MACHINES FOR AUTOMATICALLY TRACING THE CONTOUR OF
PARTS SUCH AS TURBINE OR COMPRESSOR BLADES

Fig. 1.

Fig. 2.

Fig. 3.
Fig. 6

Fig. 7
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Fig. 8

Fig. 9
FIG. 10

Fig. 11
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This invention relates to machines of the type utilized for accomplishing automatically the contour tracing of blades such as those provided in rotor and stator wheels of turbines, compressors, or the like. There is a frequent need in modern industry of checking with the highest degree of accuracy the shape or sectional contour of more or less complicated parts. This problem arises particularly and to a variable extent in the control of turbine blade manufacture, due to the development of jet engines.

Various methods are now applied in this field. As a rule, they may be divided into two groups, according as their technique is of mechanical or optical character. The optical devices are generally adapted to project a considerably enlarged image of the various sections or contour portions of the part to be controlled according to suitably selected planes. This projection is accomplished either on tracing paper or photographic, i.e. photo-sensitive paper. Under these conditions the resulting profile is obtained either by developing the photographic paper, or manually by following with a pencil the contour projection.

In both cases a substantial degree of inaccuracy is introduced in the tracing work due to the fact that the dimensions of the photographic paper vary after passing through the various developing baths and drying processes; on the other hand, the manual profile-tracing on paper is attended by a substantial lack of precision.

With mechanical tracing means this inconvenience is avoided. The contour is followed by a pointed reading stylus, amplified by a pantographic link system and the enlarged profile is drawn directly by means of another point on a sheet of paper.

However, in this method the pressure with which the reading point engages the part to be checked is limited in that the part must not be scratched or scored. The force transmitted to the tracing point varies as the bearing or reading pressure divided by the amplification ratio. This force is of same order as the friction drag developed between the tracing point and the recording paper; as a result, the greater the amplification or enlargement coefficient, the greater the divergences between the tracing and the original contour; consequently the degree of accuracy of this mechanical process is lower than that of optical systems.

It is the essential object of this invention to provide a machine adapted to trace a blade or like sectional profile through mechanical amplifying means according to the known principles but characterized chiefly in that the frictional contact limiting the precision of conventional mechanical amplifying apparatuses is avoided completely.

With a machine according to this invention the profile or sectional contour to be checked is followed or "read" not by a point but by a roller of predetermined diameter, which is caused to engage and roll on the surface to be checked, all the movements of the roller being transmitted with the desired amplification ratio to a tracing carriage supported by one end of a swivelling arm mounted on a pivoting shaft and adapted to trace on a recording circular plate circles which are homothetic with respect to the roller circumference, with a ratio of similarity equal to the aforesaid amplification ratio. Thus, the inner envelopes of these circles will constitute the amplified image of the profile of the part to be checked.

Moreover, in order to prevent any parts from jamming during the tracing operation, the relative movement of the roller along the selected sectional contour is controlled automatically by one or the other of a pair of electro-motors drivingly connected with either the recording plate, to which the part to be checked is firmly connected, when the rotational drag of the plate is lower than a predetermined value, or the shaft controlling the supporting arm, respectively, when the rotational drag of the plate is lower than this predetermined value.

The machine according to this invention also comprises an automatic stop motion operating immediately when the rotational drag of the shaft controlling the carriage-supporting arm exceeds a predetermined value, if the electro-motor drivingly connected to this shaft is operative at that time, and means for re-starting this shaft for rotation in the opposite direction after this stop.

Finally, the machine according to this invention comprises a hand-actuated control member adapted, when the recording-plate driving motor is operating, automatically to reduce the velocity of rotation of this motor if its normal speed moved this arm at an excessive angular velocity likely to cause the tracing carriage to develop frictional stresses between the tracing carriage and the underlying recording plate such as to discontinue the engagement between the roller and the part to be checked.

The invention and the manner in which it is performed is illustrated in the following drawings given in such a manner as to be understood better:

Fig. 1 is a diagrammatical perspective fragmentary view showing the tracing carriage.

Fig. 2 is a diagram showing in plan view the essential component elements of the machine.

Fig. 3 is a perspective view showing the parts of as Fig. 2.

Fig. 4 is a diagram taken upon a plane parallel to the recording plate showing the relative arrangement of the contour to be checked and of the roller with respect to the axes of the plate and roller-carrying arm control shaft, in normal operating conditions.

Fig. 5 illustrates a limit case wherein the reaction or drag produced by the contour to be checked on the roller is transmitted completely to the shaft controlling the roller-carrying arm.

Fig. 6 illustrates a condition wherein the roller cannot roll on certain portions of the contour to be checked unless its direction of rotation is reversed.

Fig. 7 shows a specific case in which the angular velocity of the roller-carrying arm becomes unduly high.

Figures 8 and 9 show in operative and inoperative conditions, respectively, the plate-driving motor and an automatic device for stopping and re-starting this motor, and drivingly connecting or disconnecting the shaft controlling the carriage-supporting arm relative to its driving motor.

Figure 10 shows the motor for driving the shaft controlling the carriage-supporting arm, and the clutch means interposed therebetween.
Figure 11 illustrates the automatic stop motion interposed in the transmission of the motor of Fig. 10, and Figure 12 is a wiring diagram of the apparatus, showing component elements of the electric circuit in block form.

The amplifying arm 1 carries at one end a tracing carriage 21 consisting of a substantially horizontal axle 5, carrying in turn at its ends a pair of identical tracing wheels, 3, 4, with milled edges; these wheels are mounted for rotation about their axes and disposed in a proper space relationship on either side of a substantially vertical shaft 7 journalled in a bearing block 6 rigid with the arm 1; this vertical shaft 5 is driven by a small electromotor 7 and has its lower end operatively connected through a ball-and-socket joint shown diagrammatically at 8 with the axle 2, so as to cause this axle to rotate in a substantially horizontal plane, together with the tracing wheels 3, 4.

The tracing carriage 21 described hereabove rests on a sheet of paper disposed either above or below a carbon paper sheet and for a given position of the carrier arm 1 this carriage will trace a circle of 9 same diameter as the distance measured between the pair of tracing wheels 3, 4. Thus, if the diameter of the roller following the contour to be checked is ½" and the amplification ratio 5:1, the tracing wheels will be spaced 2½ " apart and the diameter of the circle 9 will also be 2½"; thus, the resulting circles will correspond to the image of the follower 13 (Fig. 2) magnified five times.

When the contour-engageing roller 13 is moved along the selected sectional contour of the part to be checked, the amplifying arm 1 moves the carriage 21 and the latter traces continuously a sequence of circles representing this movement with the desired magnification or amplification. Thus, a continuous image or chart of the successive positions of the roller 13 is obtained and the carriage displacement occurs without causing any frictional engagement since the wheels 3, 4 will be positioned parallel to the resulting path twice per revolution of the axle 2.

With this arrangement, it is possible to reduce to a minimum the pressure with which the roller 13 engages the part to be checked, while obtaining an extremely accurate recorded diagram consisting of the envelope of the circles traced by the carriage.

The part 10 to be checked or analyzed is rigidly connected to a recording plate 11 mounted for rotation about a substantially vertical axis 12. The follower 13 is carried by an arm 14 rotatably fast with a substantially vertical shaft 15 to control, through a pair of crank arms 16, 17 interlocked by a parallelogram-forming link 18, a vertical shaft 19 carrying the amplifying arm 1 having secured at its opposite end the tracing carriage 21. This arm 1 is adapted to oscillate in a vertical plane about a substantially horizontal pivot pin 20 mounted across the vertical shaft 19.

The axis 12 and the axes of shafts 15, 19 are parallel are connected in a common, substantially vertical plane. The distances from the axis 12 to the axes of shafts 15 and 19 respectively are in the same ratio as the lengths of the lever arms 14 and 1. Under these conditions, when the plate 11 is rotated the path recorded by the tracing carriage 21 on this plate is similar or homothetic relative to the path followed by the roller 13 with respect to the plate axis 12. If the values selected from the diameter of roller 13 and for the distance between wheels 3 and 4 of carriage 21 correspond to the selected ratio of similarity, then the envelope of the circles traced by the carriage 21 will also be homothetic to the sectional contour followed by the roller 13, so that this envelope actually represents an enlargement of this sectional contour with the desired amplification coefficient or ratio.

The shaft 15 is formed with a prismatic portion parallel to its axis and slidable engaged by a clamping collar 22 adapted to be adjustably locked in any desired axial position therealong; this collar is carried by or formed integral on the arm 14 carrying the roller 13, as shown. With this device the position of the roller 13 can be readily adjusted along an axis parallel to that of shaft 15, while retaining its initial angular position, so that it is an easy matter to select along the height of part 10 as many cross-sectional profiles as desired without altering whatever the reference axes traced once forever on the plate 11 and corresponding to the principal axes of the part to be checked, due to the mounting of this part in a special clamp 22 formed at or as a lower extension of the shaft 12 of plate 11.

The pressure with which the roller 13 bears on the part 10 to be analyzed is produced by a relatively long tension spring 24 disposed obliquely in the parallelogram constituted by the link 18 and crank arms 16, 17; obviously the force applied by this spring may be varied by simply displacing its end along the crank arm 16.

With this arrangement the desired pressure may be obtained without occasioning a friction likely to introduce divergences in the tracing, as would be the case with the conventional devices utilizing a weight and guide-pulley arrangement.

The paper on which the tracing is to be recorded is secured on the plate 11 through any known or suitable device, for example and preferably by means of small magnets deposited at proper locations on this plate, if the latter is made of steel. This fixation is facilitated by the fact that the carriage 21 may be raised clear of the plate by pivoting the arm 14 about its pivot pin 20.

The motion producing the relative movement of the roller 13 along the sectional contour of the part 10 to be checked and the tracing of the corresponding enlarged diagram by means of the carriage 21 on the paper secured on the plate 11 may be obtained by starting a small electromotor 27 adapted to drive the plate 11 as shown more particularly in Figs. 8, 9 and 12, by means of a driving wheel 26 in rolling engagement with the milled or knurled peripheral edge of plate 11.

The diagram of Fig. 4 shows how the stress resulting from the rotation of plate 11 is transmitted to the roller-carrying arm 14 and then to the carriage-supporting arm 1 parallel thereto, through the profile of the part 10 to be checked. In this diagram, 1 is the common axis of rotation of plate 11 and of the part 10 to be checked (this axis being designated by the reference numeral 12 in Figs. 2 and 3), and P is the contour of the part 10 at a selected height or cross-section thereof. At any time the contour P applies to the roller 13 of Figs. 2 and 3 and of center A a reaction F directed normally to this contour at the contact point M and passing through the center A. The path followed by the center A of roller 13 is a circular one about the axis O of shaft 15 of Fig. 3. The reaction F may be divided into two components passing through the center A, i.e. a radial component F R meeting the axis of rotation O and a tangential component F T at right angles to the former. The radial component F R is cancelled at O by the reaction produced by shaft 15. The tangential component F T determines the movement of the roller and of the carriage-supporting arm.

If we consider the specific example of operation illustrated in Fig. 5, it will be seen that this originates a difficulty, as the normal to the contour at the contact point M meets the axis of rotation O.

In this case the tangential component F T is zero and the reaction F R merges with the component F T. Thus, the roller is no more driven and the arm and plate assembly is locked against motion.

According to this invention, the inconvenience pointed out hitherto may be avoided, when these conditions appear, by—(1) stopping the rotational movement of plate 11 driven by the motor 27; (2) starting the motion to drive the shaft 19 controlling the carriage-supporting arm 1; (3) causing this other driving motion to be stopped automatically and re-starting the former driving motion.
2,720,708 when the contour P and roller 13 have resumed their relationship indicated in Fig. 4. For this purpose the plate driving motor is carried by a dynamometric device displaceable in one of the other directions when the stress transmitted exceeds a predetermined value. In this last case the displacement of the dynamometric device will stop the motor through any known or suitable mechanical or electrical means.

On the other hand, the same displacement of this dynamometric device will operate simultaneously through clutch means, another driving device controlling the rotation of the control shaft 19 of the carriage-supporting arm 1. This causes the follower roller 13 to continue its movement along the sectional contour to be checked.

When this displacement causes the follower roller to register again with the contour P, in the case of Fig. 4, that is to say when the reaction F has its tangential component Fi of a value other than zero, the plate 11 is released and the force applied through the plate driving system to the dynamometric device becomes lower than the adjustment limit thereof, and this driving system resumes its normal position. According to this invention the resetting just described of the driving system to its initial or normal position will cause through any suitable or known mechanical or electrical means the re-starting of the elevating motor and the declutching of the shaft controlling the carriage-supporting arm, a slight time-shifting being provided between these two actions to avoid any discontinuity in the curve tracing.

As shown in Fig. 8, the motor 27 driving the plate 11 and the wheel 26 keyed or otherwise secured on the shaft of this motor are mounted at one end of a connecting-rod 28 having its other end pivotally connected through a pivot pin 31 to a crank arm 29 fulcrumed about a fixed pivot pin 32, a tension spring 30 being attached at one end to the pivot pin 31 and at the other end to another stationary pivot pin 33, as shown. This connecting rod 28 is positioned between a pair of push members 34, 35 urged against the adjacent end walls of correspondingly aligned casings 38, 39 by a pair of calibrated compression springs 36, 37 enclosed in these casings, as shown. Both casings 38, 39 are so adjusted in relation to each other that the adjacent ends of push members 34, 35 will form therebetween a gap dimensioned to permit exactly the frictionless passage of the connecting rod 28. When the force required for driving the plate 11 in one or the other direction exceeds the value corresponding to the pressure applied by the springs 38, 39, the connecting-rod 28 will be swung about its pivot pin 31 so as to compress the relevant spring, for example spring 38, through the medium of the push member 34, and the displacement of this push member will actuate a switch 40. As will be explained in a later part of this description, the actuation of the switch 40 will brake and stop almost instantaneously the motor 27, so that the now inoperative plate 11 will be subjected only to the driving force of the push member 34 which is transmitted through the plate-engaging wheel 26.

Simultaneously, the action of switch 40 will cause the device shown in Fig. 10 to operate as follows: The shaft 19 controlling the arm 1 supporting the carriage 21 is rigid with a member 44 adapted to be magnetized by causing direct current to flow through conductors 47 to a suitable winding according to any known arrangement. Registering with this member 44 is another member 45 for example of soft iron, driven for permanent slow rotation from an electromotor 46. As will be explained presently, the operation of the switch 40 will cause direct current to flow through the conductors 47, thus causing the magnetic clutch consists of members 44 and 45 to be actuated, as the member 45 then assumes Practically an integral part of member 44 due to the action exerted by its magnetic field. Under these conditions the motor 46 will drive for slow rotation the shaft 19 and therefore the complete assembly comprising the follower roller 13 and the carriage-supporting arm 1, so that the machine will continue to trace the contour of the plate 10, for example a blade of a turbine rotor or stator, although the plate 11 is no more driven by its motor 27.

When this displacement has caused the follower roller 13 to register again with the contour P, as in the case of Fig. 4, as the plate 11 continues its rotation under the influence of spring 36 and push member 34, the latter will release the switch 40 and, as will be seen later on, the motor 27 will be started again so that the plate 11 will resume its slow rotation.

The closing of switch 40 will also disconnect the magnetic clutch 44, 45 from its D. C. source and stop the slow rotation of control shaft 19 and of the assembly comprising the follower 13 and carriage-supporting arm 1. However, it has been observed in the course of practical tests that to avoid any jerks or fluctuations in the tracing it was necessary to delay this stop by about one second with respect to the time at which the motor driving the circular plate 11 is started again. This time lag is obtained automatically as will be explained presently.

Fig. 9 shows the dynamometric device carrying the plate-driving motor 27, and the wheel 26 secured on the output shaft of this motor in the inoperative condition of the machine. The wheel 26 is clear of the peripheral edge of plate 11. The spring 30 acting on the crank arm 29 has thrown the movable end thereof to an overcenter position relative to the plane passing through both axes of pins 32 and 33, thereby moving and keeping the connecting-rod 28 away from the plate 11, while operating the switch 42 to de-energize the motors 7, 27 and 46 and stop the machine.

A projection 43 provided on the peripheral edge of plate 11 causes the crank arm 29 to be reversed during the rotation of the plate 11 so that the machine will be stopped at the end of the contour-tracing operation. Under these conditions, as the plate 11 is clear of its driving wheel 26 it may rotate loosely about its axis if swung by the hand. A contour-tracing operation may be started by hand-actuating the connecting-rod 28 for a short stroke, so as to release the switch 42 and cause the wheel 26 to engage again the plate 11; this causes the plate 11 to be rotatably driven then from its motor 27, and the motors 7 and 46 to be started. When the switch 43 has been rotated to an extent sufficient to clear the projection 43 the connecting-rod 28 will resume the position in which it is shown in Fig. 8 and the tracing operation will continue automatically.

Another trouble in the operation of this machine may be encountered if, in a given zone of the contour, the path is such that after the passage through the position shown in Fig. 5 the direction of the tangential component Fi is opposite to that shown in Fig. 6. In this case the component Fi will resist the natural movement of the clutch-driven follower 13. Obviously, the follower cannot continue its displacement unless the plate supporting the part 10 having the contour P is rotated in the opposite direction.

The resiliency of the dynamometric device carrying the driving wheel 26 affords a low-amplitude rotation in the reverse direction. If that portion of the contour which has the characteristic pattern shown in Fig. 6 is rather short this resilient displacement will permit the tracing of this contour portion. If on the contrary it is relatively long, the motion will be jammed or blocked when the tangential component Fi equals the driving force applied to the follower. To avoid any abnormal stress likely to exert a detrimental influence on the machine components, a limiting device of known type or construction is interposed in the transmission from the motor 46 to the control shaft 19 of the carriage-supporting arm 1 so as to disconnect completely the machine from the source of current and to stop the machine when an excessive drag takes
The tracing operation may be resumed by rotating the plate in the other direction. Fig. 11 shows one form of embodiment of the safety device just mentioned. The clutch 44 of motor 46 is not fast with shaft 19 but rotatably mounted thereon. It carries an arm 48 adapted to drive the crank arm 17 by abutting thereagainst when it is rotated from the motor 46. By rotating the crank arm 17 and the arm 48 there is interposed an electric switch 49 of the calibrated-release pressure type, for example a microswitch. When the force applied by the arm 48 on the push button of switch 49 exceeds the selected value, the switch is operated and opens the energizing circuit of the machine.

Finally, another inconvenience may arise during the operation of the machine, for example in the case illustrated in Fig. 7 wherein one portion of the contour P forms a rather narrow angle with the radius R. In this case, a small angular movement of the plate and of the part 10 about the axis of rotation I may correspond to a large displacement of the follower 13 and, therefore, of the tracing carriage 21. But the velocity of motion of this carriage 21 is limited. In fact, as will appear from Fig. 1, this carriage must not exceed a relatively short displacement during one revolution of the tracing wheels 3, 4 if it is desired to keep its frictional engagement with the underly surface within reasonable limits. In the specific case contemplated herein, the carriage 21 cannot move at a speed sufficient to keep the follower 13 in proper engagement with the sectional contour of part 10 and the resulting curve is inaccurate.

This difficulty is avoided according to this invention by reducing the velocity of rotation of the plate to a fraction of the normal velocity, for example one-fourth of this velocity, through any known and suitable retarding device actuated by the operator at the proper time, for example by braking the driving motor electrically.

For example, a wiring diagram and the essential electric components of the machine, including the wiring-carrying driving motor 7, the driving motor 27 consisting of a couple of single-phase motors having field windings of opposite directions, both motors being mounted on a common shaft, and the motor 46 for normally driving the shaft 19 controlling the arm 1 carrying the tracing carriage 21. The current source (for example an A.C. supply of any suitable type) is connected through a line 52 with a hand control box 50, 51 for starting each motor separately or simultaneously, reversing the direction of motion of, and braking, the motor 27, and actuating the control thereof, the current source having a relay 54 in the circuits of the motors 27 and 46. The control of the motor 27 may be braked by applying D.C. produced through a rectifier 54 to the field winding corresponding to the reverse direction of rotation of this motor. The clutch means 44, 45 of motor 46 is actuated by applying a filtered D.C. from rectifier 56 to the winding of clutch member 44. The actuation of any one of switches 40 or 41 operates an interlocking relay 53 adapted to de-energize the motor 27 and to supply braking current thereto to stop this motor instantaneously while energizing the clutch means 44, 45 of motor 46. Conversely, when the switches 40 or 41 are released they release in turn the relay 53 and the latter de-energizes the braking winding of motor 27 while re-energizing this motor instantaneously with driving current. Meanwhile the time relay 55 keeps the clutch means 44, 45 energized during about one second and then disconnects this clutch according to the operating time selected by the operator.

The starting switch 42 and safety switch 49 are provided for disconnecting directly the machine from the source of electric energy, but the switch 42 may be shunted through separate control means of conventional design. It will be readily understood by anybody conversant with the subject that many modifications may be brought to the foregoing embodiment shown by way of example in the attached drawings, without departing from the spirit and scope of the invention.

What I claim:

1. A machine for tracing automatically the contour of a part which comprises a plate rotatably mounted about an axis and having a circular peripheral milled edge, means for rigidly fixing said part to said plate in the vicinity of said plate axis, a roller having a predetermined diameter and adapted to follow said contour, an arm having a certain length and carrying said roller, a first shaft mounted on the same and adapted for rotation about an axis parallel to said plate axis and at a distance from said first shaft which is greater than, and in the ratio of, said first-mentioned predetermined distance, another arm having one end rotatably driven from said second shaft and its other end overlying said plate, a first and a second crank arm of same length, keyed on said first and second shafts respectively with the same angular divergence relative to said arms, a link interposing said crank arms so as to maintain them parallel to each other, a spring resiliently connecting said crank arms to each other and urging said roller for engagement with said contour, a first electromotor for rotation at a predetermined velocity and having a shaft mounted on said rotation in that end of the second shaft which overlies said plate, an axle mounted transversely of said motor shaft, a pair of tracing wheels carried by said axle on either side of said motor shaft in rotation by said motor shaft and engaging said plate so as to describe around said motor shaft circles of a diameter greater than the roller diameter according to the aforesaid ratio, a driving wheel adapted drivingly to engage the circular peripheral milled edge of said plate, a second motor adapted to be supplied with energizing current and to carry and rotatably drive said driving wheel, a dynamometric device carrying said second motor and adapted to detect the driving wheel against said milled edge of said plate in an intermediate position when the reaction produced by said rotatably driven plate on said driving wheel is below a predetermined value, and to move away from said position in the opposite direction of rotation when said plate reaction on said driving wheel exceeds said predetermined value, a third electromotor rigid member adapted to be rotatably connected with said third motor, a dynamometric transmission for rotatably connecting said rigid member with said second shaft, means responsive to the displacement of said dynamometric device for energizing said second motor and disconnecting said dynamometric device in its intermediate position, and discontinuing the supply of energizing current to said second motor while connecting-in said rigid member when said dynamometric device is moved away from said intermediate position, other means actuated from said dynamometric transmission and adapted to stop said first, second and third motors when the reaction of said rigid member on said second shaft exceeds a predetermined value, other means adapted to limit the velocity of rotation of said second motor, a hand-actuated control for enabling said last-mentioned means to be put in operative condition, other means for stopping said first, second and third motors automatically when a given point of said circular contour of said plate moves past said dynamometric device, and other means adapted to be hand-actuated for restarting said motors according to the direction of rotation required for said second motor.

2. A machine for tracing automatically the contour of a part which comprises a plate rotatably mounted about an axis and having a circular peripheral milled edge, means for rigidly fixing said part to said plate in the vicinity of said plate axis, a roller having a predetermined diameter and adapted to follow said contour, an arm having a certain length and carrying said roller, a first shaft mounted on the same and adapted for rotation about an axis parallel to, and located at a predetermined distance from, said plate axis, said arm being rigidly mounted on said first shaft for rotation therewith, a second shaft rotatably mounted about an axis parallel to said plate axis and at a distance from said first shaft which is greater than, and in the ratio of, said first-mentioned predetermined distance, another arm having one end rotatably driven from said second shaft and of the other end over-lying said plate, a first and a second crank arm of same length, keyed on said first and second shafts respectively with the same angular divergence relative to said arms, a link interposing said crank arms so as to maintain them parallel to each other, a spring resiliently connecting said crank arms to each other and urging said roller for engagement with said contour, a first electromotor for rotation at a predetermined velocity and having a shaft mounted on said rotation in that end of the second shaft which overlies said plate, an axle mounted transversely of said motor shaft, a pair of tracing wheels carried by said axle on either side of said motor shaft in rotation by said motor shaft and engaging said plate so as to describe around said motor shaft circles of a diameter greater than the roller diameter according to the aforesaid ratio, a driving wheel adapted drivingly to engage the circular peripheral milled edge of said plate, a second motor adapted to be supplied with energizing current and to carry and rotatably drive said driving wheel, a dynamometric device carrying said second motor and adapted to detect the driving wheel against said milled edge of said plate in an intermediate position when the reaction produced by said rotatably driven plate on said driving wheel is below a predetermined value, and to move away from said position in the opposite direction of rotation when said plate reaction on said driving wheel exceeds said predetermined value, a third electromotor and rigid member adapted to be rotatably connected with said third motor, a dynamometric transmission for rotatably connecting said rigid member with said second shaft, means responsive to the displacement of said dynamometric device for energizing said second motor and disconnecting said dynamometric device in its intermediate position, and discontinuing the supply of energizing current to said second motor while connecting-in said rigid member when said dynamometric device is moved away from said intermediate position, other means actuated from said dynamometric transmission and adapted to stop said first, second and third motors when the reaction of said rigid member on said second shaft exceeds a predetermined value, other means adapted to limit the velocity of rotation of said second motor, a hand-actuated control for enabling said last-mentioned means to be put in operative condition, other means for stopping said first, second and third motors automatically when a given point of said circular contour of said plate moves past said dynamometric device, and other means adapted to be hand-actuated for restarting said motors according to the direction of rotation required for said second motor.
rigidly mounted on said first shaft for rotation therewith, a second shaft rotatably mounted about an axis parallel to said plate axis and at a distance from said first shaft which is greater than, and in a predetermined ratio to, said first-mentioned predetermined distance, another arm having one end rotatably driven from said second shaft and its other end overlying said plate, a first and a second crank arm of same length, keyed on said first and second shafts respectively with the same angular divergence relative to said arms, a link interconnecting said crank arms so as to maintain them parallel to each other, a spring resiliently connecting said crank arms to each other and urging said roller for engagement with said contour, a first electromotor actuated for rotation at a predetermined velocity and having a shaft mounted for rotation in that end of said second crank arm which overlies said plate, an axle mounted transversely of said motor shaft, a pair of tracing wheels carried by said axle on either side of said motor shaft put in rotation by said motor shaft and engaging said plate so as to describe around said motor shaft circles of a diameter greater than the roller diameter according to the aforesaid ratio, a driving wheel adapted drivingly to engage said circular peripheral milled edge of said plate, a second motor adapted to be supplied with energizing current and to carry and rotatably drive said driving wheel, a connecting-rod carrying at one end said second electromotor and having its opposite end formed as a pivotal connection, a lever arm pivotally mounted on said pivotal connection of said connecting-rod, a fixed pivot pin having fulcrum thereon the opposite end of said lever arm, a pair of aligned push members disposed on either side of said connecting-rod, a pair of casings having slidably mounted therein said push members respectively, a pair of identically calibrated springs located in said casings and urging said push members to stop positions in said casings so as to leave between the registering ends of said push member a gap acting as a guide to said connecting-rod, a spring pulling said pivotal connection of said connecting-rod so as to normally urge said connecting-rod towards said plate to cause said driving wheel to engage said circular peripheral milled edge in an intermediate position when the reaction produced by said rotatably driven plate on said driving wheel is lower than the limit-value at which one of said springs located in said casings yields under the pressure exerted by said connecting-rod, and in a position differing from said intermediate position in a direction opposite to the direction of rotation of said plate when the reaction produced by said plate on said driving wheel exceeds said limit-value, a third electromotor, a rigid member adapted to be operatively connected with said second electromotor, a dynamometric transmission rotatably connecting said rigid member with said second shaft, a pair of switches disposed on either side of said push members, one of said switches being actuated by one of said push members when said connecting-rod is moved away from its intermediate position, an interlocking relay controlled by said switches to supply said second motor with energizing current and disconnecting said rigid member from said third electromotor when said connecting-rod is in its intermediate position, and disconnecting said supply of energizing current to said second motor and drivingly connecting said rigid member with said third electromotor when said connecting-rod is moved away from said intermediate position, other means actuated through said dynamometric transmission and adapted to stop said first, second and third motors when the reaction produced by said rigid member on said second shaft exceeds a predetermined limit value, other means adapted to limit the velocity of rotation of said second motor, hand-actuated control means adapted to set said last-mentioned means in operative conditions, other means for automatically stopping said motors when a given point of said circular peripheral milled edge moves past said dynamometric device, and other means adapted to be controlled by hand for re-starting said motors according to the direction of rotation required for said second motor.

A machine for tracing automatically the contour of a part which comprises a plate rotatably mounted about an axis and having a circular peripheral milled edge, means for rigidly fixing said part to said plate in the vicinity of said plate axis, a roller having a predetermined diameter and adapted to follow said contour, said roller having a certain length and carrying said roller, a first shaft mounted for rotation about an axis parallel to, and located at a predetermined distance from, said plate axis, said arm being rigidly mounted on said first shaft for rotation therewith, a second arm rotatably mounted about an axis parallel to said plate axis and at a distance from said first shaft which is greater than, and in a predetermined ratio to, said first-mentioned predetermined distance, another arm having one end rotatably driven from said second shaft and its other end overlying said plate, a first and a second crank arm of same length, keyed on said first and second shafts respectively with the same angular divergence relative to said arms, a link interconnecting said crank arms so as to maintain them parallel to each other, a spring resiliently connecting said crank arms to each other and urging said roller for engagement with said contour, a first electromotor actuated for rotation at a predetermined velocity and having a shaft mounted for rotation in that end of said second crank arm which overlies said plate, an axle mounted transversely of said motor shaft, a pair of tracing wheels carried by said axle on either side of said motor shaft put in rotation by said motor shaft and engaging said plate so as to describe around said motor shaft circles of a diameter greater than the roller diameter according to the aforesaid ratio, a driving wheel adapted drivingly to engage said circular peripheral milled edge of said plate, a second motor adapted to be supplied with energizing current and to carry and rotatably drive said driving wheel, a connecting-rod carrying at one end said second electromotor and having its opposite end formed as a pivotal connection, a lever arm pivotally mounted on said pivot connection of said connecting-rod, a fixed pivot pin having fulcrum thereon the opposite end of said lever arm, a pair of aligned push members disposed on either side of said connecting-rod, a pair of casings having slidably mounted therein said push members respectively, a pair of identically calibrated springs located in said casings and urging said push members to stop positions in said casings so as to leave between the registering ends of said push member a gap acting as a guide to said connecting-rod, a spring pulling said pivotal connection of said connecting-rod so as to normally urge said connecting-rod towards said plate to cause said driving wheel to engage said circular peripheral milled edge in an intermediate position when the reaction produced by said rotatably driven plate on said driving wheel is lower than the limit-value at which one of said springs located in said casings yields under the pressure exerted by said connecting-rod, and in a position differing from said intermediate position in a direction opposite to the direction of rotation of said plate when the reaction produced by said plate on said driving wheel exceeds said limit-value, a third electromotor, a rigid member adapted to be operatively connected with said third electromotor, a dynamometric transmission rotatably connecting said rigid member with said second shaft, a pair of switches disposed on either side of said push members, one of said switches being actuated by one of said push members when said connecting-rod is moved away from its intermediate position, an interlocking relay controlled by said switches to supply said second motor with energizing current and disconnecting said rigid member from said third electromotor when said connecting-rod is in its intermediate position, and discontinuing said supply of energizing current to said second motor and drivingly connecting said rigid member with said third electromotor when said connecting-rod is moved away from said intermediate position.
tion, other means actuated through said dynamometric transmission and adapted to stop said first, second and third motors when the reaction produced by said rigid member on said second shaft exceeds a predetermined limit value, other means adapted to limit the velocity of rotation of said second motor, hand-actuated control means adapted to set said last-mentioned means in operative conditions, a cam-like projection secured on said circular peripheral milled edge of said plate and adapted to lift said driving wheel when said projection registers with said driving wheel during the rotation of said plate and to push said connecting-rod to an over-center position in which said tension spring normally urging said connecting-rod for engagement with said plate moves said lever arm and said connecting-rod away from said plate, a motor control switch disposed in the vicinity of said pivotal connection-forming end of said connecting-rod and adapted to stop said first, second and third motors when said tension spring has moved said connecting-rod to its overcenter position away from said plate, and other means adapted to be hand-actuated for re-starting said motors according to the direction of rotation required for said second motor.

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