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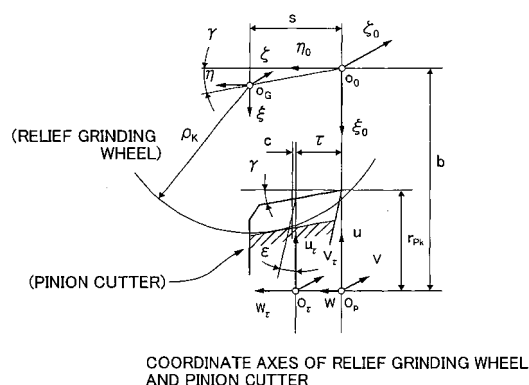
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(54) **METHOD OF EVALUATING CUTTING EDGE PROFILE OF RE-SHARPENING PINION CUTTER**

(57) A method of evaluating the error of the cutting edge profile of a re-sharpening pinion cutter provided by performing relieving grinding by a screw motion along the outer diameter relieving angle of the pinion cutter by using a relieving grinding wheel. First, based on the cross-sectional profile of the relieving grinding wheel and considering the motion of the relieving grinding by the screw motion along the outer relieving angle of the pinion cutter, the cutting edge profile of the pinion cutter after re-sharpening is determined by coordinate transformation. Next, the tooth profile of a pinion having the same outer diameter as that of the re-sharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal tooth profile of the resharpener pinion cutter. Then, a normal line is drawn from a point on the tooth profile of the obtained re-sharpening pinion cutter to the ideal tooth profile, the length of the leg thereof is obtained, and the obtained length is used as the error of re-sharpening.

FIG.3



DescriptionTECHNICAL FIELD

5 **[0001]** The present invention relates to a method of evaluating the cutting edge error produced in a resharpened pinion cutter, and more particularly to a method of evaluating the error of the cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a screw motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel.

10 BACKGROUND ART

[0002] When an internal gear or other tooth cutting work is performed using a resharpened pinion cutter, there is a need to measure the error of the tooth cutting profile of the pinion cutter after resharpening and to confirm whether the pinion cutter can perform tooth cutting work with good precision. The method of measuring the cutting edge error of a pinion cutter is stipulated by JIS.

[0003] However, the object of the measuring method stipulated by JIS is limited to pinion cutters for involute gears. It is stipulated that the error is to be measured in the cross section perpendicular to the axis about 1 mm away from the rake surface, but no consideration is given to the rake angle.

15 **[0004]** On the other hand, non-involute tooth profiles having a particular contour are currently widely used to improve performance in various ways. However, a specific method for evaluating or measuring the tooth profile error caused by resharpening a pinion cutter for a non-involute gear has not been proposed.

DISCLOSURE OF THE INVENTION

25 **[0005]** In view of the above, an object of the present invention is to provide a method for evaluating the error of a cutting edge profile that occurs when a pinion cutter having a non-involute tooth profile or another arbitrary tooth profile is resharpened.

[0006] More specifically, an object of the present invention is to provide a method of evaluating the error of the cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a screw motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel.

30 **[0007]** Also, an object of the present invention is to provide a method of evaluating the error of the cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a linear motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel.

[0008] In order to achieve the above-described objects in the method of evaluating the cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a screw motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel, the cutting edge of the pinion cutter after resharpening is first determined by transforming the coordinate system on the basis of a profile of the axial cross section of the relief grinding wheel. Next, a tooth profile of a pinion having the same outer diameter as that of the resharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the resharpening pinion cutter. Next, a normal line is drawn from a point on the cutting edge of the obtained resharpening pinion cutter to the ideal cutting edge, and the length of the normal line is calculated and used as the resharpening error.

40 **[0009]** Here, the method of evaluating the error of a cutting edge profile of a resharpening pinion cutter is characterized in that the step for determining the cutting edge profile of the resharpening pinion cutter comprises:

45 obtaining the contour of the axial cross section profile of the relief grinding wheel by a point sequence representing discrete numerical values;

interpolating the given contour of the axial cross section profile of the relief grinding wheel by the Akima method, and obtaining the coordinate points on the axial cross section profile by EQ. A, with t as the parameter expressing the profile in a fixed coordinate system $O_G - \xi\eta\zeta$ that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis

[0010]

55

EQ. A

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\} ;$$

[0011] defining by EQ. B the grinding wheel surface formed by turning the profile of an axial cross section of the relief grinding wheel given by EQ. A at an angle ϕ about an axis ζ

[0012]

EQ. B

$$\left. \begin{aligned} \xi &= g \cos \phi \\ \eta &= g \sin \phi \\ \zeta &= h \end{aligned} \right\} ;$$

[0013] expressing the movement of the relief grinding work performed by the relief grinding wheel provided with the grinding wheel surface in a static coordinate system $O_0 - \xi_0 \eta_0 \zeta_0$ of the grinding wheel and subsequently in a fixed coordinate system $O_p - uvw$ fixed to the pinion cutter that rotates at an angle θ_p about the axis w ; and thereafter defining by EQ. C the coordinate points (u_τ, v_τ) on the axially perpendicular cross section profile of the pinion cutter relief surface in an arbitrary axially perpendicular plane ($w_\tau = c$) within the range of the cutting edge surface of the resharpener pinion cutter having the rake angle ε in the coordinate system $O_\tau - u_\tau v_\tau w_\tau$ separated by τ in the positive direction of the axis w from the fixed coordinate system.

[0014]

EQ. C

$$\left. \begin{aligned} u_\tau &= \left\{ b - g \cos \phi - \left(-g \sin \phi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \cos \theta_p \\ &\quad - \left(g \sin \phi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p \\ v_\tau &= \left\{ b - g \cos \phi - \left(-g \sin \phi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \sin \theta_p \\ &\quad + \left(g \sin \phi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p \end{aligned} \right\}$$

In the formulas, b is the design center distance between the relief grinding wheel axis and the pinion cutter axis; Γ_G is the angle formed between the grinding wheel axis ζ of the fixed static coordinate system $O_0 - \xi \eta \zeta$ and the grinding wheel

axis ζ_0 of the relief grinding side of the static coordinate system $O_0 - \xi_0\eta_0\zeta_0$; v is the outer diameter relief angle of the pinion cutter; τ is the resharpener amount; and c is the distance from the tip of the cutting edge surface after resharpener to the axially perpendicular plane positioned within the range of the cutting edge surface.

[0015] The value of c may be calculated from EQ. D, wherein r_{PT} is the outside radius of the pinion cutter after resharpener, ε is the rake angle of the conically contoured cutting edge surface of the pinion cutter, and $u_{\tau 0}$, $v_{\tau 0}$ are coordinate values of the tooth profile in the cross section of $w_\tau = 0$.

[0016]

EQ. D

$$c = \left(r_{PT} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \right) \left\{ \frac{\sin \varepsilon \cos \gamma}{\cos(\varepsilon + \gamma)} \right\}$$

$$r_{PT} = r_{Pe} - \tau \tan \gamma$$

$$u_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \cos \theta_p$$

$$- \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p$$

$$v_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \sin \theta_p$$

$$+ \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p$$

[0017] Next, a method of calculating a resharpener limit of a pinion cutter of the present invention is characterized in comprising calculating an error of a cutting edge profile for the resharpener amount using the method of evaluating errors described above; setting the allowable error of the cutting edge profile of a resharpener pinion cutter; and using as the resharpener limit the maximum value of the resharpener amount obtained from the cutting edge profile of the resharpener pinion cutter using an error that is within the allowable error.

[0018] In accordance with the method of the present invention, the error of the cutting edge profile after resharpener the pinion cutter can be calculated regardless of whether the pinion cutter is for an involute gear or a non-involute gear when relief grinding is performed by a screw motion along the outer diameter relief surface of the pinion cutter by using a relief grinding wheel

[0019] Also, since the cutting edge profile of the resharpener pinion cutter formed on the sloped rake surface is determined and the error in the points on the cutting edge profile is calculated, the error can be correctly calculated with consideration given to the rake surface, which is different than measuring the error on the basis of the cutting edge profile on the axially perpendicular cross section currently defined by JIS.

[0020] Conventionally, the limit of the resharpener amount is determined by actually resharpener the pinion cutter and furthermore performing a gear-cutting test, but in accordance with the present invention, it is possible to set the cutting edge error and ascertain the resharpener limit.

[0021] Next, the present invention is a method of calculating an error of the cutting edge profile of a resharpener pinion cutter provided by performing relief grinding by a linear motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel. First, the cutting edge of the pinion cutter after resharpener is determined by transforming the coordinate system on the basis of a profile of the axial cross section of the relief grinding wheel. Next, a tooth profile of a pinion having the same outer diameter as that of the resharpener pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the resharpener pinion cutter. Next, a normal line is drawn from a point on the cutting edge of the obtained

resharpening pinion cutter to the ideal cutting edge, and the length of the normal line is calculated and used as the resharpening error.

[0022] Here, in the step for determining the cutting edge profile of the resharpening pinion cutter, the contour of the axial cross section profile of the relief grinding wheel is given by a point sequence representing discrete numerical values. The given contour of the axial cross section profile of the relief grinding wheel is interpolated by the Akima method, and the coordinate points on the axial cross section profile are obtained by EQ. E, with t as the parameter expressing the profile in a fixed coordinate system $O_G - \xi\eta\zeta$ that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis.

[0023]

EQ. E

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\};$$

[0024] Next, the coordinates of the axial cross section profile of the grinding wheel given by EQ. E are transformed, and the coordinate points on the axially perpendicular cross section profile of the pinion cutter relief surface in an arbitrary axially perpendicular plane ($w_\tau = c$) within the range of the cutting edge surface of the resharpening pinion cutter having the rake angle ε are defined by EQ. F in the coordinate system $O_\tau - u_\tau v_\tau w_\tau$ separated by τ in the positive direction of the axis w from the coordinate system $O_P - uvw$ fixed to the pinion cutter in which the axis w is a rotating axis.

[0025]

EQ. F

$$\left. \begin{aligned} u_\tau &= b - g \cos \varphi + (g \sin \varphi - \tau - c) \tan \gamma \\ v_\tau &= h \end{aligned} \right\} \Bigg|$$

In the formulas, b is the design center distance between the relief grinding wheel axis and the pinion cutter axis; v is the outer diameter relief angle of the pinion cutter; τ is the resharpening amount; and c is the distance from the tip of the cutting edge surface after resharpening to the axially perpendicular plane positioned within the range of the cutting edge surface.

[0026] Next, the value of c of EQ. F is calculated from EQ. G below on the basis of the geometrical relationship.

[0027]

EQ. G

$$c = \frac{(\sqrt{r_{P\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}) \sin \varepsilon_1 \cos \gamma}{\cos(\varepsilon_1 + \gamma)}$$

$$\varepsilon_1 = \tan^{-1} \frac{(r_{P\tau} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \tan \varepsilon)}{\sqrt{r_{P\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}}$$

[0028] The calculated value of c is substituted into EQ. F, and the cutting edge profile of the pinion cutter after resharpener can be obtained.

[0029] Next, the present invention is a method of calculating a resharpener limit of a pinion cutter, characterized in comprising calculating an error of a cutting edge profile for the resharpener amount using the method of evaluating errors described above; setting the allowable error of the cutting edge profile of a resharpener pinion cutter; and using as the resharpener limit the maximum value of the resharpener amount obtained from the cutting edge profile of the resharpener pinion cutter using an error that is within the allowable error.

[0030] In accordance with the method of the present invention, the error of the cutting edge profile after resharpener the pinion cutter can be calculated regardless of whether the pinion cutter is for an involute gear or a non-involute gear when relief grinding is performed by a linear motion along the outer diameter relief surface of the pinion cutter by using a relief grinding wheel. Also, since the cutting edge profile of the resharpener pinion cutter formed on the sloped rake surface is determined and the error in the points on the cutting edge profile is calculated, the error can be correctly calculated with consideration given to the rake surface, which is different than measuring the error on the basis of the cutting edge profile on the axially perpendicular cross section currently defined by JIS.

[0031] Conventionally, the limit of the resharpener amount is determined by actually resharpener the pinion cutter and furthermore performing a gear-cutting test, but in accordance with the present invention, it is possible to set the cutting edge error and ascertain the resharpener limit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

FIG. 1 is a schematic diagram showing the coordinate system when relief grinding is performed by a screw motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel;

FIG. 2 is a schematic diagram showing the relationship between the torsion angle and the cutting tip conical surface of a pinion cutter;

FIG. 3 is a schematic diagram showing the coordinate system when relief grinding is performed by a linear motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel; and

FIG. 4 is a graph showing the resharpener cutting edge error for each resharpener amount calculated using the method shown in FIG. 3.

BEST MODE FOR CARRYING OUT THE INVENTION

[0033] The method of the present invention is described in detail below with reference to the diagrams.

(Embodiment 1)

[0034] Described first is the method of evaluating the error of a cutting edge profile of a resharpener pinion cutter provided by performing relief grinding by a screw motion along the outer diameter relief angle of a pinion cutter by using a relief grinding wheel.

[0035] First, the analytical order is described for obtaining the contour of the relief surface of a pinion cutter that has been ground by a grinding wheel, where the axial cross section profile of the relief grinding wheel is given by a point

sequence representing discrete numerical values.

[0036] FIG. 1 is a schematic diagram showing the coordinate system when relief grinding is performed by a screw motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel. The coordinate system $O_G - \xi\eta\zeta$ is a fixed coordinate system that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis. The coordinate system $O_0 - \xi_0\eta_0\zeta_0$ is a static coordinate system for the relief grinding wheel in which the grinding wheel axis ζ and the axis ζ_0 form a grinding wheel mounting angle Γ_G . The coordinate system $O_P - uvw$ is a fixed coordinate system that is fixed to the pinion cutter in which the axis w is used as the rotating axis and which rotates at an angle θ_P about the axis w . The coordinate system $O_\tau - u_\tau v_\tau w_\tau$ is a resharpener coordinate system of a pinion cutter set at a distance τ in the direction of the axis w from the fixed coordinate system $O_P - uvw$. As used herein, τ is the resharpener amount measured in the axial direction at the outer diameter of the pinion cutter; b is the design center distance between the relief grinding wheel and the pinion cutter axis; and the angle ε is the rake angle of the conically contoured cutting edge surface of the pinion cutter.

[0037] In the relief grinding work, the grinding wheel moves a distance s in the positive direction of the axis η_0 along the outer diameter relief angle γ while the pinion cutter rotates by an amount equal to the angle θ_P , and [the grinding wheel] obliquely moves at the same time by an amount equal to $\tan \gamma$ in the positive direction of the axis ξ_0 . In this manner, the relief surface ground by a screw motion along the outer diameter relief angle of a pinion cutter is one in which the right-side of the cutting edge contour presents a right-handed tapered helical surface and the left-side of the cutting edge contour presents a left-handed tapered helical surface. If the outside contour of the cutting tips of the pinion cutter is defined to be a portion of a conical body, the generating lines in which the cutting tip points are linked in the axially perpendicular cross sections of the pinion cutter are straight lines along the vertices of cones.

[0038] In view of the above, these generating lines are considered from the geometrical relationship projected on the horizontal plane of the axis of the pinion cutter, as shown in FIG. 2. The helix angle β_C of the tapered helical surface in the radius of the pitch circle of the pinion cutter can be approximated by EQ. 1-1, wherein r_{PC} is the radius of the pitch circle of the pinion cutter, v_C is the coordinate value of the cutting edge in the pitch circle, and γ_C is the converted value in the r_{PC} of the outer diameter relief surface γ .

[0039]

EQ. 1-1

$$\tan \beta_c = \frac{v_c \tan \gamma_c}{r_{pc}}$$

[0040] The helix angle β of the tapered helical surface is determined in the following range with consideration given to the characteristics of the calculated helix angle β_C and the tooth profile.

[0041]

EQ. 1-2

$$0 \leq \beta \leq 2\beta_c$$

[0042] When r_{pk} is the outside radius of the pinion cutter, the relation of EQ. 2 holds true between the rotational angle θ_P and the movement distance s in the axial direction of the grinding wheel.

[0043]

EQ. 2

$$s = \frac{r_{Pk} \theta_P}{\tan \beta}$$

[0044] The axial cross section profile of the obtained relief grinding wheel is interpolated by the renowned Akima method, which smoothly interpolates series of points, and the intervals are obtained by EQ. 3 using the coordinate system $O_G - \xi\eta\zeta$. The variable t is a parameter for expressing the profile.

[0045]

EQ. 3

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\}$$

[0046] EQ. 4 is obtained when the axial cross section profile of the grinding wheel is turned at angle ϕ about the axis ζ and a grinding wheel surface is formed.

[0047]

EQ. 4

$$\left. \begin{aligned} \xi &= g \cos \phi \\ \eta &= g \sin \phi \\ \zeta &= h \end{aligned} \right\} \Bigg|$$

[0048] In view of the above, EQ. 5 is obtained by a procedure in which the operation of the grinding wheel in the relief grinding work described above is expressed in the static coordinate system $O_0 - \xi_0\eta_0\zeta_0$ of the grinding wheel, is subsequently expressed in the fixed coordinate system $O_P - uvw$ of the pinion cutter, and is then expressed in the coordinate system $O_t - u_tv_tw_t$, which is based on the predicted pinion cutter resharpener.

[0049]

EQ. 5

$$\begin{aligned}
 u_r &= \left\{ \begin{aligned} &b - \tau \tan \gamma - g \cos \varphi - (s - \tau) \tan \gamma \end{aligned} \right\} \cos \theta_p \\
 &\quad - (g \sin \varphi \sin \Gamma_r + h \cos \Gamma_G) \sin \theta_p \\
 v_r &= \left\{ \begin{aligned} &b - \tau \tan \gamma - g \cos \varphi - (s - \tau) \tan \gamma \end{aligned} \right\} \sin \theta_p \\
 &\quad + (g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G) \cos \theta_p \\
 w_r &= g \sin \varphi \cos \Gamma_G - h \sin \Gamma_G + s - \tau
 \end{aligned}
 \right.$$

[0050] EQ. 5 expresses the curves of the relief grinding wheel, and the enveloping surface of the curves expresses the relief surface of the pinion cutter. At this point, assuming the resharpener cutting edge to be expressed by the coordinate system $O_r - u_r v_r w_r$, the curves of the grinding wheel expressed by EQ. 5 are cut by an arbitrary plane $w_r = c$ within the range of the resharpener cutting edge surface having a rake angle, and EQ. 6 is obtained.

[0051]

EQ. 6

$$s = -g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c$$

[0052] EQ. 7 is obtained based on EQ. 6 and EQ. 2.

[0053]

EQ. 7

$$\theta_p = \frac{\tan \beta}{r_{pk}} \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right)$$

[0054] EQ. 6 is substituted into EQ. 5 to obtain EQ. 8 below.

[0055]

EQ. 8

$$\begin{aligned}
 u_r &= \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G \right. \right. \\
 &\quad \left. \left. + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \cos \theta_p \\
 &\quad - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p \\
 v_r &= \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G \right. \right. \\
 &\quad \left. \left. + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \sin \theta_p \\
 &\quad + \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p
 \end{aligned}
 \quad \left. \vphantom{\begin{aligned} u_r \\ v_r \end{aligned}} \right\}$$

[0056] Considered together with EQ. 7, EQ. 8 expresses the curves in which t and φ are variables, and the equation gives the axially perpendicular cross section profile produced by the plane $w_r = c$ of the pinion cutter relief surface as an envelope of the curves. The conditional expression of the envelope can be obtained by calculating the Jacobian of EQ. 9 below with respect to EQ. 8.

[0057]

EQ. 9

$$f(t, \varphi) = \begin{vmatrix} \frac{\partial u_r}{\partial t} & \frac{\partial v_r}{\partial t} \\ \frac{\partial u_r}{\partial \varphi} & \frac{\partial v_r}{\partial \varphi} \end{vmatrix} = \frac{\partial u_r}{\partial t} \frac{\partial v_r}{\partial \varphi} - \frac{\partial v_r}{\partial t} \frac{\partial u_r}{\partial \varphi} = 0$$

Here,
[0058]

EQ. 10

$$\begin{aligned}
\frac{\partial u_r}{\partial t} = & \left\{ -\dot{g} \cos \varphi - \left(-\dot{g} \sin \varphi \cos \Gamma_G + \dot{h} \sin \Gamma_G \right) \tan \gamma \right\} \cos \theta_p \\
& - \left(\dot{g} \sin \varphi \sin \Gamma_G + \dot{h} \cos \Gamma_G \right) \sin \theta_p \\
& - \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \sin \theta_p \dot{\theta}_p \\
& - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p \dot{\theta}_p \\
\frac{\partial v_r}{\partial t} = & \left\{ -\dot{g} \cos \varphi - \left(-\dot{g} \sin \varphi \cos \Gamma_G + \dot{h} \sin \Gamma_G \right) \tan \gamma \right\} \sin \theta_p \\
& + \left(\dot{g} \sin \varphi \sin \Gamma_G + \dot{h} \cos \Gamma_G \right) \cos \theta_p \\
& + \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \cos \theta_p \dot{\theta}_p \\
& - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p \dot{\theta}_p \\
\frac{\partial u_r}{\partial \varphi} = & \left(g \sin \varphi + g \cos \varphi \cos \Gamma_G \tan \gamma \right) \cos \theta_p \\
& - g \cos \varphi \sin \Gamma_G \sin \theta_p - \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \sin \theta_p \bar{\theta}_p \\
& - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p \bar{\theta}_p \\
\frac{\partial v_r}{\partial \varphi} = & \left(g \sin \varphi + g \cos \varphi \cos \Gamma_G \tan \gamma \right) \sin \theta_p \\
& + g \cos \varphi \sin \Gamma_G \cos \theta_p + \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \cos \theta_p \bar{\theta}_p \\
& - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p \bar{\theta}_p \\
\dot{\theta}_p = & -\frac{\tan \beta}{r_{pk}} \left(\dot{g} \sin \varphi \cos \Gamma_G - \dot{h} \sin \Gamma_G \right) \\
\bar{\theta}_p = & -\frac{\tan \beta}{r_{pk}} \left(g \cos \varphi \cos \Gamma_G \right)
\end{aligned}$$

[0059] In view of the above, EQ. 11 below is obtained for calculating c in EQ. 8 from the geometrical relationship in order to obtain the resharpened cutting edge of the pinion cutter having a rake angle. The variable $r_{p\tau}$ in the formula is the outside radius of the resharpened pinion cutter, and $u_{\tau 0}$, $v_{\tau 0}$ are the coordinate values of the cutting edge in the cross section of $w_{\tau}=0$.

[0060]

EQ. 11

$$c = \left(r_{p\tau} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \right) \left\{ \frac{\sin \varepsilon \cos \gamma}{\cos(\varepsilon + \gamma)} \right\}$$

$$r_{p\tau} = r_{pc} - \tau \tan \gamma$$

$$u_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \cos \theta_p - \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p$$

$$v_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \sin \theta_p + \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p$$

[0061] Based on the foregoing, the resharpened pinion cutter cutting edge can be calculated by repeating the following procedure.

(i) Obtain the specifications b , γ , ε , and the like.

(ii) Set the resharpening amount τ .

(iii) Establish the coordinate point number j and obtain t , and use EQ. 1 to obtain $g(t)$, $h(t)$.

(iv) Obtain by trial and error [a value of] ϕ that satisfies the expression $f(t, \phi) = 0$ with the aid of EQS. 9, 10, and 7, wherein $c = 0$.

(v) Substitute these values into EQ. 11, obtain $u_{\tau 0}$, $v_{\tau 0}$, and determine c .

(vi) Obtain by trial and error [a value of] ϕ that satisfies the expression $f(t, \phi) = 0$ with the aid of EQS. 9, 10, and 7 using the obtained [value of] c .

(vii) Substitute these values into EQ. 8, use u_{τ} , v_{τ} to obtain a single point on the cutting edge.

(viii) Repeat steps iii to vii.

[0062] As used herein, the resharpening error of the cutting edge is defined in the following manner. First, a tooth profile of a pinion having the same outer diameter as that of the resharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the pinion cutter. Next, a normal line is drawn from a point on the cutting edge of the obtained resharpening pinion cutter to the ideal cutting edge, and the length of the normal line is calculated and used as the resharpening error.

(Embodiment 2)

[0063] Described next is a method for calculating an error of a cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a linear motion along the outer diameter relief angle of a pinion cutter by using a relief grinding wheel.

[0064] First, the analytical order is described for obtaining the contour of the relief surface of a pinion cutter that has

been ground by a grinding wheel, where the axial cross section profile of the relief grinding wheel is given by a point sequence representing discrete numerical values.

[0065] FIG. 3 is a schematic diagram showing the coordinate system when relief grinding is performed by a linear motion along the outer diameter relief angle of the pinion cutter by using a relief grinding wheel. The coordinate system $O_G - \xi\eta\zeta$ is a coordinate system that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis, and the coordinate system $O_0 - \xi_0\eta_0\zeta_0$ is a static coordinate system for the relief grinding wheel. The coordinate system $O_P - uvw$ is a coordinate system that is fixed to the pinion cutter wherein the axis w is used as the rotating axis. The coordinate system $O_\tau - u_\tau v_\tau w_\tau$ is a coordinate system set at a distance τ in the positive direction of the axis w . In the above systems, τ is the resharpening amount measured in the axial direction at the outer diameter of the pinion cutter; b is the design center distance between the relief grinding wheel and the pinion cutter axis; and the angle ε is the rake angle of the conically contoured cutting edge surface of the pinion cutter.

[0066] The axial cross section profile of the obtained relief grinding wheel is interpolated by the renowned Akima method, which smoothly interpolates series of points, and the intervals are obtained by EQ. 21 using the coordinate system $O_G - \xi\eta\zeta$. The variable t is a parameter for expressing the profile.

[0067]

EQ. 21

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\}$$

[0068] EQ. 22 is obtained when the axial cross section profile of the grinding wheel is turned at angle ϕ about the axis ζ and a grinding wheel surface is formed.

[0069]

EQ. 22

$$\left. \begin{aligned} \xi &= g \cos \phi \\ \eta &= g \sin \phi \\ \zeta &= h \end{aligned} \right\}$$

[0070] In the relief grinding work, the grinding wheel moves a distance s in the positive direction of the axis η along the outer diameter relief angle γ of the pinion cutter and obliquely moves at the same time by an amount equal to $\tan \gamma$ in the positive direction of the axis ξ . EQ. 23 is obtained by a procedure in which this movement is expressed in the static coordinate system $O_0 - \xi_0\eta_0\zeta_0$ of the grinding wheel, and is subsequently expressed in the fixed coordinate system $O_P - uvw$ of the pinion cutter

[0071]

EQ. 23

$$\left. \begin{aligned} u &= b - g \cos \varphi - s \tan \gamma \\ v &= h \\ w &= g \sin \varphi + s \end{aligned} \right\} \Bigg|$$

[0072] EQ. 24 below is obtained when EQ. 23 is expressed in the coordinate system $O_\tau - u_\tau v_\tau w_\tau$, which is based on the predicted pinion cutter resharpener.

[0073]

EQ. 24

$$\left. \begin{aligned} u_\tau &= b - \tau \tan \gamma - g \cos \varphi - (s - \tau) \tan \gamma \\ v_\tau &= h \\ w_\tau &= g \sin \varphi + (s - \tau) \end{aligned} \right\} \Bigg|$$

[0074] EQ. 24 expresses the curves of the relief grinding wheel, and the enveloping surface of the curves expresses the relief surface of the pinion cutter. At this point, assuming the resharpener cutting edge to be expressed by the coordinate system $O_\tau - u_\tau v_\tau w_\tau$, the curves of the grinding wheel expressed by EQ. 24 are cut by an arbitrary plane $w_\tau = c$ within the range of the resharpener cutting edge surface having a rake angle, and EQ. 25 is obtained.

[0075]

EQ. 25

$$s = -g \sin \varphi + \tau + c$$

[0076] This is substituted into EQ. 24, and EQ. 26 is obtained below.

[0077]

EQ. 26

$$\left. \begin{aligned} u_\tau &= b - g \cos \varphi + (g \sin \varphi - \tau - c) \tan \gamma \\ v_\tau &= h \end{aligned} \right\}$$

[0078] EQ. 26 expresses the curves in which t and ϕ are variables, and the equation gives the axially perpendicular cross section profile produced by the plane $w_\tau = c$ of the pinion cutter relief surface as an envelope of the curves. The conditional expression of the envelope can be obtained by calculating the Jacobian with respect to EQ. 26.

[0079]

EQ. 27

$$f_{P\tau}(t, \varphi) = \left| \begin{array}{cc} \frac{\partial u_r}{\partial t} & \frac{\partial v_r}{\partial t} \\ \frac{\partial u_r}{\partial \varphi} & \frac{\partial v_r}{\partial \varphi} \end{array} \right| = \frac{\partial u_r}{\partial t} \frac{\partial v_r}{\partial \varphi} - \frac{\partial v_r}{\partial t} \frac{\partial u_r}{\partial \varphi} = 0$$

[0080] The following EQ. 28 is obtained thereby.

[0081]

EQ. 28

$$\varphi = -\gamma$$

[0082] This is substituted into EQ. 26, and the following EQ.29 is obtained.

[0083]

EQ. 29

$$\left. \begin{array}{l} u_r = b - g \cos \gamma - (g \sin \gamma + \tau + c) \tan \gamma \\ v_r = h \end{array} \right\}$$

[0084] Here, the profile on the cutting edge of the pinion cutter is expressed by a three-dimensional intersecting curve between the relief surface of the pinion cutter and the conical rake surface. The curve in which the intersecting curve is projected from the w axis direction onto the cross section that includes the axially perpendicular cross section of the pinion cutter is the cutting edge of the pinion cutter. It is difficult to calculate the profile on the cutting edge of the pinion cutter by using an intersecting curve of two surfaces. In view of this situation, the distance c to the rake surface that corresponds to an arbitrary point $(u_{\tau 0}, v_{\tau 0})$ on the axially perpendicular cross section of the pinion cutter of the resharpening coordinate system $O_\tau - u_\tau v_\tau w_\tau$ is expressed by the following EQ. 30 on the basis of a geometrical relationship. In the formula, r_{PT} is the outside radius of the resharpened pinion cutter.

[0085]

EQ. 30

$$c = \frac{(\sqrt{r_{p\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}) \sin \varepsilon_1 \cos \gamma}{\cos(\varepsilon_1 + \gamma)}$$

$$\varepsilon_1 = \tan^{-1} \frac{(r_{p\tau} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \tan \varepsilon)}{\sqrt{r_{p\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}}$$

[0086] The axially perpendicular cross section profile of the pinion cutter that passes through point c can be calculated using EQ. 29. Also, the point (u_τ , v_τ) on the axially perpendicular cross section profile corresponding to the point ($u_{\tau 0}$, $v_{\tau 0}$) is a point on the cutting edge.

[0087] Based on the foregoing, the resharpened pinion cutter cutting edge can be calculated by repeating the following procedure.

- (i) Obtain the specifications b , γ , ε , and the like.
- (ii) Set the resharpening amount τ
- (iii) Establish the coordinate point number j and use EQ. 1 to obtain $g(t)$, $h(t)$.
- (iv) Substitute into EQ. 30 and obtain c .
- (v) Substitute into EQ. 29 and obtain a single point on the cutting edge.
- (vi) Repeat steps iii to v.

[0088] As used herein, the resharpening error of the cutting edge is defined in the following manner. First, a tooth profile of a pinion having the same outer diameter as that of the resharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the pinion cutter. Next, a normal line is drawn from a point on the cutting edge of the obtained resharpening pinion cutter to the ideal cutting edge, and the length of the normal line is calculated and used as the resharpening error.

(Example of numerical analysis)

[0089] A numerical analysis was carried out using the internal gear and pinion cutter shown in FIG. 1 and using the specifications of the relief grinding wheel. First, the resharpening amount was set to be $\tau = 0$ to 4 mm, the cutting edge of the resharpening pinion cutter was calculated, and the error of the cutting edge due to resharpening was obtained using the above-described procedure.

[0090]

TABLE 1

Items	Values
Diametral pitch DP 1/inch	32.00
Internal gear:	
Number of profile points j	1 to 203
Number of teeth z	322
Pitch circle diameter d_c mm	255.588
Addendum circle diameter d_k mm	254.671
Dedendum circle diameter d_b mm	257.254

(continued)

Pinion cutter:			
Number of teeth	z_p		50
Pitch circle diameter	d_{pc} mm		39.688
Major diameter	d_{pk} mm		41.200
Radial rake angle	ε deg		5
Radial relief angle	γ deg		5
Relief grinding wheel:			
Major diameter	2_{pk} mm		200

[0091] FIG. 4 is a graph showing the results of the numerical analysis. From this diagram, it is apparent that a re-sharpening cutting edge error has not occurred when $\tau = 0$ and that the cutting edge of the resharpening pinion cutter and the ideal cutting edge are congruent, confirming the validity of the analytical theory for obtaining the resharpening cutting edge error described above.

[0092] From FIG. 4, the cutting edge error when $\tau = 1$ mm is $-3.9 \mu\text{m}$ at point $j = 42$, $8.9 \mu\text{m}$ at point $j = 73$, and hence $12.8 \mu\text{m}$ at the width. In the same manner, the diagram shows that the cutting edge error is $25.9 \mu\text{m}$ when $\tau = 2$ mm, $39.3 \mu\text{m}$ when $\tau = 3$ mm, and $53.0 \mu\text{m}$ when $\tau = 4$ mm.

[0093] Therefore, the limit of the resharpening amount is conventionally determined by actually resharpening the pinion cutter and furthermore performing a gear-cutting test. With the present invention, however, it is possible to set the cutting edge error and to ascertain the resharpening limit.

Claims

1. A method of evaluating an error of a cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a screw motion along the outer diameter relief angle of a pinion cutter by using a relief grinding wheel, wherein the method is **characterized in that** the cutting edge profile of the resharpening pinion cutter is determined based on a profile of an axial cross section of the relief grinding wheel;
a tooth profile of a pinion having the same outer diameter as that of the resharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the resharpening pinion cutter; and
the length of a normal line drawn from a point on the cutting edge profile of the resharpening pinion cutter to the ideal cutting edge is used as the error of cutting edge profile.

2. The method of evaluating an error of a cutting edge profile of a resharpening pinion cutter according to claim 1, **characterized in that** the step for determining the cutting edge profile of the resharpening pinion cutter comprises:

obtaining the contour of the axial cross section profile of the relief grinding wheel by a point sequence representing discrete numerical values;

interpolating the given contour of the axial cross section profile of the relief grinding wheel by the Akima method, and obtaining the coordinate points on the axial cross section profile by EQ. A, with t as the parameter expressing the profile in a fixed coordinate system $O_G - \xi\eta\zeta$ that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis

EQ. A

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\} ;$$

defining by EQ. B the grinding wheel surface formed by turning the profile of an axial cross section of the relief grinding wheel given by EQ. A at an angle ϕ about an axis ζ

EQ. B

$$\left. \begin{aligned} \xi &= g \cos \phi \\ \eta &= g \sin \phi \\ \zeta &= h \end{aligned} \right\} ;$$

expressing the movement of the relief grinding work performed by the relief grinding wheel provided with the grinding wheel surface in a static coordinate system $O_0 - \xi_0 \eta_0 \zeta_0$ of the grinding wheel and subsequently in a fixed coordinate system $O_P - uvw$ fixed to the pinion cutter that rotates at an angle θ_P about the axis w ; and thereafter defining by EQ. C the coordinate points (u_τ, v_τ) on the axially perpendicular cross section profile of the pinion cutter relief surface in an arbitrary axially perpendicular plane ($w_\tau = c$) within the range of the cutting edge surface of the resharpener pinion cutter having the rake angle ε in the coordinate system $O_\tau - u_\tau v_\tau w_\tau$ separated by τ in the positive direction of the axis w from the [fixed] coordinate system.

EQ. C

$$\left. \begin{aligned} u_\tau &= \left\{ b - g \cos \phi - \left(-g \sin \phi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \cos \theta_P \\ &\quad - \left(g \sin \phi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_P \\ v_\tau &= \left\{ b - g \cos \phi - \left(-g \sin \phi \cos \Gamma_G + h \sin \Gamma_G + \tau + c \right) \tan \gamma \right\} \sin \theta_P \\ &\quad + \left(g \sin \phi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_P \end{aligned} \right\}$$

wherein b is the design center distance between the relief grinding wheel axis and the pinion cutter axis; Γ_G is the angle formed between the grinding wheel axis ζ of the fixed static coordinate system $O_0 - \xi \eta \zeta$ and the grinding wheel axis ζ_0 of the relief grinding side of the static coordinate system $O_0 - \xi_0 \eta_0 \zeta_0$; γ is the outer diameter relief angle of the pinion cutter; τ is the resharpener amount; and c is the distance from the tip of the cutting edge surface

after resharpening to the axially perpendicular plane positioned within the range of the cutting edge surface.

3. The method of evaluating an error of a cutting edge profile of a resharpening pinion cutter according to claim 2, **characterized in that** the value of c is calculated from EQ. D, wherein r_{PT} is the outside radius of the pinion cutter after resharpening, ε is the rake angle of the conically contoured cutting edge surface of the pinion cutter, and the coordinate value of the tooth profile in the cross section of $W_\tau = 0$

EQ. D

$$c = \left(r_{P\tau} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \right) \left\{ \frac{\sin \varepsilon \cos \gamma}{\cos(\varepsilon + \gamma)} \right\}$$

$$r_{P\tau} = r_{Pc} - \tau \tan \gamma$$

$$u_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \cos \theta_p$$

$$- \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \sin \theta_p$$

$$v_{\tau 0} = \left\{ b - g \cos \varphi - \left(-g \sin \varphi \cos \Gamma_G + h \sin \Gamma_G + \tau \right) \tan \gamma \right\} \sin \theta_p$$

$$+ \left(g \sin \varphi \sin \Gamma_G + h \cos \Gamma_G \right) \cos \theta_p$$

and

the calculated value of c is substituted into EQ. C to obtain the coordinate points of the cutting edge profile of the pinion cutter after resharpening.

4. A method of calculating a resharpening limit of a pinion cutter, **characterized in** comprising:

calculating an error of a cutting edge profile for the resharpening amount using the method of evaluating errors according to claims 1, 2, and 3;

setting the allowable error of the cutting edge profile of a resharpening pinion cutter; and

using as the resharpening limit the maximum value of the resharpening amount obtained from the cutting edge profile of the resharpening pinion cutter using an error that is within the allowable error.

5. A method of evaluating an error of a cutting edge profile of a resharpening pinion cutter provided by performing relief grinding by a linear motion along the outer diameter relief angle of a pinion cutter by using a relief grinding wheel, wherein the method is **characterized in that**

the cutting edge profile of the resharpening pinion cutter is determined based on a profile of an axial cross section of the relief grinding wheel;

a tooth profile of a pinion having the same outer diameter as that of the resharpening pinion cutter and correctly meshing with the tooth profile of an internal gear to be cut is obtained, and the obtained tooth profile is used as an ideal cutting edge of the resharpening pinion cutter; and

the length of a normal line drawn from a point on the cutting edge profile of the resharpening pinion cutter to the ideal cutting edge is used as the error of the cutting edge profile after resharpening.

6. The method of evaluating an error of a cutting edge profile of a resharpening pinion cutter according to claim 5,

characterized in that the step for determining the cutting edge profile of the resharpener pinion cutter comprises:

obtaining the contour of the axial cross section profile of the relief grinding wheel by a point sequence representing discrete numerical values;

interpolating the given contour of the axial cross section profile of the relief grinding wheel by the Akima method, and obtaining the coordinate points on the axial cross section profile by EQ. E, with t as the parameter expressing the profile in a coordinate system $O_G - \xi\eta\zeta$ that is fixed to the relief grinding wheel in which the axis ζ is the rotation axis

EQ. E

$$\left. \begin{aligned} \xi &= g(t) = g \\ \eta &= 0 \\ \zeta &= h(t) = h \end{aligned} \right\} ;$$

transforming the coordinates to the axial cross section profile of the grinding wheel given by EQ. E, and defining by EQ. F the coordinate points on the axially perpendicular cross section profile of the pinion cutter relief surface in an arbitrary axially perpendicular plane ($w_t = c$) within the range of the cutting edge surface of the resharpener pinion cutter having the rake angle ε in the coordinate system $O_t - u_t v_t w_t$ separated by τ in the positive direction of the axis w from the coordinate system $O_p - uvw$ fixed to the pinion cutter in which the axis w is a rotating axis

EQ. F

$$\left. \begin{aligned} u_t &= b - g \cos \varphi + (g \sin \varphi - \tau - c) \tan \gamma \\ v_t &= h \end{aligned} \right\} \Bigg|$$

wherein b is the design center distance between the relief grinding wheel axis and the pinion cutter axis; v is the outer diameter relief angle of the pinion cutter; τ is the resharpener amount; and c is the distance from the tip of the cutting edge surface after resharpener to the axially perpendicular plane positioned within the range of the cutting edge surface.

7. The method of evaluating an error of a cutting edge profile of a resharpener pinion cutter according to claim 6, characterized in that the value of c is calculated from EQ. G, wherein r_{pT} is the outside radius of the pinion cutter after resharpener,

EQ. G

$$c = \frac{(\sqrt{r_{P\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}) \sin \varepsilon_1 \cos \gamma}{\cos(\varepsilon_1 + \gamma)}$$

$$\varepsilon_1 = \tan^{-1} \frac{(r_{P\tau} - \sqrt{u_{\tau 0}^2 + v_{\tau 0}^2} \tan \varepsilon)}{\sqrt{r_{P\tau}^2 - v_{\tau 0}^2} - u_{\tau 0}} ;$$

and

the calculated value of c is substituted into EQ. F to obtain the coordinate points of the cutting edge profile of the pinion cutter after resharpening.

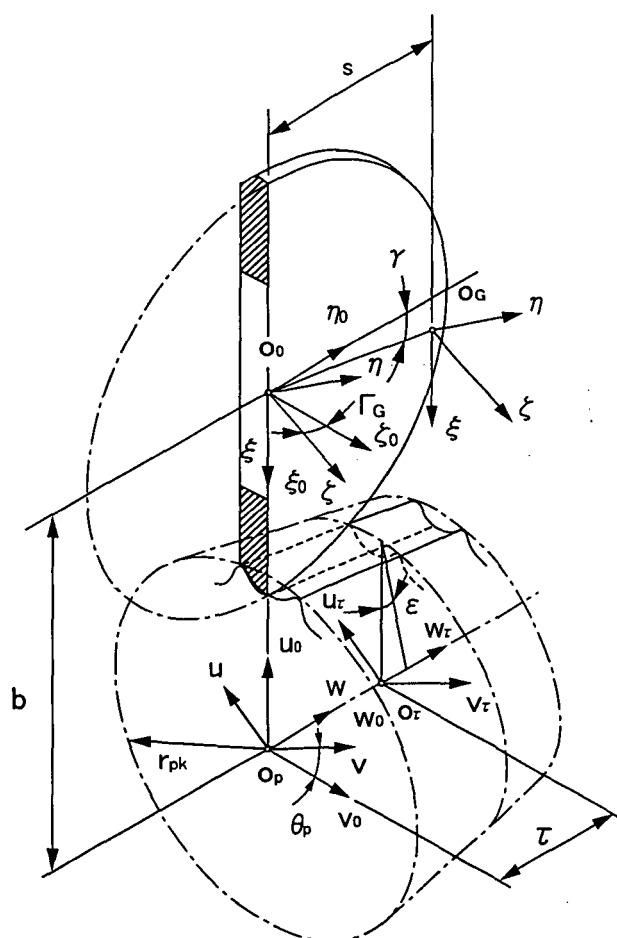
8. A method of calculating a resharpening limit of a pinion cutter, **characterized in** comprising:

calculating an error of a cutting edge profile for the resharpening amount using the method of evaluating errors according to claims 5 to 7;

setting the allowable error of the cutting edge profile of a resharpening pinion cutter; and

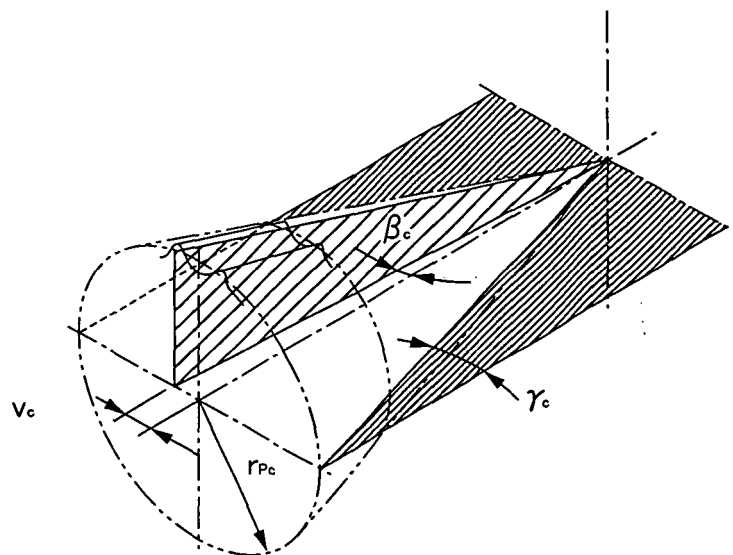
using as the resharpening limit the maximum value of the resharpening amount obtained from the cutting edge profile of the resharpening pinion cutter using an error that is within the allowable error.

FIG. 1



COORDINATE SYSTEM OF RELIEF GRINDING WHEEL
AND PINION CUTTER

FIG.2



RELATIONSHIP BETWEEN THE HELIX
ANGLE OF THE TAPERED HELICAL
SURFACE AND THE CONICAL SURFACE IN
THE PITCH CIRCLE RADIUS OF THE
PINION CUTTER

FIG.3

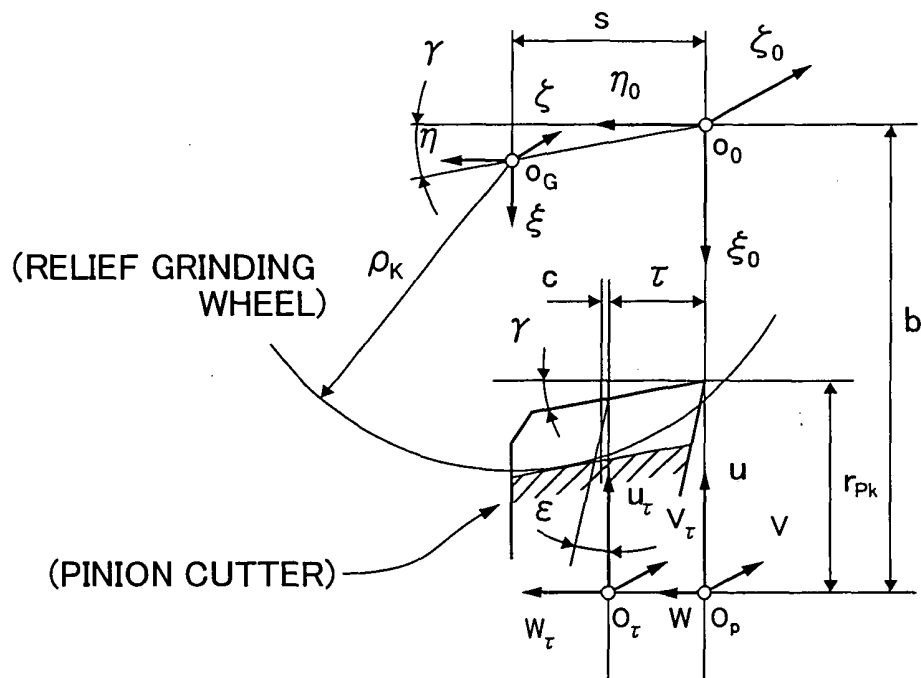
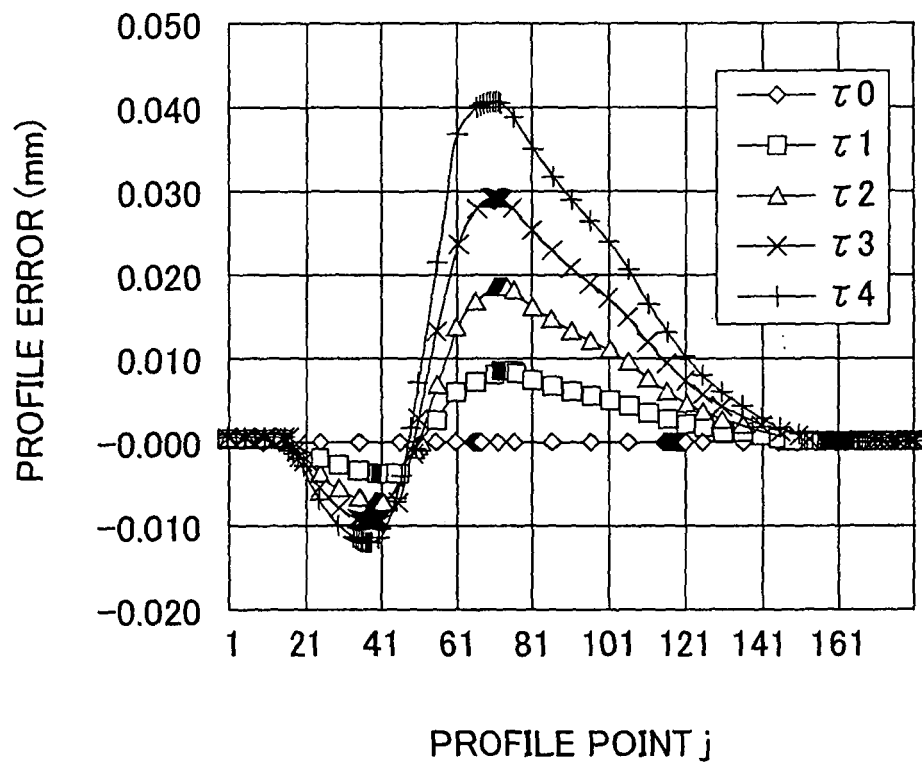
COORDINATE AXES OF RELIEF GRINDING WHEEL
AND PINION CUTTER

FIG. 4



(PROFILE ERROR OF RESHARPENING PINION CUTTER)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/015447

A. CLASSIFICATION OF SUBJECT MATTER

B24B49/00 (2006.01), **B24B3/34** (2006.01), **G01B21/20** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B24B49/00 (2006.01), **B24B3/12** (2006.01), **B24B3/34** (2006.01), **G01B21/20** (2006.01), **B23F21/10** (2006.01), **B23F23/00** (2006.01) - **B23F23/12** (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Kokai Jitsuyo Shinan Koho	1971-2005	Toroku Jitsuyo Shinan Koho	1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9-212222 A (Honda Motor Co., Ltd.), 15 August, 1997 (15.08.97), (Family: none)	1-8
A	JP 7-77420 A (Nikon Corp.), 20 March, 1995 (20.03.95), (Family: none)	1-8
A	JP 49-103293 A (Kabushiki Kaisha Sonoike Seisakusho), 30 September, 1974 (30.09.74), (Family: none)	1-8
A	JP 54-6196 A (Barber-Colman Co.), 18 January, 1979 (18.01.79), & US 4139327 A	1-8

☒ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search
22 November, 2005 (22.11.05)Date of mailing of the international search report
06 December, 2005 (06.12.05)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

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Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/015447

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 61-109654 A (Kabushiki Kaisha Karatsu Tekkosho), 28 May, 1986 (28.05.86), (Family: none)	1-8
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 163812/1985 (Laid-open No. 72024/1987) (Mitsubishi Heavy Industries, Ltd.), 08 May, 1987 (08.05.87), (Family: none)	1-8
A	JP 7-32215 A (Kobe Steel, Ltd.), 03 February, 1995 (03.02.95), (Family: none)	1-8
A	JP 7-136847 A (Kobe Steel, Ltd.), 30 May, 1995 (30.05.95), (Family: none)	1-8

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