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The invention relates to the broaching of at least one slot (3) in a part such as a turbine rotor disk (4) or a turbomachine compressor disk, said slot (3) being machined by means of a broach (1) inclined at a broaching angle (α). Said broach (1) has an inter-tooth pitch (P) that is a sub-multiple of the length to be broached (L).
BROACH AND METHOD FOR BROACHING SLOTS FOR PARTS SUCH AS TURBINE ROTOR DISKS OR TURBOMACHINE COMPRESSOR DISKS

GENERAL TECHNICAL FIELD AND PRIOR ART

0001 The present invention relates to broaching of slots for parts such as turbine rotor discs or turbomachine compressor discs.

0002 It applies especially to broaching of slots of “firing sections” or “bolts” type for rotor discs or turboengine compressors or aircraft turboprop.

0003 In classical terms, a turboengine or aircraft turboprop comprises a compressor part and a rotary turbine. This turbine in turn comprises a rotor disc which has peripheral attachments (slots in the form of “firing sections” or “bolts”) which are distributed over its circumference and which take up and hold the feet of the blades of said turbine. Some compressor discs also comprise such attachments.

0004 These attachments are generally machined by broaching.

0005 For this reason, as illustrated in FIG. 1A, several passes in a slot 3 to be machined are made using a set of broaches 1.

0006 In the case of slots 3 as “firing tree sections” or in the form of “bolts” on the periphery of a rotor disc 4 of a turbomachine turbine or a compressor disc, the broaching is often done at a specific inclination (broaching angle α in FIG. 1A). Due to this, for a given broach 1 to be advanced into the slot 3 for machining, the teeth 2 of this broach 1 (spaced at a given pitch P) exert on the walls of the slot 3 in formation alternative forces due to the entrance and exit of the teeth in this slot 3.

0007 These alternative forces (arrows F1, F2, F3 in FIG. 1A) produce variation in the direction of forces applied to the broach 1 (resulting arrow F), as illustrated in FIG. 1B. The result is deformation of the broached slot.

0008 This problem is particularly exacerbated in the case of small-sized parts.

0009 An aim of the invention is to resolve this problem.

0010 Many general multicriterion methods of optimisation of broaching tools have already been proposed.

0011 In general, manufacturers of broaches are prohibited from using sub multiple pitches of the thickness to be broached. In the most current cases where the parts to be broached are stacked, use of a sub-multiple pitch of the thickness to be broached is likely to generate substantial deformations on the parts. In general, this rule is also applied in the event where a single part is broached.


0013 The authors indicate in this article that even with this solution it is extremely difficult to produce a variation in zero force between the entry and exit of a part.

0014 Also, this article does not focus on the problems of inclined broaching.

GENERAL PRESENTATION OF THE INVENTION

0015 An aim of the invention is especially to reduce the variation in cutting forces and reduce deforming of slots.

0016 For this purpose, a broaching process is proposed of at least one slot in a part such as a turbine rotor disc or a turbomachine compressor disc, said slot being machined by means of an inclined broach with a broaching angle relative to the part. Said broach has an inter-tooth pitch as a sub-multiple of the length to be broached.

0017 So, given the difference between the thickness of the part to be broached and the length to be broached which is due to inclination of the broaching, the inter-tooth pitch of the broach is optimised so as to minimise deforming of the slots.

0018 A broach is also proposed for executing this process.

PRESENTATION OF FIGURES

0019 Other characteristics and advantages of the invention will emerge from the following description which is purely illustrative and non-limiting, and must be considered with respect to the appended figures, in which:

0020 FIGS. 1A and 1B schematically illustrate the broaching of a slot and the variation in cutting forces during descent of the broaching tool according to the known state of the art;

0021 FIG. 2 illustrates in side view a rotor disc and a machining broach of a slot of type “firing tree sections” at the periphery of this disc;

0022 FIG. 3 is a detailed view of FIG. 2;

0023 FIG. 4 is a detailed view which illustrates a tooth of the broach of FIGS. 2 and 3 in a slot machined on the rotor disc;

0024 FIGS. 5A and 5B illustrate slot broaching according to a possible embodiment of the invention, as well as the variation in cutting forces during descent of the broaching tool, FIG. 5A being a view similar to that of FIG. 1, along line A-A of FIG. 4.

EXEMPLARY EMBODIMENTS

0025 FIGS. 2 to 4 illustrate a rotor disc 4 comprising a plurality of slots 3, and a broach 1 utilised for machining the slots 3. The slots 3 in this case are in the form of “firing tree sections”, with other forms of attachment slots being possible of course (forms of “bolts” for example).

0026 The broach 1 comprises a plurality of teeth 2. Two successive teeth are separated in pairs by a core 5, the empty space between the core and the apex of the tooth constituting the chip chamber.

0027 The machining it executes is inclined (broaching angle α), such that the thickness Ep of the part to be broached constituted by the rotor disc 4 is different to the length to be broached L.

0028 As illustrated in FIG. 5A, the proposed broach utilises a broach pitch P as a sub-multiple of the length to be broached L.

0029 In this way, a tooth 2 enters the slot 3 in formation at the periphery of the machined part (rotor disc 4) at the moment when another tooth 2 exits from it.

0030 The forces (arrows F1 to F4 in FIG. 5A) of the cutting teeth 2 engaged with the walls of the machined slot 3 are balanced on either side of the slot 3. The variation in cutting forces (resulting F) is therefore limited and the alternative component of the forces is eliminated.
This principle is illustrated by FIG. 5B which represents the differential in forces of cut as a function of displacement.

Given the intervals of tolerancing admitted for the parts machined in this way, the value of the pitch is advantageously selected as equal to:

\[ P = \frac{1}{n} \cos\left(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}\right) \]

where:

\( E_{\text{pmax}} \) and \( E_{\text{pmin}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,

\( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing.

\( n \) is the preferred number of teeth engaged and being a positive whole number.

It should be noted that the thickness \( E_p \) is determined for a given pass of broach 1.

It is calculated from rim to rim between broaching edges on exit and entry of the machined slot 3.

It is likely to vary according to the depth of the slot to which the pass of the broach 1 corresponds, with a rotor disc able to have a variable thickness, especially at the level of its periphery.

The broaching angles \( \alpha \) are also determined for each pass. They correspond to the angle between the axis A of descent of the broach 1 and the thickness of the part 4 at the level of the area to be broached.

The broaching which has just been described is particularly interesting in the case of small-sized turbine rotor discs and in particular discs with reduced inter-blade spacing.

By way of example, this broaching can be used advantageously in the case of turbine discs or compressors with thicknesses less than 20 mm, a maximal slot depth (\( P_{\text{max}} \) in FIG. 4) of the order of 10 to 15 mm and a minimal slot width (\( c \) in FIG. 4) of 2 to 3 mm.

The number of teeth \( n \) is preferably equal to 2 but could also be equal to 3 or 4.

10. A broaching process of at least one slot in a part such as a turbine rotor disc or a turbomachine compressor disc, said slot being machined by means of an inclined broach with a broaching angle relative to the part, characterized in that said broach has an inter-tooth pitch \( P \) as a sub-multiple of the length to be broached (L).

11. The process according to claim 10, characterized in that the inter-tooth broach pitch \( P \) is equal to

\[ P = \frac{1}{n} \cos\left(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}\right) \]

where:

\( E_{\text{pmax}} \) and \( E_{\text{pmin}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,

\( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing.

\( n \) is a positive whole number.

12. The process according to claim 11, characterized in that \( n \) is between 1 and 4.

13. The process according to claim 12, characterized in that \( n \) is equal to 2.

14. The process according to claim 10, characterized in that a slot is a slot in the form of "fir tree sections" or in the form of "bulbs" machined at the periphery of a turbine rotor disc or a turbomachine compressor disc.

15. The process according to claim 11, characterized in that a slot is a slot in the form of "fir tree sections" or in the form of "bulbs" machined at the periphery of a turbine rotor disc or a turbomachine compressor disc.

16. The process according to claim 12, characterized in that a slot is a slot in the form of "fir tree sections" or in the form of "bulbs" machined at the periphery of a turbine rotor disc or a turbomachine compressor disc.

17. The process according to claim 13, characterized in that a slot is a slot in the form of "fir tree sections" or in the form of "bulbs" machined at the periphery of a turbine rotor disc or a turbomachine compressor disc.

18. A broach for executing a process according to claim 10, comprising a plurality of teeth distributed over its length by being separated in pairs at a given pitch, characterized in that the pitch of the broach is a sub-multiple of the length to be broached.

19. A broach for executing a process according to claim 11, comprising a plurality of teeth distributed over its length by being separated in pairs at a given pitch, characterized in that the pitch of the broach is a sub-multiple of the length to be broached.

20. The broach according to claim 14, characterized in that its pitch is equal to

\[ P = \frac{1}{n} \cos\left(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}\right) \]

where:

\( E_{\text{pmax}} \) and \( E_{\text{pmin}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,

\( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing.

\( n \) is the preferred number of engaged teeth being a positive whole number.

21. The broach according to claim 15, characterized in that its pitch is equal to

\[ P = \frac{1}{n} \cos\left(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}\right) \]

where:

\( E_{\text{pmax}} \) and \( E_{\text{pmin}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,

\( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing.

\( n \) is the preferred number of engaged teeth being a positive whole number.
22. The broach according to claim 16, characterized in that its pitch is equal to

\[ P = \frac{(\epsilon_{p}^{\text{max}} + \epsilon_{p}^{\text{min}})}{(n + \cos(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}))} \]

where:
- \( \epsilon_{p}^{\text{max}} \) and \( \epsilon_{p}^{\text{min}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,
- \( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing,
- \( n \) is the preferred number of engaged teeth (being a positive whole number).

23. The broach according to claim 17, characterized in that its pitch is equal to

\[ P = \frac{(\epsilon_{p}^{\text{max}} + \epsilon_{p}^{\text{min}})}{(n + \cos(\frac{\alpha_{\text{max}} + \alpha_{\text{min}}}{2}))} \]

where:
- \( \epsilon_{p}^{\text{max}} \) and \( \epsilon_{p}^{\text{min}} \) are the maximum and minimum thicknesses of the disc part given the tolerancing,
- \( \alpha_{\text{max}} \) and \( \alpha_{\text{min}} \) are the maximum and minimum broaching angles given the tolerancing,
- \( n \) is the preferred number of engaged teeth (being a positive whole number).

24. The broach according to claim 20, characterized in that \( n \) is between 1 and 4.

25. The broach according to claim 21, characterized in that \( n \) is between 1 and 4.

26. The broach according to claim 22, characterized in that \( n \) is between 1 and 4.

27. The broach according to claim 23, characterized in that \( n \) is between 1 and 4.

28. The broach according to claim 20, characterized in that \( n \) is equal to 2.

29. The broach according to claim 21, characterized in that \( n \) is equal to 2.

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