Nov. 20, 1945. E. R. FROST 2,389,425

METHOD AND APPARATUS FOR FORGING

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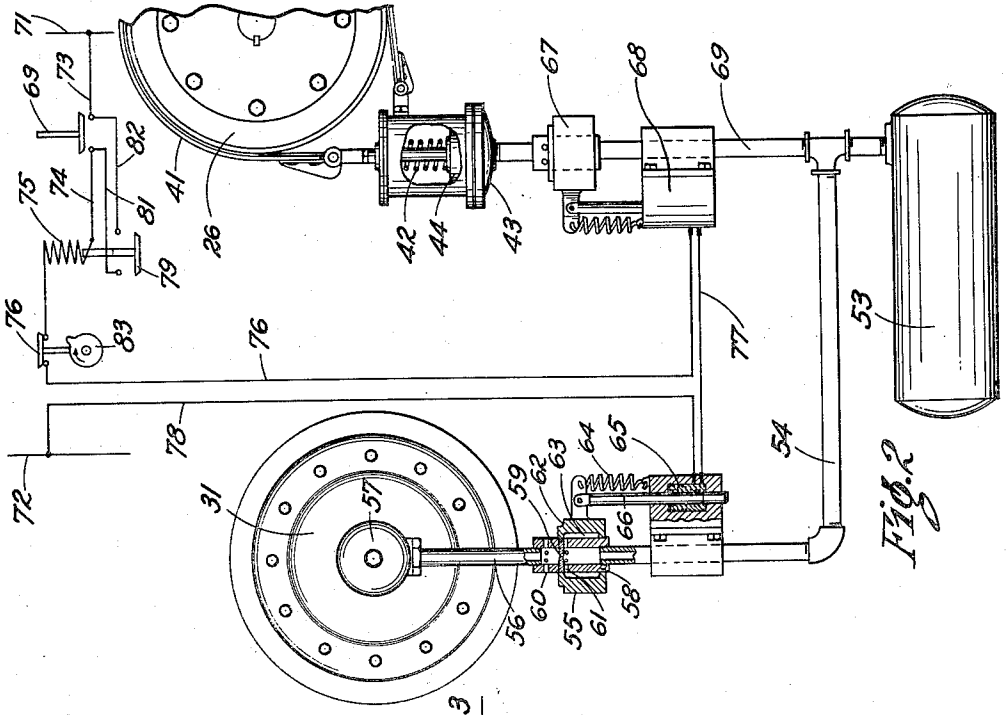


Fig. 2

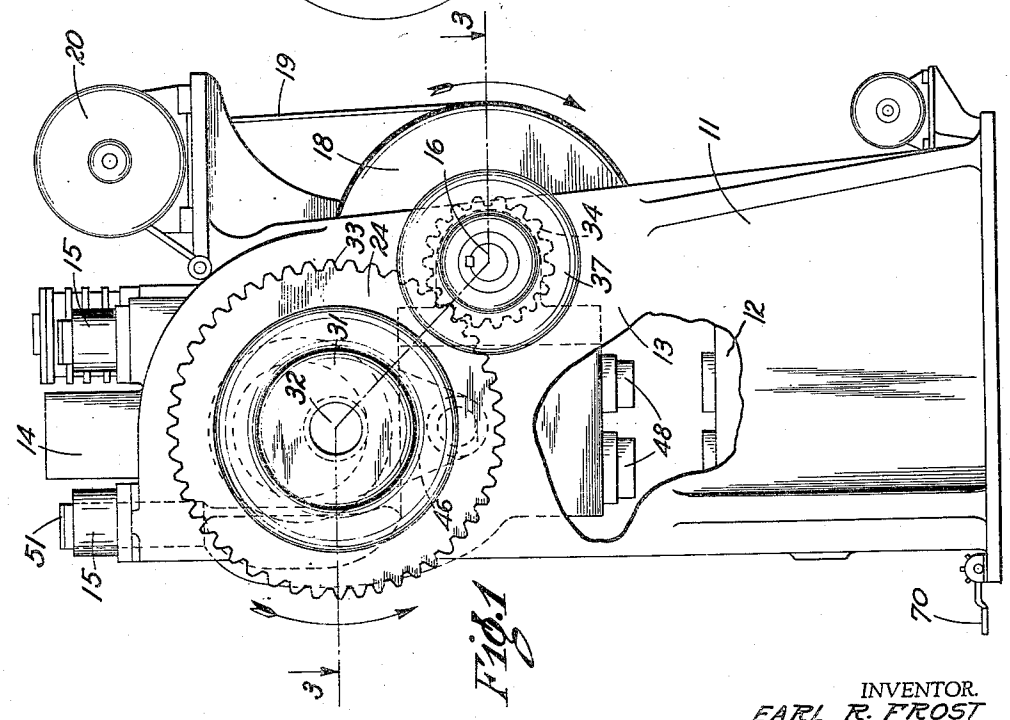


Fig. 1

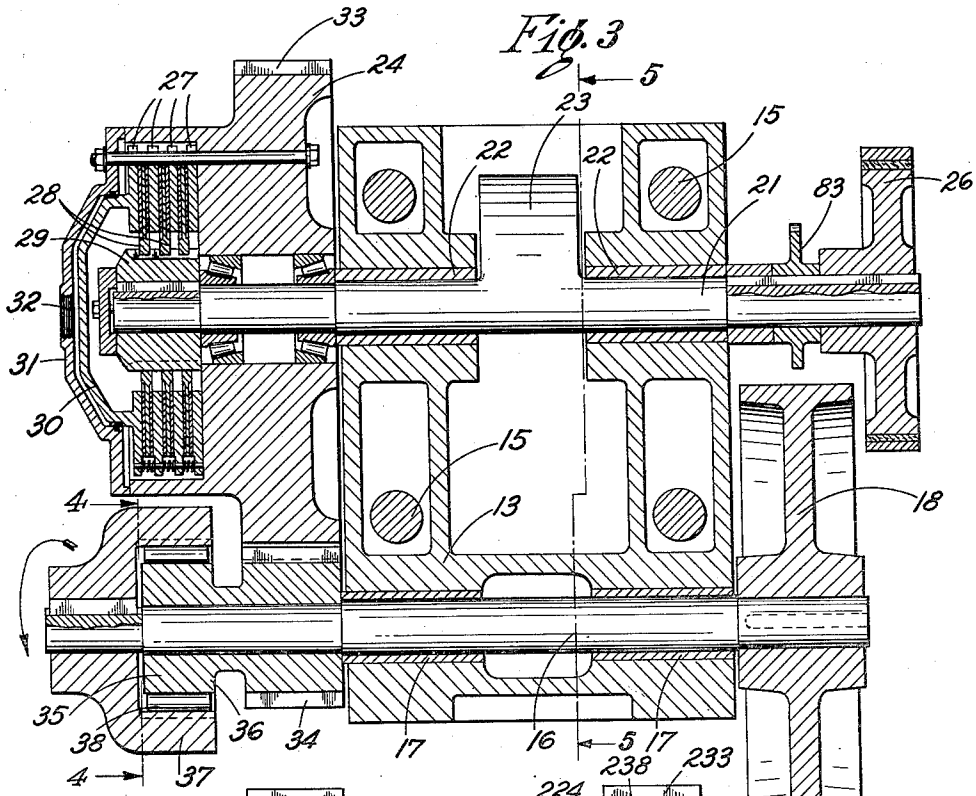
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METHOD AND APPARATUS FOR FORGING

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Fig. 3



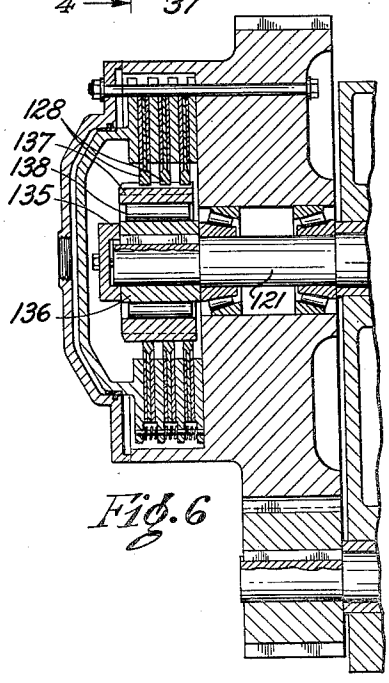


Fig. 6

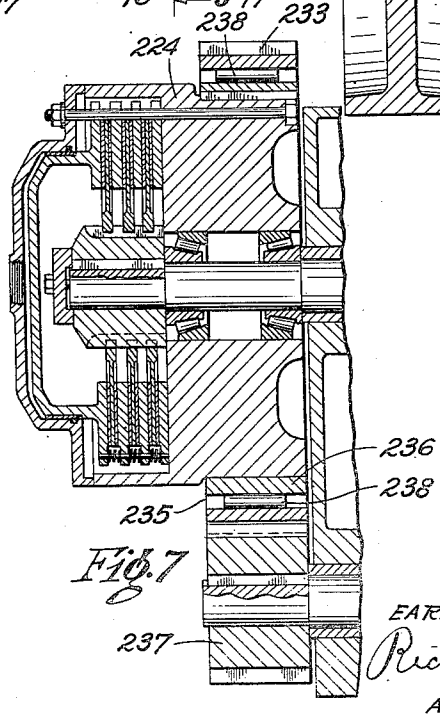


Fig. 7

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Fig. 8

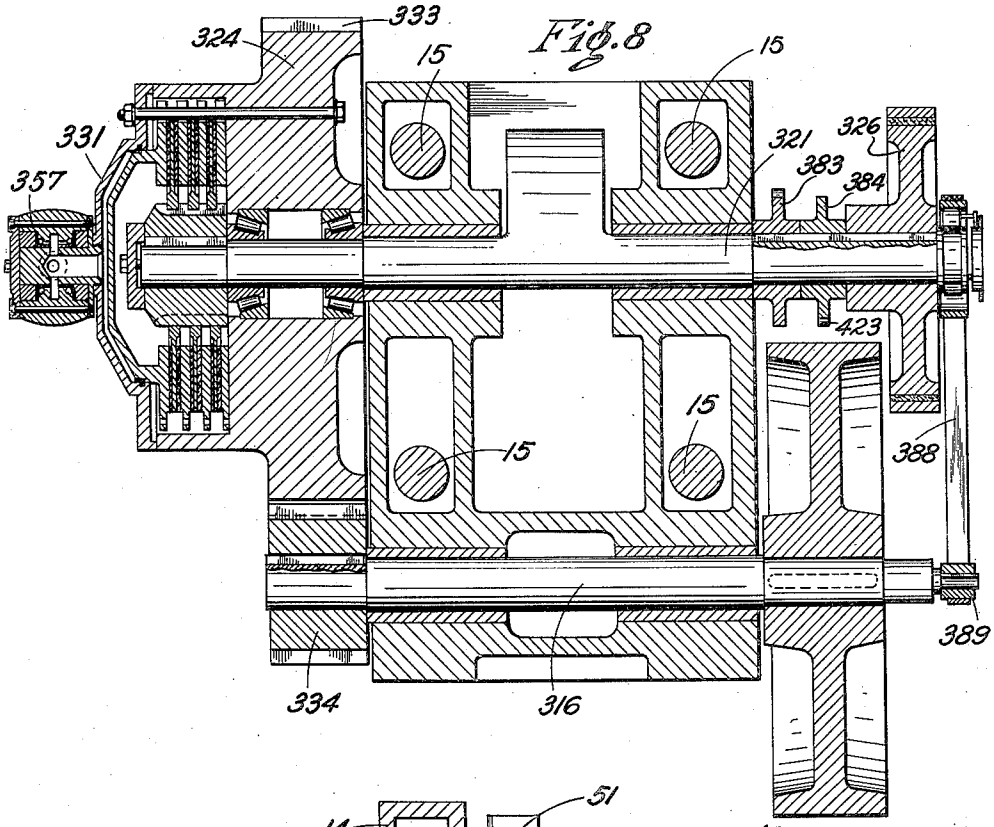


Fig. 5

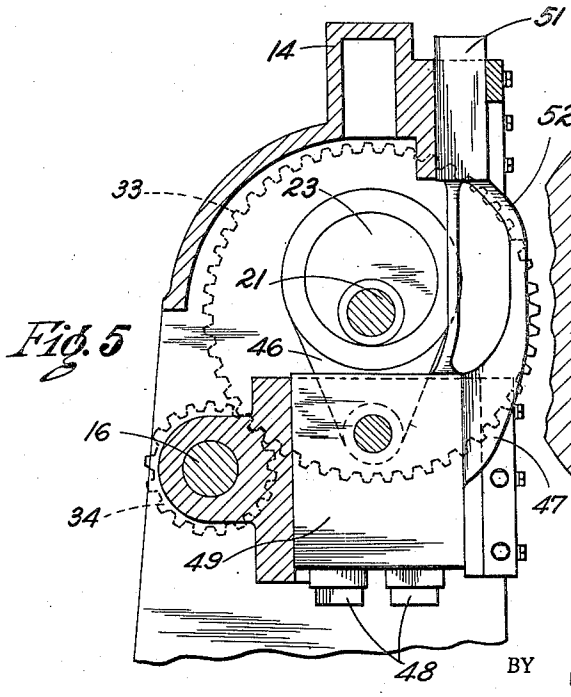
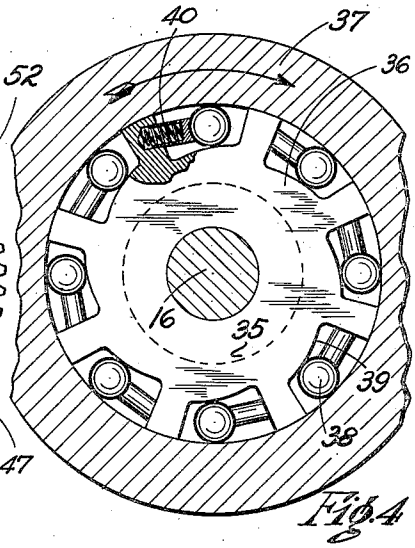


Fig. 4



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Fig. 9

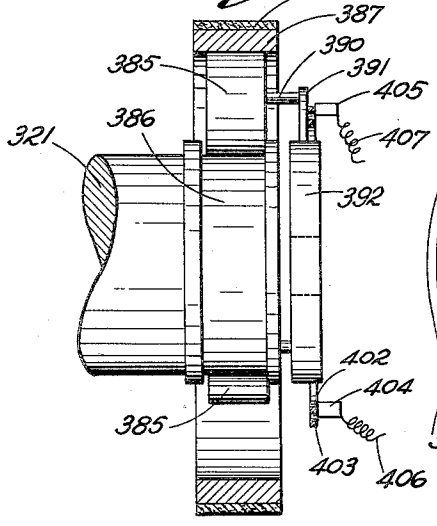
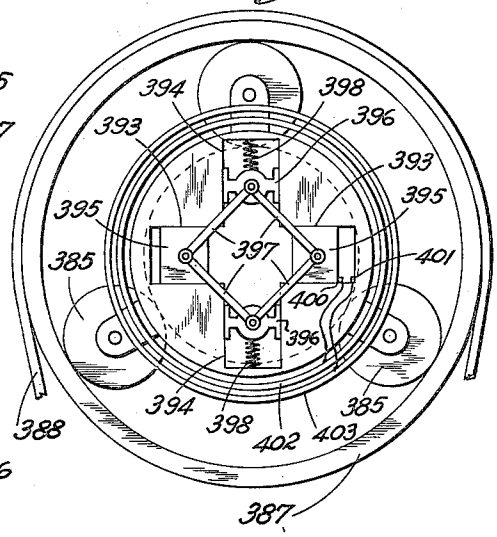


Fig. 10



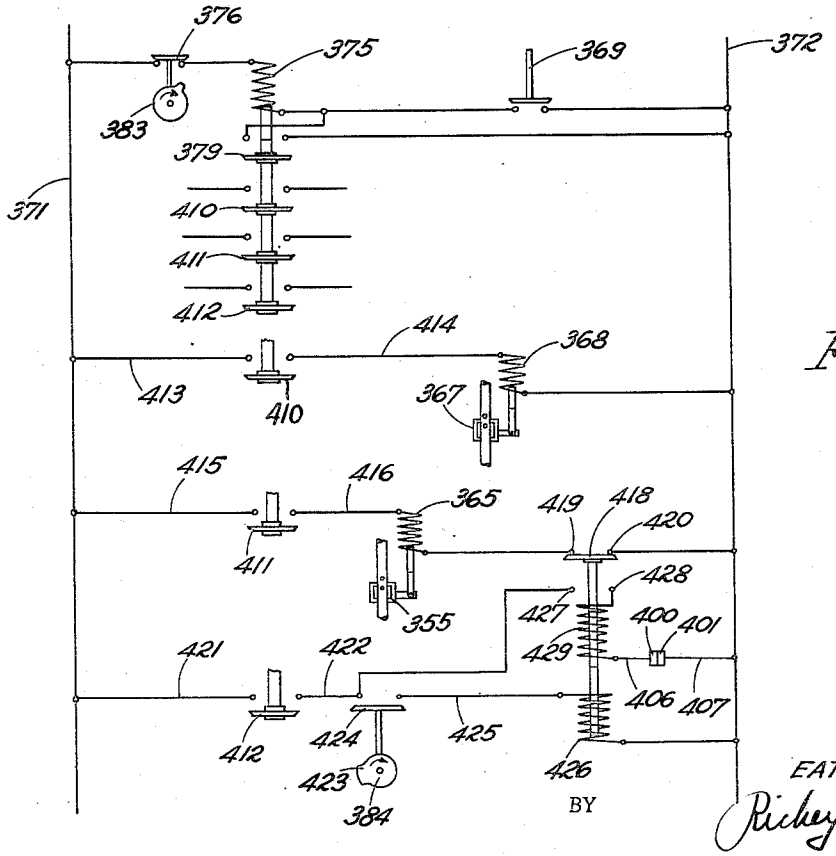


Fig. 11

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Patented Nov. 20, 1945 2,389,425

UNITED STATES PATENT OFFICE

2,389,425

METHOD AND APPARATUS FOR FORGING

Earl E. Frost, Tiffin, Ohio, assignor to The National Machinery Company, Tiffin, Ohio, a corporation of Ohio

Application December 5, 1940, Serial No. 368,638

36 Claims. (Cl. 78—39)

This invention relates to methods and apparatus for forging.

Forging apparatus is broadly divided into two classes; that in which the metal is deformed by impact of a moving ram or tool, and that in which the deformation is accomplished by pressing or forcing the ram or tool into or against the metal. The former class includes drop hammers, steam hammers, and the like, and the latter forging machines, forging presses, and similar machines in which a slide carrying suitable tools is driven against the metal by a crank or other translating means. In impact apparatus, the driving means lifts the ram to a starting position from which it is permited to fall, acquiring kinetic energy, and the work is done as an incident to the collision of the ram with the anvil and work piece. In pressing apparatus, on the contrary, the working force is applied gradually to the work piece, without a blow or impact, the slide and driving mechanism acting to transmit the energy stored in a flywheel and the reaction being taken through the frame work which holds the stationary die support and the crankshaft together.

Each of these types of mechanism has certain advantages inherent in its distinctive mode of operation. For example, in impact apparatus the dies remain in contact with the hot metal being worked through but a relatively short period of time, resulting in less heating of the dies and longer die life. The relatively quick, sharp blow of the impact machine is also capable of causing the metal being worked to extrude or flow upwardly into recesses in the upper die much better than the slower although more positive progression of the press die into the metal. On the other hand, the movable die in the press may be moved to exactly the desired position on each stroke, and much greater pressures and deeper and more thorough working of the metal can be obtained than in the case of impact apparatus.

Each of these types of mechanism likewise has inherent limitations. In impact apparatus the energy of the ram must ultimately be absorbed and the ram stopped in its downward travel by the anvil. A fraction of the kinetic energy of the ram equal to the mass of the anvil divided by the sum of the masses of the ram and the anvil is available for doing work on the piece being forged, while the remaining fraction of the kinetic energy of the ram, equal to the mass of the ram divided by the sum of the masses of the ram and the anvil is absorbed by the anvil, a fraction of this energy, determined from the coefficient of restitution of the material of the anvil, being recovered by causing the ram to rebound upwardly after its downward motion has been stopped. A portion of the energy available for doing useful work is also lost in producing sound, heat and vibrations as a result of the impact. The operation of such apparatus necessarily requires that there be sufficient metal in the work piece to prevent contact between the ram and the anvil or between the dies carried by these parts. This is ordinarily accomplished by designing the dies so as to insure the throwing out of a substantial flash around the work piece which prevents contact between the dies. In order to obtain the desired flash it is usually impossible to completely fill out the die impression on the first stroke so that it is customary to restrike the piece a number of times. In restriking a relatively small amount of forging work is done upon the work piece itself the major portion of the energy being absorbed in reducing the thickness of the flash so as to permit the dies to approach each other more closely.

In pressing apparatus in which the movable die is positively driven a serious limitation is experienced because it is necessary for the ram to be slowing down as it engages the work. The speed of forward movement of the ram relative to the speed of rotation of the flywheel continues to decrease through the working stroke. Thus the advantages of the sharp blow of the ram against the work in impact apparatus resulting from the fact that the ram is accelerating when it engages the work cannot be obtained in pressure apparatus.

In addition the ultimate force which may be exerted upon the metal in a pressing stroke is limited by the stiffness of the machine or the ability of the frame connecting the stationary die and the crankshaft to resist stretching and the ability of the ram and driving mechanism to resist compression. Since some stretching of the frame and compressing of the parts necessarily occurs when the pressures are applied and increases with an increase in pressure the relative speed at which the moving die approaches the fixed die further decreases near the end of the stroke because of the springing of the machine.

It has been discovered that greater definition, a sharper filling of recesses in the dies with less metal thrown out in flash, and a better flowing of the metal being worked, with less pressure, can be obtained if the speed of movement of a

forging die can be increased so as to maintain a higher rate of flow in the metal after the deformation of the metal has started. Neither of the two general classes of forging apparatus described above is capable of taking full advantage of this phenomenon. In impact apparatus the amount of energy that the ram can be permitted to acquire before contact with the work is limited, in proportion to the amount of work to be done, by the fact that all of the energy must be absorbed and the ram must be stopped before the dies contact each other. In pressing apparatus it is necessary to do the work near the end of the stroke at which time the forward movement of the ram is being rapidly slowed down by the driving mechanism in order to obtain the large pressures which may be obtained by the increased mechanical advantage of the driving mechanism as it approaches the limit of its forward movement.

I have discovered that greatly improved results may be obtained by combining in a forging stroke a sharp blow of the impact type of apparatus at the beginning of the stroke followed by the positive advance with increasing pressure and definite limitations of movement characteristic of a pressing stroke. In this way I am able to obtain all of the advantages of the impact mechanism without the disadvantages which have heretofore limited this type of apparatus, and at the same time retain all of the advantages of the pressing type of apparatus, with improved results heretofore unobtainable in pressing apparatus because the complete working stroke is performed in less time and therefore with a higher rate of movement of the metal. I have also discovered that improved results from a forging stroke of the impact type can be obtained without the necessity of restriking by limiting the forward motion of the ram independently of the anvil or the fixed die so that it is unnecessary to absorb the residual energy of the ram in the anvil itself or to transmit the same through the flash. Likewise in this type of stroke the useful energy is not limited by the relation of the mass of the ram and the anvil but rather by the stiffness of the machine, as in pressing apparatus, and the energy which may be initially imparted to the ram and consequently the speed with which the work is done is not limited by the size of the work piece or the amount of energy required to complete the filling of the die as in conventional apparatus.

The present invention includes a new method of forging in which the forging stroke begins with impact from a freely moving or accelerating ram and continues, before the motion of the ram has stopped, with positive progression with increasing pressure; and likewise a new method of forging solely by impact in which the residual energy of the ram is absorbed and the forward motion is stopped by a driving mechanism independently of the anvil.

The present invention further includes apparatus for carrying out either or both of these methods and more particularly an apparatus capable, without adjustment or change, of carrying out both of these methods successively, as for a preliminary or gathering stroke followed by a final finishing stroke.

The apparatus of this invention consists generally of a relatively stiff framework corresponding to the frame of a forging press, a slide connected to a crankshaft by a pitman or similar linkage, means to stop the slide in a retracted position or to couple it to a driving means to initiate a stroke, and means to uncouple the slide from the driving mechanism after it has been accelerated from its driving position and to automatically recouple the slide to the driving mechanism in time to prevent the forward movement of the slide dropping below the driving speed of the crankshaft. In one embodiment of the apparatus the drive from the flywheel to the slide, when the same are coupled through a suitable starting clutch, is transmitted through an overrunning clutch permitting the slide to overrun the driving speed but preventing it from dropping below the driving speed. In another form means are provided to disconnect the driving clutch and to automatically reconnect it at such a time as to prevent the slide dropping below the driving speed. Other and more specific objects and features of the invention will appear in the following detailed description of preferred embodiments of the invention.

In the accompanying drawings which illustrate preferred embodiments of the invention:

Figure 1 is a side elevation of a machine embodying the present invention;

Figure 2 is a diagrammatic showing of controls for the main clutch and brake;

Figure 3 is a sectional view taken substantially on the line 3—3 of Figure 1 illustrating one arrangement of the driving mechanism;

Figure 4 is a detailed sectional view taken on the line 4—4 of Figure 3;

Figure 5 is a vertical sectional view illustrating the slide taken on the line 5—5 of Figure 3;

Figure 6 is a sectional view corresponding to a portion of Figure 3 showing a modified arrangement;

Figure 7 is a similar view showing a further modification;

Figure 8 is a view corresponding to Figure 3 showing a further modification of the driving arrangement;

Figure 9 is an enlarged detail sectional view of a speed responsive mechanism shown in Figure 8;

Figure 10 is a side elevation of the same;

Figure 11 is a wiring diagram for the apparatus illustrated in Figures 7, 9 and 10.

To simplify the descriptions and claims in this specification certain terms will be arbitrarily defined. In connection with crank driven slides, the end of the slide movement away from the stationary die bed is termed the inner dead center, and the opposite end of the slide movement, the outer dead center. In the usual arrangement of forging apparatus the wrist connection of the pitman is disposed between the crankshaft and the working end of the slide, so that at the inner dead center the centers of the two ends of the pitman are on opposite sides of the crankshaft, and at the outer dead center they are on the same side. However, this arrangement of the crank may be reversed, so the terms inner and outer dead centers will be used solely in connection with the positions of the slide. The rotation of the crankshaft to move the slide from its inner dead center to its point of maximum velocity is termed the first quadrant of crankshaft rotation, although occupying more than ninety degrees of rotation, in the usual arrangement, because of the departure of crank motion from harmonic motion. Similarly, the rotations to move the slide from the point of maximum velocity to its outer dead center, from the outer dead center to the opposite point of maximum velocity, and from that point to the inner dead center are termed

respectively, the second, third, and fourth quadrants of crankshaft rotation, regardless of the exact number of degrees of rotation occupied by each.

The forging blow carrying out the novel method of this invention in which the work is performed solely by impact, and in which the striking member is stopped and its residual energy is prevented from being transmitted to the work piece will be termed a "free impact" blow. The forging blow carrying out the novel method of this invention in which the work is started by impact of an accelerating or free moving striking member and completed by positive progression under increasing pressure will be termed an "impact-pressing" blow.

Referring first to the arrangement illustrated in Figures 1 to 5, inclusive, the numeral 11 designates the main frame which corresponds to the frame of a forging press. This general type of press is disclosed more in detail in the patent to Clouse No. 2,017,784. The frame includes a die base 12 and side frame members 13 rising above the base and connected by a crown 14. The side members 13 are made relatively stiff and rigid so as to take in tension the reaction to the pressing force exerted between the crankshaft and the die bed during the latter portion of an impact-pressing stroke, and to absorb in compression the residual energy of the slide on a free impact stroke. Preferably, the side frame members 13 are stiffened by pre-loaded tension rods 15 so as to minimize spring. A pinion shaft 16 is journalled in suitable bearings 17 in the frame side members 13 and is provided at one end with a flywheel 18 which may be arranged to be driven in any suitable manner, as by a belt 19 driven by a motor 20.

A crankshaft 21 is also journalled in suitable bearings 22 in the frame side members 13 and is provided with a crank or eccentric 23, located between the frame bearings 22, for reciprocating the slide or ram. The driving member 24 of a fluid operated friction clutch is journalled upon the crankshaft 21 at one side of the frame 11 through suitable bearings 25, and a brake wheel 26 is carried by the crankshaft 21 at the other side of the frame.

The type of clutch illustrated is constructed generally as shown in the co-pending application of Clouse, Ser. No. 241,224 filed Nov. 18, 1938. The driving member 24 of the clutch carries a series of driving clutch plates 27 intercalated with driven clutch plates 28 splined to a hub 29 secured to the end of the crankshaft 21. The clutch plates are slidable upon, but are held against rotation with respect to, the driving and driven members of the clutch. As illustrated the outermost of the driving clutch plates 27 is formed integral with a piston 30 fitting within a cylinder 31 carried by the driving member of the clutch. Pressure fluid may be admitted through a central aperture 32 in the cylinder to press the clutch plates axially into firm frictional engagement and thereby clutch the crankshaft 21 to the driving member 24 of the clutch.

As shown, the driving member 24 of the clutch is formed with gear teeth 33 at its periphery which are in mesh with a pinion 34 on the pinion shaft 16. In the arrangement shown in Figure 3 the pinion 34 is driven by the pinion shaft 16 through an overrunning clutch 35. The pinion 34 is formed integral with the driven member 36 of the overrunning clutch, and these members are journalled upon the pinion shaft 16. The driving member 37 of the overrunning clutch is keyed or otherwise suitably secured to the end of the shaft 16, and encompasses the driven member 36 of the clutch. Any suitable form of clutch may be employed. That illustrated in Figures 3 and 4 includes rollers 38 seated in wedging recesses 39 formed in the driven member 36 and pressed toward engaging position by springs 40. By this arrangement the pinion shaft 16, which is driven in the direction indicated by the arrows in Figures 3 and 4, normally drives the pinion 34 through the rollers 38 wedged in the recesses 39, but the pinion is permitted to over-run the shaft 16.

The brake wheel 26 is provided with a brake band 41 which is contracted upon the brake wheel in braking engagement therewith by means of a spring 42 which may be released, to permit rotation of the crankshaft, by a fluid operated cylinder 43 and piston 44.

A pitman 46 is journalled upon the crank or eccentric 23, as shown in Figure 5, and has its opposite end connected to a slide or ram 47 guided in the frame and carrying one or more dies 48. Preferably this slide is constructed, as disclosed in the aforesaid patent to Clouse No. 2,017,784, with a lower guiding and die supporting portion 49 bearing in guideways located between the crankshaft and the die bed of the machine, and an upper guiding portion 51 bearing in guideways formed in the frame above the crankshaft and connected to the lower portion by a rigid offset connecting arm 52.

A suitable arrangement of controls is illustrated diagrammatically in Figure 2. A reservoir 53 is connected by a pipe 54 to a three-way solenoid operated valve 55 from which a conduit 56 leads through a rotatable coupling 57 to the central aperture 32 in the clutch cylinder 31. The valve 55 may be any desired form of three-way valve, but the form illustrated comprises a tubular member 58 divided into upper and lower compartments by a partition 59. A series of apertures 60 is formed through the tubular member 58 above the partition 59, and a similar series of apertures 61 is formed below the partition 59. A sleeve 62 is slidably mounted on the outside of the tubular member 58 and is provided with a recess 63 arranged, in its lowermost position as shown in Figure 2, to cover the apertures 61, leaving the apertures 60 open to atmosphere, and, in its uppermost position, to cover both sets of apertures and provide communication between the upper and lower compartments of the tubular member 58.

The sleeve 62 is normally held by a spring 64 in its lowermost position, opening the apertures 60 and the clutch cylinder 31 to atmosphere. A solenoid 65 is supported adjacent the valve 55 and has a core 66 connected to the sleeve 62. When the solenoid is energized it overcomes the spring 64, moving the sleeve 62 to its uppermost position and establishing communication between the apertures 60 and 61, so that pressure fluid flows from the reservoir 53 to the clutch cylinder 31, causing engagement of the clutch. A three-way valve 67 similar to the valve 55 and operated in the same manner by a solenoid 68 is placed between the brake cylinder 43 and a pipe 69 which also leads to the reservoir 53. Preferably the brake valve 67 differs from the clutch valve 55 by having the two series of apertures closer together, so that when the solenoids 65 and 68 are simultaneously energized the brake valve 67 opens a predetermined time before the clutch valve 55 opens.

A wiring diagram for the solenoids 65 and 68 is also included in Fig. 2. A normally open switch 69 is arranged to be closed by the foot pedal 70 (see Fig. 1) to establish a circuit from the supply lines 71 and 72 through the solenoids 65 and 68.

Closing the switch 69 connects the wire 73, leading from the line 71, with the wire 74, which leads through the solenoid 75, normally closed switch 76, and through the solenoids 65 and 68, connected in series by wires 76, 77, and 78, to supply line 72. Energization of solenoid 75 closes normally open switch 79 and establishes a holding circuit around the switch 69 through wires 81 and 82.

The cam 83, mounted on the crankshaft 21, is arranged to open switch 76 after the crankshaft has substantially completed one revolution, which breaks the circuit through solenoids 65, 68, and 75, manually operated switch 69 having been previously opened, releasing the friction clutch and applying the brake.

In operation, the flywheel 18 is driven at a relatively high speed by the motor 20. The pinion 34 is driven by the shaft 16 through the overrunning clutch 35, and in turn drives the driven member 24 of the friction clutch, which rotates freely upon the stationary crankshaft 21 which is normally positioned at inner dead center, as shown. To initiate a cycle, the operator closes switch 69, thereby admitting pressure fluid to the brake and clutch cylinders to release the brake and engage the clutch. When the clutch is engaged the energy of the rotating flywheel 14 acts to start the crankshaft 21 from rest and to accelerate the slide 47 downwardly through the first quadrant of crankshaft rotation. The flywheel 18 is preferably driven at a speed sufficiently high so that the acceleration imparted to the slide 47 by the crank or eccentric 23 exceeds the acceleration of gravity acting upon the slide during this quadrant. Thus the slide is positively driven downwardly at a rapidly increasing speed through the first quadrant, when the slide reaches the maximum velocity that can be imparted to it by the speed of the crank. From this point and through the second quadrant, gravity tends to further accelerate the slide whereas the crank tends to decelerate the downward movement of the slide with respect to the speed of rotation of the crankshaft. As a consequence the energy which has already been imparted to the slide applies a force to the crankshaft 17 tending to increase its speed of rotation. Such increase of speed of the crankshaft would normally be prevented by the inertia of the flywheel, but the overrunning clutch 35 permits the crankshaft, friction clutch and pinion 34 to accelerate, the pinion 34 overrunning the pinion shaft 16.

As the slide approaches the lower limit of its movement, which is determined by the outer dead center of the crank 23, one of the dies carried by the accelerating slide strikes the work with a sharp blow.

If the machine is being used to perform an impact-pressing blow in accordance with this invention, a part of the energy stored in the slide immediately starts the desired flow of the metal being forged, the slide being decelerated as energy is absorbed by the work. As the speed of movement of the slide decreases, the speed of rotation of the crankshaft 21 and pinion 34 correspondingly decreases until the pinion reaches the relatively constant speed of the pinion shaft 16. Immediately that this occurs, the overrunning clutch 35 re-engages and the downward progression of the slide is continued under increasing pressure until the outer dead center of the crank is reached.

During this final portion of the impact-pressing blow, all of the energy of the flywheel 18 is available to complete the stroke with the rapidly increasing mechanical advantage of the crank as it approaches its outer dead center. Less pressure is needed to complete the stroke, however, than would be required if it were attempted to do all the work with a conventional pressing stroke, since the faster rate at which the metal is caused to flow in the beginning of the stroke results in less pressure being required to complete it. This, in turn, results in less springing of the frame and consequently a better filling out of the die impression, making it possible to fill out to close tolerances sharp and deep recesses in the die and to produce forgings which could not be made upon prior types of forging apparatus.

On the other hand if the machine is being used to perform a free impact blow the energy stored in the accelerating or freely moving slide acts to complete the work of the forging blow without slowing the pinion down to the speed of the pinion shaft so that the overrunning clutch does not re-engage during the second quadrant of the stroke. In this type of forging blow the residual energy of the slide is absorbed and the forward motion of the slide is stopped by the crank passing over outer dead center. This is in sharp distinction to the prior types of impact machines in which the residual energy of the slide must be absorbed by the impact or collision of the slide against the anvil. In accordance with the characteristic action of a crank movement the energy of the forward movement of the slide is absorbed smoothly although at a rapid rate because of the tendency of the slide to accelerate the crank near outer dead center. The energy imparted to the crankshaft in passing over outer dead center and stopping the forward movement of the slide immediately starts the slide on its upward movement through the third quadrant of crankshaft rotation. Before the third quadrant is completed the crankshaft has been decelerated, by the work of lifting the slide, to the driving speed of the pinion shaft so that the overrunning clutch again engages and imparts an upward acceleration to the slide.

In either type of blow the upward acceleration imparted to the slide during the third quadrant normally exceeds the acceleration of gravity so that the crankshaft again overruns the drive during the fourth quadrant. Near the end of the fourth quadrant of rotation the cam 83 opens the switch 76 causing the main driving clutch to be disengaged and the brake band 41 to be applied bringing the crankshaft to rest at its inner dead center.

Which of the two novel types of forging blow is to be performed during an operation of the machine is determined from the job to be done and the dies are designed accordingly. For example, if metal flow and refinement from working are desired primarily at the surfaces, or if a substantial gathering or flow of metal into die recesses with a minimum of lateral flow are desired, the free impact blow may be selected. On the other hand, if deeper working of the metal is desired, or is made necessary by the shape to be imparted to the piece, the impact-pressing blow may be selected. Similarly, on an impact-pressing blow, the relative proportions of the

work performed by the energy of the slide and by the energy of the flywheel are determined and the dies designed and adjusted accordingly.

It is also frequently necessary to work a blank in two or more stages, gathering the metal under a drop hammer or the like, and then pressing it to the final shape. With the present apparatus and method it is possible to provide the slide and die bed with two or more sets of dies to perform the preliminary operations by a free impact blow or blows and immediately transfer the blank without re-heating to the final set of dies and press it to form with an impact-pressing blow. In this way it is possible to produce on a single machine, without adjustment of the apparatus or re-heating of the piece, work which heretofore required two separate machines and in most instances a re-heating of the blank between its treatment on the two machines.

In such operations the working stroke is completed in less time than would be possible with a conventional crank driven press, resulting in better metal flow and longer die life, since the energy of the overrunning slide performs at least part of the working operation before the crank shaft has slowed down to a speed corresponding to the drive speed of the flywheel. Thus the initial part of the working of the metal on an impact-pressing blow is obtained by a sharp hammer action and, without permitting the flow of metal to stop, the blow is completed by the positive drive of the crank with increasing pressure, all of the energy of the flywheel being available to complete the stroke.

Figure 6 illustrates a modified arrangement. The overrunning clutch 135 is located between the crankshaft 121 and the driven plates 128 of the friction clutch. This is accomplished by making the outer or driving portion of the overrunning clutch in the form of a ring 137 to which the driven plates 128 of the clutch are splined, while the inner member 136 of the overrunning clutch is keyed or otherwise secured to the end of the crankshaft 121. As in the form previously described the rollers 138 disposed between the inner and outer members of the overrunning clutch normally drive the crankshaft 121 in the forward direction, but permit the crankshaft and the slide to overrun. The operation of this type of apparatus is substantially the same as that previously described except that the energy of the descending slide acts to accelerate only the crankshaft 121, all of the remaining elements of the drive continuing to rotate at the relatively constant speed of the flywheel.

Figure 7 illustrates a slightly different modification in which the overrunning clutch 235 is located between the gear teeth 233 and the driving member 224 of the friction clutch. In this embodiment the rollers 238 are seated upon a ring 236 secured to the periphery of the driving member of the friction clutch, and are surrounded by the driving member 237 of the overrunning clutch, which also carries the main gear teeth 233. As in the embodiments previously described the rollers transmit the drive to the driving member of the friction clutch but permit overrunning of the crankshaft and friction clutch from the acceleration of the slide.

A somewhat different embodiment of the invention is illustrated in Figures 8–11. In this construction no overrunning clutch is employed but means are provided to disengage the friction clutch at the point in the first quadrant of the crankshaft rotation when the slide tends to overrun the drive, and to re-engage the same clutch when the speed of the crankshaft has been reduced to correspond to the speed of the drive.

As shown in Figure 8 the apparatus is substantially the same as that shown in Figure 3 except that the pinion 334 is keyed to the pinion shaft 316 and meshes with the gear teeth 333 on the driving member 324 of the friction clutch. The crankshaft 321 is extended beyond the brake-wheel 326 and is provided with a speed responsive mechanism illustrated in detail in Figures 9 and 10. A suitable pressure fluid supply pipe is connected to the central opening in the clutch cylinder 331 through a rotatable coupling 357 and is provided near the clutch with a valve 355 operated by a solenoid 365, similar in construction and operation to the clutch valve 55 and solenoid 65 described in connection with the embodiment shown in Figures 1 to 5, inclusive.

A similar valve 367 controlled by a solenoid 368 is arranged to control the admission and exhaust of pressure fluid to and from the brake cylinder so that the brake is released by the pressure fluid when the solenoid is energized and is permitted to be engaged by its spring when the current is cut off from its solenoid.

The speed responsive device carried by the outer end of the crankshaft 321 and shown in Figures 9 and 10 embodies a plurality of rollers 385 bearing upon a raceway 386 on the shaft and within a ring 387. The ring 387 is connected by a belt 388 or the like to a pulley 389 carried upon the outer end of the pinion shaft 316. The relative sizes of the ring 387 and pulley 389 are proportional to the relative sizes of the pinion 334 and the gear 333 so that when the friction clutch is engaged and the crankshaft is being driven the ring 387 rotates at the same speed as the crankshaft 321, but in the opposite direction.

The rollers 385 are journalled upon pins 390 which are secured at their outer ends to ears 391 projecting radially from a disk 392. The disk 392 is provided with a pair of radial aligned guideways 393 and a similar pair of aligned guideways 394 perpendicular to the guideways 393. Weights 395 are slidably disposed in the guideways 393 and cross heads 396 are similarly slidably disposed in the guideways 394. Four links 397 connect the oppositely disposed weights 395 and the oppositely disposed cross heads 396. Springs 398 are arranged to normally pull outwardly upon the cross heads 396 causing the weights 395 to be positioned at the radially inner ends of their guideways 393. Centrifugal force from rotation of the disk 392 causes the weights 395 to move to the radially outer ends of their guideways 393.

An electrical contact 400 is carried by one of the weights 395 and is arranged to engage a cooperating contact 401 when the weights 395 are moved outwardly by centrifugal force. The contacts 400 and 401 are connected by suitable conductors to slip rings 402 and 403, respectively. Brushes 404 and 405 are disposed in engagement with the slip rings 402 and 403, respectively, and are connected to conductors 406 and 407. Thus the speed responsive mechanism constitutes a switch which establishes a circuit between the conductors 406 and 407 when the disk 392 is rotated, and breaks the circuit when the disk is stationary, or when its speed of rotation is so slow that the springs 398 overcome the centrifugal force of the weights 395.

In addition to the speed responsive device the crankshaft 321 is provided with a pair of cams

383 and 384 shown in Figure 6 and arranged to operate electrical switches illustrated diagrammatically in Figure 11.

The various controls and electrical connections are illustrated in Figure 11. Supply lines 371 and 372 are connected to a suitable source of current. A switch 369 is arranged to be closed manually to initiate a cycle of operation of the machine. Closing of the switch 369 establishes a circuit through solenoid 375 which simultaneously closes switches 379, 410, 411, and 412. These switches are illustrated at the upper part of Figure 11 connected to the movable core of the solenoid 375, and switches 410, 411, 412 are repeated in separate circuits to avoid confusion of the diagram.

Closing of the switch 379 establishes a holding circuit around the manual switch 369 and through normally closed switch 376, as explained in connection with Figure 2, so that after the manually operated switch 369 is closed it can be released and the cycle proceeds automatically. Closing the switch 410 establishes a circuit through conductors 413 and 414 which energizes solenoid 368 controlling the fluid valve 367 for the brake. Energization of the solenoid 368 opens the brake valve 367 admitting fluid pressure to the brake cylinder to disengage the brake band. This circuit remains closed, so that the brake remains released, until the switch 376 is opened by the cam 383.

Closing of the switch 411 establishes a circuit through the conductors 415 and 416 and through switch 418, which is normally in engagement with contacts 419 and 420, to energize the solenoid 365 and open the clutch valve 355.

Closing of the switch 412 connects the conductors 421 and 422 but establishes no circuit at the beginning of the operation of the machine.

The brake having been released by actuation of the valve 367 and the friction clutch having been engaged by the actuation of the valve 355, the crankshaft of the press is coupled to the drive and begins to rotate, turning the cams 383 and 384 in the direction indicated by the arrows in Figure 11. Prior to the engagement of the clutch the ring 387 of the speed responsive device is being rotated by the belt 388, whereas the crankshaft 321 is stationary, causing the rollers 385 to travel around the raceway 386 and thereby rotate the disk 392. Thus the weights 395 are held outwardly by centrifugal force and conductors 406 and 407 are connected throughout the contacts 400 and 401, but no circuit is established through these contacts at the beginning of the operation. As soon as the clutch has been engaged the crank shaft 321 is driven at the same speed as the ring 387 but in the opposite direction so that the rollers 385 rotate upon their own axes but cease travelling about the center of the shaft 321, and therefore the disk 392 comes to rest and the contact points 400 and 401 are separated by the action of the springs 398.

As soon as the crank has turned substantially to its point of maximum velocity, or when the slide tends to overrun the drive, the cam 384 has turned so that its nose 423 engages the stem of the switch 424 and closes the same, connecting the conductors 422 and 425 and establishing a circuit through the solenoid 426. The solenoid 426 moves the switch 418 to its lowermost position, breaking the circuit between the contacts 419 and 420 and establishing a circuit between the contacts 427 and 428. The breaking of the circuit between the contacts 419 and 420 de-energizes the solenoid 365, closing the clutch valve 355 and releasing the clutch. The crankshaft and the driven elements of the clutch are then free to overrun the driving member of the clutch.

The nose 423 of the cam 384 has sufficient circumferential extent to maintain the switch 424 closed until the crankshaft 321 has accelerated sufficiently with respect to the normal driving speed to rotate the disk 392 and close the contacts 400 and 401. Closure of these contacts 400 and 401 establishes a holding circuit through the conductors 421 and 422, connected by switch 412, through the solenoid 429, the switch contacts 427 and 428, and the conductors 406 and 407. At or about this point the nose 423 of the cam 384 passes the switch 424, breaking the circuit through the solenoid 426, so that the switch 418 is maintained in its lowered position in engagement with the contacts 427 and 428 solely by the solenoid 429.

This solenoid 429 is energized by the circuit through the contacts 400 and 401 established by rotation of the disc 392, which in turn results from the crankshaft 321 overrunning the drive. As the speed of the crankshaft 321 slows down to the speed at which it would normally be driven by the pinion shaft 316, the rotation of the disk 392 slows correspondingly. Just before the speed of rotation of the ring 387 and the crankshaft 321 become equal, at a point which is determined by the strength of the springs 398, these springs overcome the centrifugal force of the weights 395 and open the contacts 400 and 401 breaking the circuit through the solenoid 429 and permitting the switch 418 to return to its upward position out of engagement with the contacts 427 and 428 and into engagement with the contacts 419 and 420. Thereupon the circuit through the clutch solenoid 368 is re-established, opening the clutch valve 355 and re-engaging the clutch. As previously explained this slowing down of the crankshaft 321 to a speed corresponding to the normal driving speed may occur either in the second or third quadrant of crankshaft rotation, depending upon whether the machine is being used to deliver an impact-pressing stroke or a free impact stroke. Thereafter the clutch remains in engagement during the third and fourth quadrants of rotation, until the nose of the cam 383 engages the switch 376 and breaks the circuit through the solenoid 375. When this occurs all of the switches 379, 410, 411, and 412 are opened, releasing the clutch and engaging the brake. The crankshaft continues to turn through a few degrees while the clutch is being disengaged and the crankshaft is being stopped by the brake, and the driven parts again come to rest with the cams 383 and 384 in the position illustrated in Figure 11, ready for another cycle when the manual valve 369 is again closed.

The operation of this apparatus on the downward stroke is substantially the same as the operation of the other forms previously described which embody the overrunning clutch, except that the point at which the clutch opens to release the crankshaft for overrunning must be pre-selected by the proper location of the nose 423 of the cam 384. However this point at which the crankshaft tends to overrun is substantially the same on all operations of the machine, so that it may be readily predetermined. Likewise the point at which the control mechanism operates to reengage the clutch occurs slightly before the crankshaft 321 has slowed down to its nor-

mal driven speed, the exact point depending upon the tension of the springs 398 which may be selected to insure complete re-engagement of the clutch before the shaft 321 has a chance to slow down to less than its normal driven speed.

On the return or upward stroke of the slide, during the third and fourth quadrants, this apparatus operates somewhat differently than the forms previously described in that no overrunning of the crankshaft is permitted. It will be apparent that during the third quadrant the slide is accelerated from its outer dead center to the maximum velocity imparted by the crank in substantially the same way that it is accelerated downwardly in the first quadrant. Thus in the forms of the apparatus embodying the overrunning clutch the crankshaft again tends to overrun the drive during the fourth quadrant, and the energy thus imparted to the slide must be absorbed by the brake in stopping the crankshaft. However, in the form illustrated in Figures 8 to 11, inclusive, the clutch remains in engagement throughout the upward stroke of the slide so that the excess energy imparted to the slide during the third quadrant is returned to the flywheel during the fourth quadrant. Thus the excess energy of the slide is absorbed by the flywheel which decelerates the slide to rest at the inner dead center and it is only necessary for the brake to absorb the energy of the crankshaft and the driven parts of the clutch.

While the novel method and various embodiments of the apparatus have been described in considerable detail, it is to be understod that numerous modifications and re-arrangements can be made therein, and further that various novel features may be used in different combinations or independently. For example, the method may comprise a free impact blow followed by an impact-pressing blow, or either of these two novel forging operations may be used alone or in combination with other operations. Similarly, the invention in its broader aspects is not limited to a vertically moving slide or to the types of clutches and control devices shown. Many other variations may be resorted to without departing from the scope of the invention as defined in the following claims.

I claim:

1. The method of forging comprising striking a metal work piece an impact blow with a freely falling member, and before the metal flow initiated by the impact has stopped, pressing the work piece to continue the forging thereof.

2. The method of forging comprising striking a metal work piece an impact blow with an accelerating member, and before the metal flow initiated by the impact has stopped, pressing the work piece to continue the forging thereof.

3. The method of forging comprising striking a metal work piece an impact blow with a freely falling member, and before the metal flow initiated by the impact has stopped, pressing the work piece with increasing pressure to further flow the metal thereof.

4. The method of forging comprising striking a metal work piece an impact blow with an accelerating member, and before the metal flow initiated by the impact has stopped, pressing the work piece with increasing pressure to further flow the metal thereof.

5. The method of forging comprising striking a metal work piece an impact blow with a freely falling member, and before the metal flow initiated by the impact has stopped, pressing the work piece with increasing pressure to further flow the metal thereof and stopping such metal flow at a definite pre-determined point.

6. The method of forging comprising striking a metal work piece an impact blow with an accelerating member, and before the metal flow initiated by the impact has stopped, pressing the work piece with increasing pressure to further flow the metal thereof and stopping such metal flow at a definite pre-determined point.

7. The method of forging comprising moving a striking member toward a work piece so as to impart kinetic energy to the member, forging the work piece solely by a portion of the kinetic energy of the member, exerting a positive limiting pull upon the member to absorb the remaining energy thereof and limiting the distance the member moves after striking the work piece, immediately thereafter again forging the work piece by moving a striking member toward the same so as to impart kinetic energy to the member, striking the work piece with the member and forging the work piece by impact and, before the metal flow in the work piece initiated by the impact has stopped, further moving the member toward the work piece with increasing pressure.

8. Forging apparatus comprising a frame carrying a die, a slide mounted in said frame for reciprocation toward and away from said die, driving mechanism for reciprocating said slide including a flywheel rotating at a relatively constant speed, said mechanism being arranged to move the slide toward the die so as to impart kinetic energy to the slide, said driving mechanism including means to release the slide to permit the same to overrun the driving speed of said flywheel, said means being arranged to again couple said slide to said driving mechanism to prevent the speed of said slide dropping below the driving speed of said flywheel.

9. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel and a clutch for coupling said crankshaft to said flywheel to move said slide on its working stroke and impart kinetic energy to the slide, said driving mechanism including means to release said crankshaft from said flywheel to prevent deceleration of said slide by said flywheel, said means being arranged to again couple said crankshaft to said flywheel to prevent said crankshaft dropping below the driving speed of said flywheel, and means for releasing said clutch and stopping said crankshaft at the end of one revolution.

10. Forging apparatus comprising a frame carrying a stationary die, a slide reciprocably mounted in said frame and carrying a movable die, driving mechanism for moving said slide toward said stationary die, said driving mechanism including means to release the slide and permit the same to overrun the drive, and said driving mechanism being arranged to positively limit the movement of said slide toward said stationary die to prevent contact between said movable die and said stationary die.

11. Forging apparatus comprising a frame carrying a stationary die, a slide reciprocably mounted in said frame and carrying a movable die, a crankshaft journalled in said frame, a pitman connecting said crankshaft to said slide, driving mechanism including a flywheel and a clutch to couple the flywheel with said crankshaft, said driving mechanism including means to

permit the crankshaft to overrun the drive of the flywheel, and said crank, pitman and slide being of such length as to positively prevent contact of said movable die with said stationary die.

12. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

13. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

14. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a friction clutch for coupling said flywheel with said crankshaft and an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

15. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a friction clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

16. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

17. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between said flywheel and said slide arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

18. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a clutch for coupling said flywheel to said crankshaft, a brake for stopping the rotation of said crankshaft, said driving mechanism including means to release said crankshaft from said flywheel to permit said crankshaft to overrun, said means being arranged to again couple said crankshaft with said flywheel to prevent the speed of said crankshaft dropping below the driving speed of said flywheel, means controlled by said crankshaft to release said clutch and apply said brake to stop said crankshaft at its inner dead center position, and manually controlled means to release the brake and engage the clutch to initiate a cycle of operation.

19. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said main clutch arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

20. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a main clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said main clutch arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

21. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a friction clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said flywheel and said friction clutch arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

22. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a friction clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between the flywheel and the friction clutch arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

23. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between the flywheel and the main clutch arranged to transmit the drive of said flywheel to said slide and to

permit said slide to overrun the flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

24. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between said flywheel and the main clutch arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

25. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between the main clutch and the crankshaft arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

26. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a main clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said main clutch and said crankshaft arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

27. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a friction clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between the friction clutch and said crankshaft arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel.

28. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a friction clutch for coupling said flywheel with said crankshaft, and an overrunning clutch located between said friction clutch and said crankshaft arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel.

29. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, a pinion shaft journalled in said frame and geared to said crankshaft, a flywheel on said pinion shaft, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between said main clutch and said crankshaft arranged to transmit the drive of said flywheel to said slide and to permit said slide to overrun the flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

30. Forging apparatus including a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a main clutch for coupling said flywheel with said crankshaft, an overrunning clutch located between said main clutch and crankshaft arranged to transmit the drive of said flywheel to said slide but permit said slide to overrun said flywheel, a brake for stopping the rotation of said crankshaft, and means controlled by said crankshaft for releasing said main clutch and applying said brake at the end of one revolution.

31. Forging apparatus comprising a frame, a slide reciprocably mounted on said frame, driving mechanism for reciprocating said slide including a friction clutch, means for engaging said clutch to start said slide on a working stroke, means for disengaging said clutch during the working stroke to permit the slide to overrun the drive, and means for automatically re-engaging said clutch to prevent the speed of movement of the slide from dropping below the driving speed.

32. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel and a friction clutch to couple said flywheel to said crankshaft, means for engaging said clutch to start said crankshaft from its inner dead center and move said slide on its working stroke, means to disengage said clutch during the working stroke, and means to automatically re-engage said clutch to prevent the speed of said crankshaft dropping below the speed of said flywheel.

33. Forging apparatus comprising a frame, a slide reciprocably mounted on said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft to said slide, driving mechanism including a flywheel and a friction clutch for coupling said flywheel to the crankshaft, means for disengaging said clutch during the working stroke of said slide, and a differential governor driven by said flywheel and by said crankshaft operating to re-engage said clutch when the speed of said crankshaft reaches a predetermined relation with the speed of said flywheel.

34. Forging apparatus comprising a frame, a slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel and a clutch to couple said flywheel to said crankshaft, means for engaging said clutch to start said crankshaft from its inner dead center and move said slide on its working stroke, said driving mechanism including means to release said slide from said flywheel to prevent the energy of said slide being absorbed by said flywheel during the second quadrant of rotation of said crankshaft and means to again couple said slide to said flywheel to prevent the speed of the slide dropping below the driving speed of said flywheel, said driving mechanism maintaining the slide coupled to said flywheel so that the energy of said slide is absorbed by the flywheel during the fourth quadrant of rotation of said crankshaft.

35. Forging apparatus comprising a frame, a

slide reciprocably mounted in said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft with said slide, driving mechanism including a flywheel, a pinion shaft driven by said flywheel and geared to said crankshaft, said driving mechanism including means to release said crankshaft from said flywheel to permit the crankshaft to overrun the driving speed of said flywheel and to again couple said crankshaft to said flywheel to prevent the speed of said crankshaft dropping below the driving speed of said flywheel, said means being controlled by a differential governor driven by said crankshaft and by said flywheel.

36. Forging apparatus comprising a frame, a slide reciprocably mounted on said frame, a crankshaft journalled in said frame, a pitman connecting said crankshaft to said slide, driving mechanism including a flywheel arranged to drive a pinion shaft geared to said crankshaft and a friction clutch for coupling said flywheel to the crankshaft, means for disengaging said clutch during the working stroke of said slide, a rotatable member carried by planetary wheels engaging said crankshaft, a ring surrounding and engaging said planetary wheels and belted to said flywheel and a governor carried by said rotatable member operating to re-engage said clutch when the speed of said crankshaft reaches a predetermined relation to the speed of said flywheel.

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