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None

(58) Field of search
UK CL (Edition K) B3R
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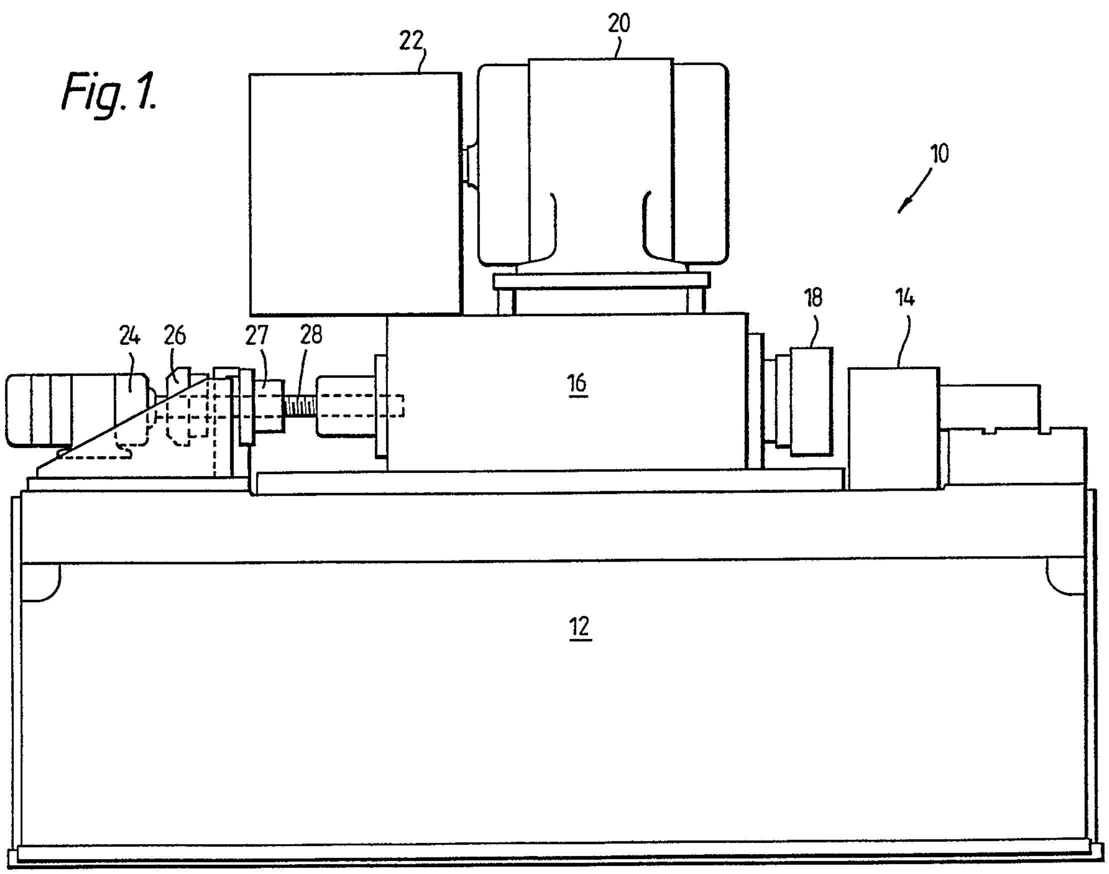
(54) Apparatus for and method of friction welding

(57) A friction welding machine includes a servo motor 24 driven ball screw 28 for the achievement of movement of workpieces towards each other. By this means, precise magnitude of movement and consequent repeatability of finished length of the resulting integral workpiece is achieved, as is relative angular attitudes of features on each workpiece.

Fig. 1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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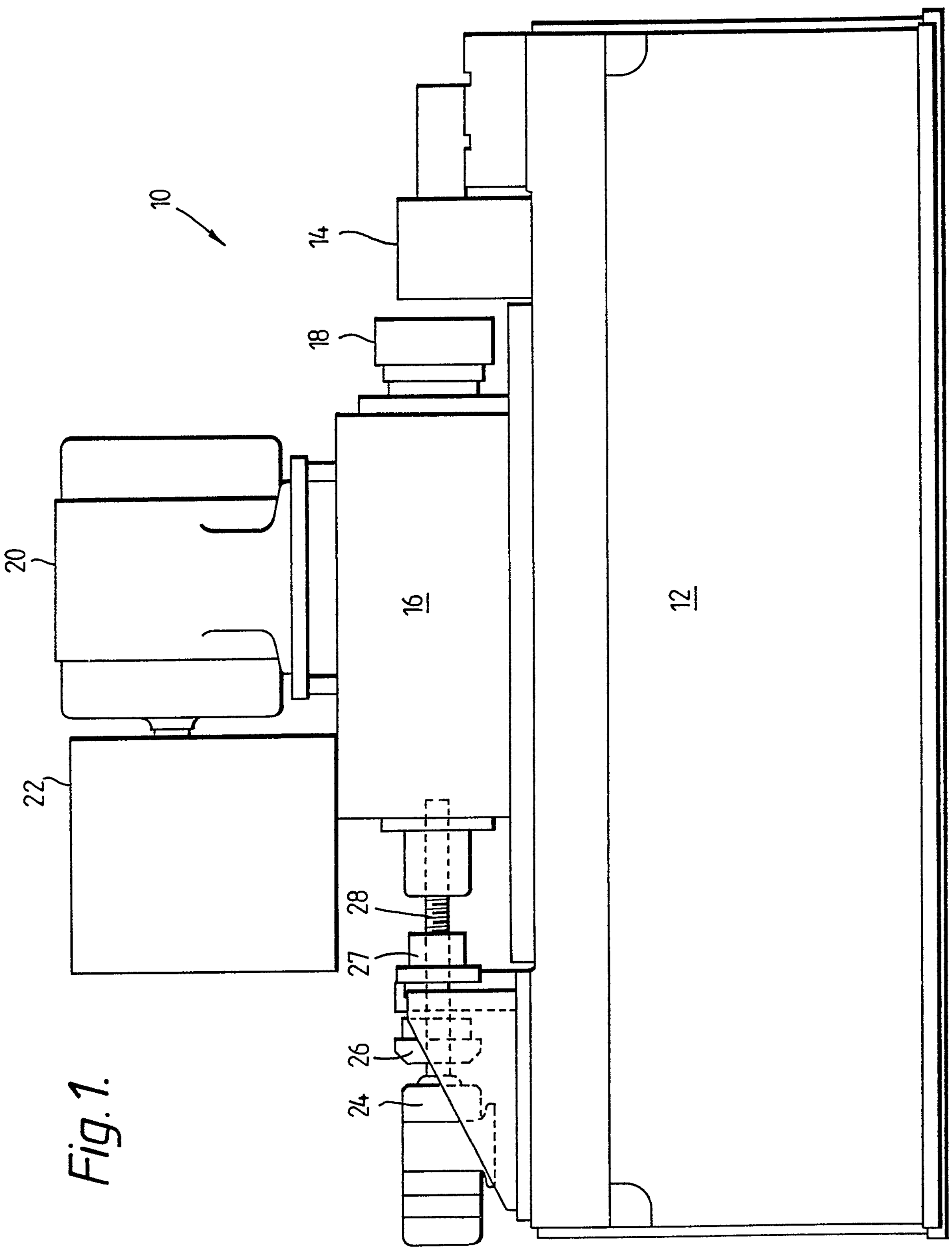

Fig. 1.

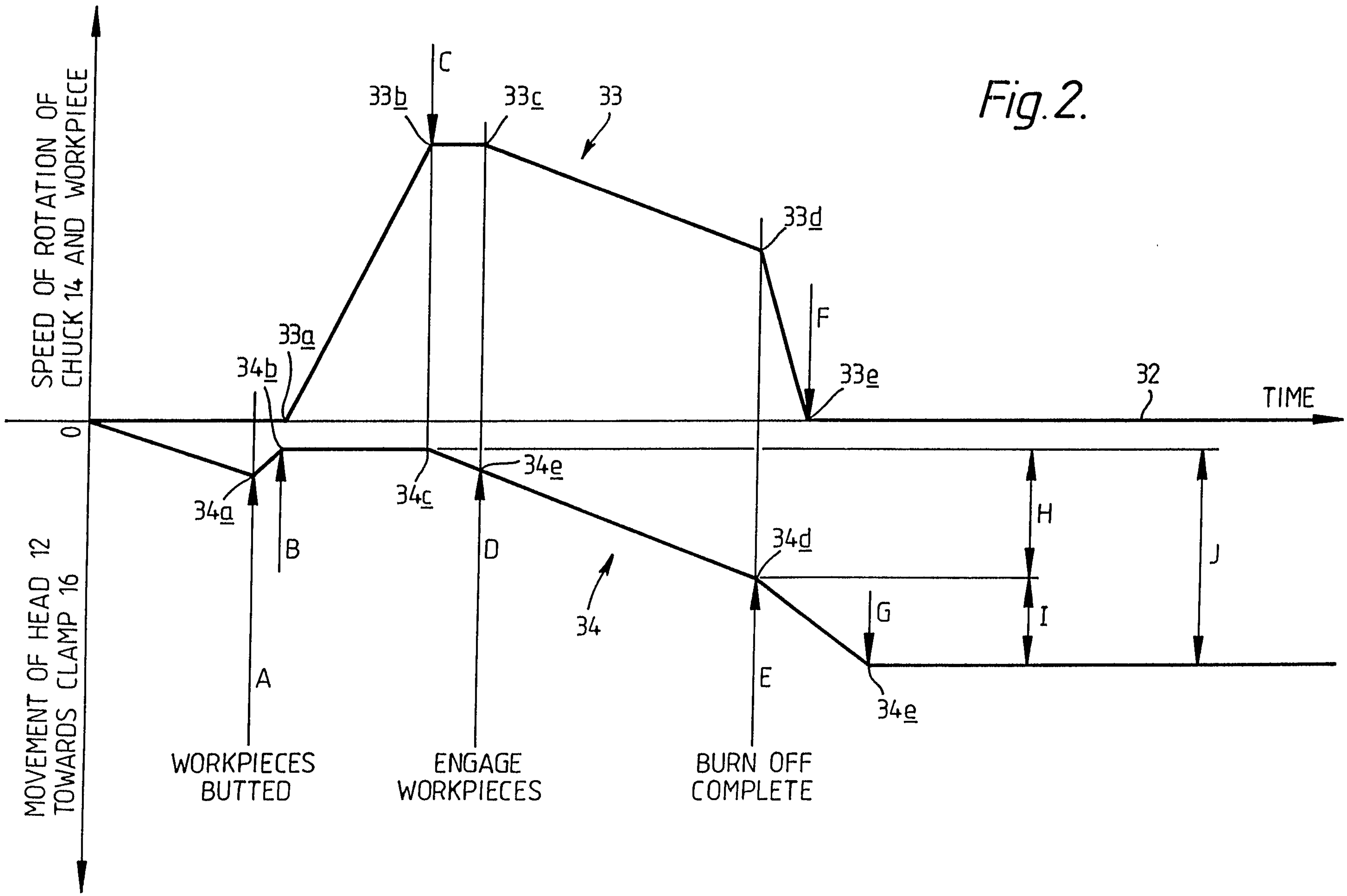
SPEED OF ROTATION OF CHUCK 14 AND WORKPIECE
MOVEMENT OF HEAD 12 TOWARDS CLAMP 16
0
TIME
32
33
33a
33b
33c
33d
33e
34
34a
34b
34c
34d
34e
34e
A
B
C
D
E
F
G
H
I
J
WORKPIECES BUTTED
ENGAGE WORKPIECES
BURN OFF COMPLETE

Fig. 2.

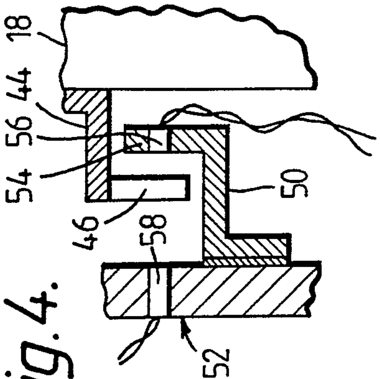
18
44
56
54
46
58
50
52

Fig.4.

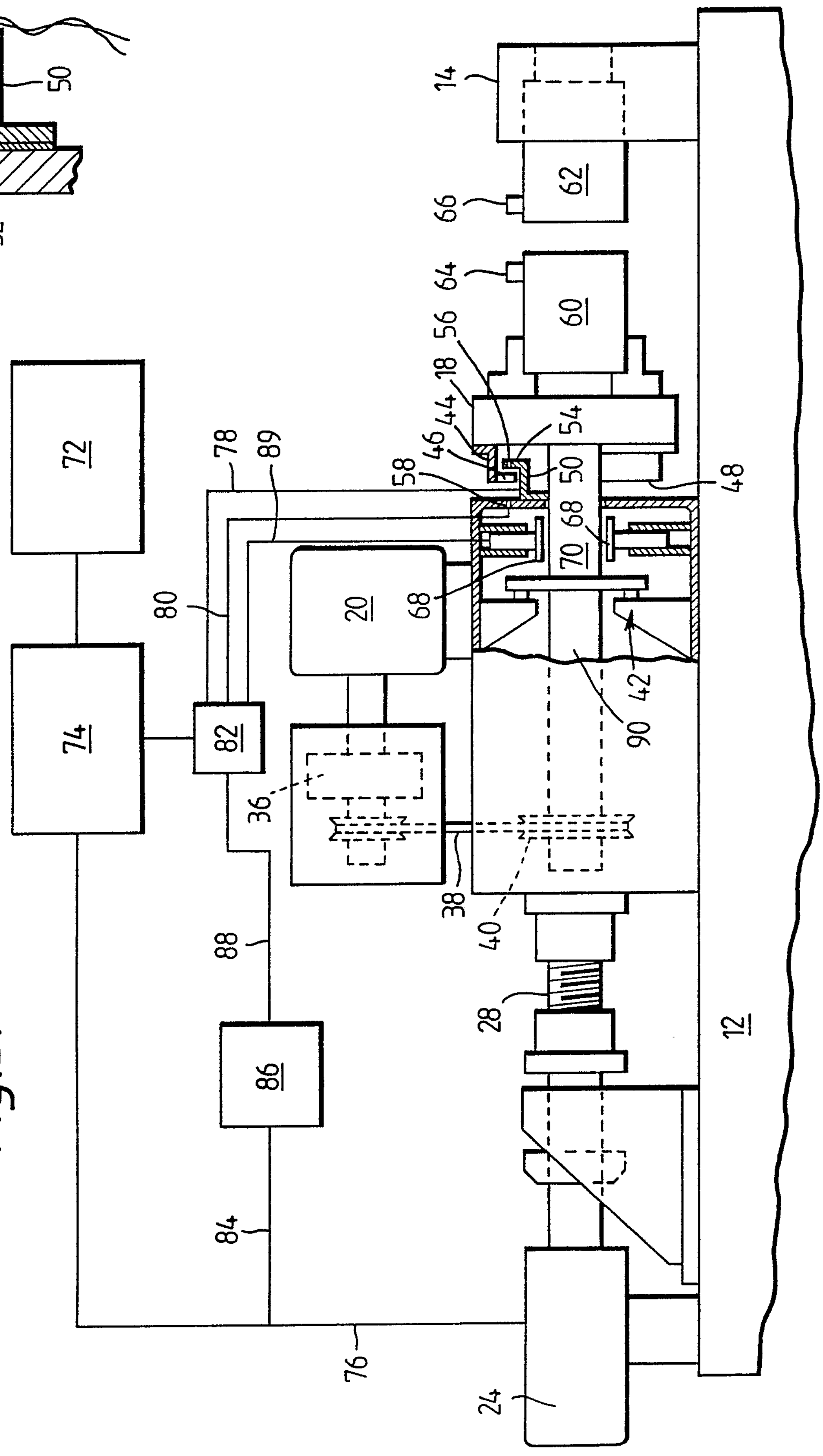
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Fig.3.

Fig. 5.

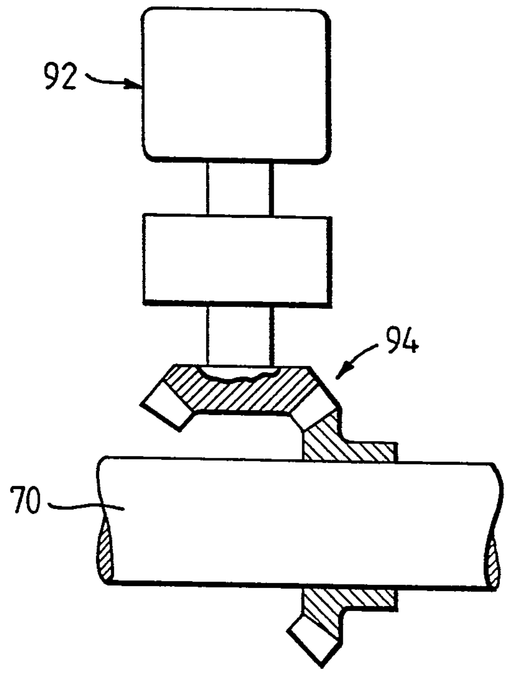
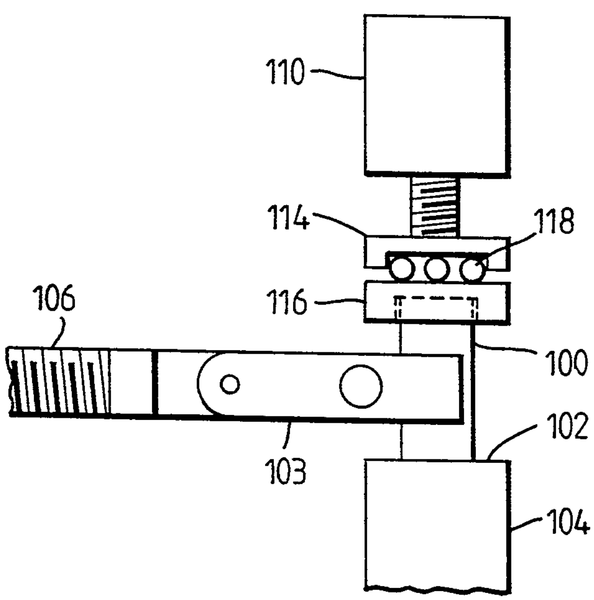


Fig. 6.



APPARATUS FOR AND METHOD OF FRICTION WELDING

The present invention relates to a friction welding apparatus and a method of operation thereof so as to achieve the friction welding together of two or more objects to make an integral structure.

Friction welding is a well known way of joining by effecting abutting engagement, and relative movement between rods, spindles and other members.

Elongate members can also be joined to flat members by the same technique. In all cases one of the members is fixed against any kind of movement, whilst one or two other members is or are reciprocated or rotated at high speed and during the reciprocation or rotation, forced against the stationary member.

The first patent for the method of joining by friction welding was derived in 1891. An ordinary lathe of that period was adapted so that the tailstack could hold a member against rotation, but could still be moved forwards, towards the lathe chuck which held a member to be rotated therewith.

The tailstock screw was rotated manually, to force the member held by the tailstock, into engagement with the rotating member. The resulting friction generated sufficient heat to effect welding. Since the operation included manual manipulation, no parameters could be achieved which would ensure consistent results.

The relative axial movement of the members towards each other by manually operated screw action, was abandoned in favour of pneumatic and, later, hydraulic power, which was delivered by piston and cylinder arrangements, and such arrangements represent the present stage of the art.

It was discovered that a good quality weld is obtained over a wide range of movements of the members once they had made contact. At first, and for a long time, weld quality was the only important criteria, the result being that when a production run of structure were made from friction welded members, there was great variance in the overall length of the structures relative to each other. This resulted in the need for a great deal of variable machining requirements after welding, to achieve common dimensions.

The problem of differing lengths of structures was solved as described and claimed in British patent no. 2,137,774. The problem was solved however, in respect of apparatus which utilises hydraulic or pneumatic power to achieve relative movement of members towards each other. It thus necessitates the fine control of fluid flow into and out of ram cylinders.

The present invention seeks to provide an improved apparatus and further, to provide a method of operating said apparatus.

According to one aspect of the present invention, a friction welding apparatus comprising means for holding at least two workpieces such that relative movement therebetween is enabled, which movement is in two direction which are normal to each other, said means including a servo motor driven ball screw arranged so as to effect relative movement of the at least two workpieces in a first direction which results in them being forced together and further means for effecting relative movement between the at least two workpieces in a direction which is normal to said first direction.

The invention will now be described, by way of example and with reference to the accompanying drawings in which:

Figure 1 is a schematic view of a friction welding machine tool in accordance with one aspect of the present invention.

Figure 2 is a graph exhibiting the relative times of movement, distances moved and speeds of rotation of respective parts of the machine of Figure 1.

Figure 3 depicts an alternative embodiment of the present invention.

Figure 4 is an enlarged part view of Figure 3.

Figures 5 and 6 are further embodiments of the present invention.

Referring to Figure 1. A friction welding machine tool 10 has a bed 12 on which a clamp 14 is fixedly mounted at one end. the clamp 14 is used to clamp a workpiece (not shown) against movement in any direction.

A head 16 which is made up of generally rectangular walls is mounted on the bed for movement relative thereto in directions left and right as viewed in Figure 1.

The head 16 supports a chuck 18 for rotation relative to the clamp 14. The chuck 18, in operation and in known manner, carries a further workpiece (not shown) in alignment with the first mentioned workpiece (not shown).

A motor 20 is mounted on the top of the head 16 and is connected to rotate a flywheel (not shown) and a belt drive pully (not shown) both of which are contained in a protective cover 22.

A drive belt (not shown) connects the pulley (not shown) to the chuck 18 so as to enable the chuck to be rotated, firstly by the motor 20, and subsequently by the flywheel (not shown) in known manner,.

That end of the bed 16 remote from the clamp 14 carries a servo motor 24, which is connected via a torque clutch 26, a load cell 27 and a ball screw 28, to a ball screw nut 30 on the adjacent end of the head 16.

The servo motor 24 is fixed and when operated, causes the ball screw 28 to rotate at a fixed station and relative to the ball screw nut 30. The ball screw 28 consequently applies a load via the nut 30, to the head 16 and moves it along the bed 12. the chuck and its associated workpiece (not shown) are thus moved towards or away from the fixed workpiece (not shown).

Referring now to Figure 2. A composite graph 31 depicts above the horizontal line 32, the profile 33 of the varying speeds of rotation of the workpiece (not shown) which in operation is held by the chuck 18, during a friction welding operation. The profile 34 shown below the horizontal line represents the magnitude and direction of movement of the same workpiece relative to the fixed workpiece (not shown) and further, the relationship between those movements and the speeds of rotation, with respect to time. Thus, the horizontal line 32 represents units of time.

A preferred manner of controlling the operation of the machine 10, is to devise a computer programme which, on initiation of the process, causes the servo motor to rotate sufficiently to move the head 16 to achieve butting of the rotatable workpiece (not shown) against the fixed workpiece (not shown). The butting contact would indicate a datum point from which to retract the head 16 a given number of rotations of the servo motor. The butting position and the position to which the head is retracted are indicated at 34a and 34b respectively.

On completion of retraction of the head 16 and the associated chuck 18 to point 34b, the motor 20 will start to spin the flywheel not shown and therefore, the chuck 18 from zero at point 32a, up to a desired maximum speed of revolutions 32b. That speed being reached, the computer (not shown) instructs the motor 20 to maintain it for a time period up to point 32c, and, at the same time instructs actuation of the servo motor 24 to move the head 16 towards the fixed workpiece (not shown). There results a second abutting of the rotating workpiece (not shown) at point 34c.

The second abutting coincides with an instruction from the computer (not shown) for the disconnection of the drive of the motor 20 from the flywheel (not shown), so that thereafter, the flywheel freewheels for a time period defined by points 32c and 32d. During that period, the servo motor 24 continues to drive the head 16 towards the fixed workpiece (not shown) and thus causes friction between the relatively rotating workpieces (not shown). The friction is such as to generate heat and displace metal.

It is important to force the workpieces (not shown) together, by application of a preselected load. This is achieved in the present invention by the load cell 27 being reacted upon by the ball screw 28 and sending signals to the computer (not shown), which are representative of the forces which it is experiencing and which correspond to the forces being applied to the workpieces (not shown). The computer (not shown) then adjusts the speed of rotation of the servo motor 24 as appropriate, to substantially maintain the desired force on the workpieces (not shown).

In friction welding, there is a first stage wherein metal is softened and displaced. It is known as "burn off". When burn off is complete, movement of the workpieces together is continued and forging occurs, which is the actual joining process.

In the present example, burn off is complete at point 34d on the servo motor profile 34. By that time, the flywheel (not shown) has slowed to a speed indicated at joint 33d on its profile 33. The speed of rotation of the servo motor is now increased and thus the load exerted thereby on the workpieces (not shown(, whereupon the flywheel (not shown) further reduces speed, but at a much more rapid rate, to zero i.e. point 33e. The servo motor 24 however, continues to force the workpieces together as far as point 34e. The process is then stopped and the now integral workpiece removed from its clamp 14 and chuck 18.

In each operation during a production rung, the computer ensures that, although the speed of rotation of the servo motor 20 may be varied in order to control the load applied, the number of rotations over the whole operation is constant. It therefore follows, that the rotating workpiece (not shown) always moves the same distance. Consequently, the overall lengths of the finished products should be the same. If they are not, the differences are likely to be caused by wear in the machine tool.

It will be appreciated from the foregoing description, that the workpiece (not shown) is brought to rest by action of the load applied and the changing viscosity of the material of the workpieces. It is not in any way related to the number of rotations performed by the servo motor 24 and therefor, is not closely related to the distance moved by the rotating workpiece (not shown) relative to the bed 12.

Thus as described so far, the invention cannot achieve a specific final angular position of the rotatable workpiece with respect to the fixed workpiece.

Such control can be achieved however, as described hereinafter, with reference to Figure 3.

The machine depicted in Figure 3 is essentially the same as the machine depicted in Figure 1. Extra detail consisting of a flywheel 36, drive belts 38, the driven pulleys 40 and a thrust bearing 42 are shown, and should be taken as representing those features as described with respect to Figure 1.

The machine of Figure 3 however, includes further apparatus as follows:

The chuck 18 has an annular cowl 44 fastened to its back face. The cowl has a slot 46 in its flange portion 48.

The head 16 has a bracket 50 fastened to its end wall 52. The bracket 50 has an upwardly turned portion 54 which carries a light source 56, which may be any suitable known type.

The upwardly turned portion 54 of the bracket 50 resides within the annular cowl 44. Consequently, the light from the light source 56 can only be observed when, during rotation of the chuck 18, the slot 46 momentarily becomes aligned therewith.

A light receiving and signal generating device 58 is fixed in the end wall 52 of the head 16, in a position opposite the upturned portion 54 of the bracket 50, so that when the slot 46 in the cowl 44 passes the light source 56, the device 58 receives the light and generates a signal, in the form of an electrical pulse. The arrangement is more clearly seen in Figure 4.

A rotating workpiece 60 and a fixed workpiece 62 oppose each other as described hereinbefore. Each workpiece has a projection, numbered 64 and 66 respectively, which need to be in axial alignment when the two workpieces 60 and 62 have been joined by friction welding. In order to achieve this, the two workpieces 60,62 must be positioned so that the projections 64 and 66, have specific positional relationships with each other and with the light source 56 i.e. the chuck 18 and the clamp 14 must be in the form of appropriately designed jigs, which enable the positioning to be repeatedly attained.

Assuming that the desired positioning is such that the light source 56, and the projections 64 and 66 are all axially aligned, then on each rotation of the chuck 18, the projections 64,66 will be aligned again and the device 58 will generate a signal, which effectively will be saying that this is so. Thus, if the chuck can be caused to stop rotating, by utilising the signal to that effect, the projections 64,66 will be in alignment. To this end, a set of brake shoes 68 are arranged around the shaft 70 and are connected as follows for operation as a result of the generation of the signal.

In operation, a computer 72 will instruct a controller 74 to issue a number of actuating pulses via line 76 to the servo motor 24 as will cause rotation of the ball screw 28 to push the rotating workpiece 60 towards the workpiece 62, and into the zone of the graph in Figure 2 and which is defined between aligned points 33d and 34d, and point 33e. The number of pulses which are required to achieve this will have been decided beforehand, by experiment, along with all of the other necessary parameters.

At the same time, the light source 56 will be continuously activated via line 78 and so the device 58 will emit all pulse on completion of each rotation of the chuck 18. Those pulses pass via line 80 to a gate circuit 82.

The pulses which are sent to the servo motor 24, also go via line 84, to a counter 86, and when the counter 86 has counted the preselected number of pulses which causes traversing of the workpiece 60 to the aforementioned zone, it emits a signal which goes via line 88, to the gate 82, which enables the passing of the next pulse to be received from the device 58, via line 89, to a brake applying mechanism (not shown) which results in the brake array 68 being applied to the shaft 70 to which the chuck 18 is fastened. Rotation of the chuck 18 and therefor the workpiece 60 is stopped, with the projections 64 and 66 in alignment with each other, or at least, in relative positions so close to alignment as to require the minimum of machining in order to achieve perfect alignment.

Having read this specification, the man skilled in the art will realise, that the relative orientation of features on opposing workpieces can be arranged in any desired angular relationship.

If the braking action lags behind the signals, experiment will show the magnitude of offset which will have to be effected between the light source and the features on the workpieces when setting up the machine for a production run.

The brake operating mechanism (not shown) may be electrical e.g. a solenoid device. Alternatively, the mechanism could be pneumatic or hydraulic, in which case the actuating pulse when delivered from the gate 82, will be caused to manipulate fluid valves, to allow pressurised fluid to move the brakes 68.

Referring now to Figure 5. a servo motor 92 and a gear connection 94 may be substituted for the motor 20 and belt drive 38. Thus the shaft 70 is directly driven.

If the gear ratio is 1:1, then each rotation of the servo motor 92 results in a complete rotation of the shaft 70 and its associated chuck 18 (Figure 3).

Such an arrangement will obviate the need for the light source method of observing the relative angular positions of the workpieces 60,62 (Figure 3) as pulse devices of other known kinds can be utilised for the purpose of counting the rotations which are being effected.

Figure 6 depicts apparatus for friction welding an elongate workpiece 100 via one end, to a surface 102 of another workpiece 104.

The workpiece 100 by way of example, is an aerofoil blade of the kind used in a gas turbine engine (not shown) and the workpiece 104 a disc. The blade 100 is thus being friction welded to the rim of the disc 104.

Friction welding is achieved via the ball screw 106 being rotated and moved axially of itself by a servo motor (not shown in Figure 6) of the kind described hereinbefore. In this case however, the servo motor is intermittently reversed, so as to cause the ball screw 106 to move in a short reciprocatory path, and at a very rapid rate.

The ball screw 106 is clamped to the workpiece 100 by a pinch clamp 108.

A further servo motor 110 drives a further ball screw 112, such that a thrust plate 114 acts to force the workpiece 100 against the workpiece surface 102. This is achieved via a cap 116 which fits over the free end of the workpiece 100 and sandwiches a number of roller bearings 118 between itself and the thrust plate 114. Thus friction between the workpiece 100 and the thrust plate 114 is substantially obviated when the ball screw 106 reciprocates the workpiece 100 horizontally as viewed in Figure 6.

The servo motor (not shown) which drives the ball screw 106, the servo motor 110 and the lower workpiece 104 are suitably fixed in relation to each other.

Use of the servo motor (not shown) and its associated ball screw 106, and the associated servo motor and ball screw 112 enable accuracy of movement and final positioning of the workpiece 100 on the workpiece 104, in the same way as described hereinbefore, with respect to Figures 1 to 4.

The servo motor (not shown) which drives ball screw

106, and the servo motor 110 are connected to control by a computer, not shown in Figure 6, but which will be programmed generally similarly to the computer described in connection with Figures 1 to 5, but adapted as appropriate for the different kinds of relative movements which occur between the workpieces 100 and 104.

Claims:-

1. Friction welding apparatus comprising means for holding at least two workpieces such that relative movement therebetween is enabled, which movement is in two direction which are normal to each other, said means including a servo motor driven ballscrew arranged so as to effect relative movement of the at least two workpieces in a first direction which results in them being forced together and further means for effecting relative movement between the at least two workpieces in a direction which is normal to said first direction.

2. Friction welding apparatus as claimed in claim 1 wherein the further means comprises a servo motor driven ballscrew arranged so as to effect relative reciprocatory movement between the at least two workpieces the directions of which are in shear planes in their area of joining.

3. Friction welding apparatus as claimed in claim 1 wherein the further means comprises a servo motor arranged so as to effect relative rotary movement between the workpieces in a direction normal to their direction of movement towards each other.

4. Friction welding apparatus as claimed in claim 3 wherein the arrangement comprises making a part of the workpiece holding means rotatable so as to enable rotating of at least one workpiece and connecting said one part of the means for holding at least two workpieces and the servo motor by a belt drive transmission.

5. Friction welding apparatus as claimed in claim 3 wherein the arrangement comprises connecting the means for holding at least two workpieces and the servo motor by a toothed gear transmission.

6. Friction welding apparatus as claimed in claim 5 wherein the gear ratio is 1:1.

7. Friction welding apparatus as claimed in claim 4 comprising a bed, a first clamp mounted thereon for fixedly retaining a first workpiece against movement in any direction, a head structure slidably mounted on the bed, a second clamp rotatably mounted in the head structure, and

for clamping a further workpiece therein in a desired alignment with the first workpiece, said means for rotating the second clamp, a ball screw thread at that end of the head structure remote from the second clamp, a servo motor fixed to the bed adjacent that end of the head structure which includes the ball screw thread, a ball screw connected to the servo motor for rotation thereby at a fixed station, and in screw engagement with the ball screw thread, so that on rotation of the ball screw by the servo motor, the head structure and its associated second clamp is driven by the ball screw thread towards or away from the first clamp, and means for actuating the servo motor such that in operation it rotates the ball screw through a pre-selected number of revolutions which in turn causes movement of the head structure, the second clamp and a workpiece clamped therein, along the bed for a pre-selected distance.

8. Friction welding apparatus as claimed in any previous claim wherein the or each servo motor is computer controlled.

9. Friction welding apparatus substantially as described in this specification and with reference to Figure 1 of the drawings.

10. Friction welding apparatus substantially as described in this specification and with reference to Figures 3 and 4 of the drawings.

11. Friction welding apparatus substantially as described in this specification and with reference to Figure 5 of the drawings.

12. Friction welding apparatus substantially as described in this specification and with reference to Figure 6 of the drawings.

13. A method of controlling a friction welding apparatus substantially as described in this specification with reference to Figures 1,3,4 and 5 of the drawings, so as to achieve the ratios of speed of rotation of the rotatable workpiece and movement thereof towards the fixed workpiece as depicted in Figure 2 of the drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number 9016628.1

Relevant Technical fields

(i) UK Cl (Edition K) B3R

(ii) Int Cl (Edition 5) B23K

Search Examiner: D Butters

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search: 18 September 1990

Documents considered relevant following a search in respect of claims all

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

SF2(p)

S5JAAJ

Category	Identity of document and relevant passages	Relevant to claim(s)

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