

A BORING TOOL

The present invention relates to a boring tool.

5 For example, the invention relates to a boring tool for a finish machining operation on through bores, which tool can be rotated at very high speeds and yet perform the machining operation with ultra precision.

10 In this respect, the current state of the art for ultra precision requirements does not permit positive or negative deviations relative to a pre-established nominal dimension either for components or for micrometric pre-setting to exceed 1 micron.

15 Several types of devices for tool pre-setting are known and widely used. However, in general these have an operating mechanism acting directly on the tool shank. This does not provide enough accuracy for fine settings and
20 is not satisfactory in that it does not provide consistent pre-setting repeatability. The known devices are not provided with means to eliminate backlash.

25 The deficiencies of conventional pre-setting devices do not allow a very precise and fine micrometric setting (within the micron magnitude) of the cutting tool relative to the workpiece, and make the finish machining operation of high precision bores difficult and slow.

30 It is an object of the present invention to provide a boring tool which reduces such inconveniences.

35 According to the present invention there is provided a boring tool having a substantially cylindrical body having a first bore therein, and a second bore opening in the circumferential surface of said body and intercepting said

first bore, said boring tool comprising a tool shank for carrying a tool tip movably received within said second bore, a rotatable control knob carried by said body for enabling the position of the tool shank in said second bore to be set, and moving means in said first bore for moving said tool shank, said moving means being coupled to said control knob and being arranged to move said tool shank in said bore in response to rotation of said control knob, and further comprising backlash suppression means for suppressing backlash of said tool shank, said backlash suppression means acting on said tool shank to bias the tool shank in a direction substantially along the second bore generally inwardly of the circumferential surface of said body.

With an embodiment of the invention the control knob actuates the tool shank indirectly in a sequence of subsequent steps or phases, as is explained below.

Furthermore, the tool edge can be pre-set with ultra high accuracy by way of the ultra-precision sub-micron boring tool control knob thereby eliminating the need for any additional pre-setting as is required when using state of the art boring tool devices.

Preferably, the tool edge position of a rotatable tool is preset, the pre-set dimension being the distance between the most distant or farthest point on the tool edge and the geometric axis of rotation around which the tool revolves.

In an embodiment, said backlash suppression means comprises resilient means housed in a tool shank bore extending within said tool shank.

Preferably, said resilient means comprise a first threaded stud threaded into said tool shank bore and urged

in a direction inwardly of the circumferential surface of said body by means of a spring. For example, said spring is received in said tool shank bore and has a first end acting on said first threaded stud and a second end acting on a second threaded stud, said second threaded stud being threaded into a further bore which extends in said body and intercepts said tool shank bore.

In an alternative embodiment, said backlash suppression means comprises a plunger slidably received within a bore extending generally axially within said tool shank, said plunger carrying engagement means for engagement with said moving means.

Preferably, said moving means carries teeth or indentations for engagement with corresponding teeth or indentations carried by said tool shank whereby said tool shank is movable by said moving means, and wherein said engagement means of the plunger comprise teeth or indentations carried by said plunger for engagement with the teeth or indentations carried by said moving means. For example, a threaded stud is engaged within said axial bore of said tool shank in abutment with said plunger such that adjustment of the position of the threaded stud within said axial bore adjusts the position of the plunger.

In a preferred embodiment, said moving means comprises a rotatable micrometric screw extending along said first bore, said micrometric screw being connected to said control knob at or near one end of the screw such that rotation of the control knob rotates the screw, and transmission means located within said first bore, said transmission means having an axial bore therethrough through which said micrometric screw extends, said screw being coupled to said transmission means such that rotation of the screw moves said transmission means, and said

transmission means being coupled to said tool shank.

5 Preferably, said transmission means comprises a toothed segment arranged to be reciprocated by rotation of said micrometric screw, and wherein teeth of said toothed segment engage with corresponding teeth on said tool shank.

10 In one embodiment for suppressing backlash between the tool shank and the toothed segment a movement demultiplier mechanism is provided comprising teeth or indentations arranged longitudinally in a secant plane to the toothed segment and inclined relative to the geometric axis of the toothed segment, said teeth or indentations being selectively engageable in a backlash free manner on
15 corresponding teeth or indentations provided in the secant plane of the tool shank.

20 Preferably, a bushing is retained within said first bore, said bushing having an internal thread with which said transmission means is engaged.

25 In an embodiment of a boring tool of the invention all contact surfaces of all the co-operating parts are under a metal to metal contact condition to set (to accomplish and establish) the tool edge position. In this position the tool edge is at its farthest point from its geometric axis of rotation. The metal to metal contact between the sliding surfaces positively ensures that the displacement of the parts is always exempt from lost motion, backlash
30 and/or other deviations. This is a necessary condition for ultra-precision pre-setting and to ensure consistent ultra-fidelity of pre-setting repeatability within ultra-precision standards.

35 Embodiments of the present invention will hereinafter be described, by way of example, with reference to the

accompanying drawings, in which:-

Figure 1 shows a longitudinal view of a sub-micron boring tool of the present invention for use for finishing
5 through bores,

Figure 2 shows a longitudinal section of the boring tool taken along the line A-A of Figure 1,

10 Figure 3 shows a cross section of the boring tool taken on the line B-B of Figure 2,

Figure 4 shows a cross section similar to that of Figure 3 but illustrating an alternative embodiment of a
15 boring tool,

Figure 4a is a cross section taken on line C-C of Figure 4,

20 Figure 4b is an enlarged detail of the arrangement shown in Figure 4, and

Figure 4c is an enlarged detail of the arrangement illustrated in Figure 4b and showing the reactions of parts
25 thereof during adjustment.

The Figures show embodiments of a sub-micron boring tool of the present invention which is provided with a motion reducing mechanism or motion demultiplier mechanism
30 consisting of two toothed segments which teeth have converging flanks. The boring tool has a micrometric screw which is useful for tool pre-setting, and is preferably used to finish the machining of through bores.

35 The boring tool illustrated in Figures 1 to 3 has a substantially cylindrical main body 10 through the interior

of which a first bore 1 extends. The first bore 1 is stepped along the length of the body 10 where a toothed segment 20 is lodged. A micrometric screw 30 arranged on a common geometric axis with said toothed segment 20 is also received within said first bore 1. The micrometric screw 30 is provided with a threaded external section 31 at one of its ends which extends through an axial bore in the toothed segment 20. The threaded section 31 of the micrometric screw 30 engages with a thread 21 provided internally of a bushing 24. This bushing 24 is received within an extension 25 of a hollow stud 26, said extension 25 being fixed at one of its ends to the toothed segment 20 at a thread 20a of the toothed segment 20. The bushing 24 is retained by the hollow stud 26 and its fixed extension 25.

The micrometric screw 30 is supported by rings 40 and 42 which are spaced by a spacer ring 41. A rotation control knob 43 is supported on the micrometric screw 30 close to its other end opposite to its threaded external section 31. A locknut 44 provided with a fastening stud 44a and a pad 44b is threaded on a thread 32 provided externally on the other end of the micrometric screw 30. A locating ring 13 is lodged at the end of the cylindrical body 10 and is covered by protection 14.

From Figure 3, it can be seen that the cylindrical body 10 has a second bore 2 which opens in the circumferential surface of the body 10 and intercepts the first bore 1. In the illustrated embodiment, the bore 2 extends substantially perpendicular to said first bore 1. However, it is possible for the bore 2 to be inclined or oblique relative to the geometric axis of the cylindrical body 10. A tool shank 50 carrying a tool 51 is received within said second bore 2. The tool 51 is held in position by tightening a screw 55 acting on a clamp 55'.

As is shown in Figure 2, the bushing 24 is provided with a male tapered section 24a in its ends, which adjust to corresponding female tapered sections 25a and 26a provided respectively internally of the extension 25 and the hollow stud 26. The bushing 24 is also provided with slotted sections 24b which extend longitudinally of its body from both ends and are mutually interposed such that the slots starting from one end do not extend through to the other end of the bushing 24.

Backlash elimination between the thread of micrometric screw 30 and the internal thread 21 within the bushing 24 is accomplished by tightening the hollow stud 26. When the stud 26 is rotated within an internal thread provided in the extension 25, with which it is engaged, the stud 26 presses the bushing 24 between the female tapered sections 25a and 26a. The male tapered section 24a of the bushing, in co-operation with slotted sections 24b act on the bushing to impose a contraction, thereby causing an elastic decrease in the outside diameter of the bushing 24. There is a consequent decrease in the diameter of the internal thread 21 of the bushing which tightens on the thread of the micrometric screw 30 until it eliminates entirely the backlash between said threads, whilst still allowing the micrometric screw to be smoothly rotated.

A pin 27 is fixed in the extension 25 to extend radially and its free end is fitted in one of the slotted sections 24b of the bushing 24. The pin 27 prevents rotation of the bushing 24 relative to the extension 25.

The first bore 1 of the cylindrical body 10 opens into a larger diameter longitudinal bore 3 in which the support rings 40 and 42 and their spacer ring 41 are received without clearance. These rings 40 to 42 constitute a

bearing system on which the micrometric screw 30 rotates and which support the screw 30 both radially and axially. The rings 40, 41 and 42 are fixed by screws 45 which extend through the rings and are threaded in a wall of the body 10 defining the length of the bore 3.

In this way, the rings 40 and 42 act as a radial bearing for the micrometric screw 30 at an intermediate portion. In the radial direction, this support bearing supports without clearance a portion 33 of the micrometric screw 30 in the bore of the ring 40. In the axial direction the support bearing forms a thrust bearing in that adjoining faces of the rings 40 and 42, spaced by spacer ring 41, retain a collar 35 of the micrometric screw 30 interposed between sections 33 and 34 thereof. Thus, any axial play of the micrometric screw 30 is also suppressed.

At its end external to the cylindrical body 10, the micrometric screw 30 has a tapered seat 36 whose diameter converges (reduces) towards the outer end of the micrometric screw 30. The knob 43 encloses and is rigidly connected to the tapered seat 36 of the screw 30 to permit its radial and axial positioning. The positioning is assured through tightening of the locknut 44, which in its turn is securely fastened or locked on the thread 32 of the micrometric screw 30 by way of the stud 44a and the pad 44b. This pad 44b is made of brass or any other material of less hardness so that it can ensure proper locking without damaging fillets of the thread 32.

As is shown in Figure 1, the external periphery of the rotation control knob 43 at its rim adjacent to the cylindrical body 10 is engraved with a scale 43a. The scale 43a is graduated with engraved equidistant lines to provide means for indicating the displacement of the tool

51 when the knob 43 is manually turned. A reference index or point 43b is engraved on the protection cover 14 adjacent to the graduated scale 43a.

5 The tapered coupling between the micrometric screw 30 and the knob 43, that is, the coupling of the knob 43 in the tapered seat 36, enables the graduated scale 43a to be selectively zeroed or reset relative to the index 43b to establish a certain edge position of the tool 51 relative
10 to the geometric centre of the cylindrical body 10 so that the zero of the graduated scale 43a coincides with the index 43b. After zeroing or resetting, the rotation control knob 43 is set in the tapered seat 36 by way of the lock nut 44, once said knob 43 is solidly connected to the
15 micrometric screw 30.

Returning to Figure 2, it can be seen that rotating the rotation control knob 43 by hand rotates the micrometric screw 30 in its turn. The threaded section 31
20 of the screw 30 engages in the internal thread 21 of the bushing 24, and the rotation of the screw 30 thereby causes axial sliding of the toothed segment 20 along the first bore 1 of the cylindrical body 10. The movement of the toothed segment 20 may be selectively in either of the
25 directions indicated by arrows X and Y, depending upon the direction of rotation of the knob 43.

It can be seen from Figures 2 and 3 that with axial sliding of the toothed segment 20 relative to the
30 cylindrical body 10, the tool shank 50 is displaced radially by way of a motion demultiplier mechanism, defined by indentation 22, in approximately rack fashion. The indentation 22 is provided externally of the toothed segment 20 in a plane secant to its cylindrical body, and
35 the indentation 22 is longitudinally indented and at a slight inclination α relative to its geometric axis. The

teeth 22 mesh in a sliding manner totally free from any backlash with corresponding teeth 52 provided in a secant plane of the cylindrical body of the tool shank 50.

5 As can be seen from Figures 1 and 2, in order to cause an increment in the depth of cut, that is, to displace the tool shank 50 radially, the control knob 43 is rotated by hand in the direction of arrow I so that threaded section 31 of the screw 30 causes axial displacement of the toothed
10 segment 20 in the direction of arrow X. The indentation 22 of the segment 20, being slightly inclined and in close contact with the teeth 52 of tool shank 50, thereby cause radial displacement of the tool shank 50 in relation to the cylindrical body 10 in the direction of arrow Z. In a
15 similar manner, withdrawal of the tool shank 50, that is, its displacement in the direction of arrow W is made by turning control knob 43 in the direction of arrow R.

 As is shown in Figure 3, to assure accurate
20 displacement and to guarantee a stable position of the tool shank 50 relative to the cylindrical body 10, a resilient backlash eliminator system 60 is provided to suppress backlash of said tool shank. This backlash suppression system 60 has a spring 61 lodged in a hole 53 provided in
25 the tool shank 50. One end of the spring 61 acts on an inner end of a stud 62 threadedly received in the entrance of the hole 53. The other end of the spring 61 acts on an end 63a of a stud 63 threadedly received in a hole 4 provided in the cylindrical body 10. The end 63a of the
30 stud 63 extends through an opening 54 in the tool shank 50 into the hole 53. The spring 61 acts on the stud 62 and reacts at the end 63a of the stud 63, and thereby applies a biasing force to the tool shank 50 in the direction of arrow W, that is, in a direction generally along the second
35 bore 2 inwardly of the circumferential surface of the body and in the direction of withdrawal of the tool shank.

The boring tool described above may be coupled directly to the main spindle of a machine and/or it may be coupled to a shank extension 70 for machining deep holes, such shank extension being coupled to the machine spindle.

As is indicated in Figures 1 and 2, when the tool is coupled to the shank extension 70, the coupling end of the cylindrical body 10 is provided with a recessed section having a threaded portion 5 and a centring portion 6.

Thus, the cylindrical body 10 is fixed in shank extension 70 by screwing the threaded portion 5 to a corresponding internally threaded portion 71 of said shank extension 70, the screwing tightness being obtained by resting the extreme face 72 of the shank extension 70 on a face 7 defined in this end of the cylindrical body 10.

Centring and perfect alignment of the cylindrical body 10 with respect to the shank extension 70 is assured by precision fitting the centring portion 6, perfectly concentric with the geometric axis of the cylindrical body 10, in a corresponding bore provided in the interior of the shank extension 70 which is also perfectly concentric with the geometric axis of the shank extension 70. The extreme face 72 of the shank extension 70 is abutted on the extreme face 7 which extends at a right angle to the longitudinal axis of the cylindrical body 10.

When machining deep bores, and when the boring tool is maintained stationary relative to the feed movement, a seat 37 arranged concentric in the free end of the micrometric screw 30, makes it possible to rest the boring tool on the machine tailstock 73. This totally eliminates overhang and further ensures rigidity in the tool which is an important condition for precision machining.

Even when equipped with a live centre, the tailstock 73 may cause slight resistance due to friction at the cone of the seat 37 and thus tend to rotate the micrometric screw 30 relative to the cylindrical body 10. This could accidentally change the pre-set radial distance GF-EG, GF'-EG' during machining. To avoid accidental alteration of the pre-set distance GF-EG, GF'-EG', the control knob 43 is provided with a ratchet indent 43c in its face adjoining the extreme face of the cylindrical body 10. The teeth 43c are coupled to a ratchet indent 13a provided on the face of a loaded spring locating ring 13 which is received in a sliding manner at the end of the cylindrical body 10. The ring 13 is pressed against the ratchet indent 43c by way of loaded springs 15, and retained radially by way of a pin 16 which prevents rotation of the ring 13 relative to the cylindrical body 10.

When the control knob 43 is rotated manually, the ratched indent 43c is also rotated. The teeth thereof, which have a notched profile with flanks converging in the direction of the teeth top, act in the ratched indent 13a, which also has teeth with a notched profile with flanks converging in the direction of the teeth top, and the ring 13 is displaced in the direction of arrow 13b (Figure 2) thereby disconnecting the ratched indents 43c and 13a. As the ratched indents 43c and 13a have a number of teeth, which may be double, or any multiple of, the number of divisions of the graduated scale 43a, it can be assured that when the ratched indents are again coupled to subsequent ratched indents, the maximum radial displacement of rotation control knob 43 is half or any sub-multiple of the value read between two adjacent lines of the graduated scale 43a.

The boring tool can be used for ultra precision

machining where an extremely low level of vibration during operation is required. Furthermore, the system may be operated at very high speeds. The cylindrical body 10 is therefore provided with a balancing system to balance the rotating masses as is shown in Figure 3. The balancing system is comprised of two blocks 80 and 81 lodged in a slot 8 provided at the middle of the cylindrical body 10 and positioned in a secant plane extending parallel relative to the geometric axis of the bore 2. The blocks 80 and 81 are provided with elongated openings 82 in which fastening screws 83 are received to allow the displacement, positioning and subsequent fastening of the blocks 80 and 81 in the slot 8 during a balancing operation. Even though it is not illustrated in Figure 4, this balancing system may also be provided in the alternative embodiment shown in Figure 4 and described below.

The cylindrical body 10 also incorporates in its periphery in a secant position and substantially at a right angle to the second bore 2, a rounded slot 9 which provides space for receiving the screw 55 which clamps the tool tip 51 onto the tool shank 50 as is shown in Figures 1 and 3.

Figures 4, 4a, 4b and 4c show an alternative embodiment of a boring tool for the finish machining of through bores. In this embodiment, and as shown in Figure 4b, backlash suppression between the teeth 22, provided in the toothed segment 20, and the teeth 52' provided in the tool shank 50', is also accomplished in a positive manner by having the teeth 22 and 52' interact under force one against the other. In this embodiment, an indented plunger 90 is precision mounted and slidable in axial bore 53' provided internally in the body of the tool shank 50'. The indented plunger 90 is provided with teeth or indentations 91 in the same plane as the teeth 52' of the tool shank 50' and engaging the teeth or indentations 22 of

the toothed segment 20.

Backlash elimination between the teeth, schematically illustrated in Figure 4b, is accomplished by adjusting a stud 92, which is threaded in an internal thread provided in the tool shank 50', such that the adjustment of the stud 92 displaces the indented plunger 90 relative to the tool shank 50' in the direction of arrow 93. This causes flanks 94 of the teeth 52' of the tool shank 50' to abut flanks 22a of the teeth 22 of the toothed segment 20, and similarly flanks 95 of the teeth 91 of the indented plunger 90 are caused to abut flanks 22b of the teeth 22 of the toothed segment 20.

Once the adjustment has been made by way of the stud 92 so that the teeth flanks are put into contact under a metal to metal condition, the arrangement is totally free of backlash but still enables smooth sliding of the toothed segment 20 and the tool shank 50'. The stud 92 may then be locked by tightening the lock stud 96.

As illustrated in Figures 4, 4a and 4b, and as already explained, rotation of the stud 92 moves it in the interior of the shank 50', and it thereby pushes the indented plunger 90 forcing it to travel in the direction of arrow 93. The body of the tool shank 50' is thereby simultaneously forced or pushed to travel in the direction indicated by arrow 93a, that is, in the opposite direction to the movement of the plunger 90 and in its withdrawal direction.

As shown in Figure 4b, the relative movement of the two parts 90 and 50' is in opposite directions and their teeth, that is, teeth 52' of tool shank 50' and teeth 91 of plunger 90, act on respective opposed flanks 22a and 22b of teeth 22 of the toothed segment 20. The profiles of the teeth flanks are not parallel but are convergent flanks.

The teeth may have a triangular prismatic shape, the shape of an involute, a shape in which the flanks are of unequal profiles, or any other shape in which the thickness of the teeth decreases as the profile approaches the converging line at the top of the teeth. Their profiles cause the withdrawal or retraction of the toothed segment 20 in the direction indicated by arrow 100 and the withdrawal or retraction of the parts 90 and 50' in the direction of arrows 101 and 102 respectively. It will be seen that the retraction of the parts 90 and 50' is in the direction opposite to the direction of retraction of the toothed segment 20.

As can be seen in Figure 4, the parts 20 and 50' are lodged in a slidable manner in appropriate bores provided in the cylindrical body 10, and the plunger 90 is lodged, also in a slidable manner, in the axial bore 53' of the tool shank 50'. The withdrawal movements will cease when all clearances have been suppressed. These clearances are between the inclined teeth, and also on one side between the toothed segment 20 and the cylindrical body 10 and on the other side between the plunger 90 and the tool shank 50' against which the plunger 90 is pushed by the effect of the inclined teeth. The clearances which are suppressed also include clearances between the shank 50' and the cylindrical body 10, against which the tool shank 50' is pushed either by the inclined teeth or by the reaction effect of the plunger 90 on the tool shank 50'.

When a displacement of the toothed segment 20 and the tool shank 50' is reached under a metal to metal sliding condition, with zero clearance and zero interference, a condition of absolute prevention of angular displacement of the toothed segment 20 relative to the cylindrical body 10 is established. In this respect, the bearing contact in opposite flanks 22a and 22b of the teeth of the toothed

segment 20 in its external portion form with the centre (axis) B of the micrometric screw 30 rectangular triangles ABC and DBC as illustrated in Figure 4c. In points A and D of the hypotenuses AB and DB, the teeth of the toothed segment 20 are in contact metal to metal at points E and F of corresponding teeth 91, 52' of the plunger 90 and the tool shank 50'. This prevents any angular movement of the toothed segment 20 even though where the toothed segment 20 slides in the bore 1 of the body 10 the cross sectional configuration of the toothed segment 20 and the mating geometric shape of the bore 1 perpendicular to the sliding axis, correspond to a perfect circle. In this respect, the toothed segment 20 has a flat plane cut secant extending parallel to the axis of said toothed segment 20 which bears on a flat and parallel plane on the tool shank 50' and on the plunger 90.

Looking at Figures 2, 3 and 4b, the sliding action of the tool shank 50, 50' and of the toothed segment 20 within the bores 2 and 1, respectively is totally free from backlash or play. Similarly, the sliding action is also totally free from any backlash between the flanks of the teeth 22, 52 or 22, 52' and 91. The rotation of the micrometric screw 30 is totally free from backlash at the internal thread 21, and totally free from axial backlash since the adjacent faces of rings 40 and 42 that are spaced by the spacer ring 41 retain the collar 35 of the micrometric screw 30 between the portions 33 and 34 prevent axial play of said micrometric screw 30. Furthermore, the components of the system can be engaged to ensure that the pre-set radial distance GF-EG, as shown in Figure 4, is precisely maintained to within a micron. In ensuring that the displacement of all moving parts is free from backlash it can be ensured that stability is provided to the position of the edge of the tool 51 such that the GF-EG radial distance from the tool edge farthest point to the

geometric axis of the cylindrical body 10 is guaranteed to within a micron μ . Thus, in a revolution of 360° precision repeatability is positively assured in a constant way until tool wear occurs.

5

To sum up, the degree of reading fineness in micrometric devices either for through or blind bores depends upon a combination of two effects generated by two motion reduction systems or demultipliers. The first of these effects is the displacement of the toothed segment 20 along the axial direction of the micrometric screw 30 obtained from one completed turn of the knob 43. The consequent rotation of the micrometric screw 30 can be mathematically represented by a quotient QI which is defined as being the ratio between the pitch thread in millimetres of the micrometric screw 30 and the number of divisions or lines on the graduated scale 43a of the knob 43. The quotient QI represents an initial stage of the displacement of the toothed segment 20. Whilst this initial displacement is taking place in the toothed segment 20, it imposes a displacement on the tool shank 50, 50' in a manner such that the final displacement of the tool shank 50, 50' is only a fraction of the initial displacement of the toothed segment 20, as explained below.

25

Suppose, for example, that the micrometric screw 30 has a 0.5mm pitch and is connected to a knob 43 having a scale 43a with 50 divisions (lines). This will enable readings at 0.01mm, that is, one hundredth of a millimetre of each division (line) in relation to the displacement imposed on the toothed segment 20. Thus, QI is $0.5/50 = 0.01\text{mm/line}$.

30

The second effect can be mathematically represented by the quotient QII, which is the ratio between the amount of displacement of the toothed segment 20 and the amount of

35

radial displacement of tool shank 50, 50', and consequently of tool tip 51 produced by this displacement. The quotient QII is a function of angle α , and is defined as the resolution ratio of refinement or improvement of the system.

As an example, if the displacement of the toothed segment 20 is 0.01mm for each division (line) of the graduated scale 43a, and if the radial displacement caused to the tool shank 50, 50' is, for instance, 0.0005mm for each division (line), the resolution ratio is represented by the expression $0.01/0.0005 = 20$ or 1:20. That is, the radial displacement of the tool tip 51 is as many times smaller than the displacement of the toothed segment 20, as is the resolution ratio.

This means that by varying the angle α according to the mathematical ratio that connects it to other parameters, any resolution ratio can be obtained. That is, a given amount of displacement of the toothed segment 20 causes a radial displacement to the tool shank 50, 50' of greater or lesser magnitude than the displacement of the toothed segment 20 according to the value of the angle α .

The resolution ratio is so called because it represents the resolution refinement of the system, that is, the ratio between the variation that can be obtained in the distance GF-EG and the displacement variation of the toothed segment 20. It should be noted that the resolution refinement is nothing but the demultiplying ratio.

A third and final effect is the proper radial displacement caused to the tool shank 50, 50', and to the tool tip 51 as a result of the rotation of the graduated knob 43 and consequently, of the micrometric screw 30. This third effect is an association of the two previously

described effects, and can be represented mathematically by a quotient QIII which is the ratio of quotients QI and QII.

5 As an example, if $QI = 0.5/50 = 0.01\text{mm/line}$ and if $QII = 0.01/0.0005 = 20$, quotient QIII will be: $QI/QII = 0.01/20 = 0.0005\text{mm/line}$.

10 From the above it will be seen that the distance GF-EG which is the radius described by the farthest point on the tool tip from its geometric axis of rotation can be changed by only three conditions, namely:

- 15 1. change and/or alteration in the position of the geometric axis;
2. tool wear; and
- 20 3. change made by an operator or other external means to the graduated scale 43a by way of through knob rotation.

20 No other condition makes it possible to change the distance GF-EG within ultra precision standards, since the maximum permitted axial motion of the micrometric screw, and the maximum permitted backlash between the thread of
25 said screw and the thread of its nut, results in negligible deviation of the tool edge relative to its rotational geometric axis.

30 Furthermore, it should be considered that a maximum backlash of 0.002mm between the collar 35 of the micrometric screw 30 and its rings 40, 41, 42 can be reduced by utilising the elastic property of the materials from which the rings 40, 41, 42 are made, which when submitted to compression through the proper tightening of
35 the screws 45, said maximum 0.002mm backlash can be progressively reduced to very minute amounts in the order

of 0.0001mm tending towards zero.

As is explained above, the maximum permitted backlash of 0.002mm in the screw collar can be reduced to of the order of 0.0001mm (one tenth of a micron) through the effect produced by elastic deformation of the rings 40, 41, 42. Furthermore, the maximum permitted backlash or play between the thread of the micrometric screw 30 and its bush 24, can also be reduced through backlash suppression by acting on the hollow stud 26. This enables a reduction in backlash or play between the micrometric screw 30 and the bush 24 down to of the order of 0.0001mm (one tenth of a micron). Thus, a boring tool as illustrated and described meets the requirements imposed by the definition of ultra-precision class or precision degree as it is accepted and understood within the present state of the art. It is also important to point out that the effect produced by the peculiar elastic deformation of materials to which rings 40, 41, 42 can be submitted, has been foreseen, duly considered and theoretically analysed at the conception (design) stage and then evidenced by laboratory tests, and that the research carried out has positively confirmed the validity of what was foreseen and previously considered.

Although a specific construction of a sub-micron boring tool and pre-setting system has been described and illustrated, it will be understood that structural changes can be made to the embodiments illustrated within the scope of the claims of the present application.



CLAIMS

1. A boring tool having a substantially cylindrical body having a first bore therein, and a second bore opening in
5 the circumferential surface of said body and intercepting said first bore, said boring tool comprising a tool shank for carrying a tool tip movably received within said second bore, a rotatable control knob carried by said body for enabling the position of the tool shank in said second bore
10 to be set, and moving means in said first bore for moving said tool shank, said moving means being coupled to said control knob and being arranged to move said tool shank in said bore in response to rotation of said control knob, and further comprising backlash suppression means for
15 suppressing backlash of said tool shank, said backlash suppression means acting on said tool shank to bias the tool shank in a direction substantially along the second bore generally inwardly of the circumferential surface of said body.
- 20 2. A boring tool as claimed in Claim 1, wherein said backlash suppression means comprises resilient means housed in a tool shank bore extending within said tool shank.
- 25 3. A boring tool as claimed in Claim 2, wherein said resilient means comprise a first threaded stud threaded into said tool shank bore and urged in a direction inwardly of the circumferential surface of said body by means of a spring.
- 30 4. A boring tool as claimed in Claim 3, wherein said spring is received in said tool shank bore and has a first end acting on said first threaded stud and a second end acting on a second threaded stud, said second threaded stud
35 being threaded into a further bore which extends in said body and intercepts said tool shank bore.



5. A boring tool as claimed in Claim 1, wherein said backlash suppression means comprises a plunger slidably received within a bore extending generally axially within said tool shank, said plunger carrying engagement means for engagement with said moving means.

6. A boring tool as claimed in Claim 5, wherein said moving means carries teeth or indentations for engagement with corresponding teeth or indentations carried by said tool shank whereby said tool shank is movable by said moving means, and wherein said engagement means of the plunger comprise teeth or indentations carried by said plunger for engagement with the teeth or indentations carried by said moving means.

7. A boring tool as claimed in Claim 5 or Claim 6, wherein a threaded stud is engaged with said axial bore of said tool shank in abutment with said plunger such that adjustment of the position of the threaded stud within said axial bore adjusts the position of the plunger.

8. A boring tool as claimed in any preceding Claim, wherein said moving means comprises a rotatable micrometric screw extending along said first bore, said micrometric screw being connected to said control knob at or near one end of the screw such that rotation of the control knob rotates the screw, and transmission means located within said first bore, said transmission means having an axial bore therethrough through which said micrometric screw extends, said screw being coupled to said transmission means such that rotation of the screw moves said transmission means, and said transmission means being coupled to said tool shank.

9. A boring tool as claimed in Claim 8, wherein said transmission means comprises a toothed segment arranged to



be reciprocated by rotation of said micrometric screw, and wherein teeth of said toothed segment engage with corresponding teeth on said tool shank.

- 5 10. A boring tool as claimed in Claim 9, wherein to suppress backlash between the tool shank and the toothed segment a movement demultiplier mechanism is provided comprising teeth or indentations arranged longitudinally in a secant plane to the toothed segment and inclined relative to the geometric axis of the toothed segment, said teeth or indentations being selectively engageably in a backlash free manner on corresponding teeth or indentations provided in the secant plane of the tool shank.
- 10
- 15 11. A boring tool as claimed in any of Claims 8 to 10, further comprising a bushing retained within said first bore, said bushing having an internal thread with which said transmission means is engaged.
- 20 12. A boring tool as claimed in Claim 11, wherein said micrometric screw is provided with a threaded portion at its end remote from the control knob which extends through the axial bore provided in the toothed segment and meshes with the internal thread provided in the bushing, and wherein said bushing is received with an extension of a hollow stud, and the end of said hollow stud being threadedly connected to said toothed segment.
- 25
- 30 13. A boring tool as claimed in Claim 12, wherein the toothed segment is axially slidable within said first bore of said cylindrical body, sliding movement of said toothed segment being caused by rotation of the control knob and consequent rotation of the micrometric screw.
- 35 14. A boring tool as claimed in any of Claims 9 to 13, wherein said backlash suppression means comprises a plunger



slidably received within a bore extending generally axially within said tool shank and carrying teeth or indentations for engagement with corresponding teeth or indentations of said toothed segment, and wherein adjustment of said
5 plunger is by way of an axial bore and wherein the plunger is adjusted such that metal to metal contact occurs between flanks of teeth or indentations of the toothed segment with flanks of the teeth or indentations of both the plunger and the tool shank, said adjusting stud being lockable in the
10 adjusted position by way of a lock stud.

15. A boring tool as claimed in Claim 14, wherein movement of the adjusting stud inwardly of the tool shank causes movement of the plunger in the direction radially outwardly
15 and movement of the tool shank in the opposite direction generally inwardly of the circumferential surface of said body.

16. A boring tool as claimed in any preceding Claim,
20 wherein said micrometric screw is held positively within said first bore by one or more rings which are held in said first bore and prevented from axial movement in said first bore.

25 17. A boring tool as claimed in Claim 16, wherein said first bore extends longitudinally of said substantially cylindrical body and is stepped to have a first portion with a diameter which is larger than that of a second portion, wherein the rings supporting the micrometric screw
30 are received in said first, larger diameter, portion of the stepped first bore and wherein screws extend through said rings are fastened into a wall of said first portion to positively hold said micrometric screw.

35 18. A boring tool as claimed in Claim 17, wherein at an end external to the cylindrical body said micrometric screw



has a tapered seat whose diameter converges towards the external end of the micrometric screw, and wherein said control knob encloses and is rigidly connected to said tapered seat.

5

19. A boring tool as claimed in any preceding Claim, wherein said rotatable control knob has an external, peripherally extending graduated scale thereon, and wherein a reference index or point is provided on said cylindrical
10 body adjacent to said graduated scale.

20. A boring tool substantially as hereinbefore described with reference to the accompanying drawings.
