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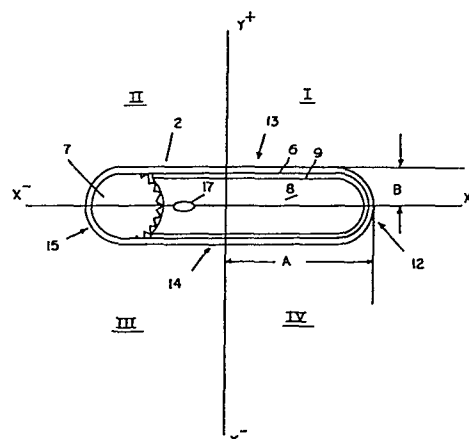
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54 **Guide bar for cutter chain.**

57 A chain saw guide bar 8 having a substantially flat, elongated shape is disclosed. The guide bar 8 is used for supporting and guiding an endless cutter chain 2, rotatable thereabout, in a chain saw. The profile of the guide bar 8 is fashioned so as to minimize shock and stress on the bar 8 and on the cutter chain 2 during rotation of the cutter chain. At the front end 12 of the guide bar 8, the radii of curvature of any two immediately adjacent points on the path of travel of the chain 2 are substantially identical, thereby avoiding instantaneous infinite acceleration during rotation of the cutter chain 2.



"GUIDE BAR FOR CUTTER CHAIN"

Power driven, portable chain saws are known in the art. Such saws have an endless cutter chain running
5 along a guide rail on the periphery of a guide bar.

Mitchell et al, U.S. Patent 1,195,945, discloses a guide bar described as an elliptical frame formed from a curved guide bar or backing blade and a bow-shaped or semi-elliptical frame member.

10 Gelinas, U.S. Patent 2,807,292, discloses a portable, self-powered wood saw wherein the guide bar is in the form of a flat plate or member which extends from a frame which carries the power plant, e.g., an internal combustion engine.

15 Nielsen, U.S. Patent 2,913,020, discloses a chain saw guide bar comprising a longitudinally forwardly projecting bar which is flat-sided, relatively thin transversely and of generally elliptical form in side elevation. In order to provide positive and effective lubrication of the
20 endless cutter chain and to avoid replacement of the guide bar because of wear or damage, a continuous guide rail is seated on the peripheral edge of the guide bar for the full length of said edge and in matching relation thereto. This guide rail is of generally elliptical form but is open at
25 the rear end; the rail being made of a metal which permits the rail to be snap-engaged onto the bar from its forward end. The guide rail is H-shaped in cross-section, providing a continuous outwardly opening channel, a continuous inwardly opening channel, and a central dividing web between such
30 channels. The outwardly opening channel engages projections from the links of the cutter chain, so as to guide the cutter chain about the periphery of the bar. The inwardly opening channel engages the edge of the guide bar to locate the guide rail on the bar and to form a continuous hollow
35 channel around the periphery of the guide bar. Oil is fed into this hollow channel and a plurality of holes in the

web of the rail feed oil to the cutter chain. Thus, oil is fed at a plurality of points over the full length of the run of the cutter chain on the guide bar. Additionally, the guide rail when it becomes worn can be replaced without the necessity of replacing the entire guide bar.

Bye, U.S. Patent 2,599,608, discloses a guide bar for chain saws which because of its asymmetrical form provides supporting contact between the guide bar and the traveling chain with uniform minimum pressure at all points, thereby reducing excessive wear at the localized pressure points which are built up between the traveling chain and the normal symmetrical guide bar. The guide bar departs from conventional symmetrical form to the extent that the portion of the rail which adjoins the sprocket at one side is shaped so that the chain at that side of the sprocket may assume a concave contour; while the portion of the bar adjoining the opposite side of the sprocket exhibits a generally convex edge contour merging smoothly into the sprocket periphery.

Pratt, U.S. Patent 2,618,298, discloses a bow frame chain saw that will produce maximum centrifugal action in the chain under operating conditions whereby the chain may be forced by the centrifugal force outwardly from the guide rail so as to reduce friction between the rail and the chain. The guide rail is in the form of an open frame or bow with a well-rounded outer end portion of ample radius, i.e. the open bow guide rail approximates a circle at its outer free end. As a result, a considerable centrifugal force is developed in the rapidly moving chain. This centrifugal force is utilized for two primary goals, first to reduce friction between the guide rail and the chain, in that the chain tends by centrifugal action to leave the edge of the rail, and secondly, to dynamically tension the chain for optimum operating efficiency.

Gudmundsen, U.S. Patent 2,964,073, discloses a chain saw bar comprising a saw bar with a wheel attached to the nose end of the bar. The chain saw bar includes an elongated support bar having upper and lower edges provided with grooves to receive the center link extensions of the chain and a wheel disposed between the ends of the upper and lower edges of the bar having a peripheral groove to receive the center link extensions of the chain and guide the same as the chain moves from one of the bar edges to the other, there being means for controlling the position of the wheel so that the wear of the chain thereon will be distributed. In one form of the invention, the wheel is supported on the bar so that it will rotate very slowly, thereby presenting different portions of the periphery of the wheel to the chain which travels thereover. In another form of the invention, the rotatably supported wheel is provided with detent or stop means making it possible to periodically rotate the wheel through a small angular distance, so as to bring new portions of the periphery of the wheel into position for engagement by the chain as the previously exposed portion has become worn by the movement of the chain thereover.

Lahtinen, U.S. Patent 3,323,561, discloses a chain saw cutter bar of an asymmetrical shape. In a boring operation using a chain saw of symmetrical cutter bar configuration, it is usually found that the cutter teeth entering the bore are more effective than the cutter teeth leaving the bore. This tends to kick the saw out of the bore, and the portion of the chain entering the bore becomes slack and the linkage elements thereof tend to bunch up resulting in excessive vibration. The Lahtinen cutter bar, accordingly, has a nose end formed so that the degree of curvature is less on the cutting run guide portion side of the medial line than it is on the other side of the line. In particular, the cutter bar is asymmetrical in that its outer end is formed as a

spiral easement curve, the degree of curvature thereof gradually decreasing from a tangential juncture with a return portion towards its juncture with the cutting run portion. Additionally, the cutting run guide portion is
5 formed having a greater degree of curvature than its return guide portion , which is substantially straight.

Hille, U.S. Patent 4,060,895, discloses a guide for a chain saw having a configuration such as that in the aforementioned Lahtinen patent. However, the Lahtinen bar
10 cannot be inverted so as to reverse the top and bottom edges. Because the bottom edge of the bar is where most cutting takes place, it wears much faster than the top edge. When the bottom edge wears, the conventional symmetrical bar is inverted to expose the relatively unused top
15 edge to the cutting forces and thereby increase bar life. Hille overcomes this defect of Lahtinen by providing a symmetrical main body portion that is detachable from a non-symmetrical nose portion. Thus, only a small portion of the bar, the nose portion, is non-invertible; the remainder
20 of the bar being invertible as the side subjected to the most cutting action becomes worn.

As may be readily ascertained from the above-noted patents, chain saw guide bars of various profiles (symmetrical, non-symmetrical, generally elliptical, gene-
25 rally circular and bow-shaped) have been used in the prior art, as well as chain saw guide bars of varying degrees of ease of construction (unitary, fitted with a guide rail, fitted with a nose wheel and fitted with a nose piece). A need continues to exist for a chain saw guide bar which
30 exhibits reduced wear due to chain travel thereover and which is economical to fabricate.

SUMMARY OF THE INVENTION

5 The present invention overcomes the aforementioned difficulties of wear on the bar in a manner which allows easy and economical fabrication of the chain saw guide bar. In particular, it has now been discovered that by control of the shape of the outer periphery of the bar, chain wear on the bar (or chain guide means, where such guide means are not integral with the bar) can be reduced, especially at the points where the chain makes a transition from one path of travel to another path of travel (e.g. from a substantially linear path of travel, at the top and bottom edges of the bar, to a substantially curved path of travel, at the front end of the bar). These transition points are generally high wear areas of conventional guide bars. Moreover, by such reduction of bar wear, the present invention reduces the noise and vibration produced in operation of the saw after a period of use as compared to conventional guide bars.

20 The bar, in one embodiment, can be formed as a unitary member, thereby eliminating the need for precision machining to form fitted pieces which can be assembled into a guide bar. In one preferred embodiment, the chain saw guide bar having a front end and a rear end and a top edge and a bottom edge and having a substantially flat, elongated shape is provided with top edge means for supportingly and guidingly engaging an endless cutter chain, rotatable about the guide bar, along the top edge thereof; bottom edge means for supportingly and guidingly engaging the cutter chain along the bottom edge thereof; and front end means for guidingly and supportingly engaging the cutter chain in a substantially curved path of travel around the front end of the bar from the top edge means to the bottom edge means. The top edge means, bottom edge means and front end means define the path of travel about the bar such that the radii curvature of any two immediately adjacent points

on the path of travel are essentially identical. In a preferred embodiment, it is only necessary to control the path of travel of the cutter chain at one of the above-mentioned transition points in order to achieve a reduction in bar/chain wear and concomitantly extend the bar life while reducing noise and vibration. In a further preferred embodiment, the guide bar can be of a substantially elliptical profile with at least a portion of the profile defined by the equation

$$Y = B(1 - (X^2/A^2))^C$$

wherein Y is the vertical coordinate of the guide bar profile in a Cartesian coordinate system; X is the horizontal coordinate of the guide bar profile in a Cartesian coordinate system; A is the length of the semi-major axis of the ellipse; B is the height of the semi-minor axis of the ellipse; and C is a predetermined constant. In a particularly preferred embodiment, the front end of the bar is fitted with a rotatable sprocket wheel to guide and engage the cutter chain in its path of travel around the front end of the bar.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

Figure 1 is a side elevation view of a chain saw incorporating the guide bar of the invention showing the components thereof.

Figure 2 is a side elevation of the profile of a unitary guide bar according to the present invention.

Figures 3-7 are diagrammatic views illustrating the principle of the invention.

Figures 8A and 8B are graphs showing angular velocity of the cutter chain as a discontinuous function of arc length along the guide bar and the concomitant angular acceleration of the cutter chain as a function of arc length along the guide bar, respectively.

Figures 9A and 9B are graphs showing angular

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velocity of the cutter chain as a substantially continuous function of arc length along the guide bar and the concomitant angular acceleration as a function of arc length along the guide bar, respectively.

5 Figure 10 is a side elevation of the profile of a guide bar having a front end sprocket wheel according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

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Figure 1 illustrates an embodiment of the invention comprising a chain saw having a guide bar unit indicated generally at 1, and an endless cutter chain 2 extending around the guide bar unit. A housing 3 contains any
15 suitable and conventional prime mover such as an internal combustion engine (or an electric motor) 10 for rotating the cutter chain 2 about the guide bar unit. A front handle 4 and a rear handle 5 are mounted on the housing 3. The
20 guide bar unit 1 projects forwardly from the housing 3 and comprises a forwardly projecting guide bar 8, which is substantially flat and of elongated shape, e.g., flat-sided, relatively thin transversely, and of generally elliptical outline in side elevation. The forwardly projecting
25 guide bar 8 is provided with support and guide means for the endless cutter chain 2. In this respect, the outer edge portion 9 of the guide bar 8 may have mounted thereon (as illustrated) or integrally formed therewith a continuous
30 guide rail 6 for supporting and guiding a continuous, articulated cutter chain 2, as is well-known in the chain saw art.

Figure 2 shows a diagram of the profile of a guide bar 8 wherein the guide rail 6 for supporting and guiding cutter chain 2 is integrally formed with the outer edge portion 9 of the guide bar 8. The guide rail supports
35 and guides the continuous, articulated cutter chain 2 along the top 13 and bottom 14 edges of the bar and around the

front end 12 of the bar. The links of the cutter chain and their cutter teeth may be of any suitable and well-known construction, and may be of unitary construction as illustrated in Figure 3. The chain links 11 may be provided with rivets 16 or other means for securing the articulated elements together. For a major portion of its length, the endless cutter chain 2 is slidably supported on and travels in a substantially linear path along the top 13 and bottom 14 edges of the guide bar 8, and, at its rear end 15, the chain 2 is driven by a rotating sprocket wheel indicated diagrammatically at 7 in Figure 2. The sprocket wheel 7 is in turn driven by engine 10.

A Cartesian coordinate system (y^+/y^- versus x^+/x^-) is superposed on the generally elliptical guide bar 8 to illustrate the semi-major axis length of an ellipse, a , and the semi-minor axis height of an ellipse, b . The major axis of the ellipse is its long axis and the minor axis of the ellipse is its short axis. The semi-major axis is one-half the length of the major axis and the semi-minor axis is one-half the height of the minor axis. The major axis and the minor axis also correspond to the horizontal and vertical medial lines, respectively, of the guide bar 8 which divide the generally elliptical shape of the bar into four quadrants, I (top front quadrant), II (top rear quadrant), III (bottom rear quadrant) and IV (bottom front quadrant), which are found between the x^+/y^+ axes, y^+/x^- axes, x^-/y^- axes and y^-/x^+ axes, respectively.

Assuming that the chain 2 travels at a constant linear velocity around the bar, i.e. sprocket 7 is driven at a constant rotational speed, a single element, such as tooth 11 (shown in Figure 3) will experience acceleration in response to the constant speed of the sprocket 7, by virtue of the force transmitted to such a single element through the rivets 16 or other means for securing the articulated elements together. As may be seen in Figure 3, the normal component of acceleration A_N forces the element

11 to follow the guide path of the bar and the forces transmitted through the rivets cause the element 11 to remain "upright" to its path of travel when traveling over a curved peripheral surface of the bar at a constant linear velocity V.

In discussing motion over curved surfaces, the following relationships should be borne in mind:

$$V = rW \quad (A)$$

$$A_N = W^2 r = V^2 / r \quad (B)$$

$$A_T = r \alpha \quad (C)$$

wherein:

V = linear velocity;

W = angular velocity;

A_N = normal component of acceleration;

A_T = tangential component of acceleration;

α = angular acceleration; and

r = radius.

If the chain 2 travels on a curved path of constant radius, such as the circle as shown in Figure 4, at a constant linear velocity V; then A_N is a constant ($= V^2/r$), W is a constant ($= V/r$), and A_T is zero ($\alpha = dW/dt = 0$).

However, guide bars of the prior art generally are constructed with two or more radii to describe the bar contour, and hence the cutter chain path. In such a case, a single element of chain will experience a different normal acceleration A_N and angular velocity W (the linear velocity being constant) for each radius used. Where the first radius surface is tangent to the second radius surface, there will be an instantaneous change in the angular velocity W (i.e., an instantaneous tangential acceleration) and a concomitant change in the normal acceleration. This is illustrated in Figure 5, wherein an element traveling over a surface defined by radius r_1 is shown to have a normal acceleration A_{N1} and an angular velocity W_1 ; and when traveling over a surface defined by radius r_2 is shown to

have a normal acceleration A_{N2} and angular velocity W_2 . In other words, when the linear velocity V is constant, then:

$$\begin{aligned} A_{N1} &= V^2/r_1; \\ W_1 &= V/r_1; \\ 5 \quad A_{N2} &= V^2/r_2; \text{ and} \\ W_2 &= V/r_2. \end{aligned}$$

The effects of these changes at the tangent point are illustrated in Figures 8A and 8B. Figure 8A is a graph showing angular velocity W as a function of arc length s along the contour of the guide bar. As may be readily ascertained, at the tangent point the angular velocity makes an instantaneous leap from W_1 to W_2 . Figure 8B is a graph showing angular acceleration as a function of arc length s along the contour of the guide bar. As may be readily ascertained, at the tangent point the angular acceleration instantaneously goes from zero to infinity (∞), i.e. at the tangent point the chain is subjected to an "infinite jerk".

The physical effect of this instantaneous transition is illustrated in Figure 6. The chain has mass and, when traveling from a large radius to a small radius (upper element in Figure 6), this will cause the instantaneous increase in A_N and W (and the instantaneous angular acceleration α which gives rise to a tangential acceleration $A_T = r\alpha$) to take place over a finite period of time. During this time, the chain element will raise off the path and lean backwards to the path. This causes lift-off at the tip of the bar and high rivet stress in the leading rivet and chain link pulling the following link down and forcing it to rotate. Additional resistive forces are produced by the friction in the rivets and related parts. When the chain goes from a small radius to a large radius (lower element in Figure 6), there will be an instantaneous decrease in A_N and W (and an instantaneous negative angular acceleration α which gives rise to a negative tangential acceleration $A_T = r\alpha$). The instantaneous decrease in A_N is not a

problem when mass is considered; the element is simply free to travel along the new radius. The instantaneous decrease in W lets the chain element continue to rotate until acted upon by the pulling link or the bar. This causes the rail to wear at the front end (indicated by the dotted line). Thus, it becomes clear that the stress or shock on the bar and chain can be alleviated by eliminating the substantially instantaneous change in angular velocity (and concomitant infinite angular acceleration) as the chain moves over the bar contour. In other words, the angular velocity of the chain must be a substantially continuous function of arc length s along the contour of the bar. By a substantially continuous function is meant a function such that at all points, arbitrarily designated s , within the function:

$$\lim_{h \rightarrow 0} [f(s+h) - f(s)] = 0, \text{ where } f(s) = W.$$

Preferably, the angular acceleration of the chain is also a substantially continuous function of arc length along the contour of the bar, so as to insure that there are no finite instantaneous jumps in acceleration which would also produce stress or shock on the bar and chain, albeit of a lower order of magnitude. Such a situation is illustrated in Figures 9A and 9B. Figure 9A is a graph showing angular velocity W as a continuous function of arc length s along the contour of the guide bar. As may be readily ascertained, the transition between W_1 and W_2 has been spread out over a length $(s_2 - s_1)$ of the guide bar, thereby eliminating the instantaneous jump in angular velocity and producing a continuous function of W as a function of arc length s . Figure 9B is a graph showing angular acceleration as a function of arc length s along the contour of the guide bar. As may be readily ascertained, the angular acceleration has now been spread out over a length $(s_2 - s_1)$ of the guide bar, thereby eliminating the "infinite jerk" produced by an instantaneous infinite acceleration and producing a continuous function of W as a function of arc length s .

Physically, this elimination or alleviation of shock or stress on the bar and chain can be achieved by controlling the bar contour. It follows that a bar where the radii of curvature of any two immediately adjacent points on the bar contour are essentially identical, would produce a continuous function of W as a function of arc length s when the chain is rotated about the bar at constant linear velocity. In this case, r_1 (as shown in Fig. 5) would vary to define the bar profile, but any two immediately adjacent points on the bar profile would have essentially identical radii of curvature, thereby eliminating the "infinite jerk" produced by an instantaneous infinite acceleration. It should be noted that in this case, at least a portion of the bar profile could have a constant radius of curvature without detrimental effect on the wear characteristics of the bar, e.g. at the front end of the bar $r_1 = r_2 = \text{constant}$, r_2 defining a rotatable sprocket wheel mounted on the bar. Alternatively, a bar contour could be defined by at least two curves of constant radius of curvature, each curve of constant radius of curvature being separated from adjacent curves of constant radius of curvature by a transition zone wherein the radii of curvature of any two immediately adjacent points in the transition zone are essentially identical, thereby assuring a smooth transition from one constant radius curve to another. In this case, r_1 and r_2 (as shown in Fig. 5) would each be constant, and a transition zone between points s_1 and s_2 on the bar profile would have a constantly changing radius of curvature from r_1 to r_2 such that the radii of curvature of any two immediately adjacent points on the bar profile within the transition zone are essentially identical. This would eliminate the "infinite jerk" produced by an instantaneous infinite acceleration, as previously discussed with respect to Figs. 9A and 9B. It should be noted that in this case, r_1 could be of sufficiently large magnitude to define a substantially linear path of travel

for either the top edge, bottom edge or both edges of the bar. Additionally, r_2 could define a portion of the bar profile, per se, or the pitch radius of a rotatable sprocket wheel mounted on the front end of the bar. In the case of guide rails being mounted on the bar for engagement with the cutter chain, the guide rail can be formed to integrally include both a linear portion defined by r_1 and a transition zone wherein the radii of curvature constantly change from r_1 to r_2 such that the radii of curvature of any two immediate points within the transition zone are essentially identical. This latter embodiment is especially useful for the case where r_2 defines the pitch radius of a sprocket wheel mounted for rotation on the front end of the bar. As a further alternative, a bar having an elliptical shape could be utilized to reduce the wear on the bar and the stress on the chain links.

The equation for an ellipse (the plane locus of a point such that the sum of the distance of the point from two fixed points is constant) is:

$$\frac{x^2}{A^2} + \frac{y^2}{B^2} = 1 \quad (1)$$

wherein:

Y is the vertical coordinate of the guide bar contour in a Cartesian coordinate system;

X is the horizontal coordinate of the guide bar contour in a Cartesian coordinate system;

A is the length of the semi-major axis; and

B is the height of the semi-minor axis.

To give more control to the shape of the guide bar, an ellipse generated by a section through a cone (the section of a right circular cone by a plane, the whole of the section lying on one side of the vertex of the cone) can be used. The equation for such an ellipse is:

$$\frac{x^2}{A^2} + \frac{y^n}{B^n} = 1 \quad (2)$$

5 wherein Y,X,A and B are as defined above, and

$$n = \frac{1}{C}$$

where C is a predetermined constant; preferably, C is selected so that the outer edge of said guide bar passes
10 through the point of tangency of a circle of predetermined radius with the profile of the ellipse, the radius of the circle being equal to the radius of curvature of the elliptical profile at the point of tangency.

In the construction of a guide bar according to
15 the present invention, the elliptical bar profile is based on specific geometric parameters, e.g. the length of the bar, the width of the bar and the desired tangency pass through point of the contour of the bar. In practice, the bar is to have the shape of a modified ellipse with at
20 least a portion of the profile defined by equation (2), which when rearranged gives the expression:

$$Y = B \left(1 - \frac{x^2}{A^2} \right)^C \quad (2a)$$

25

Using this expression there would be a tendency to lose a root; however, since the ellipse is symmetrical about both axes, only the first quadrant need be of concern. Thus, given a point on the bar profile (e.g. the tangency pass
30 through point of the contour of the bar (x_T, y_T)), the value of the exponent, C, can be obtained.

However, in many instances, the particular geometric parameters will not be set in advance. In these instances acceleration at the tangent point must be coordinated with acceleration at constant radius, i.e. a circle
35 of given radius, R, must be placed tangent to the ellipsoid. Figure 7 diagrammatically illustrates the parameters

to be taken into account in the solution of this problem, i.e. tangent point length $Q = X_T$, tangent point delta width $S = \Delta Y$, pitch radius R , lift-off angle F , and the radius of curvature at the point of tangency, r_T , which must equal R . A method to solve for A (length of the semi-major axis), B (the height of the semi-minor axis) and C (the exponent) of the ellipsoid from the given formulae (3), (4), and (5) is as follows:

$$F = \text{TAN}^{-1} \left[\frac{dY}{dX} \right] \quad (3)$$

therefore

$$\text{TAN } F = - \left. \frac{dY}{dX} \right|_{X=X_T} \quad (3a)$$

$$R = r_T = \left. \frac{\left[1 + \left(\frac{dY}{dX} \right)^2 \right]^{3/2}}{\left| \frac{d^2 Y}{dx^2} \right|} \right|_{X=X_T} \quad (4)$$

$$\Delta Y = Y_{@X=0} - Y_{@X=X_T} = B - B \left(1 - \frac{X_T^2}{A^2} \right)^C \quad (5)$$

$$B = \frac{\Delta Y}{1 - \left(1 - \frac{X_T^2}{A^2} \right)^C} \quad (5a)$$

The equation for the ellipsoid from equation (2) is:

$$\frac{X^2}{A^2} + \frac{Y^{1/C}}{B^{1/C}} = 1 \quad (6)$$

$$\frac{Y^{1/C}}{B^{1/C}} = 1 - \frac{X^2}{A^2} \quad (6a)$$

$$Y^{1/C} = B^{1/C} \left(1 - \frac{X^2}{A^2} \right) \quad (6b)$$

$$Y = B \left(1 - \frac{X^2}{A^2} \right)^C \quad (7)$$

differentiating with respect to X gives:

$$\frac{dY}{dX} = - \frac{2BCX}{A^2} \left(1 - \frac{X^2}{A^2}\right)^{(C-1)} \quad (7a)$$

differentiating again gives:

$$\frac{d^2Y}{dX^2} = - \frac{2BC}{A^2} \left(1 - \frac{X^2}{A^2}\right)^{(C-1)} + \frac{4BCX^2(C-1)}{A^4} \left(1 - \frac{X^2}{A^2}\right)^{(C-2)} \quad (7b)$$

factoring (7b) gives:

$$\left. \frac{d^2Y}{dX^2} \right|_{X=X_T} = - \frac{2BCX_T}{A^2 X_T} \left(1 - \frac{X_T^2}{A^2}\right)^{(C-1)} + \frac{[-2X_T(C-1)]}{A^2} \left(1 - \frac{X_T^2}{A^2}\right)^{-1} \left(\frac{-2BCX_T}{A^2} \right) \left(1 - \frac{X_T^2}{A^2}\right)^{(C-1)} \quad (8)$$

rearranging and reducing:

$$\left. \frac{d^2Y}{dX^2} \right|_{X=X_T} = - \frac{TAN(F)}{X_T} + \frac{2X_T(C-1)TAN(F)}{A^2 \left(1 - \frac{X_T^2}{A^2}\right)} \quad (9)$$

substituting from (3a) gives:

$$\frac{d^2Y}{dX^2} = - \frac{TAN(F)}{X_T} + \frac{2X_T(C-1)TAN(F)}{A^2 \left(1 - \frac{X_T^2}{A^2}\right)} \quad (10)$$

then from (4) and (3a):

$$\left. \frac{d^2 y}{dx^2} \right|_{x=x_T} = - \frac{\left[1 + \left(\frac{dy}{dx} \right)^2 \right]^{3/2}}{R} = - \frac{(1 + \tan^2 F)^{3/2}}{R} \quad (11)$$

combining (10) and (11):

$$- \frac{\tan F}{x_F} + \frac{2x_T (C-1) \tan F}{(A^2 - x_T^2)} = - \frac{(1 + \tan^2 F)^{3/2}}{R} \quad (12)$$

rearranging gives:

$$\frac{2x_T (C-1) \tan F}{A^2 - x_T^2} = \frac{\tan F}{x_T} - \frac{(1 + \tan^2 F)^{3/2}}{R} \quad (13)$$

and dividing by $\tan F$ gives:

$$\frac{2x_T (C-1)}{A^2 - x_T^2} = \frac{1}{x_T} - \frac{(1 + \tan^2 F)^{3/2}}{(\tan F) R} \quad (14)$$

using variable K :

$$K = \frac{1}{x_T} - \frac{(1 + \tan^2 F)^{3/2}}{(\tan F) R} \quad (15)$$

and rearranging gives:

$$A^2 - x_T^2 = \frac{2x_T (C-1)}{K} \quad (16)$$

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solving for A:

$$A = \sqrt{X_T^2 + \frac{2X_T(C-1)}{K}} \quad (17)$$

then combining (3a) and (7a):

$$\text{TAN } F = \frac{2BCX_T}{A^2} \left(1 - \frac{X_T^2}{A^2} \right)^{(C-1)} \quad (18)$$

substituting (5a) gives:

$$\text{TAN } F = \frac{2 \Delta Y C X_T \left(1 - \frac{X_T^2}{A^2} \right)^{(C-1)}}{A^2 \left[1 - \left(1 - \frac{X_T^2}{A^2} \right)^C \right]} \quad (19)$$

and rearranging:

$$\text{TAN } F = \frac{2 \Delta Y C X_T \left(1 - \frac{X_T^2}{A^2} \right)^C}{\left[A^2 \left(1 - \frac{X_T^2}{A^2} \right) \right] \left[1 - \left(1 - \frac{X_T^2}{A^2} \right)^C \right]} \quad (20)$$

substituting from (16):

$$\text{TAN } F = \frac{2 \Delta Y C X_T \left(1 - \frac{X_T^2}{A^2} \right)^C}{\frac{2X_T(C-1)}{K} \left[1 - \left(1 - \frac{X_T^2}{A^2} \right)^C \right]} \quad (21)$$

dividing by $K \Delta Y$ gives:

$$\frac{\text{TAN } F}{K \Delta Y} = \frac{C \left(1 - \frac{X_T^2}{A^2} \right)^C}{(C-1) \left[1 - \left(1 - \frac{X_T^2}{A^2} \right)^C \right]} \quad (22)$$

inverting rearranging and substituting from (16a) yields:

$$\frac{K \Delta Y}{\text{TAN } F} = \left[\left(1 - \frac{X_T^2}{A^2} \right)^{-C} - 1 \right] \frac{(C-1)}{C} =$$

$$\frac{(C-1)}{C} \left[\left(1 - \frac{X_T^2}{X_T^2 + \frac{2X_T^2(C-1)}{K}} \right)^{-C} - 1 \right] \quad (23)$$

rewriting gives:

$$\frac{K \Delta Y}{\text{TAN } F} = \left(1 - \frac{1}{C} \right) \left[\frac{1}{\left(1 - \frac{X_T^2}{X_T^2 + \frac{2X_T^2(C-1)}{K}} \right)^C} - 1 \right] =$$

$$\left(1 - \frac{1}{C} \right) \left[\frac{1}{\left(1 - \frac{1}{1 + \frac{2}{X_T K} (C-1)} \right)^C} - 1 \right] \quad (24)$$

calling this expression a function of C gives $F(C) = 0$:

$$F(C) = \left(1 - \frac{1}{C} \right) \left[\frac{1}{\left(1 - \frac{1}{1 + \frac{2}{X_T K} (C-1)} \right)^C} - 1 \right] - \frac{K \Delta Y}{\text{TAN } F} = 0$$

To find C for which $F(C) = 0$, requires a trial and error solution. This can be done as an iterative process on a computer. Then using C in (5a) and (17) will give values for A and B

5

$$A = \sqrt{X_T^2 + \frac{2X_T(C-1)}{K}}$$

10

$$B = \frac{\Delta Y}{1 - \left(1 - \frac{X_T^2}{A^2}\right)^C}$$

15

Thus, given the lift-off angle F, the tangent point length $Q = X_T$, the tangent point delta width $S = Y$ and the pitch radius R, an ellipsoid can be determined for which the radius of curvature at the point of tangency with the circle is identical to the circle's pitch radius. In other words, no instantaneous change occurs at the transition from the ellipsoid to the circle.

20

Turning again to Figure 7, it will be seen that in accord with this invention the ellipsoid GPH is tangent to the circle of radius R at point P, and the radius of curvature of the ellipsoid at point P is equal to the radius R of the circle. Thus, the bar profile would be defined by the ellipsoid between points G and P and by the circle of radius R after point P. When producing a symmetrical bar, it is necessary that the center of the circle of radius R lie on the horizontal medial line of the guide bar (i.e. the line $x^{1-} - x^{1+}$). In this case, the equation defining the ellipsoid would be

25

30

$$Y = B \left(1 - \frac{X^2}{A^2}\right)^C + L$$

where X, Y, A, B and C are as previously defined, and L would be the displacement of the X-axis to bring the horizontal medial line into alignment with the center of

the circle of radius R. The value of the constant L can be readily calculated from the formula

$$L = R \cos F - Y_T$$

5 where R and F are as previously defined and

$$Y_T = B \left(1 - \frac{X_T^2 C}{A^2} \right)$$

10 where A, B, C and X_T are as previously defined. Thus, the bar profile would be defined between points G and P by the equation

$$Y = B \left(1 - \frac{X^2}{A^2} \right)^C + L$$

15 and between the point P and the intersection with the X^{1+} axis by the circumference of the circle. The lower quadrant of the bar would be defined by a mirror image projection of the upper quadrant profile.

20 In an example of the invention, a symmetrical 14-inch guide bar has a nose radius (R) of 18.67 mm, a tangent point length (Q) of 253.86 mm and the ellipsoid defining at least a portion of the profile of the top and bottom front quadrants is defined by the equation:

$$25 \quad Y = 27.6341071673 \left(1 - \frac{X^2}{(259.068523531)^2} \right)^{0.23271740646} + 2.36589283272$$

30 The benefits of the present invention are obtainable when only one quadrant of the guide bar is shaped in accordance with the present invention, preferably a quadrant at the front end of the guide bar. Preferably both quadrants at the guide bar front end are shaped in accordance with the present invention.

35 In this regard, it should be noted that the correct bar profile is most important at the front end of

the bar, since at the rear end of the bar movement of the bar relative to the drive sprocket will be used to adjust the chain tension, as the chain wears; and any previously set profile will lose its effectiveness when such adjustments are made.

In a preferred embodiment of the invention, the above-noted formula (2) can be used not only for a solid bar but also for a bar having a front end sprocket wheel for supporting and guiding the chain. Such a bar is illustrated in Figure 10 showing a diagram of the profile of a guide bar 8' wherein the guide rail for supporting and guiding cutter chain 2' along the top 13' and the bottom 14' edge portions define the top and bottom contour of the bar and a sprocket wheel 20' fixed to the front end of said bar and rotatable about an axis 21' defines the contour of the front end of the bar. By utilizing formula (2), i.e. determining the value of C so that sprocket wheel 20' is tangent to the contour of the bar at the point where the radius of curvature of the bar contour equals the pitch radius of sprocket wheel 20', for at least one quadrant at the front end 12', a bar can be fashioned having the reduced wear characteristics previously described. The cutter chain 2' is rotated about the bar 8' by drive sprocket 7', located at the rear end 15' of the bar, which in turn is driven by engine 10 (see Figure 1). A slot 17' which can receive a bolt is provided at the rear end of the guide bar for attaching the guide bar to the housing 3 (see Figure 1) and this slot allows backward and forward movement of the bar 8' with respect to drive sprocket 7' so as to adjust the tension in cutter chain 2'. As in Figure 2, a Cartesian coordinate system superposed on the horizontal and vertical medial lines can be seen to divide the bar contour into four quadrants.

CLAIMS

1. A chain saw guide bar having a front end and a rear end and a top edge and a bottom edge and having a substantially flat, elongated shape; said guide bar provided with edge means for supportingly and guidingly engaging an endless cutter chain, rotatable about said guide bar, along substantially the entire edge thereof; said edge means, defining the path of travel of said chain about said bar such that in at least one front quadrant of said guide bar the radii of curvature of any two immediately adjacent points on said path of travel are essentially identical, thereby eliminating instantaneous infinite acceleration during rotation of the cutter chain.

2. The guide bar as claimed in Claim 1, wherein said at least one front quadrant is the bottom front quadrant.

3. The guide bar as claimed in Claim 1, wherein said at least one front quadrant is the bottom front quadrant and the top front quadrant.

4. The guide bar as claimed in Claim 1, wherein said edge means comprises top edge means for supportingly and guidingly engaging said cutter chain along the top edge thereof, bottom edge means for supportingly and guidingly engaging said cutter chain along the bottom edge thereof, and front end means for guidingly and supportingly engaging said cutter chain in a substantially curved path of travel around the front end of said bar from said top edge means to said bottom edge means.

5. The guide bar as claimed in Claim 4, wherein said top edge means comprises a top linear edge means for

supportingly and guidingly engaging said cutter chain in a substantially linear path of travel and a top transition edge means for supportingly and guidingly engaging said cutter chain in the transition from said substantially linear path of travel along said top linear edge means to the substantially curved path of travel around said front end means.

6. The guide bar as claimed in Claim 5, wherein said top linear edge means and said top transition edge means are integrally formed with one another.

7. The guide bar as claimed in Claim 5, wherein said top linear edge means has a constant radius of curvature.

8. The guide bar as claimed in Claim 4, wherein said bottom edge means comprises a bottom linear edge means for supportingly and guidingly engaging said cutter chain in a substantially linear path of travel and a bottom transition edge means for supportingly and guidingly engaging said cutter chain in the transition from said substantially linear path of travel along said bottom linear edge means to the substantially curved path of travel around said front end means.

9. The guide bar as claimed in Claim 8, wherein said bottom linear edge means and said bottom transition edge means are integrally formed with one another.

10. The guide bar as claimed in Claim 8, wherein said bottom linear edge means has a constant radius of curvature.

11. The guide bar as claimed in Claim 4, wherein said top edge means and said bottom edge means are each integral with said guide bar.

12. The guide bar as claimed in Claim 4, wherein said front end means is integral with said guide bar.

5 13. The guide bar as claimed in Claim 4, wherein said front end means comprises a sprocket wheel of fixed radius, rotatably mounted on the front end of said guide bar.

10 14. A chain saw guide bar having a front end and a rear end and having a top edge and a bottom edge; said guide bar having a horizontal medial line and a vertical medial line dividing said bar into a top front quadrant, a bottom front quadrant, a top rear quadrant and a bottom rear quadrant; top edge means for guidingly and supportingly
15 ly engaging an endless cutter chain, rotatable about said guide bar, in its path of travel along the top edge of said guide bar; bottom edge means for guidingly and supportingly engaging said endless cutter chain in its path of travel along the bottom edge of said guide bar; front end means
20 comprising a sprocket wheel rotatably mounted on the front end of said guide bar, said sprocket wheel engageable with said cutter chain, for supportingly and guidingly engaging said endless cutter chain in its path of travel around the front end of said bar; said top edge means, said bottom
25 edge means, and said front end means, together, defining the path of travel of said chain about said guide bar, such that in at least one of said front quadrants the radii of curvature of any two immediately adjacent points on said path of travel are essentially identical.

30

15. The guide bar as claimed in Claim 14, wherein said top edge means and said bottom edge means are each integral with said bar.

16. The guide bar as claimed in Claim 14, wherein in both of said front quadrants the radii of curvature

of any two immediately adjacent points on said path of travel are essentially identical.

17. The guide bar as claimed in Claim 14, where-
5 in said top edge means comprises a top linear edge means for supportingly and guidingly engaging said cutter chain in a substantially linear path of travel and a top transition edge means for supportingly and guidingly engaging said cutter chain in the transition from said substantially
10 linear path of travel along said top linear edge means to the path of travel around said front end means.

18. The guide bar as claimed in Claim 14, where-
in said bottom edge means comprises a bottom linear edge
15 means for supportingly and guidingly engaging said cutter chain in a substantially linear path of travel and a top transition edge means for supportingly and guidingly engaging said cutter chain in the transition from said path of travel around said front end means to substantially linear
20 path of travel along said bottom linear edge means.

19. A chain saw guide bar having a front end and a rear end and having a top edge and a bottom edge; said guide bar having a horizontal medial line and a vertical
25 medial line dividing said bar into a top front quadrant, a bottom front quadrant, a top rear quadrant and a bottom rear quadrant; said guide bar having a substantially flat, elongated shape of substantially elliptical profile; said guide bar having an outer edge portion of the profile
30 supportably and guidably engageable with an endless cutter chain, rotatable about the profile of said guide bar, wherein at least a portion of the profile of at least one quadrant of said front end of said guide bar is defined by the equation

$$Y = B(1 - (X^2/A^2))^C$$

wherein:

Y is the vertical coordinate of the guide bar profile in a Cartesian coordinate system;

5 X is the horizontal coordinate of the guide bar profile in a Cartesian coordinate system;

A is the length of the semi-major axis of the ellipse;

B is the height of the semi-minor axis of the ellipse; and

10 C is a predetermined constant.

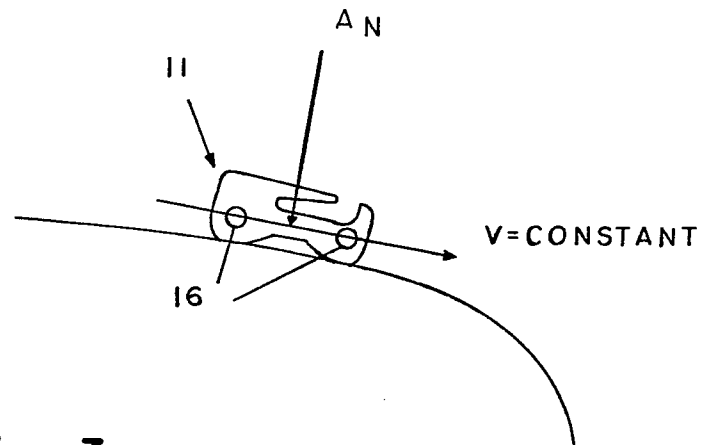
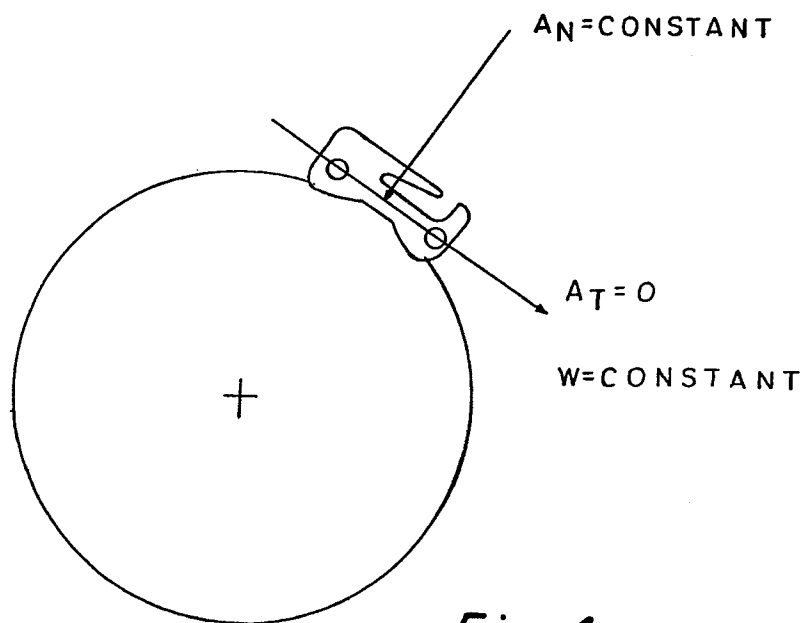
20. The guide bar as claimed in Claim 19, wherein C is selected so that the outer edge portion of said guide bar passes through the point of tangency of a circle
15 of predetermined radius with the elliptical profile, the radius of the circle being equal to the radius of curvature of the elliptical profile at the point of tangency.

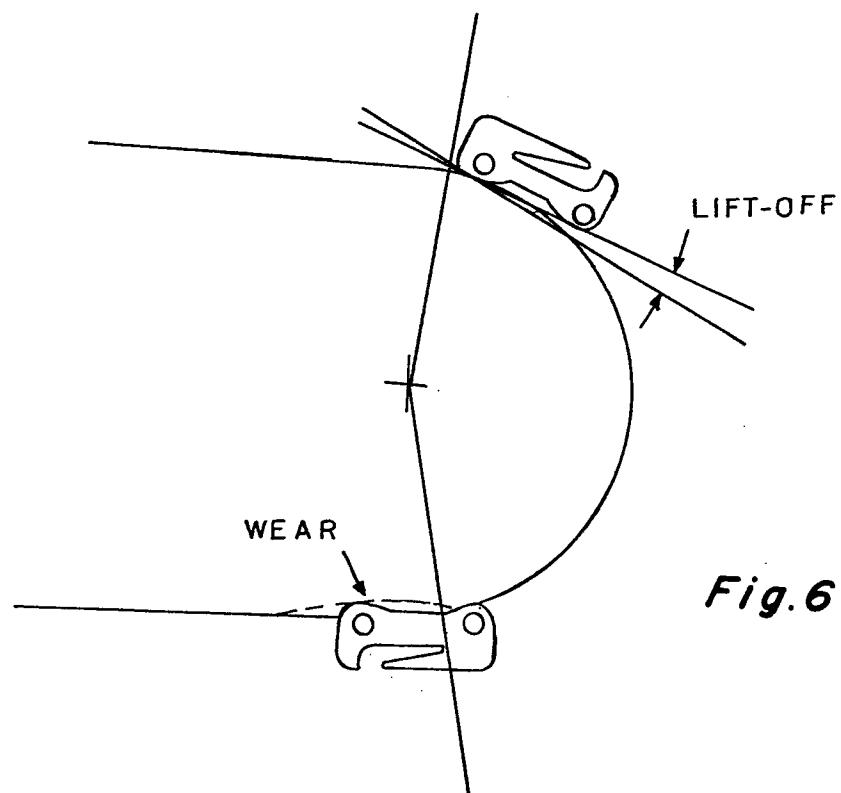
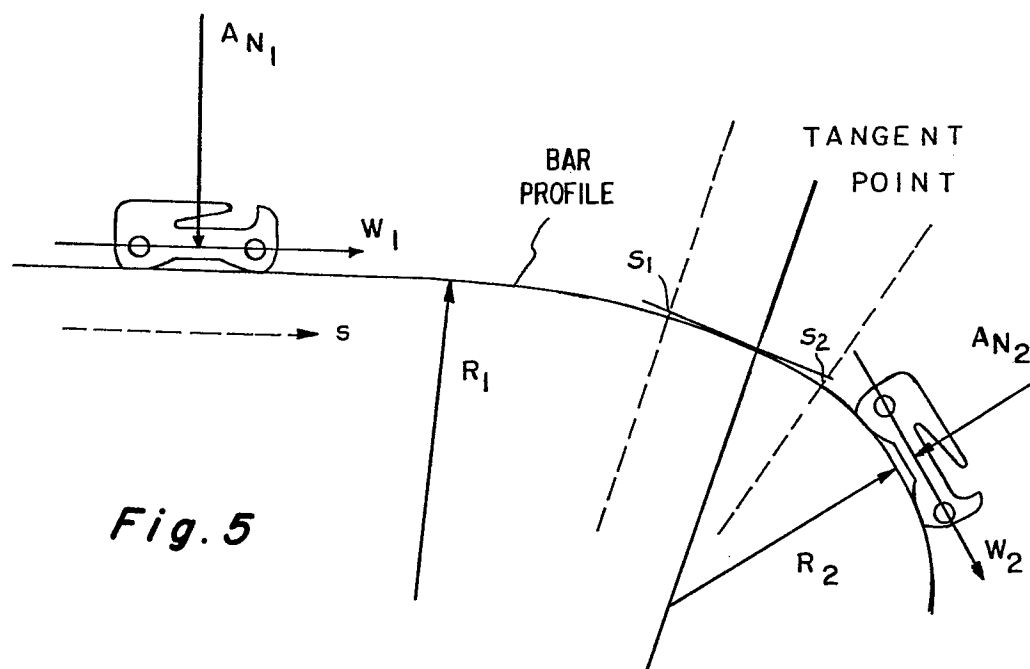
21. The guide bar as claimed in Claim 19, wherein, at said front end, both quadrants of the profile of
20 said guide bar are defined by said equation.

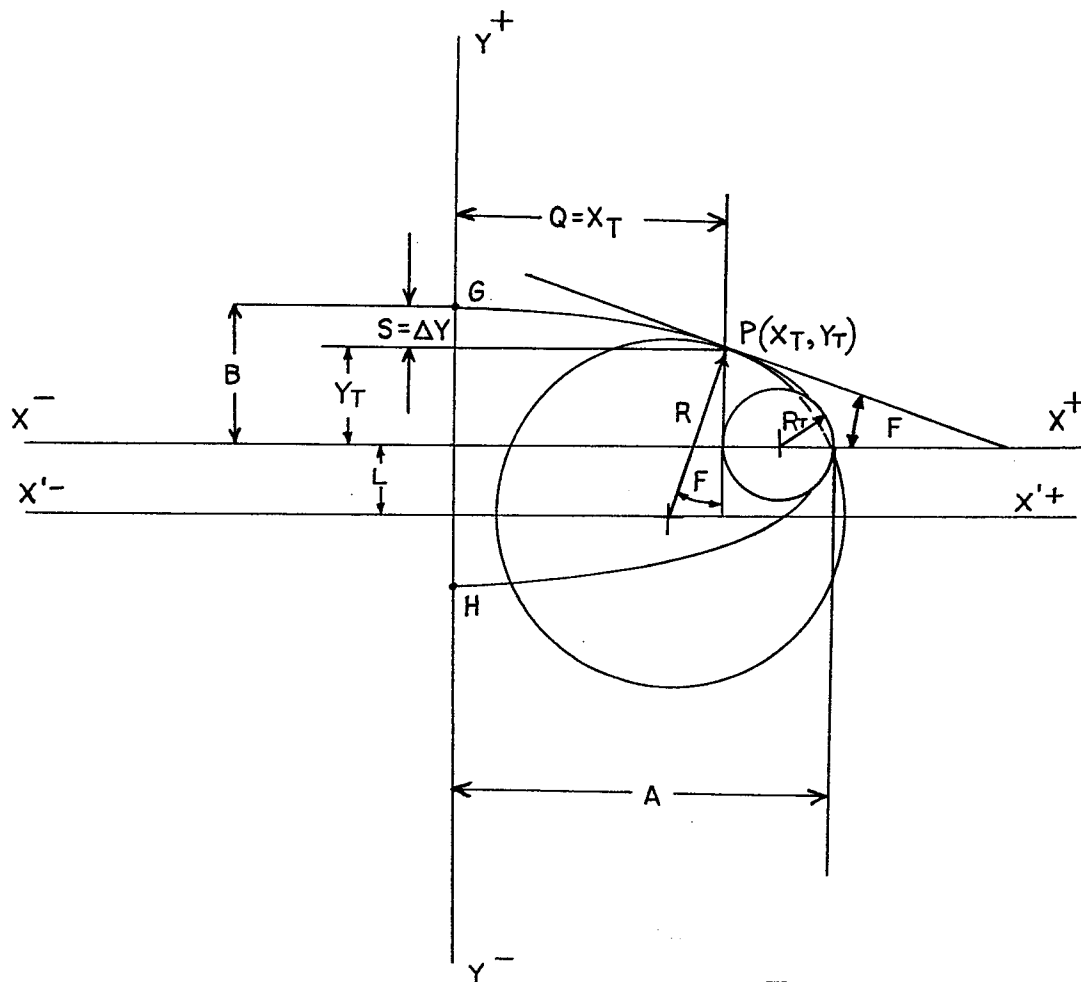
22. The guide bar as claimed in Claim 19, wherein said outer edge portion comprises a top edge portion
25 along said top edge, a front edge portion around said front end and a bottom edge portion along said bottom edge and said front edge portion is defined by a sprocket wheel of predetermined pitch radius mounted for rotation on the front end of said bar.

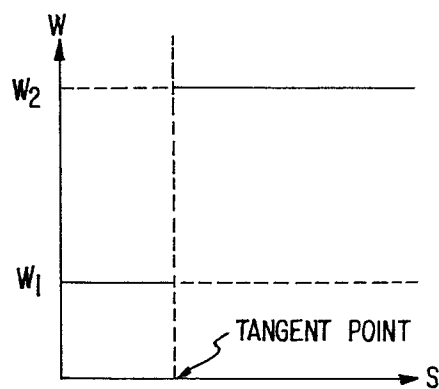
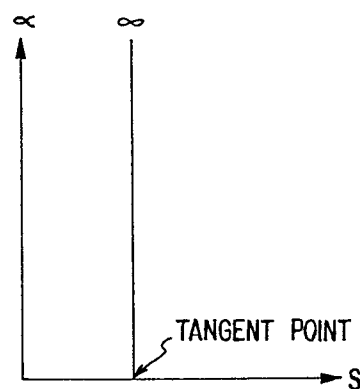
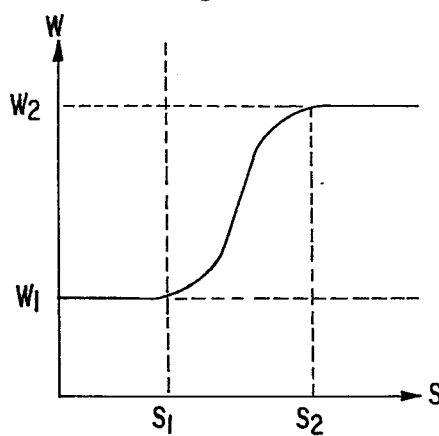
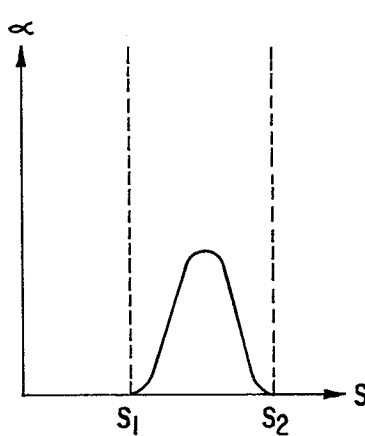
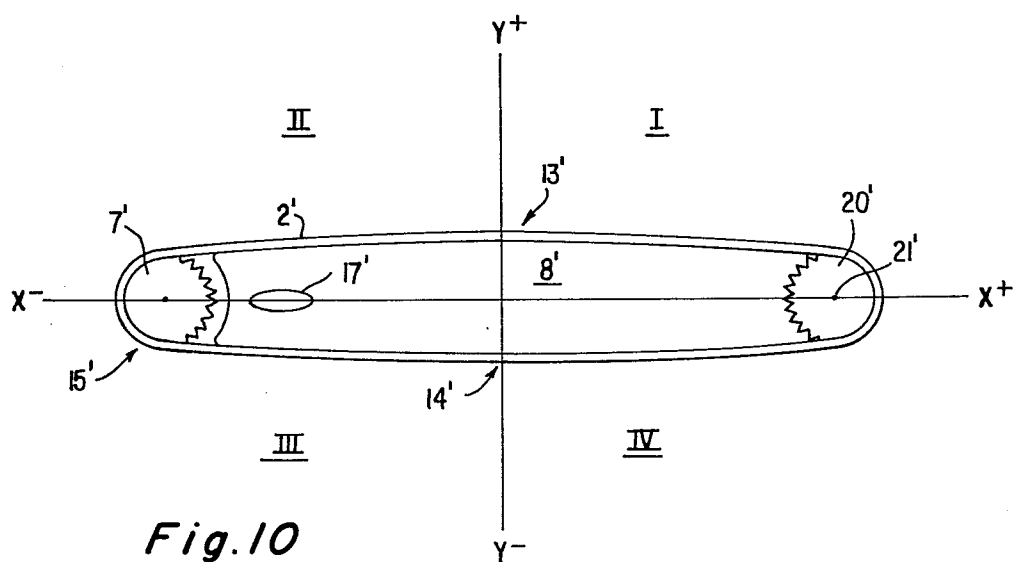
30 23. The guide bar as claimed in Claim 22, wherein C is selected so that the outer edge portion of said guide bar passes through the point of tangency of said sprocket wheel with said elliptical profile, the pitch radius of the sprocket wheel being equal to the radius of curvature of the elliptical profile at the point of tangency.



**Fig. 3****Fig. 4**



*Fig.7*

*Fig. 8A**Fig. 8B**Fig. 9A**Fig. 9B**Fig. 10*