

SPECIFICATION

Electroerosion machining

The present invention relates to electroerosion and, more particularly, to a wire-cut electroerosion machine and a method of operating the same for machining a workpiece by advancing a continuous wire electrode in juxtaposition therewith to form a machining gap therebetween, across which an electrical machining energy is applied in the presence of a machining fluid to remove material from the workpiece, there being a relative displacement between the workpiece and the traveling wire electrode as material removal proceeds.

In an electroerosion machine of this type, the continuous wire electrode unrolled from a supply reel is advanced through a machining region in which the workpiece is positioned between a pair of guide members which serve to position the wire precisely in a predetermined machining relationship with the workpiece and to stretch under tension the traveling wire across the machining region, the wire then being continuously wound on a take-up reel. The continuous advancement or travel of the wire is effected typically by traction drive roller means disposed between the guide member on the downstream side and the take-up reel. A desired tautness and consequently a desired tension and tension stress may be established in the traveling wire by providing brake drive roller means at a location between the guide member on the upstream side and the supply reel.

A change in the tautness and hence in the tension stress and the tension strain, in the traveling wire spanned between the guide members is undesirable, as the resulting deflection and oscillation of the wire in the form of a drum across the machining zone hampers the achievement of a stable electroerosion cutting action and yields inaccurate machining results; and moreover may also cause the wire to break upon contacting and hence short-circuiting against the workpiece. The wire electrode when elongated and bowed (i.e. bent out of the desired straight path) causes the cutting width to become excessively large, the workpiece edge portions to be undesirably rounded, and the machined shape to deviate from a required shape or size.

It has now been observed that constancy of the tautness and hence of the tension stress and strain in the traveling wire cannot be attained simply by applying constant drive and brake forces to the wire with a known arrangement. Thus, while a wire produced and rolled on the supply reel with a due precision for electroerosion purposes is commonly employed, it still unavoidably suffers from unevenness in diameter and composition over its entire useful length, and also may be bent or distorted when wound on to the supply reel. Additionally, in a machining operation the wire passing adjacent and opposed to the workpiece may undergo electrical discharge

wear to variable extents, and the guide members supporting the wire may also frictionally wear variably or with change in effective tension induced in the wire. Change in the tautness, and hence in the tension stress and tension strain, caused by these and other operational factors (such as electrical discharge pressure) causes varying elongation over the wire lengths, and may cause unfavorable bending, distortion, twisting or oscillation of the wire which leads to wire breakage, unstable machining and machine inaccuracy.

The present invention therefore seeks to provide an improved wire-cut electroerosion machine and a method of operating same, whereby the aforementioned difficulties encountered in conventional electroerosion machines may, at least in part, be overcome.

Thus, in accordance with the present invention, there is provided a wire-cut electroerosion machine for machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, which machine comprises: wire supply means; wire take-up means; a pair of guide members for guiding the wire across a machining zone in which a machinable portion of the workpiece is located in the presence of a machining fluid; rotary traction means having a first rotary shaft for advancing the wire through the machining zone from the supply means and permitting it to be collected onto the take-up means; rotary brake means having a second rotary shaft for applying a braking to the wire to cause it under strain to be stretched tautly between the guide members while permitting it to continuously travel through the machining zone; first sensing means arranged to sense rotation of the first rotary shaft and to provide a first sensing signal representing the rate of rotation thereof; second sensing means arranged to sense rotation of the second rotary shaft and to provide a second sensing signal representing the rate of rotation thereof; and circuit means responsive to said first and second sensing signals for deriving therefrom an output signal representing a deviation of the tension stress or the tension strain of the wire traveling between the rotary brake and traction means from a predetermined value.

The invention also provides a method of operating a wire-cut electroerosion machine having wire supply means, wire take-up means, a pair of guide members for guiding the wire across a machining zone in which a machinable portion of the workpiece is located in the presence of a machining fluid, rotary traction means having a first rotary shaft for advancing the wire through the machining zone from the supply means and permitting it to be collected onto the take-up means, and rotary brake means having a second rotary shaft for applying a braking force to the wire to cause it under strain to be stretched tautly between the guide members while permitting it to continuously travel through the machining zone, which method comprises the steps of sensing rotation of the first rotary shaft and producing a

first sensing signal representing the rate of rotation thereof; sensing rotation of the second rotary shaft and producing a second sensing signal representing the rate of rotation thereof; and
 5 deriving from said first and second sensing signals an output signal representing a deviation of the tension stress or the tension strain of the wire traveling between the brake and traction rotary means from a predetermined value.

10 The invention also contemplates a method of electroerosion-machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, in which method the continuous wire is advanced by traction drive
 15 means from wire supply means to wire take-up means through a machining or cutting zone defined between a pair of guide members, and brake means is also provided which, in cooperation with the traction drive means, stretches the wire tautly
 20 between the guide means while permitting it to continuously travel through the machining zone, and which method further comprises the steps of applying a mechanical vibration to the wire traveling between the guide means and
 25 monitoring a vibrational response of the wire to ascertain a change, when it occurs, in the tension stress or the tension strain caused in the traveling wire. An apparatus for carrying out the method according to this aspect of the invention may
 30 include an electromechanical oscillator energizable by a high-frequency alternating-current source to impart a mechanical vibration to the traveling wire, and sensing means coupled with the electrochemical oscillator to thereby
 35 ascertain a change in the tension stress or the tension strain caused in the wire.

These and other features and advantages of the present invention will become more readily apparent from the following description of certain embodiments thereof taken with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic elevational view illustrating a wire-cut electroerosion machine showing the basic components thereof and
 45 adapted to embody the principles of the invention;

FIG. 2 is a block diagram of a circuit element in the system of FIG. 1;

FIG. 3 is a diagrammatic elevational view of a second electroerosion machine with a traveling wire electrode and embodying the present
 50 invention; and

FIGS. 4 and 5 are side and front elevational views respectively of a portion of FIG. 3.

Referring now to FIG. 1, a continuous wire 1 which may be copper, brass or the like metal or alloy and have a diameter of 0.05 to 0.5 mm, constitutes an electroerosion electrode, and is shown being unwound from a supply reel 2 and wound on to a take-up reel 3 while being
 55 transported through a machining or cutting zone defined between a pair of wire guides 4a and 4b. The guide members 4a and 4b serve to provide a stretch of the wire 1 traveling therebetween accurately positioned in a predetermined
 60 machining relationship with a workpiece 5

disposed in the machining zone and supplied with a machining fluid, i.e. a liquid dielectric or electrolyte. A power supply 6 is provided with output terminals electrically connected to the wire 1 and the workpiece 5 so as to apply across the machining gap between them an electric machining energy, which is usually in the form of pulses, to electroerosively remove material from the workpiece 5.

70 As material removal proceeds, a table 7 on which the workpiece 5 is fixedly mounted is displaced by a pair of motors 8 and 9, e.g., stepping motors, to move the workpiece along X and Y axes in accordance with a numerical control
 80 program or copying pattern, so that electroerosion with the wire electrode 1 may continue in the workpiece 5 along a prescribed cutting path.

Means for transporting, i.e. axially advancing, the wire 1 includes a traction drive roller 10 downstream of the guide member 4b and having a rubber or the like formed or surfaced frictional rotatable pinch roller 11 in engagement therewith to urge the wire 1 introduced between them against the supporting drive roller 10. The drive roller 10 has a rotary shaft 12 driven by a motor 13. The rollers 10 and 11 position the wire 1 introduced therebetween and apply a traction force to the wire 1 to cause it to be continuously unrolled from the supply reel 2 and to travel
 90 continuously through the machining zone between the guide members 4a and 4b. The drive shaft 12 is provided with an encoder 14 responsive to rotation of that shaft and arranged to provide a signal representing the rate of rotation of that drive shaft. Upstream of the guide members 4a and 4b there is provided a braking roller 15 having a rubber or the like formed or surfaced frictional rotatable pinch roller 16 in engagement therewith to urge the wire 1 introduced between them against the supporting roller 15. The braking roller 15 has a rotary shaft 17 driven by a torque motor 18 to apply a brake force to the wire 1 being continuously unwound from the supply reel 2, passing over and between the guide members 4a and 4b, being driven between and by the rollers 10 and 11, and being wound on the take-up reel 3. The braking shaft 17 is provided with an encoder 19 responsive to rotation of that shaft and arranged to provide a signal representing the
 100 rate of the rotation of that rotary shaft.

The outputs of encoders 14 and 19 are fed via amplifiers 21 and 22, respectively, to a logic circuit 20 where they are compared to provide a logic output which is applied on one hand to a control circuit 23 and on the other to an indicator device 27. The logic circuit 20 provides a logic output which represents in different ways the tension stress, the tension strain, and the bowing or bending of the wire 1, and which output is
 110 ascertained from the two amplified signals received from the encoders 14 and 19. A desired value of wire tension stress, the wire tension strain and/or the extent of wire bowing may be keyed in the control circuit 23 at terminals 24 for
 120 comparison with the corresponding input signal

from the logic circuit 20 whereby to provide at the output circuits of the control circuit 23 a control signal which acts on one or both of drive control circuits 25 and 26 for controlling the wire traction and braking motors 13 and 18, respectively. The indicator device 27 may provide conveniently a visible indication of the tension stress, the tension strain and/or the extent of bowing of the wire 1 as determined by the logic circuit 20.

10 In operation, the drive assembly 10, 11, 12 and 13 causes the wire 1 to be unrolled from the supply reel 2 and to be rolled on to the take-up reel 3, thereby to cause continuous travel of the wire electrode through the machining zone between the guide members 4a and 4b under a tension induced by the brake assembly 15, 16, 17 and 18 in the wire 1, which tension tends to straighten and elongate the wire. It has been found difficult to maintain constant a tension stress or tension strain in the wire by applying constant drive and brake forces to the wire 1 with these assemblies 10 to 13 and 15 to 18 alone. Thus, while a wire produced and rolled on the supply reel with a due precision for electroerosion purposes is commonly employed, it still unavoidably suffers from unevenness in diameter and composition over its entire useful length, and also it may be bent or distorted when wound on to the supply reel. Additionally, in machining operations the wire passing in juxtaposition with the workpiece may undergo electrical discharge wear to a variable extent, and the guide members supporting the wire may also frictionally wear variably or with change in effective tension stress or tension strain caused in the wire. Changes in the tension stress or tension strain caused by variations in the wire size, composition and other operational factors cause varying elongation over its length, and this may cause unfavorable bowing, distortion or twisting of the wire which may lead to wire breakage, unstable machining and machining inaccuracy.

In accordance with the invention, the encoder 14 is provided to detect or sense rotation of the wire traction drive shaft 12 and provide a corresponding signal, which after amplification by the amplifier 21 is fed to the logic circuit 20. Simultaneously, the encoder 19 detects or senses rotation of the wire braking shaft 17 to provide a corresponding signal, which after amplification by the amplifier 22 is fed to the logic circuit 20. The logic circuit 20 functions to provide a difference between the two signals received and thereby to determine changes in the tension stress, the tension strain and the bowing caused in the wire 1. One output from the logic circuit 20 is used to operate the display network 27 so as to cause it to display the tension stress, the tension strain or the wire bowing actually monitored, in numerical or other form. The second output of the circuit 20, applied to the control circuit 23, is logically compared with the preset signal keyed in at the terminals 24 and representing a desired value of the tension stress, the tension strain or the wire bowing to provide the said control signal. Here,

the logical output of the circuit 20 may provide an output representing the tension stress, the tension strain, or the extent of wire bowing, or some combination of them, which is output is applied to the control circuit 23. The latter may be designed to include a control arrangement appropriate to any one of those tension-related variables, or to provide an output corresponding to a logical sum or logical product of such variables. The said control signal may make use of a deviation of an input signal from a preset value, or may discriminate the incoming signal with reference to the preset value. The control is effective to regulate one or both of the drive circuits 25 and 26 for the traction and braking motors 13 and 18 respectively, by controlling the electrical drive energy for such motors or, where a pulsed drive is employed, the duration or frequency of drive pulses for such motors.

85 In FIG. 2 there are illustrated three exemplary arrangements (a), (b) and (c) for the logic circuit 20. In the system (a), pulse signals from the encoders 14 and 19 are applied to counters 28 and 29, respectively, which are combined at a comparator 30 which provides a difference in count which is discriminated by a discriminator or threshold circuit 31. In the system (b), the two rotation-dependent signals are applied to an up/down or reversible counter 32 at its count-up and count-down inputs, respectively, to provide a differential count level which is discriminated by a discriminator or threshold circuit 33. In the system (c), the said two signals are initially applied to a comparator 34 which provide a difference in magnitude in the form of pulses which are accumulated in a counter 35 whose output is applied to and discriminated in a discriminator or threshold circuit 36. In any of the arrangements (a), (b) and (c), the difference between the sensed rates of rotation of the traction drive shaft 12 and the braking shaft 17 provides a measurement of the tension strain, from which values of the tension stress and wire bowing are also ascertainable. The drive circuit 25, 26 for one or both of the motors 13 and 18 may be controlled manually, or alternatively automatically with the output signal of the logic circuit 20, thus causing the tension strain, the tension stress, or the bowing in the wire 1 to be varied automatically so as to approach a desired or preset value, so that electroerosion may continue with the continuous wire electrode maintained substantially straight between the guide members under a given tension and with a predetermined tension stress, tension strain, or elongation. Operational instability tending to cause wire breakage and undesirable oscillation can thereby be largely eliminated, thus allowing high precision and high efficiency wire-cut electroerosion to be effected.

125 The drive motors 13 and 18 may be constituted either by a DC motor or a stepping motor. In the case of the latter, the direct-current control signal is converted into pulses by a voltage-frequency converter. A pulsed control signal may also be used with the DC motor, in which case the DC

drive signal is obtained by D—A conversion.

FIG. 3 shows another form of a wire tension detector system embodying the present invention. In this system, a continuous wire 40 constituting a

5 tool electrode in electroerosion machining is shown guided through a pair of coolant conduits 41 and 42 between which a workpiece 43 is mounted in machining relationship with the wire 40. The wire 40 is unwound from a supply reel 10 and wound on to a take-up reel, both of which, as well as the traction and brake rollers, are omitted in this FIGURE and may be the same as those which form the arrangement of FIG. 1. In the path of the wire 40, rollers 44 and 45 serve to change 15 the direction of wire travel into and away from the machining zone, while rollers 41a and 41b and guide 41c in the guide conduit 41 and rollers 42a and 42b and guide 42c in the guide conduit 42 act to place the traveling wire 40 precisely in a 20 machining position relative to the workpiece 43. The conduits 41 and 42 are provided respectively with fluid inlets 41d and 42d through which a machining fluid W1, W2, such as distilled water, is supplied for delivery to the machining zone and 25 also to serve as a coolant for the machining wire electrode 40. An electroerosion power supply 46 is electrically connected on one side to the workpiece 43 and on the other to the wire 40 at rollers 41b and 42b in the conduits 41 and 42, respectively. The rollers 41a and 42a constitute liquid-tight rolls.

In the region of the machining zone between the machining positioning guides 41c and 42c there is provided a mechanical oscillator 47 which 35 is in contact with or close proximity to the wire 40, and which, when energised, applies to the wire an oscillation or vibration, and thus acts as a signal source. Enlarged lateral and frontal views of the oscillator 47 are shown in FIGS. 4 and 5, 40 respectively, with elements associated therewith also seen in the latter. The oscillator 47 has an oscillatile or vibratile surface for imparting a vibration to the wire 40 traveling in contact therewith or proximate thereto. The oscillator 47 45 may be composed of quartz, barium titanate (BaTiO_3), lead zirco-titanate or a solid solution of lead zirconate and lead titanate ($\text{PbZrO}_3 + \text{PbTiO}_3$) or the like electromechanical transducer oscillating material, and is energized through first 50 terminals by a high-frequency alternating current source 48 at a frequency of 1 to 100 KHz or higher to generate mechanical vibrations of the corresponding frequency. The oscillator 47 has second terminals connected to a detector 49 for 55 sensing a vibrational response of the wire 40.

In operation, the oscillator 47 applies to the wire 40 a vibration with an amplitude of 0.1 to 10 μm at a frequency of 1 to 100 KHz. If there is no change in tension caused in the wire 40, there will 60 be no change in the vibrational response detected by the circuit 49. If there is any elastic change such as a change in the tension stress or the tension strain, or an occurrence of bowing of the wire, or if the wire tends to break, there will be a 65 change in the vibrational response frequency (e.g.

in the vibration) of the wire which is sensed by the detector 49. Actually, it has been found that slight changes in the tension caused in the wire 40 can be monitored at a high accuracy when sensed by 70 means of vibration response. The sensed signal can be used to actuate an indicator display and to control the drive circuit for the motor applying a traction force and/or the motor applying a brake force to the wire 40 in the manner as described 75 earlier.

There is thus provided in accordance with the present invention an improved wire-cut electroerosion machine as well as a method of operating the same, which effectively protects the 80 wire electrode from breakage and permits an improved machining performance while assuring an enhanced machining accuracy.

CLAIMS

1. A wire-cut electroerosion machine for 85 machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, comprising:
 - wire supply means;
 - wire take-up means;
 - 90 a pair of guide members for guiding said wire across machining zone in which a machinable portion of said workpiece is positioned;
 - rotary traction means having a first rotary shaft for advancing said wire through said machining 95 zone from said supply means and permitting said wire to be collected onto said take-up means;
 - rotary brake means having a second rotary shaft for applying a braking force to said wire to cause it under tension to be stretched between 100 said guide members while being continuously advanced through said machining zone;
 - first sensing means arranged to sense rotation of said first rotary shaft and to provide a first sensing signal representing the rate of rotation 105 thereof;
 - second sensing means arranged to sense rotation of said second rotary shaft and to provide a second sensing signal representing the rate of rotation thereof; and
 - 110 circuit means responsive to said first and second sensing signals for deriving therefrom an output signal representing a deviation from a predetermined value of the tension strain, or the tension stress, of said wire advancing through said 115 machining zone between said brake and traction means.
2. The machine defined in claim 1, wherein said first sensing means includes first encoder means for producing a series of first pulses in response to 120 angular displacement of said first rotary shaft, and said second sensing means includes second encoder means for producing a series of second pulses in response to angular displacement of said second rotary shaft; the respective series of said 125 first and second pulses constituting said first and second sensing signals.
3. The machine defined in claim 1 or claim 2 wherein said circuit means includes comparator means for comparing said first and second sensing



drive signal is obtained by D—A conversion.

FIG. 3 shows another form of a wire tension detector system embodying the present invention. In this system, a continuous wire 40 constituting a tool electrode in electroerosion machining is shown guided through a pair of coolant conduits 41 and 42 between which a workpiece 43 is mounted in machining relationship with the wire 40. The wire 40 is unwound from a supply reel 10 and wound on to a take-up reel, both of which, as well as the traction and brake rollers, are omitted in this FIGURE and may be the same as those which form the arrangement of FIG. 1. In the path of the wire 40, rollers 44 and 45 serve to change the direction of wire travel into and away from the machining zone, while rollers 41a and 41b and guide 41c in the guide conduit 41 and rollers 42a and 42b and guide 42c in the guide conduit 42 act to place the traveling wire 40 precisely in a machining position relative to the workpiece 43. The conduits 41 and 42 are provided respectively with fluid inlets 41d and 42d through which a machining fluid W1, W2, such as distilled water, is supplied for delivery to the machining zone and also to serve as a coolant for the machining wire electrode 40. An electroerosion power supply 46 is electrically connected on one side to the workpiece 43 and on the other to the wire 40 at rollers 41b and 42b in the conduits 41 and 42, respectively. The rollers 41a and 42a constitute liquid-tight rolls.

In the region of the machining zone between the machining positioning guides 41c and 42c there is provided a mechanical oscillator 47 which is in contact with or close proximity to the wire 40, and which, when energised, applies to the wire an oscillation or vibration, and thus acts as a signal source. Enlarged lateral and frontal views of the oscillator 47 are shown in FIGS. 4 and 5, respectively, with elements associated therewith also seen in the latter. The oscillator 47 has an oscillatile or vibratile surface for imparting a vibration to the wire 40 traveling in contact therewith or proximate thereto. The oscillator 47 may be composed of quartz, barium titanate (BaTiO_3), lead zirco-titanate or a solid solution of lead zirconate and lead titanate ($\text{PbZrO}_3 + \text{PbTiO}_3$) or the like electromechanical transducer oscillating material, and is energized through first terminals by a high-frequency alternating current source 48 at a frequency of 1 to 100 KHz or higher to generate mechanical vibrations of the corresponding frequency. The oscillator 47 has second terminals connected to a detector 49 for sensing a vibrational response of the wire 40.

In operation, the oscillator 47 applies to the wire 40 a vibration with an amplitude of 0.1 to 10 μm at a frequency of 1 to 100 KHz. If there is no change in tension caused in the wire 40, there will be no change in the vibrational response detected by the circuit 49. If there is any elastic change such as a change in the tension stress or the tension strain, or an occurrence of bowing of the wire, or if the wire tends to break, there will be a change in the vibrational response frequency (e.g.

in the vibration) of the wire which is sensed by the detector 49. Actually, it has been found that slight changes in the tension caused in the wire 40 can be monitored at a high accuracy when sensed by means of vibration response. The sensed signal can be used to actuate an indicator display and to control the drive circuit for the motor applying a traction force and/or the motor applying a brake force to the wire 40 in the manner as described earlier.

There is thus provided in accordance with the present invention an improved wire-cut electroerosion machine as well as a method of operating the same, which effectively protects the wire electrode from breakage and permits an improved machining performance while assuring an enhanced machining accuracy.

CLAIMS

1. A wire-cut electroerosion machine for machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, comprising:
 - wire supply means;
 - wire take-up means;
 - a pair of guide members for guiding said wire across machining zone in which a machinable portion of said workpiece is positioned;
 - rotary traction means having a first rotary shaft for advancing said wire through said machining zone from said supply means and permitting said wire to be collected onto said take-up means;
 - rotary brake means having a second rotary shaft for applying a braking force to said wire to cause it under tension to be stretched between said guide members while being continuously advanced through said machining zone;
 - first sensing means arranged to sense rotation of said first rotary shaft and to provide a first sensing signal representing the rate of rotation thereof;
 - second sensing means arranged to sense rotation of said second rotary shaft and to provide a second sensing signal representing the rate of rotation thereof; and
 - circuit means responsive to said first and second sensing signals for deriving therefrom an output signal representing a deviation from a predetermined value of the tension strain, or the tension stress, of said wire advancing through said machining zone between said brake and traction means.

2. The machine defined in claim 1, wherein said first sensing means includes first encoder means for producing a series of first pulses in response to angular displacement of said first rotary shaft, and said second sensing means includes second encoder means for producing a series of second pulses in response to angular displacement of said second rotary shaft, the respective series of said first and second pulses constituting said first and second sensing signals.

3. The machine defined in claim 1 or claim 2 wherein said circuit means includes comparator means for comparing said first and second sensing



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signals to produce a differential signal, and discriminator means for comparing said differential signal with a reference value to produce said output signal.

- 5 4. The machine defined in any one of the preceding claims, further comprising display means for displaying said output signal.
- 10 5. The machine defined in any one of the preceding claims, further comprising control means for controlling at least one of said traction and brake means in response to said output signal so as to maintain said wire tension strain, or stress, substantially constant.
- 15 6. A method of operating a wire-cut electroerosion machine having supply means for providing a continuous wire constituting an electroerosion electrode, take-up means for said wire; a pair of guide members for guiding said wire across a machining zone in which a machinable portion of a workpiece is located, rotary traction means having a first rotary shaft for advancing said wire through said machining zone from said supply means and permitting it to be collected onto said take-up means, and rotary brake means
- 20 having a second rotary shaft for applying a braking force to said wire to cause it to be stretched between said guide members while permitting it to continuously travel through said machining zone therebetween, said method comprising the steps of: sensing rotation of said first rotary shaft to produce a first sensing signal representing the rate of rotation thereof; sensing rotation of said second rotary shaft to produce a second sensing signal representing the rate of rotation thereof;
- 25 and deriving from said first and second sensing signals an output signal representing a deviation from a predetermined value of the tension strain, or the tension stress, of said wire traveling through said machining zone between said rotary brake means and said rotary traction means.
- 30 7. The method defined in claim 6, wherein each of said first and second sensing signals is in the form of a series of pulses.
- 35 8. The method defined in claim 6 or claim 7, wherein said first and second sensing signals are compared to produce a differential signal, said differential signal is compared with a reference value to produce said output signal.
- 40 9. The method defined in any one of claims 6 to 8, further comprising the step of visually displaying said output signal.
- 45 10. The method defined in any one of claims 6 to 9, further comprising the step of controlling at least one of said traction and brake means in response to said output signal so as to maintain said wire tension strain, or tension stress, substantially constant.
- 50 11. A method of electroerosion-machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, wherein the continuous wire is advanced by traction drive means from supply means onto take-up means through a machining zone defined between a pair of guide members, and brake means is provided
- 55 operable in conjunction with said traction drive

means for stretching said wire across said guide members while permitting it to continuously travel through said machining zone, and wherein a mechanical vibration is applied to said wire traveling between said guide members, and a vibrational response of said wire is monitored for ascertaining a change in the tension strain, or tension stress caused in said traveling wire.

- 60 12. The method defined in claim 11, wherein said vibration is of a frequency in the range of 1 to 100 KHz.
- 65 13. The method defined in claim 11 or 12, wherein said vibration is of an amplitude in the range of 0.1 to 10 μ m.
- 70 14. Apparatus for electroerosion-machining a workpiece with a continuous traveling wire constituting an electroerosion electrode, said apparatus comprising wire supply means, wire take-up means, a pair of wire-guide members for defining a machining zone therebetween in which a machinable portion of said workpiece is located, traction drive means for advancing said wire from said supply means onto said take-up means through said machining zone, and brake means
- 75 operable in cooperation with said traction drive means for stretching said wire across said guide members while permitting it to continuously travel through said machining zone, and said apparatus further comprising means disposed in the path of said wire between said guide members for applying a mechanical vibration to said wire advancing between said guide members, and detector means for sensing a vibrational response of said wire whereby to sense a change in the tension strain, or tension stress, in said wire.
- 80 15. The apparatus defined in claim 14, wherein said means for applying vibration includes an electromechanical transducer and a high-frequency power supply means for energizing said transducer.
- 85 16. The apparatus defined in claim 15, wherein said detector means is connected to said electrochemical transducer.
- 90 17. The apparatus defined in claim 15 or claim 16, wherein said electrochemical transducer is composed of at least one substance selected from the group which consists of quartz, barium titanate, lead zirconate and lead titanate.
- 95 18. A wire-cut electroerosion machine constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, any single figure or group of associated figures of the accompanying diagrammatic drawings.
- 100 19. A method of operating a wire-cut electroerosion machine, said method being substantially as hereinbefore described with reference to any single figure or group of associated figures of the accompanying diagrammatic drawings.
- 105 20. A method of electroerosion machining, said method being substantially as hereinbefore described with reference to any single figure or group of associated figures of the accompanying diagrammatic drawings.
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21. Apparatus for electroerosion machining, said apparatus being constructed, arranged and adapted to operate substantially as hereinbefore described with reference to, and as illustrated in, any single figure or group of associated figures of the accompanying diagrammatic drawings.

22. A workpiece which has been machined by use of a method according to any one of claims 6 to 13, 19 and 20, or by use of a machine according to any one of claims 1 to 5 and 18, or by use of apparatus according to any one of claims 14 to 17 and 21.