Claims

1. Method for machining a rotary cutting tool (10) by a grinding machine, comprising:

a) mounting a workpiece (10a) in a spindle (20) of the grinding machine;

b) machining a calibration portion (CP) of the workpiece (10a) by performing one or a plurality of marks (M1, M2, M3, M4) on said workpiece with one abrasive wheel or with a corresponding plurality of abrasive wheels (W1, W2, W3, W4) of different shapes, wherein said one mark or each mark (M1, M2, M3, M4) comprises at least one geometrical feature (R1, R2, a1, a2, *L*) and two position features (D1, D2) corresponding respectively to a geometrical feature ($R1^w$, $R2^w$, $a1^w$, $a2^w$, L^w) and to 3D coordinates ($D1^w$, $D2^w$) of the corresponding abrasive wheel, in a X-Y-Z coordinate system of the grinding machine, that has ground the corresponding mark (M1, M2, M3, M4);

c) performing measurements of said at least one geometrical feature (R1, R2, a1, a2, *L*) and said two position features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP);

d) generating a sequence of instructions based on said at least one geometrical feature and on said two position features of said one mark or each mark as measured under step c) to grind said workpiece (10a) to the final and desired shape of the cutting tool (10), and

e) controlling the 3D coordinates of said one or more abrasive wheels (W1, W2, W3, W4) in said X-Y-Z coordinate system during grinding operations on the workpiece or on another workpiece according to said sequence of instructions to obtain said cutting tool (10).

2. Method according to claim 1, wherein at least one geometrical feature ($R1^w$, $R2^w$, $a1^w$, $a2^w$, L^w) of the abrasive wheel (W1, W2, W3, W4) that has ground a mark corresponds to an angle or an edge radius of said abrasive wheel.

3. Method according to any preceding claim, wherein the measurements of one or more geometrical features (R1, R2, a1, a2, L) and of said two position

features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) are performed automatically by a laser imaging system embedded in the grinding machine once step b) completed, for example by performing a laser scan along the calibration portion (CP) of the workpiece (10a).

4. Method according to any preceding claim, wherein each of said plurality of marks (M1, M2, M3, M4) is ground with one abrasive wheel of a corresponding plurality of abrasive wheels (W1, W2, W3, W4) of different shapes that are necessary to grind said workpiece (10a) to the final and desired shape of the cutting tool (10).

5. Method according to any preceding claim, further comprising a step of performing a direct measurement of one or more geometrical features of said one abrasive wheel or each of said plurality of abrasive wheels (W1, W2, W3, W4) by means of a pre-setting device before machining said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) under step b).

6. Method according to any preceding claim, further comprising the step of performing a measurement of the position of the workpiece, along one axis (Z) of the X-Y-Z coordinate system of the grinding machine, wherein the 3D coordinates ($D1^w$, $D2^w$) of said one abrasive wheel or each of said plurality of abrasive wheels (W1, W2, W3, W4), in the X-Y-Z coordinate system of the grinding machine, are determined based on said measured position of the workpiece along said axis and said two position features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion performed under step b).

7. Method according to any preceding claim, wherein said plurality of marks (M1, M2, M3, M4) of the calibration portion (CP) are performed on the workpiece (10a) next to each other along the longitudinal axis (Z) of said workpiece or along a transverse axis (A^T) extending from one end to an opposite end of the calibration portion.

8. Method according to any preceding claim, wherein the measurements of said at least one geometrical feature (R1, R2, a1, a2, *L*) and of said two position features (D1, D2) of each mark (M1, M2, M3, M4) performed under step c) are saved for each abrasive wheel of said plurality of abrasive wheels (W1, W2, W3, W4), and wherein said measurements are retrieved for performing at least two successive grinding operations on the workpiece to obtain said rotary cutting tool.

9. Method according to any preceding claim, wherein the first position feature (D1) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) defines a first position along a first axis (Z) of the three coordinate axes of the X-Y-Z coordinate system of the grinding machine, said first axis coinciding with the longitudinal axis of the workpiece.

10. Method according to the preceding claim, wherein the second position feature of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) is used to determine a diameter (D2) of the corresponding abrasive wheel (W1, W2, W3, W4) used for performing said one mark or each mark, and wherein a second and a third position along respectively a second and a third axis of said coordinate system are determined based on said diameter to compute the 3D coordinates of said corresponding abrasive wheel.

11. Method according to any preceding claim, wherein said one mark or each mark (M1, M2, M3, M4) of the calibration portion comprises at least one radius (R1, R2) to determine at least one radius of the corresponding abrasive wheel (W1, W2, W3, W4).

12. Method according to any preceding claim, wherein said calibration portion (CP) is machined at a distal end portion (10b) of the workpiece.

13. Method according to any preceding claim, wherein said rotary cutting tool is made from the workpiece (10a) which has been previously machined to obtain said calibration portion (CP).

14. Method according to any preceding claim, wherein said rotary cutting tool comprises a helical flute (12) which is machined by controlling the 3D coordinates position of a fluting wheel (W1) based at least in part on at least a first and a second distinct geometrical feature ($R1^w$, $a1^w$) of the fluting wheel.

15. Method according to the preceding claim, wherein the control of the 3D coordinates position of the fluting wheel (W1) for machining the helical flute is further based on one or more of three additional distinct geometrical features (L^w, $a2^w$, $R2^w$) of the fluting wheel.

16. Method according to any claims 1 to 13, wherein the cutting tool is an end-mill cutter comprising end relief faces which are machined by controlling the 3D coordinates of an end-relief wheel (W4) based at least in part on at least one geometrical feature (R1') of the end-relief wheel.

17. Method according to the preceding claim, wherein the end-mill cutter comprises end gashes which are machined by controlling the 3D coordinates position of a gashing wheel (W3) based at least in part on two distinct geometrical features of the gashing wheel.

18. Method according to claim 16 or 17, wherein the end-mill cutter comprises outer diameter relieve lands which are machined by controlling the 3D coordinates position of an outer diameter relief wheel (W2) based at least in part on three distinct geometrical features ($R1^w$, $a1^w$, $a2^w$) of the OD relief wheel.

19. Computer-readable storage medium storing instructions that when executed by a computer of a grinding machine cause the machine to perform a calibration routine and to grind a cutting tool comprising:

a) retrieving and storing a first set of measurement values of geometrical

features (R1, R2, a1, a2) and position features (Z, ØD) of the specific shape of one or of each abrasive wheel of a set of abrasive wheels (W1, W2, W3, W4) of different shapes, wherein the first set of measurement values is obtained by a pre-setting device,

b) computing a first sequence of instructions based on said first set of measurement values for grinding one or more marks (M1, M2, M3, M4) on a workpiece,

c) retrieving and sorting a second set of measurement values of at least one geometrical feature (R1, R2, a1, a2, L) and position features (D1, D2) of one or more marks (M1, M2, M3, M4) performed on the workpiece (10a) by said one or each corresponding abrasive wheel of said set of abrasive wheels (W1, W2, W3, W4),

d) computing a second sequence of instructions based on said second set of measurements values, and

e) grinding the cutting tool by executing said second sequence of instructions.

20. Computer-readable storage medium according to the preceding claim, wherein the first set of measurements values is retrieved under step a) for each of at least two abrasive wheels, preferably for each of at least three abrasive wheels of a said set of abrasive wheels (W1, W2, W3, W4) of different shapes, and wherein the sequence of instructions under step b) is computed for grinding at least two marks, preferably at least three marks (M1, M2, M3, M4) next to each other along a distal portion of the workpiece.

Claims

1. Method for machining a rotary cutting tool (10) by a grinding machine, comprising:

a) mounting a workpiece (10a) in a spindle (20) of the grinding machine;

b) machining a calibration portion (CP) of the workpiece (10a) by performing one or a plurality of marks (M1, M2, M3, M4) on said workpiece with one abrasive wheel or with a corresponding plurality of abrasive wheels (W1, W2, W3, W4) of different shapes, wherein said one mark or each mark (M1, M2, M3, M4) comprises at least one geometrical feature (R1, R2, a1, a2, *L*) and two position features (D1, D2) corresponding respectively to a geometrical feature ($R1^w$, $R2^w$, $a1^w$, $a2^w$, L^w) and to 3D coordinates ($D1^w$, $D2^w$) of the corresponding abrasive wheel, in a X-Y-Z coordinate system of the grinding machine, that has ground the corresponding mark (M1, M2, M3, M4);

c) performing measurements of said at least one geometrical feature (R1, R2, a1, a2, *L*) and said two position features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP);

d) generating a sequence of grinding instructions based on said at least one geometrical feature and on said two position features of said one mark or each mark as measured under step c) to grind said workpiece (10a) to the final and desired shape of the cutting tool (10), and

e) controlling the 3D coordinates of said one or more abrasive wheels (W1, W2, W3, W4) in said X-Y-Z coordinate system during grinding operations on the workpiece or on another workpiece according to said sequence of grinding instructions to obtain said cutting tool (10).

2. Method according to claim 1, wherein at least one geometrical feature ($R1^w$, $R2^w$, $a1^w$, $a2^w$, L^w) of the abrasive wheel (W1, W2, W3, W4) that has ground a mark corresponds to an angle or an edge radius of said abrasive wheel.

3. Method according to any preceding claim, wherein the measurements of one or more geometrical features (R1, R2, a1, a2, L) and of said two position

features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) are performed automatically by a laser imaging system embedded in the grinding machine once step b) completed, for example by performing a laser scan along the calibration portion (CP) of the workpiece (10a).

4. Method according to any preceding claim, wherein each of said plurality of marks (M1, M2, M3, M4) is ground with one abrasive wheel of a corresponding plurality of abrasive wheels (W1, W2, W3, W4) of different shapes that are necessary to grind said workpiece (10a) to the final and desired shape of the cutting tool (10).

5. Method according to any preceding claim, further comprising a step of performing a direct measurement of one or more geometrical features of said one abrasive wheel or each of said plurality of abrasive wheels (W1, W2, W3, W4) by means of a pre-setting device before machining said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) under step b).

6. Method according to any preceding claim, further comprising the step of performing a measurement of the position of the workpiece, along one axis (Z) of the X-Y-Z coordinate system of the grinding machine, wherein the 3D coordinates ($D1^w$, $D2^w$) of said one abrasive wheel or each of said plurality of abrasive wheels (W1, W2, W3, W4), in the X-Y-Z coordinate system of the grinding machine, are determined based on said measured position of the workpiece along said axis and said two position features (D1, D2) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion performed under step b).

7. Method according to any preceding claim, wherein said plurality of marks (M1, M2, M3, M4) of the calibration portion (CP) are performed on the workpiece (10a) next to each other and spaced apart from each other along the longitudinal axis (Z) of said workpiece or along a transverse axis (A^T) extending from one end to an opposite end of the calibration portion.

8. Method according to any preceding claim, wherein the measurements of said at least one geometrical feature (R1, R2, a1, a2, *L*) and of said two position features (D1, D2) of each mark (M1, M2, M3, M4) performed under step c) are saved for each abrasive wheel of said plurality of abrasive wheels (W1, W2, W3, W4), and wherein said measurements are retrieved for performing at least two successive grinding operations on the workpiece to obtain said rotary cutting tool.

9. Method according to any preceding claim, wherein the first position feature (D1) of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) defines a first position along a first axis (Z) of the three coordinate axes of the X-Y-Z coordinate system of the grinding machine, said first axis coinciding with the longitudinal axis of the workpiece.

10. Method according to the preceding claim, wherein the second position feature of said one mark or each mark (M1, M2, M3, M4) of the calibration portion (CP) is used to determine a diameter (D2) of the corresponding abrasive wheel (W1, W2, W3, W4) used for performing said one mark or each mark, and wherein a second and a third position along respectively a second and a third axis of said coordinate system are determined based on said diameter to compute the 3D coordinates of said corresponding abrasive wheel.

11. Method according to any preceding claim, wherein said one mark or each mark (M1, M2, M3, M4) of the calibration portion comprises at least one radius (R1, R2) to determine at least one radius of the corresponding abrasive wheel (W1, W2, W3, W4).

12. Method according to any preceding claim, wherein said calibration portion (CP) is machined at a distal end portion (10b) of the workpiece.

13. Method according to any preceding claim, wherein said rotary cutting tool is made from the workpiece (10a) which has been previously machined to obtain said calibration portion (CP).

14. Method according to any preceding claim, wherein said rotary cutting tool comprises a helical flute (12) which is machined by controlling the 3D coordinates position of a fluting wheel (W1) based at least in part on at least a first and a second distinct geometrical feature ($R1^w$, $a1^w$) of the fluting wheel.

15. Method according to the preceding claim, wherein the control of the 3D coordinates position of the fluting wheel (W1) for machining the helical flute is further based on one or more of three additional distinct geometrical features (L^w, $a2^w$, $R2^w$) of the fluting wheel.

16. Method according to any claims 1 to 13, wherein the cutting tool is an end-mill cutter comprising end relief faces which are machined by controlling the 3D coordinates of an end-relief wheel (W4) based at least in part on at least one geometrical feature (R1') of the end-relief wheel.

17. Method according to the preceding claim, wherein the end-mill cutter comprises end gashes which are machined by controlling the 3D coordinates position of a gashing wheel (W3) based at least in part on two distinct geometrical features of the gashing wheel.

18. Method according to claim 16 or 17, wherein the end-mill cutter comprises outer diameter relieve lands which are machined by controlling the 3D coordinates position of an outer diameter relief wheel (W2) based at least in part on three distinct geometrical features ($R1^w$, $a1^w$, $a2^w$) of the OD relief wheel.

19. Computer-readable storage medium storing instructions that when executed by a computer of a grinding machine cause the machine to perform a calibration routine and to grind a cutting tool comprising:

a) retrieving and storing a first set of measurement values of geometrical features (R1, R2, a1, a2) and position features (Z, ØD) of the specific shape of one or of each abrasive wheel of a set of abrasive wheels (W1, W2, W3, W4) of different shapes, wherein the first set of measurement values is obtained by a pre-setting device,

b) computing a first sequence of instructions based on said first set of measurement values for grinding one or more marks (M1, M2, M3, M4) on a workpiece according to step b) of claim 1,

c) retrieving and sorting a second set of measurement values of at least one geometrical feature (R1, R2, a1, a2, L) and position features (D1, D2) of one or more marks (M1, M2, M3, M4) performed on the workpiece (10a) by said one or each corresponding abrasive wheel of said set of abrasive wheels (W1, W2, W3, W4), and

d) computing a second sequence of instructions based on said second set of measurements values to generate said sequence of grinding instructions according to step d) of claim 1.

20. Computer-readable storage medium according to the preceding claim, wherein the first set of measurements values is retrieved under step a) for each of at least two abrasive wheels, preferably for each of at least three abrasive wheels of said set of abrasive wheels (W1, W2, W3, W4) of different shapes, and wherein the sequence of instructions under step b) is computed for grinding at least two marks, preferably at least three marks (M1, M2, M3, M4) next to each other along a distal portion of the workpiece.