feed magazine **28** of FIG. **1** with the exception that it has a top load opening **41** rather than a side opening **29** as shown in FIG. **1.**

The feed magazine **40** is shown with a plurality of bales **42** positioned in it and a further bale **43** in the process of being delivered to the load opening **41.** A ram **44** and its connected ramrod **30** are shown in the retracted position for the bale-supplying operation.

The magazine **40** has a base bale supporting structure **45.** The base bale suporting structure defines a guide path for the bales in their feed from the left to the right as seen in FIGS. **2** and **3.**

The magazine **40** has a top structure **46** which includes the load opening **41.** The magazine **40** also has side structures **47, 48** which are fixed to the base and top structures **45, 46.** The structures **45–48** together provide a perimetral confinement for the bales as they are forced along their guide path by the ram **44.**

FIG. **4** is a sectional view of the magazine of FIG. **3** as seen from the plane indicated by the line **4—4.** While the magazine of FIG. **3** differs somewhat from the magazine of FIG. **2,** in the plane of cross section of FIG. **4** they are identical.

As shown in FIG. **4,** the four structure **45–48** are an integral tube. Internal walls **50** defined by the structures are of serrated configuration. The perimetral surface **51** of the ram **44** is of a complemental serrated configuration. Thus the ram **44** has serrations with lands **52** which project into grooves **53,** of the wall structures and vice versa.

The functions of the serrations are to prevent pieces of scrap from the bale developing a wedge-like action between the ram and the walls of the magazine and thereby jamming the feed operation of the magazine. More specifically, if steel pieces in the bale tend to project from the bale, as they will especially under the compressive forces applied by the ram, their outward movement will be limited by the lands of the wall **53.** Since the lands of the ram project perimetrally outwardly past such scrap pieces, they will cam the scrap pieces inwardly. Thus, the serrations prevent a wedging action and a wedge-like build up of scrap pieces between the ram and the surrounding magazine walls.

In FIG. **3,** bales **55** are configured somewhat differently from the generally cubicle bales **42** of FIG. **2.** To accomplish this, inserts are placed in the baler **11** so that recesses and projections are formed on the bales that interfit when the bales are pressed together. This assists in producing a finished slab without any weakness along a parting line where two bales have been joined.

The avoidance of any weakness along the lines where bales are joined can be further enhanced by welding the bales together. More specifically, and referring to FIG. **5,** a pair of bales **56, 57** is shown. A cake or package **58** of a mixture of thermite and steel powder is interposed between the bales. When the bales **56, 57** are inserted in a magazine hot and compressed together by the pressure of a ram, the thermite will ignite and effect welding at spaced locations between the bales **56, 57.** It is important that the welding be only at spaced locations so that the joinder between the bales **56, 57** is somewhat porous in nature like the bales. Thus, when the weld passes through the compression station, the weld joint will behave in a manner virtually identical to the bales themselves.

In its preferred form, the cake **58** is formed by forming an apertured body of steel powder by known powder metallurgy techniques. The apertures are then filled with thermite. This approach assures spaced welds between the bales and prevents welding of the bales to the magazines.

Referring again to FIg. **2,** the top and bottom structures **46, 45** have tapering portions **92, 93** adjacent the outlet end of the magazine and near the harmonic press **34.** Corresponding taper portions are preferably provided in the side structures **47, 48** and not shown in FIG. **2,** but one of them is shown at **98** in FIG. **5.** These four tapering portions define a magazine funnel section. This funnel section provides a precompression zone in which the pool of precompressed metal, which has been mentioned previously and will be described in greater detail presently, is formed and controlled.

Referring to FIGS. **3** and **13,** movable top, bottom and side funnel portions **95, 96, 97, 98** are shown. Recipricating drives in the form of eccentrics **110, 111,** 112, 113 are connected to the top, bottom and side funnel portions **95–98** respectively. These eccentrics are operated in synchronism with a harmonic press so that the funnel portions **95–98** are moved out of contact with the bales in the magazine during the feed portion of a press compaction cycle. Thus, the difference between the magazine **40'** of FIGS. **3** and **13** and the magazine **40** of FIG. **2** is that the funnel portions of the top, bottom and side structures of FIG. **3** are designed to be out of contact during the feed portion of a cycle. Moving the funnel portions facilitates feed of the bales. The funnel portions are returned to compressive contact at other times in the cycle, especially when forces are transmitted laterally through a workpiece.

Again referring to FIGS. **2** and **3,** the cycling of the feed of further bales to the magazine should be timed with the feed of a bale to the anvils. Thus, in FIG. **2,** the ram **44** is retracted and a further bale **43** is being fed. Three bales **42** are shown in the magazine with the lead one of those extending into the funnel. A bale on the

downstream side has already entered the anvils so that the self-feed action is occuring and the ram can be withdrawn without interfering with the compaction operation occuring at the anvils.

The three bales **55** shown in FIG. **3** have not progressed along the magazine to the extent of the bales **42**. Withdrawal of the ram **44** for the feed of further bales in FIG. **3** will wait until the bale being fed into the anvils as shown in FIG. **3** is further fed in, so the self-feed action has fully commenced.

It will also be appreciated that the magazine with its ram can function as a baler. Accordingly, during the replenishment cycle shown in FIG. **2**, instead of prebaled metal being fed, preheated scrap of the appropriate temperature can be passed through the load opening **41** and then compressed by the ram **44** so that the magazine serves as a baler as well as a feed magazine.

Bale Compaction

FIG. **6** is a vertical sectional view of the harmonic press **34**. A pair of eccentric shafts **60, 61** are journaled in a frame. Gears (not shown) are connected to the shafts to drive them in synchronized and opposite rotation.

The shafts **60, 61** have eccentric central portions **62, 63**, respectively. These eccentric portions are each cylindrically contoured and each has an axis which is offset from the axis of its shaft so that on rotation of the shaft, the axis of the eccentric portion orbits about its shaft axis. A pair of platen supports **65, 66** are journaled on the eccentrics **62, 63**, respectively. Platens **67, 68** are carried by the platen supports **65, 66**, respectively.

Upper and lower restraining rods **70, 71** are provided. The restraining rods **70, 71** are pivotally connected to the frame of the press at **72, 73** and the platen supports **65, 66** at **74, 75** respectively. This connection to the platen support connects the restraining rods to the platens to control the movement of the platens during a forging operation.

The arms **70, 71** include adjustment nuts **77, 78** for varying the lengths of the arms. As shown, this may be a manual adjustment. Obviously, servo motors may be mounted on the adjustment nuts to effect remote control and automatic adjustment.

The pivots **74, 75** ride in curved slots **79, 80** in platen attachment blocks **81, 82**. The pivots may be secured in any suitable manner in an adjusted position such as by nuts. Alternately, servo motors, or other remotely-controllable mechanisms, can be used to adjust the arm-to-platen pivots.

The adjustment of the frame-to-arm pivots **72, 73** is shown as controlled by a lead screw **84**. The lead screw **84** has worm portions **85, 86** which threadably engage upper and lower adjustment blocks **87, 88**. These adjustment blocks are suitably guided in the frame and move up and down to achieve the adjustment of the pivots **72, 73**. The lead screw **84** is rotationally driven by motor **89** to provide synchronous adjustment of the pivots **72, 73**. Delivery pinch rolls **90** are provided for assisting in removing a finished slab strip **35**.

Adjustment of the pivots **72–75** controls the movement of the anvils **67, 68**. Thus, movement of the anvils by rotation of the eccentric shafts is modified by the constraint imposed by the tensioned control rods **70, 71**. More specifically, if the frame pivots **72, 73** are moved toward one another and the anvil pivots **74, 75** away from one another so that the constraining rods **70, 71** generally parallel the path of the workpiece, a movement of the anvil relative to the workpiece path of travels becomes a very thin ellipse. This thin ellipse has a major axis which approaches being perpendicular to the path of travel.

As feed of a bale is commenced, the control rods are positioned for this thin ellipse so that the impaction forces imposes are predominantly vertical with a slight horizontal moment along the horizontal path of travel. As the lead edge of a bale advances through the anvils, the anvil pivots **74, 75** are brought toward one aother and/or the press pivots **72, 73** are moved away from one another so that the control rods **70, 71** are then at a more acute angle with the path of workpiece travel. This increases the horizontal component of the movement of any point on the anvil so that there is greater horizontal movement at any point on the anvil than vertical. This variation in the shape of the path which any point on the anvil transcribes as the control rods are adjusted is described in greater detail in the referenced prior applications.

Even though the horizontal component is increased, it has been discovered that the vertical movement of anvil portions can be magnified during that small, approximately **30°**, segment of a revolution in which the anvils are actually performing work on the workpiece.

More specifically, viewing FIG. **6**, the upper shaft **60** is rotating in a clockwise direction while the lower shaft **61** is counterclockwise. The eccentric action of the shafts coupled with the constraint of the control rods **71**, provides a compound lever effect which causes a rocking action of the anvils relative to the workpiece, in addition to the generally elliptical anvil travel.

FIG. **10** shows the position of the anvil **67** when the eccentric portion **62** is in its most elevated position, assuming the workpiece travel horizontal. The anvil pivot and frame pivots **75, 73** are in central positions, vertically speaking. As the eccentric rotates **90°** counterclockwise, the anvil moves to the position of FIG. **7**. A further **90°** clockwise rotation is depicted by the position shown in FIG. **8** which is the position of the anvil at the time when the eccentric is in its lowermost position. FIG. **9** shows the position of the anvil after a further **90°** rotation from the position of FIG. **8**.

The work on the workpiece is performed, as indicated above, during about **30°** of arc. This **30°** of arc is predominantly during the time the anvil is moving from its position of FIG. **9** to its position of FIG. **1** but it also occurs as the anvil is moving from its FIG. **8** to its FIG. **9** position. Any point toward the right, as viewed in FIGS. **8, 9,** and **10**, of the anvil, such as point **115**, has moved a greater vertical distance than have other points further to the left, such as point **116** which is at a lower part of the anvil. This relatively great vertical movement is most pronounced if one compares FIGS. **8** and **9**.

It will be seen that this rocking action causes relatively great vertical movement of upper and lower bullhorn members **119, 120** which are secured to the anvil supports **65, 66**, FIG. **6**. The rocking action also results in the application of forces which have substantial horizontal components in directions opposite the path of workpiece travel.

The lower shoe **68** has a chamfer **123** at its outlet end. A corresponding chamfer is provided on the upper shoe **67** but is not visible in FIG. **6**. The purpose of this

chamber is to avoid contact of a trailing edge of the anvil is it rock and rotates from the position of FIG. 7 to the position of FIG. **10.** Through the provisions of the funnel in the compaction zone at the outlet end of the magazine and the precompaction which has been previously mentioned, metal in that zone becomes somewhat more dense than in the bales further to the right as seen in FIG. **6** in the magazine. This more dense metal becomes further compacted by these horizontal forces applied in a direction opposite the workpiece travel so that a pool indicated by the dashed lines **121** in FIG. **6** of relatively dense but not fully compacted metal, is developed on the feed side of the harmonic press.

As an examination of FIG. **6** will shown, the pool is hemi-torodial in shape. This hemi-toroidal shape is developed because the temperature of portions of the bales near the surface is higher than central portions. Since the surface portions of the bales are hotter, they are more plastic and extrude rearwardly more than the central, cooler portions. The bale temperature is not uniform because the bales in the preferred heating step do not undergo a soak period.

As has been stated previously, this pool **121,** once developed is, with proper control, stable in size. Thus, there is continuous replenishment of the pool by further scrap material as it is fed so that the pool size is relatively constant.

As has been indicated, in addition to peripheral restraint and rate of strain control, the size of pool can be controlled by varying the rate of feed to the workpiece. Expressed another way, control of the size of the pool and therefore control of the extend of rearward dissipation of compressive forces can be effected by adjusting the volume of material passing through the press.

This volume control can be achieved by varying the position of the control rods **70, 71** to increase the horizontal feed component of the anvil motion. It can also be achieved by adjusting the spacing of the anvils to control the amount of material flowing through the press.

In connection with volume control, it should be appreciated that with a solid state transformation of scrap or other small-sized material to a solid, longitudinal dissipation of forces is different than in a conventional rolling mill or other compressive action. One reason for this difference is the feed rate of the workpiece is controlled and metered by the harmonic press. Another reason is the solid material on the output side of the press has greater resistance to longitudinal force than does the porous material on the feed side. With conventional rolling techniques, compression results primarily in elongation of the workpiece on the output side of the mill. As we have noted, the press in this instance controls feed rate so that elongation on the output side of the press will not occur. Thus, volume control is primarily a function of the spacing of the anvils and the horizontal feed component in the motion of them.

The total effect of this precompaction in the funnel portions coupled with further compaction by the bullhorns **119, 120** and thorough densification by the anvils **67, 68** results in bales being reduced to of the order of one-third of their original dimension in a single pass through a harmonic press. Thus, in a single pass through the press of FIG. **6,** there is a transition of porous bales to full, dense, intimately welded and united slabs of steel. This obviates, in most cases, the need for cold harmonic press compaction or a second pass through a hot harmonic press as is taught in the referenced prior applications.

Where the magazine is used because the metal is fed continuously and while hot into a strip mill, any slight imperfections in the slab which might occur will be perfected in the strip forming operation.

In FIG. **11,** an alternate technique for achieving this described rocking or "duckbill" action of the anvils is shown. Here the anvil **68'** is offset to the right as viewed in the drawing so that forces applied by the eccentric do not achieve the balance of the anvil of FIG. **6** during the force application portion of a cycle. This results in a rocking or the anvil relative to the workpiece and effecting a result similar to the result achieved with the control rods **70, 71.**

Rate of Strain

As the referenced prior cases teach, it is desirable for the application of welding forces to be accomplished by high-speed, sharp impaction of a workpiece during the slab formation operation. It has now been recognized that the optimization of force application requires a control of the extrudability or the plasticity of the workpiece. Thus, if good, thorough welding is to be effected, it is necessary to control the loss of force through extrusion or plastic flow of the workpiece. The control of extrusion or plastic flow is a function of: (*a*) the temperature of the product; (*b*) the degree of solidity of the workpiece; and (*c*) rate of strain.

Since three variables affect extrusion, an analysis of one of them, rate of strain and how it is derived, requires the other two to be considered constant. Thus, the discussion will assume a constant temperature and that the bale is in a solid or virtually solid condition.

In analyzing rate of strain, it is also well to recognize why rate of strain is analogous to, but different than, strain rate and thus the two cannot be correlated. The reasons that one cannot correlate rate of strain to strain rate are:

A. The peculiar path of travel of the anvils which, after the initial feed portion of the cycle is, as we have seen, a relatively flat ellipse with a substantial horizontal component.

B. The porosity of the workpiece.

C. The press is equipped with side restraints which result in a substantial increase in stess as contrasted with conventional presses or rolling mills.

D. There is a temperature gradiant in the workpiece because there is no "soaking" time in the bale heating as is described in greater detail in the concurrently-filed copending and referenced application.

Rate of strain is a function of force and time. It is derived from the formula

$$RS = \frac{V}{TB}$$

where:

RS equals rate of strain;

V equals the vertical travel of a selected point on the anvils;

T equals the time that the selected point will be in work-performing engagement with the workpiece. This is derived by first determining that portion of a platen revolution where there is workpiece

contact. For example, assuming the point selected is in engagement with the workpiece for 30° of the 360° rotation of the eccentric, the point will be in engagement with the workpiece for 1/**12** of a revolution; i.e.

$$\frac{30°}{360°}$$

Thus, T is derived by the formula:

$$\frac{\text{Angle of arc of workpiece contact}}{360} \times \text{Rotational speed of Platen.}$$

B equals the beginning of thickness of the workpiece. To derive

B for a harmonic press of the type disclosed in the present application, one takes one-half the beginning thickness of the workpiece.

As examples of the application of the above formula, let us assume an initial bale thickness of 4.8 inches so that the value B for a half bale thickness is 2.4 inches. Assuming an eccentric with a radius of 1½ inch, we find that with the anvil pivot points **74, 75** and the press pivot points **72, 73** both relatively widely spaced, a point corresponding to the point **115** (FIG. **6**) will move 0.156 inch vertically. If the eccentric is slowed to 2.5 revolutions per second as a bale is initially fed into the press and the point **115** will engage the bale being fed for 25° of rotation. Under these conditions, the strain rate is 2.3 which is derived by

$$RS = \frac{.156 \text{ inch}}{\frac{25°}{360°} \times .4 \text{ sec.} \times 2.4 \text{ inches}} = 2.3 \text{ sec}^{-1}.$$

An analysis of the formula will show that rate of strain can be increased by either increasing the vertical travel V or the speed of rotation. It can also be increased by decreasing the arc of contact which thus decreases the time in which the forces are applied. Further, the rate of strain increases as the thickness of the workpiece decreases.

Thus, if, as the initial feed progresses, the pivot points **74, 75** are moved closer together and the contact arc increases to 36°. This changes the ellipse to provide a vertical deformation component of 0.406 inch and the rate of strain is increased to 4.1 sec.

$$RS = \frac{.406 \text{ inch}}{\frac{36°}{360°} \times .4 \text{ sec.} \times 2.4 \text{ Inch}} = 4.1 \text{ sec}^{-1}.$$

It has been found that by moving the press pivot points **72, 73** closer together in addition to maintaining the anvil pivot points **74, 75** close together or moving them even more closely together, the rocking motion of the anvil is increased and the vertical component is also increased. Thus, to achieve high rates of strain in excess of a desired 4, the press pivot points **72, 73** are moved more closely together rather than further apart as suggested in the prior referenced cases. The value of vertical travel can be increased, for example, to 0.88 inch, with the specific example we have given, which also results in a slight increase in the art of contact to 40°. When so positioned:

$$RS = \frac{.88 \text{ inch}}{\frac{40°}{360°} \times .4 \text{ sec.} \times 2.4 \text{ inch}} = 8.2 \text{ sec}^{-1}.$$

At other points, say the point **116,** the strain rate becomes very high. This is true because at that point (*a*) the workpiece is thin and (*b*) the proportion of the workpiece along the feed path but behind the point of impaction is solid, providing greater resistance to rearward dissipation of forces than does the semi-solid pool. Accordingly, with the examples we have given, strain rates on the order of **4–24** should be achieved beneath the point **116** as the desired reduction of about 20% beyond the thickness when a solid piece was first achieved is carried out.

FIG. **12** is a table showing various strain rates calculated according to varying conditions and according to the formula

$$RS = \frac{V}{TB}$$

SUMMARY

There is disclosed:

A. A novel feed magazine to achieve a continuous slab output.

B. Precompaction prior to the harmonic pressure full compression station. This is achieved in part through the use of a feed funnel portion which may be provided when the feed magazine is not used.

C. The control of the anvils to achieve a rocking action increasing vertical motion with a compound lever action.

D. The control of rate of strain.

Thus, it has been recognized that, theoretically an ideal compaction of the material would have forces which were either only perpendicular to the path of workpiece travel or along that workpiece travel. It has now been recognized that this ideal is not achievable and that the conversion of scrap or other small metal pieces to a solid slab can be optimized by controlling (1) the feed rate or volume, (2) controlling the rate of strain and (3) confining the material being fed to the press so that a controlled pool of relatively dense material is developed on the feed side of the press.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example, and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. The method of forging a workpiece with a press of the harmonic type having opposed platens mounted on eccentrics for relative movement comprising:

a. positioning a workpiece for travel along a feed path between said platens;

b. constraining the platens for movement such that any point on each of said platens transcribes an ini-

tial forging path which is substantially reciprocal and transverse to said feed path;

c. feeding a leading end of said workpiece along said feed path and between said platens to commence a forging compaction of said workpiece;

d. thereafter changing the constraint on said platens such that each such point traverses another foring path having workpiece feed motion paralleling said feed path such that the press self feeds the workpiece as it is forged; and,

e. perimetrically confining the workpiece at a location along said feed path and near said platens.

2. The method of claim **1** wherein said another forging path is substantially elliptical having a major axis which extends longitudinally relative to said feed path.

3. The method of claim **1** wherein the change to said another forging path is effected by adjusting adjustable link means connected to said platens.

4. The method of claim **3** wherein said link means includes a separate adjustable linkage connected to each of said platens, and said step of adjusting said link means is effected by adjusting said linkages in synchronism.

5. The method of claim **1** wherein each of said platens has a forward initial engagement portion, a central serrated feed portion and a trailing smoothing portion, and wherein said step of changing the constraint on said platens is effected after the leading surface of a workpiece has been fed betweem said central portions.

6. The method of claim **1** wherein said step of perimetrically confining the workpiece is effected with members that surround the workpiece in at least one plane transverse to said feed path.

7. The method of claim **6** wherein said members are tapered inwardly at angles of 5° to 15° relative to said feed path to funnel workpieces along said feed path.

8. The method of claim **6** wherein said members are reciprocated along paths transverse to said feed path as a workpiece is fed along said feed path.

9. The method of claim **1** wherein the workpiece is formed from a plurality of bales and the bales are fed to the press by a process including the steps of:

a. depositing bales in an elongated magazine;

b. feeding the bales along a path of travel in said magazine toward said press by pressing the bales with a ram and thus feeding a lead one of the bale into said press;

c. cyclically replenishing the supply of bales in the magazine be retracting said ram and depositing a further bale between the ram and the bales previously in the magazine; and,

d. thereafter advancing the ram to press the further bale against the previous bales and recommence the pressing of the bales.

10. The process of claim **9** wherein said cyclic bale replenishment is coordinated with forging of the bales in said press such that said further bale is added to the magazine at a time shortly after a lead one of said bales has commenced a self feed portion of a forging cycle in said press and such that said further bale has been added to the magazine and bale feeding recommenced prior to the time the next bale after said lead bale has begun to feed into said press.

11. In combination with a harmonic press of the type having opposed platens mounting on eccentrics for relative movement and means for constraining platen movement to cause any point on the platen to transcribe an initial forging path which is substantially reciprocal and transverse to the path of travel of a workpiece through the press, and to subsequently cause such point to transverse another path such that the press self feeds the workpiece as it is forged, a feed magazine for supply workpiece bales to said press comprising:

a. a bale supporting structure defining a guide path for a plurality of such bales;

b. a structure extending along said guide path for confining said bales and inhibiting lateral expansion of said bales on application of compressive forces; and,

c. ram means for forcing bales along said guide path.

12. The feed magazine of claim **11** wherein said ram means is reciprocal along said guide path and retractable to a bale load position and wherein said structure defines a bale load opening for depositing further bales.

13. The apparatus of claim **11** wherein said structure defines a load opening.

14. The apparatus of claim **13** wherein said ram means is reciprocal along said guide path and retractable to a bale load position exposing said load opening for depositing further bales.

15. The feed magazine of claim **13** wherein said ram means and said structure define complemental land and groove formations extending longitudinally of said guide path.

16. A harmonic press for forging a workpiece, comprising:

a. feeding means for feeding a workpiece along a feed path;

b. opposed platen means positioned on opposite sides of said feed path to forge a workpiece engaged between said platens;

c. linkage means constraining said platen means for movement such that any point on said platen means transcribes an initial forging path which is substantially reciprocal and transverse to said feed path;

d. said linkage means being adjustable after a leading end of a workpiece has been fed along said feed path between said platen means to commence a forging operation such that each point on said platen means transverses another forging path having a workpiece feed motion paralleling said feed path to enable the press to self feed the workpiece as it is forged; and,

e. constraint means perimetrically confining the workpiece at a location along said feed path near said platen means.

* * * * *