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(54) **GRINDING METHOD AND APPARATUS**

SCHLEIFFVERFAHREN UND VORRICHTUNG

PROCEDE ET APPAREIL DE MEULAGE

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- **VDI Z, vol. 132, no. 9, 1 September 1990 pages 120-125, XP 000108346 JANOCHA H ET AL 'AKTIVE DAMPFUNG DYNAMISCHER VORGANGE IN EINER AUSSENRUNDSCHLEIFMASCHINE'**

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## Description

### Field of the invention

[0001] This invention relates to a method of grinding a cylindrical workpiece surface.

### Background to the invention

[0002] It is well known that, when a cylindrical workpiece is being ground, the grinding process produces vibrations which generate lobes on the workpiece surface. This phenomenon is commonly known as chattering, and the resulting distortions on the workpiece are known as chatter-marks.

[0003] To some extent chatter-marks can be reduced by absolute truing of the grinding wheel, but this is time consuming and expensive, especially when the grinding surface is a super-abrasive such as diamond or CBN.

[0004] It is an object of the present invention to provide a method of reducing the tendency for generation of chatter-marks during grinding.

[0005] In GB-A-2268895 there is described and claimed a method of grinding a cylindrical workpiece surface in which the speed of rotation of the grinding wheel and/or the speed of rotation of the workpiece is changed one or more times during the final stage of grinding, the period of such rotational speed variation including at least part of the final dwell period in which sizing occurs, thereby to reduce chatter-marks on the workpiece.

### Summary of the invention

[0006] According to the present invention there is provided a method of grinding a cylindrical workpiece surface in which the speed of rotation of the grinding wheel and/or the speed of rotation of the workpiece is changed one or more times during the final stage of grinding in response to corresponding changes in a target value, the period of such rotational speed variation including at least part of the final dwell period in which sizing occurs, thereby to reduce chatter-marks on the workpiece, characterised by performing the steps of: measuring the speed of rotation of the wheel and/or of the workpiece during said final stage of grinding at each such desired change of speed, calculating a theoretical ratio of the rotational speed of the wheel to that of the workpiece for any given target value, and controlling the speeds of the wheel and/or workpiece in such a manner that if the fractional component of the theoretical ratio is 0.5 or less the fractional component of the actual ratio of the speed of the wheel to that of the workpiece for that target value is 0.25, and if the fractional component of the theoretical ratio is above 0.5, the fractional component of the actual ratio for that target value is 0.75.

[0007] In this way it is ensured that the ratio of the or each changed speeds is not a whole integer or in the

ratios of the second or third harmonics, and thereby any chatter marks in the workpiece are further reduced.

[0008] The method may be applied to internal as well as external grinding.

[0009] Moreover, it is to be noted that the speed variation effected is not dependent on vibration sensing of the grinding wheel or the workpiece.

[0010] The rotational speed change is preferably practised by a rotational speed change which includes a change in the rotational speed of the workpiece.

[0011] If the speed variation includes change in the rotational speed of the grinding wheel, any change made will usually be decelerative. Preferably, however, the rotational speed of the grinding wheel is kept constant.

[0012] The rotational speed change may be initiated either after a predetermined number of rotations of the workpiece, where the number of turns per grinding cycle is controlled, and/or at a predetermined feed distance before the feed position for final sizing, as indicated in more detail below.

[0013] Thus, the possibilities for workspeed variation are limitless if its rotational speed is servo-controlled relative to time, grinding wheel feed position, component size and/or number of component turns.

[0014] The speed change effected may therefore be linear, reduce or increase at a rate relative to the above variables, or be of another controlled forms such as sinusoidal.

[0015] However, the speed change is normally initiated during the slow approach to size feed, extending into the final dwell period in which sizing occurs.

### Description of embodiment

[0016] The practical implementation of the method of the invention is exemplified with reference to the accompanying drawings, in which:-

Figure 1 is a graph showing the feed of the grinding wheel, in terms of its distance from the workpiece, against time; and

Figure 2 is a much simplified diagram of a grinding machine.

[0017] Figure 1 is a typical feed diagram for the grinding wheel in a grinding process for grinding a cylindrical workpiece.

[0018] The grinding wheel feed includes a fine feed period 10 immediately prior to a stationary final dwell period 12 (size dwell) in which sizing occurs.

[0019] In accordance with the invention, at least one change in the rotational speed of the workpiece is initiated in the fine feed period, and this speed change is extended into at least part of the final dwell period 12.

[0020] Means are provided for measuring the speed of the grinding wheel immediately prior to a change of

speed of the workpiece, and the value of wheel speed is fed into a microprocessor associated with a servo controller for altering the speed of the workpiece. The target speed of the workpiece is also fed into the processor, which then calculates the ratio of the speed of the wheel to that of the workpiece. If the fractional part of the ratio (ie the mantissa) is 0.5 or less, the workpiece speed which was demanded by the operator of the grinding machine is adjusted slightly so that the mantissa becomes 0.25; alternatively if the calculated mantissa is above 0.5 it is adjusted to 0.75. In this manner any tendency for chatter marks to form on the workpiece is significantly improved, in that the harmonics of the speed ratios of wheel/workpiece up the third harmonics are eliminated.

[0021] In the simplified grinding machine shown in Figure 2, wherein the grinding wheel is referenced 14, the wheel feed indicated at 16, the workpiece at 18 and the workpiece support at 20, a means 22 is incorporated for changing the rotational speed of the workpiece 18, as aforesaid.

[0022] The means 22 is preferably constituted by a servo-controller, which automatically initiates a change in the workspeed at the aforesaid time and for the aforesaid period, for example dependently on the feed position, the number of turns of the workpiece in the grinding cycle, and/or component size.

[0023] The change effected is preferably not sudden, but is a relatively slow change which may be linear, sinusoidal or of any other desired form.

### Claims

1. A method of grinding a cylindrical workpiece surface in which the speed of rotation of the grinding wheel (14) and/or the speed of rotation of the workpiece (18) is changed one or more times during the final stage of grinding in response to corresponding changes in a target value, the period of such rotational speed variation including at least part of the final dwell period (12) in which sizing occurs, thereby to reduce chatter-marks on the workpiece, characterised by performing the steps of: measuring the speed of rotation of the wheel (14) and/or of the workpiece (18) during said final stage of grinding at each such desired change of speed, calculating a theoretical ratio of the rotational speed of the wheel to that of the workpiece for any given target value, and controlling the speeds of the wheel and/or workpiece in such a manner that if the fractional component of the theoretical ratio is 0.5 or less the fractional component of the actual ratio of the speed of the wheel to that of the workpiece for that target value is 0.25, and if the fractional component of the theoretical ratio is above 0.5, the fractional component of the actual ratio for that target value is 0.75.
2. A method according to claim 1 in which the rotational speed variation is practised by a rotational speed change which includes a change in the rotational speed of the workpiece.
3. A method according to claim 1 or claim 2 in which the speed variation includes a change in the rotational speed of the grinding wheel, such speed change being decelerative.
4. A method according to claim 1 in which the workpiece speed is adjusted, while that of the grinding wheel is maintained constant.
5. A method according to any one preceding claim in which the rotational speed variation is initiated either after a predetermined number of rotations of the workpiece, where the number of turns per grinding cycle is controlled, and/or at a predetermined feed distance before the feed position for final sizing.
6. A method according to any one preceding claim in which the rotational speed of the workpiece is servo-controlled relative to the variables of time, grinding wheel feed position, workpiece size and/or number of workpiece rotations.
7. A method according to any one preceding claim in which the speed change effected is linear, or reduces or increases at a rate relative to said variables, or is of another controlled form such as sinusoidal.
8. A method according to any one preceding claim in which the speed change is initiated during the slow approach to size feed, extending into the final dwell period in which sizing occurs.
9. A method according to any of the preceding claims in which the target value corresponds to a target rotational speed of the workpiece, which target speed is demanded by an operator of apparatus on which the method is performed.
10. A method according to any one preceding claim in which internal and/or external grinding is performed on the cylindrical workpiece.

### Patentansprüche

1. Verfahren zum Schleifen einer zylindrischen Werkstückoberfläche, bei dem die Drehzahl des Schleifrades (14) und/oder die Drehzahl des Werkstückes (18) ein oder mehrere Male während der Endstufe des Schleifvorganges in Abhängigkeit von entsprechenden Änderungen eines Zielwertes geändert wird, wobei die Periode einer solchen Drehzahlän-

- derung mindestens einen Teil der Endverweilperiode (12) einschließt, in der das Kalibrieren erfolgt, um Rattermarken auf dem Werkstück zu reduzieren, **dadurch gekennzeichnet**, daß folgende Schritte ausgeführt werden: Messen der Drehzahl des Rades (14) und/oder des Werkstückes (18) während der Endstufe des Schleifvorganges bei jeder solchen gewünschten Drehzahländerung, Berechnen eines theoretischen Verhältnisses der Drehzahl des Rades zu der des Werkstückes für einen gegebenen Zielwert, und Steuerung der Drehzahlen des Rades und/oder des Werkstückes in solcher Weise, daß die Teilkomponente des theoretischen Verhältnisses 0,5 oder weniger der Teilkomponente des tatsächlichen Verhältnisses der Drehzahl des Rades zu der des Werkstückes für diesen Zielwert 0,25 beträgt, und wenn die Teilkomponente des theoretischen Verhältnisses über 0,5 liegt, die Teilkomponente des tatsächlichen Verhältnisses für diesen Zielwert 0,75 beträgt.
2. Verfahren nach Anspruch 1, bei dem die Drehzahltoleranz durch eine Drehzahländerung praktiziert wird, die eine Änderung in der Drehzahl des Werkstücks einschließt.
  3. Verfahren nach Anspruch 1 oder 2, bei dem die Drehzahltoleranz eine Änderung in der Drehzahl des Schleifrades umfaßt, wobei eine solche Drehzahländerung verzögernd wirkt.
  4. Verfahren nach Anspruch 1, bei dem die Werkstückdrehzahl eingestellt wird, während die des Schleifrades konstant gehalten wird.
  5. Verfahren nach einem der vorausgehenden Ansprüche, bei dem die Drehzahltoleranz entweder nach einer vorbestimmten Anzahl von Umdrehungen des Werkstückes eingeleitet wird, wobei die Anzahl von Umdrehungen pro Schleifzyklus gesteuert wird, und/oder bei einem vorbestimmten Zustellabstand vor der Zustellposition für das abschließende Kalibrieren eingeleitet wird.
  6. Verfahren nach einem der vorausgehenden Ansprüche, bei dem die Drehzahl des Werkstückes relativ zu den Zeitvariablen, der Schleifrad-Zustellposition, der Werkstückgröße und/oder der Anzahl von Werkstückdrehungen servogesteuert wird.
  7. Verfahren nach einem der vorausgehenden Ansprüche, bei dem die erzielte Drehzahländerung linear ist, mit einer Rate relativ zu den Variablen reduziert oder erhöht wird, oder eine andere gesteuerte Form, z.B. einen sinusförmigen Verlauf hat.
  8. Verfahren nach einem der vorausgehenden

Ansprüche, bei dem die Drehzahländerung während der langsamen Annäherung an den Kalibrierorschub eingeleitet wird, die sich in die Endverweildauer erstreckt, in der das Kalibrieren erfolgt.

9. Verfahren nach einem der vorausgehenden Ansprüche, bei dem der Zielwert einer Ziel-Drehzahl des Werkstückes entspricht, wobei die Ziel-drehzahl durch eine die Maschine bedienende Person vorgegeben wird, an der das Verfahren durchgeführt wird.
10. Verfahren nach einem der vorausgehenden Ansprüche, bei dem das Innen- und/oder Außen-Schleifen an dem zylindrischen Werkstück durchgeführt wird.

#### Revendications

1. Une méthode de meulage d'une surface de pièce à usiner cylindrique dans laquelle la vitesse de rotation de la meule (14) et/ou la vitesse de rotation de la pièce à usiner (18) sont changées une ou plusieurs fois au cours de la phase finale du meulage en réponse aux changements correspondants d'une valeur ciblée, la durée d'une telle variation de vitesse de rotation incluant au moins une partie du temps d'arrêt final (12) au cours duquel le calibrage a lieu, afin de réduire les marques de broutage sur la pièce à usiner, caractérisée par l'exécution des étapes suivantes : mesure de la vitesse de rotation de la meule (14) et/ou de la pièce à usiner (18) au cours de ladite phase finale du meulage à chaque changement de vitesse désiré, calcul d'un rapport théorique de la vitesse de rotation de la meule en fonction de celle de la pièce à usiner pour n'importe quelle valeur ciblée donnée, et contrôle des vitesses de la meule et/ou de la pièce à usiner de façon à ce que, si la composante fractionnaire du rapport théorique est de 0,5 ou moins, la composante fractionnaire du rapport réel de la vitesse de la meule en fonction de celle de la pièce à usiner pour cette valeur ciblée est de 0,25, et si la composante fractionnaire du rapport théorique est supérieure à 0,5, la composante fractionnaire du rapport réel pour cette valeur ciblée est 0,75.
2. Une méthode conformément à la revendication 1 dans laquelle la variation de la vitesse de rotation est effectuée par un changement de vitesse de rotation qui inclut un changement de la vitesse de rotation de la pièce à usiner.
3. Une méthode conformément à la revendication 1 ou à la revendication 2 dans laquelle la variation de vitesse inclut un changement de vitesse de rotation de la meule, un tel changement de vitesse étant du

type à décélération.

4. Une méthode conformément à la revendication 1 dans laquelle la vitesse de la pièce à usiner est ajustée, alors que celle de la meule est gardée constante. 5
  
5. Une méthode conformément à l'une des revendications précédentes dans laquelle la variation de vitesse de rotation est initiée soit après un nombre prédéterminé de rotations de la pièce à usiner, où le nombre de tours par cycle de meulage est contrôlé, et/ou à une distance d'avance prédéterminée avant la position d'avance pour le calibrage final. 10  
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6. Une méthode conformément à l'une des revendications précédentes dans laquelle la vitesse de rotation est servocommandée en fonction des variables de temps, de la position d'avance de la meule, de la taille du composant et/ou du nombre de tours de la pièce à usiner. 20
  
7. Une méthode conformément à l'une des revendications précédentes dans laquelle le changement de vitesse de vitesse effectué est linéaire ou diminue ou augmente à un taux relatif auxdites variables, ou est d'une autre forme contrôlée, sinusoïdale par exemple. 25
  
8. Une méthode conformément à l'une des revendications précédente dans laquelle le changement de vitesse est initié au cours de l'approche lente d'avance de calibrage, se prolongeant dans le temps d'arrêt final au cours duquel le calibrage a lieu. 30  
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9. Une méthode conformément à l'une des revendications précédentes dans laquelle la valeur ciblée correspond à une vitesse de rotation ciblée de la pièce à usiner, la vitesse ciblée est demandée par un opérateur de l'appareil sur lequel la méthode est exécutée. 40
  
10. Une méthode conformément à l'une des revendications précédentes dans laquelle le meulage interne et/ou externe est exécuté sur la pièce à usiner cylindrique. 45

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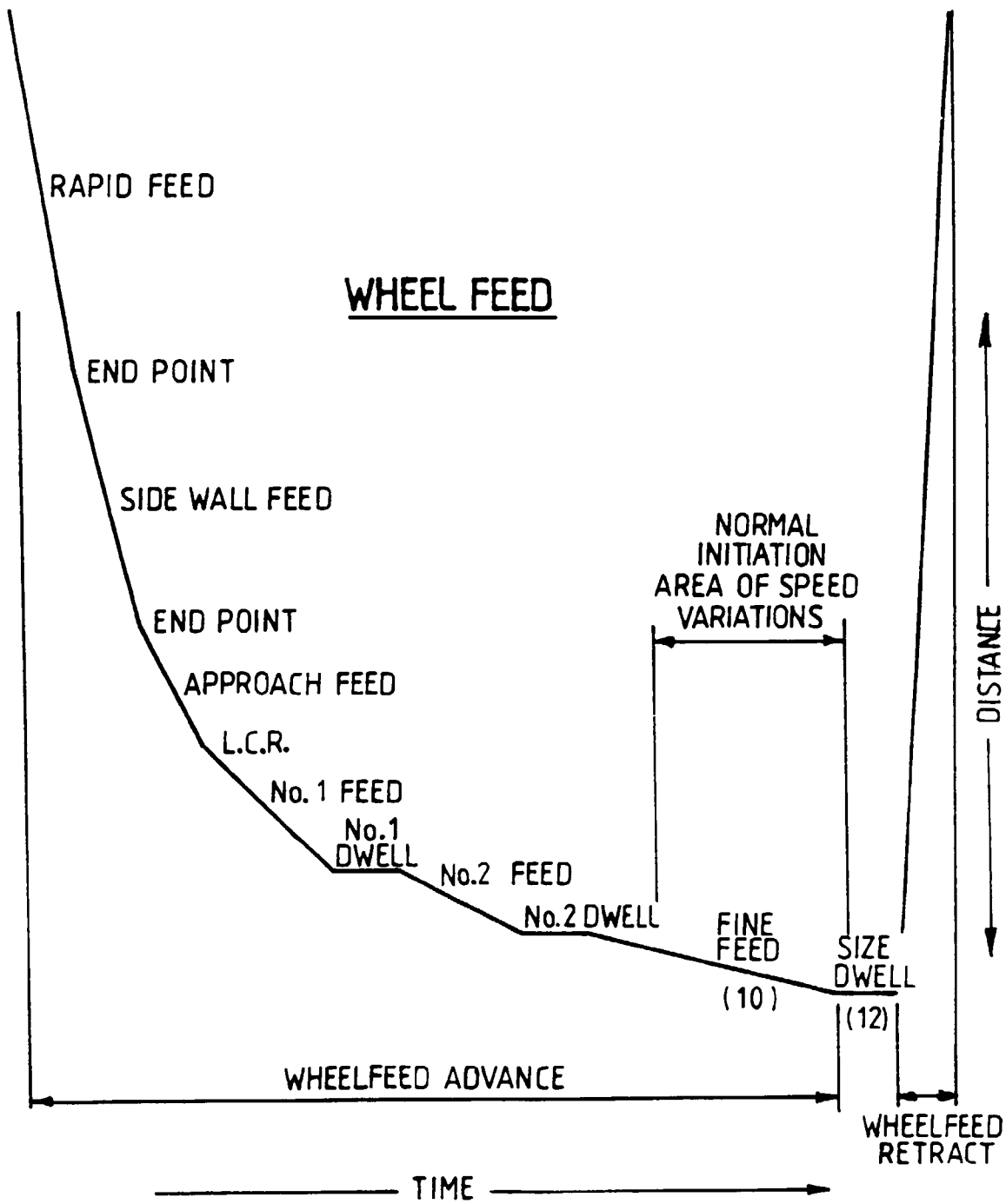


Fig. 1

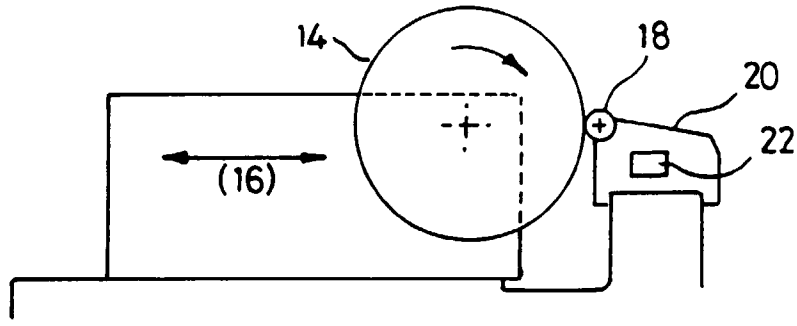


Fig. 2