United States Patent [19]

Sakai et al.

[11] **3,889,372**

[45] **June 17, 1975**

[54] **ELECTRIC DRY SHAVER BLADE ASSEMBLY**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **30/43.6;** 30/346.51
[51] **Int. Cl.** **B26b 19/14;** B26b 21/54
[58] **Field of Search** 30/43.4, 43.5, 43.6, 346.51

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[57] **ABSTRACT**

A blade assembly for electric dry shaver including an outer blade fixed to the shaver body and an inner blade rotated to shave hairs in cooperation with the outer blade, wherein the outer blade has a plurality of slits extending substantially in radial direction. The inner blade and the slits in the outer blade are so arranged that the intersection of their cutting edge lines will define an optimum hair holding or cutting angle which is constant at all positions over the blade surface. The slits in the outer blade may be arranged in a plurality of spiral arrays extending between the center and the outer periphery of the outer blade.

5 Claims, 10 Drawing Figures

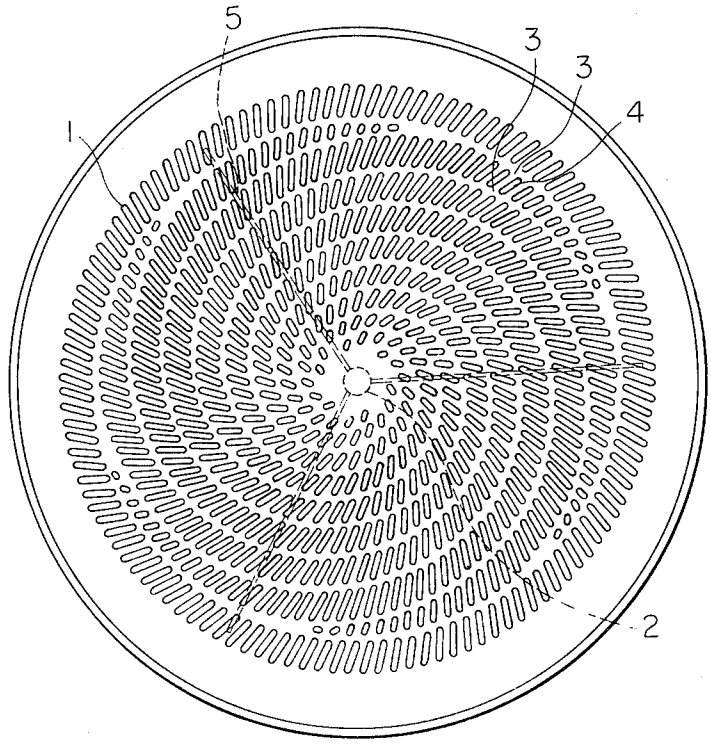


Fig. 1 (PRIOR ART)

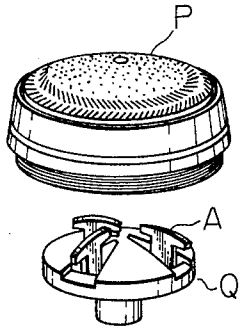


Fig. 2A
(PRIOR ART)

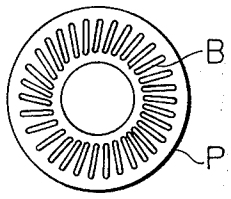


Fig. 2B

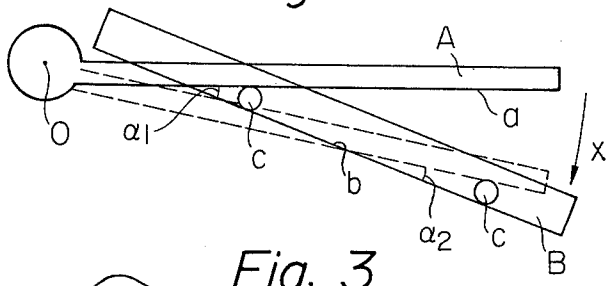


Fig. 3

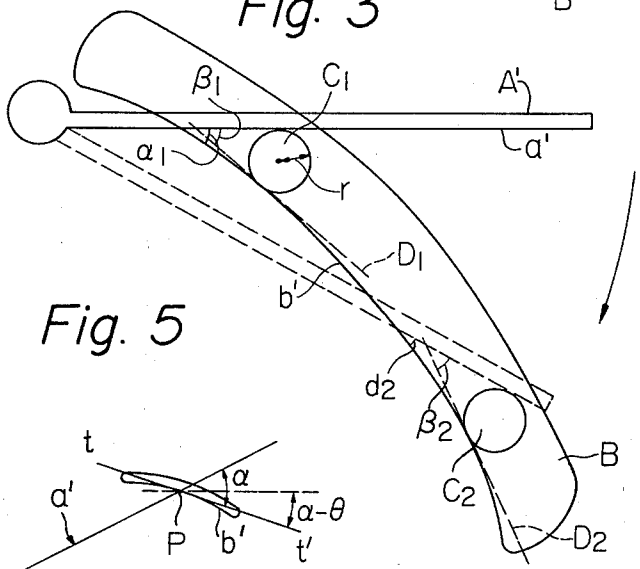


Fig. 5

Fig. 4

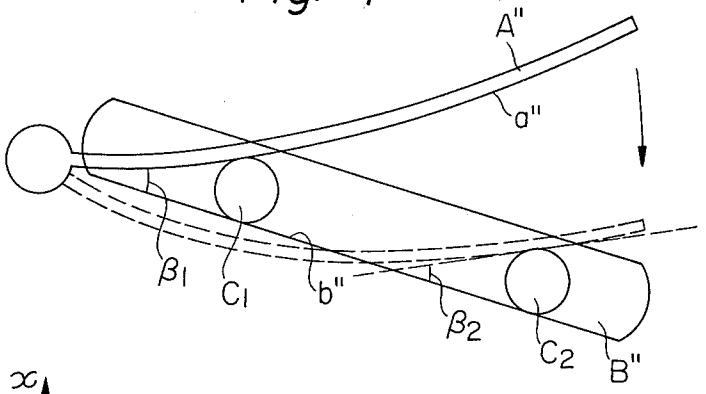


Fig. 6

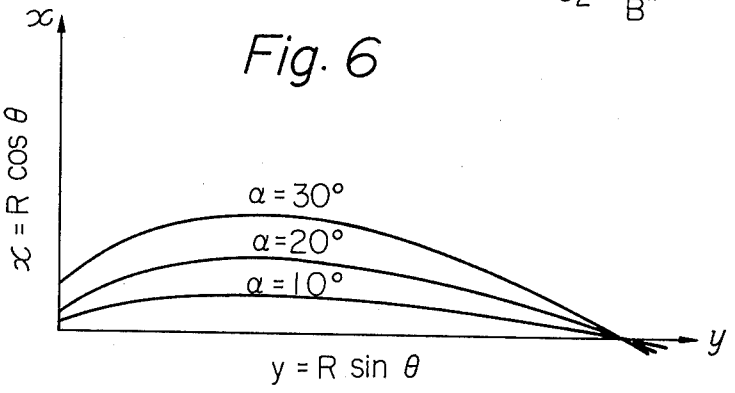


Fig. 8A

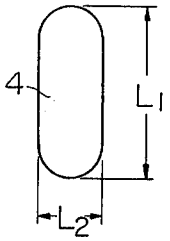


Fig. 8B

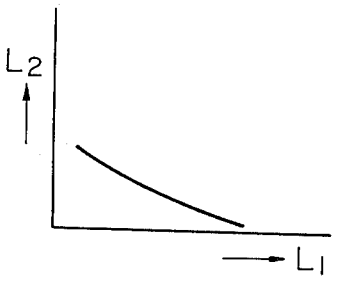
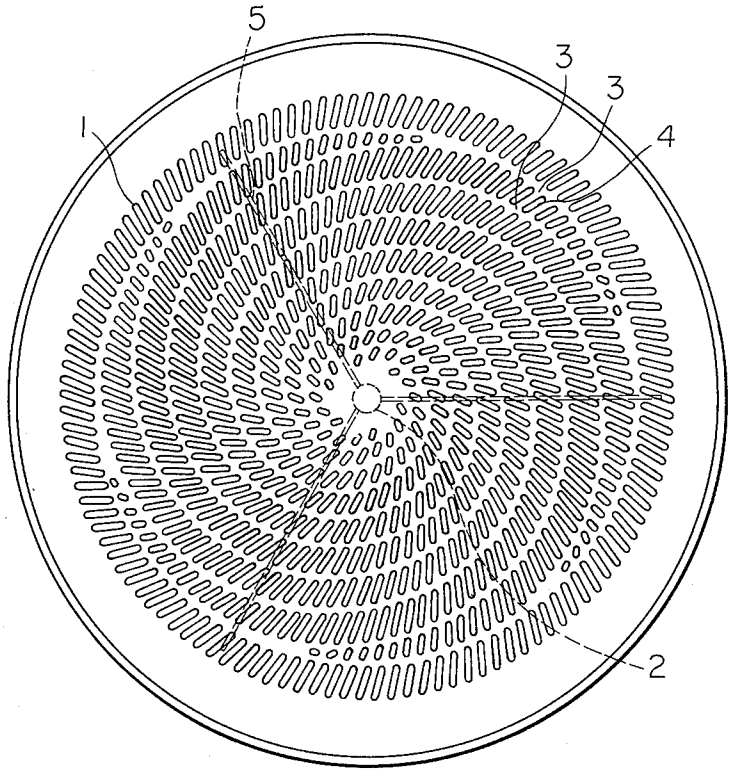


Fig. 7



ELECTRIC DRY SHAVER BLADE ASSEMBLY

This invention relates to a blade assembly for electric dry shavers.

Such a blade assembly for electric dry shavers of a structure as shown in FIG. **1** is already known. In the drawing, P is an outer blade block formed of a dome-shaped outer blade in the upper part and a substantially cylindrical body fixing this outer blade thereto, which body is to be screwed to shaver case. This outer blade is provided with many slits or holes into which hairs to be cut are to be inserted. Q is an inner blade block housed in the above mentioned outer blade block and rotated generally by a motor so that inner blades A provided in the inner blade block Q will rotate in contact with the inside of the outer blade to cut the hairs inserted in the slits or holes on the outer blade. The present invention is to define the relation between the side edge of the respective inner blades and the slit provided on the outer blade.

In the blade of the conventional rotary electric dry shaver, as shown in FIGS. **2A** and **2B**, as the side edge or cutting edge line *a* of the inner blade A rotated at a fixed velocity around an axis **0** as a center in the direction indicated by the arrow X by the motor and the side edge or cutting edge line *b* of the slit B on the outer blade are formed respectively of straight lines, the hair holding angle made by both cutting edge lines *a* and *b* will be different between the case that the hair enters the slit in a position near the rotating axis **0** and the case that the hair enters the slit in a position near the outer end of the inner blade. For example, in comparing the hair holding angle α_1 in case the hair is near the rotating axis and the hair holding angle α_2 in case the hair is far from the rotating axis with each other, their relationship will be $\alpha_1 > \alpha_2$. Generally, in case the hair holding angle is large, the hair will escape and will be hard to cut the same and, in case the hair holding angle is too small, the cutting resistance will be high. Further, in the conventional shaver, even though the hair holding angle is constant in a very few of many slits on the outer blade, it is not consciously designed to be so. As a whole, the hair holding angle made by the side edge of the slit of the outer blade and the side edge of the inner blade is not constant and, therefore, there has been a defect that the so-called cutting efficiency is low. The present invention is suggested to eliminate the above mentioned defect and, according to the present invention, the hair holding angle made by both cutting edge lines of the inner blade and the slit of the outer blade is made constant in any position on the blade surface so that the conventional defect will be successfully eliminated.

According to the present invention, the cutting edge line of each of a plurality of slits of an outer blade or the cutting edge line of each of a plurality of inner blades is curved so that the hair holding angle made by the outer blade and inner blade will be the most reasonable in any position in the lengthwise direction of the outer blade slit and, therefore, the cutting efficiency will be improved and any irritation to the skin will be prevented.

The present invention shall be described in detail with reference to certain preferred embodiments shown in accompanying drawings, in which:

FIG. **1** is a perspective view of a general blade assembly as disassembled;

FIG. **2A** shows an example of an outer blade of a conventional shaver;

FIGS. **2B** is a view showing schematically the relation between both cutting edge lines of the inner blade and outer blade of the shaver in FIG. **2A**.

FIG. **3** is a view showing schematically the same relation as in FIG. **2B** in an embodiment of the present invention;

FIG. **4** is a view showing another embodiment of the present invention in the same manner as in FIG. **3**;

FIG. **5** is an explanatory view of the present invention;

FIG. **6** shows curves of a slit in the case that the angle α made by the intersection of the straight cutting edge lines of the inner blade and the slit of the outer blade is 10°, 20° and 30°;

FIG. **7** shows a practical embodiment of the present invention in a plan view; and

FIGS. **8A** and **8B** are explanatory views showing the relation between the longitudinal diameter and short diameter of the slit of the outer blade.

In the embodiment of the present invention shown in FIG. **3**, the cutting edge line *a'* of the inner blade A' is made straight, the cutting edge line *b'* of the slit B' of the outer blade is curved and C_1 is a hair of a radius *r*. In this embodiment, there can be considered such cases (*i*) that the above described hair holding angles α_1 and α_2 are made constant and (ii) that, where the tangent of the cutting edge line *b'* at the point of contact of the hair C_1 with the cutting edge line *b'* of the slit B' of the outer blade is made D_1 and the tangent of the cutting edge line *b'* at the point of contact of the hair C_2 with the cutting edge line *b'* in the same manner is made D_2, the hair holding angles β_1 and β_2 made by the intersections of the respective tangents D_1 and D_2 with the cutting edge line *a'* of the inner blade are made constant.

In the case of the embodiment shown in FIG. **4** wherein the cutting edge line *b''* of the slit B'' of the outer blade is made straight and the cutting edge line *a''* of the inner blade A'' is curved, the equation of the curve is determined as follows:

i. When the angle of the intersection of the cutting edge line *a''* of the inner blade and the cutting edge line *b''* of the slit of the outer blade is α, with reference to FIG. **5**, as the cutting edge line *a''* of the inner blade is represented by **0P**, if the tangent to the slit curve at the point P on the cutting edge line of the slit of the outer blade is *t* - *t'*, as the angle made by this tangent and the inner edge line *a''* is α, the equation in case α is constant is $dy/dx = \tan(\theta - \alpha)$. If the above differential equation is solved by using the relative formulas

$$y = x \tan\theta \text{ and } R = \sqrt{x^2 + y^2}$$

and the initial conditions

R_0 : Outermost diameter of the slit and

θ_0 : Angle at a point on the outermost diameter of the slit

in it, there will be obtained

$$X = R_0 e^{\frac{\theta_0 - \theta}{k}} \cos\theta,$$

$$Y = R_0 e^{\frac{\theta_0 - \theta}{k}} \sin\theta$$

where $k = \tan \alpha$, If it is represented by polar coordinates,

$$\theta = \theta_0 - k \log \frac{R}{R_0}.$$

ii. The angle of the intersection of the cutting edge line a'' of the inner blade and the cutting edge line b'' of the slit of the outer blade as holding a hair is made β. The equation in the case that β is constant is, in the same manner,

$$\frac{dy}{dx} = \tan(\theta - \alpha)$$

where $y = x \tan \theta$ and

$$\alpha = \beta - \sin^{-1}\left\{\frac{r}{\sqrt{x^2+y^2}}(\cos\beta + 1)\right\}$$

where r is a radius when the hair is considered to be circular in the cross-section. The initial conditions are the same as in the case of (i). When it is solved,

$$\theta = \cos^{-1}\frac{P}{R} - \cos^{-1}\frac{P}{Ro} + s.\log_e\left\{\frac{PS + \sqrt{R_o^2 - P^2}}{PS + \sqrt{R^2 - P^2}}\right\} + \theta_o$$

where

$$S = \tan \beta \text{ and}$$

$$P = r(\cos\beta + 1).$$

If the hair holding angle β is made always constant, then the equation for the shearing curvature is given by the above equation for θ. However, while the thickness of hair (the radius r) is not always constant and it is impossible to render the hair holding angle θ to be precisely constant, the above equation for θ will become the already derived equation $\theta = \theta_o - k \log_e R/R_o$, since $R \geqq r$, that is, $\alpha = \beta$. Thus the hair holding angle is substantially constant irrespective of the hair thickness (the radius r).

A more rigorous derivation based upon FIG. 5 follows:

a' is cutting edge line of inner rotary blade (straight line);

b' is cutting edge line of outer blade;

0 is rotary center of the inner blade;

P is intersection of both cutting edge lines a' and b';

t - t' is tangent line of the line b' at the point P;

θ is angle of the line a' with respect to x-axis;

α is angle of the line a' with respect to the tangent line t - t';

e is the base of natural (Naperian) logarithms;

Additionally, R should represent the length $\overline{0P}$.

Now, an equation for the curvature of the cutting edge line b' of the slit which has always a constant angle α when the inner cutter edge line a' rotates about the point **0** as the center, shall be derived.

The gradient of any optional point P on the curve b' is shown by the following equations (7) and (2):

$$\frac{dy}{dx} = -\tan(\alpha - \theta)$$

-Continued

$$= \tan(\theta - \alpha) \quad (1)$$

$$= \frac{\tan\theta - \tan\alpha}{1 + \tan\theta \cdot \tan\alpha} \quad (2)$$

As will be evident from FIG. 5,

$$y = x \tan \theta \quad (3)$$

In order to simplify the equation, the following substitution shall be made:

$$V = \tan \theta \quad (4)$$

$$K = \tan \alpha \quad (5)$$

Left hand side of the equation (2) will be the following equation (6) due to the above equations (3) and (4):

$$\frac{dy}{dx} = \frac{dV}{dx} \cdot x + V \quad (6)$$

Therefore, the equation (2) becomes the following equation (7) due to equations (4) - (6):

$$\frac{dV}{dx}x + V = \frac{V - K}{1 + V \cdot K}$$

$$\int \frac{1}{x}dx = \int -\frac{1 + V \cdot K}{K(1 + V^2)}dV \quad (7)$$

Answer to the equation (7) will be derived as follows by means of well known formula:

$$\log_e x = -\frac{1}{K}\int (1 + K \cdot V)\frac{d\tan^{-1}V}{dV}dV + C$$

$$= -\frac{1}{K}\{(1 + K \cdot V)\tan^{-1}V - \int \tan^{-1}V \cdot K dV\} + C$$

$$= -\frac{1}{K}\tan^{-1}V - \frac{1}{2}\log(1 + V^2) + C \quad (8)$$

Initial conditions $\theta = \theta_o$, $R = R_o$, $(x = R_o \cos\theta_o)$ are inserted into the equation (8) to obtain C and the following equation (9) is obtained:

$$C = \frac{\theta_o}{K} + \log_e R_o \quad (9)$$

Therefore, if the equation (9) is inserted into the equation (8), the following equation (10) is obtained and, from the equations (3) and (10), the further equation (11) is obtained as follows:

$$x = R_o \cdot e^{\frac{(\theta_o - \theta)}{K}} \cdot \cos\theta \quad (10)$$

$$y = R_o \cdot e^{\frac{(\theta_o - \theta)}{K}} \cdot \sin\theta \quad (11)$$

If polar coordinate indication is made here, the following equation (12) is obtained since $R = \sqrt{x^2 + y^2}$:

$$\theta = \theta_0 - K \log_e \frac{R}{R_0} \quad (12)$$

In FIG. 6, there are shown curves in the case that the hair holding angle α is varied to 10°, 20° and 30° in case $x = R \cos \theta$ is taken on the abscissa and $y = R \sin \theta$ is taken on the ordinate.

In the embodiment of the outer blade shown in FIG. 7, slits 1 of a fixed length are formed at regular intervals on concentric circles on the outer periphery, a plurality of spiral ribs 3 are provided in the outer peripheral direction from the center between the slits 1 on the concentric circles and the center part 2 and slits 4 are provided between the adjacent spiral ribs 3 so that the hair holding angle with the inner blade will be always constant in any position. The length of the slit 4 is made gradually shorter toward the center part and the outer peripheral part, the ratio of the longitudinal diameter L_1 to the short diameter L_2 (see FIGS. 8A and 8B) of the slit 4 is made substantially inverse and both ends of the slit is formed to be substantially arcuate. In the illustrated case, α is about 20°. 5 shows an inner blade. α is preferably 15° to 25°. It has been experimentally confirmed that, if this range of numerical values is adopted, the escape of the hair will be little and the shearing force will be large.

A die for obtaining such blade block is obtained by the following process. That is, first of all, a pattern of a blade block is described on a masking film with a plotter of an electronic computer and a blade block pattern is photo-etched on a copper plate by using this masking film as an original picture.

The photo-etched copper plate is etched by a chemical corrosion process so that the pattern will be engraved on the copper plate. Then a die is formed by a discharging process by using this copper plate as an electrode.

We claim:

1. A cutting blade assembly for an electric dry shaver including a circular stationary blade in the form of a metallic membrane having an apertured field and a rotating blade having a generally radially oriented cutting edge rotating concentrically against the stationary blade, the stationary blade having a pattern of smoothly continuous spaced ribs each lying in an arcuate locus, the ribs being interfittingly spiralled and uniformly spaced from one another in generally parallel relation, adjacent ribs having formed between them a plurality of elongated hair inlet openings spaced adjacent to one another in generally parallel relation with the longitudinal dimension of each opening spanning the space between adjacent ribs, the openings being spaced closely to one another with a latteral spacing which is of the same order of magnitude as the width dimensions of both the openings and the ribs throughout the pattern, the hair inlet openings being oriented in a generally radial direction but so angled with respect to the cutting edge of the blade that the cutting edge progresses along the length of each of the hair inlet openings at a substantially constant shearing angle.

2. The combination according to claim 1 in which the cutting edge of the rotating blade is substantially straight and in which each hair inlet opening defines a cooperating cutting edge which is curved forwardly in the direction of rotation of the rotating blade.

3. The combination according to claim 1 in which the cutting edge of the rotating blade is retreatingly curved and in which the cooperating cutting edge defined by each hair inlet opening is substantially straight.

4. The combination according to claim 1 in which the shearing angle is within the range of substantially 10 degrees to substantially 30°.

5. The combination as claimed in claim 1 in which the spiraled ribs are concentrically encircled by a circular rib, the hair receiving openings formed between the spiraled ribs being of progressively decreasing longitudinal dimension at the region of convergence and at the periphery so that the entire field of the stationary blade is patterned with closely spaced hair receiving openings in substantially uniform density.

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