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Ellis

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[45] July 29, 1975

[54] **PAVEMENT GROOVING MACHINE INCLUDING A CUTTING BLADE GUIDANCE SYSTEM**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 261,360, June 9, 1972.

[52] **U.S. Cl.** **299/39;** 280/442; 404/96

[51] **Int. Cl.²** **E01C 23/09**

[58] **Field of Search** 299/39–41; 404/84, 96; 280/442; 104/244.1

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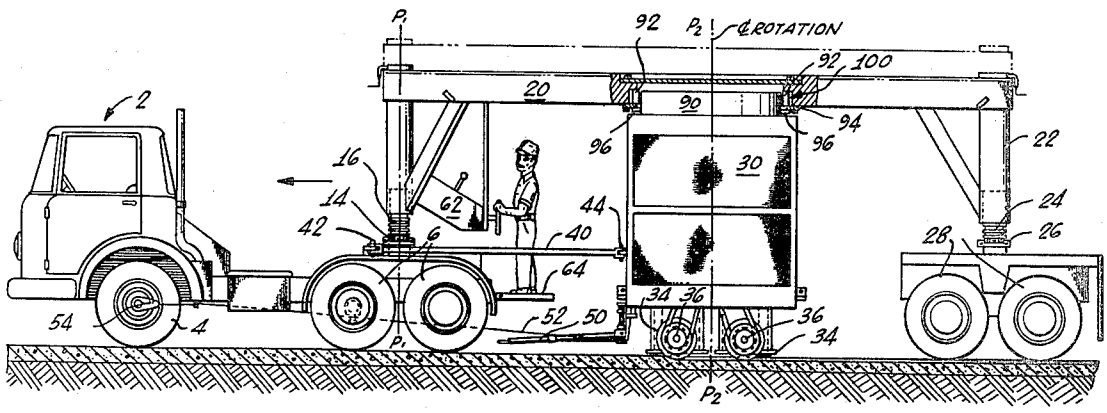
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Primary Examiner—Ernest R. Purser

[57] **ABSTRACT**

A pavement grooving machine of the type including a cutting assembly having a plurality of rotary cutting blades mounted on a drive shaft for grooving the pavement, wherein a guidance system is provided to enable the cutting blades to maintain parallel inclination to a curve in the pavement as the machine passes around the curve. The machine includes a truck and a trailer connected to the truck for articulated motion. The guidance system includes a module rotatably mounted on the trailer, supporting the blade drive shaft with the blades in cutting engagement with the pavement. A linkage connects the truck with the module to rotate the module relative to the trailer during relative turning motion between the trailer and the truck in such a relationship that the axis of the drive shaft is continuously aligned with the center of the curve throughout the turn. A positioning assembly connected with the truck front wheels and the module enables the truck to be steered so that the foregoing positional relationship of the blade drive shaft is maintained.

22 Claims, 9 Drawing Figures



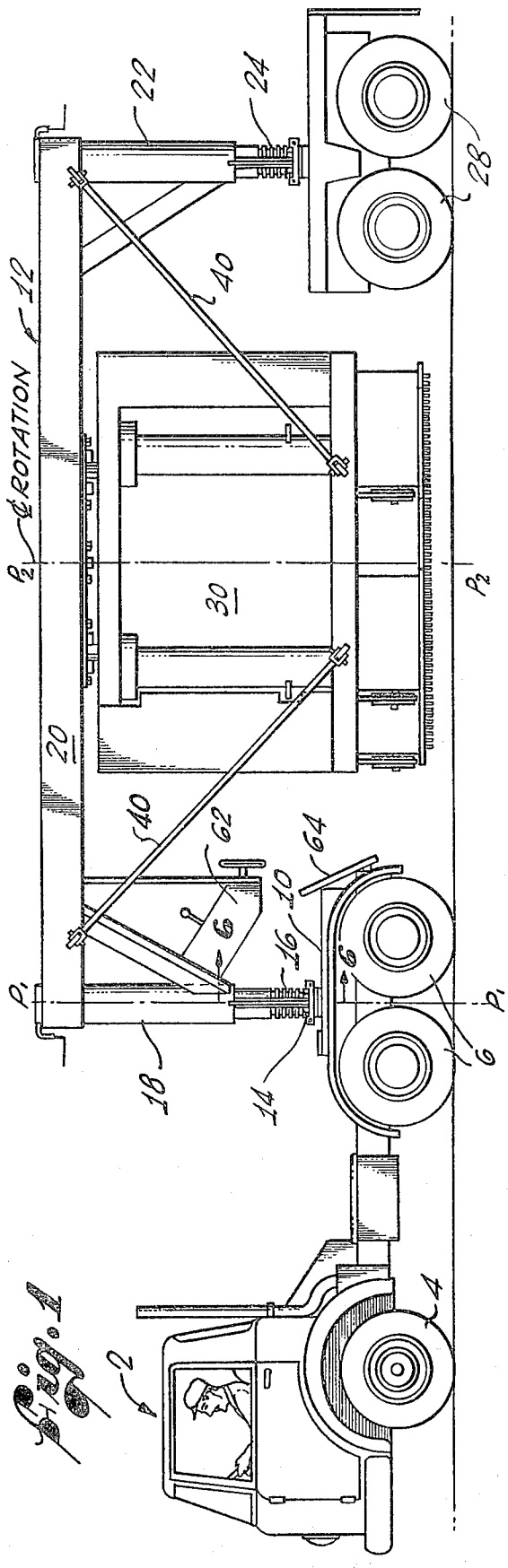

22
24
28
12
40
¢ ROTATION
P2
30
20
62
64
10
16
6
P1
18
14
4
2

Fig. 1

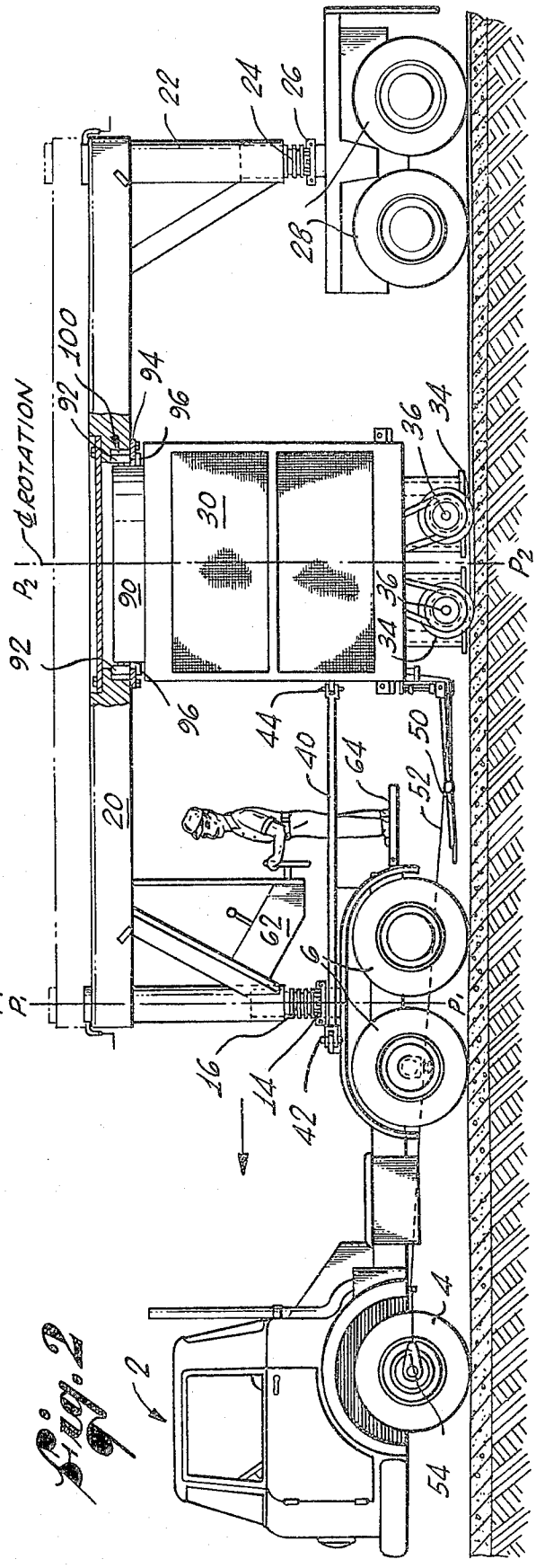

22
24
26
28
92
100
94
96
¢ ROTATION
P2
30
36
34
90
44
40
64
50
52
20
62
6
P1
16
14
42
4
2
54

Fig. 2

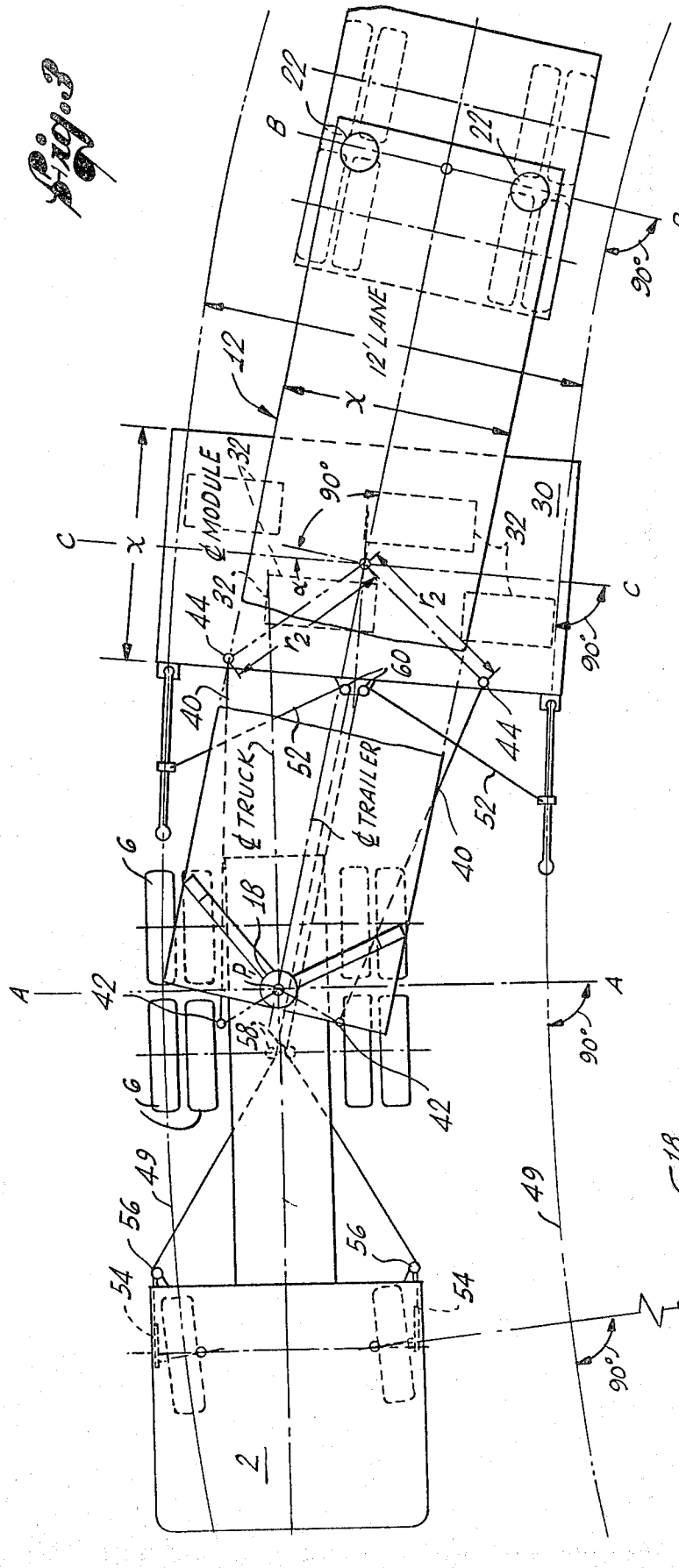


Fig. 3

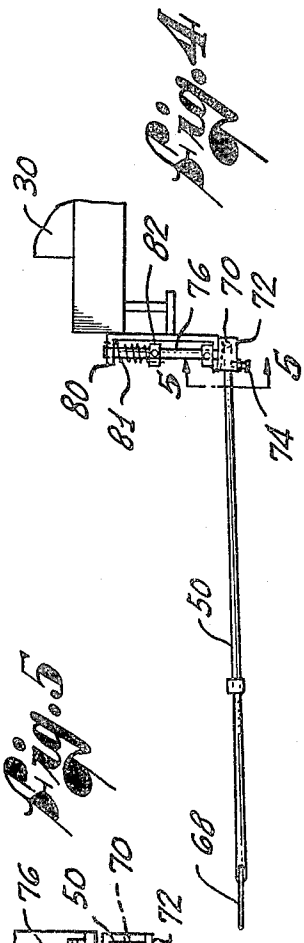


Fig. 4

Fig. 5

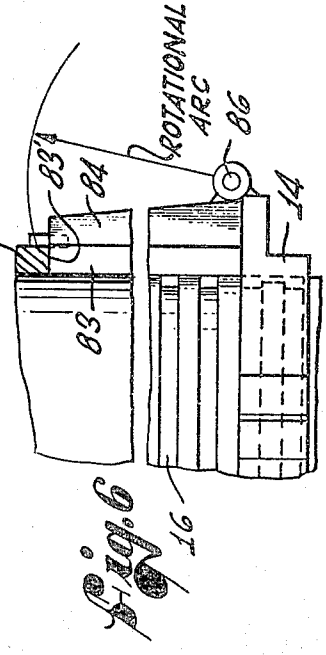


Fig. 6

Fig. 7

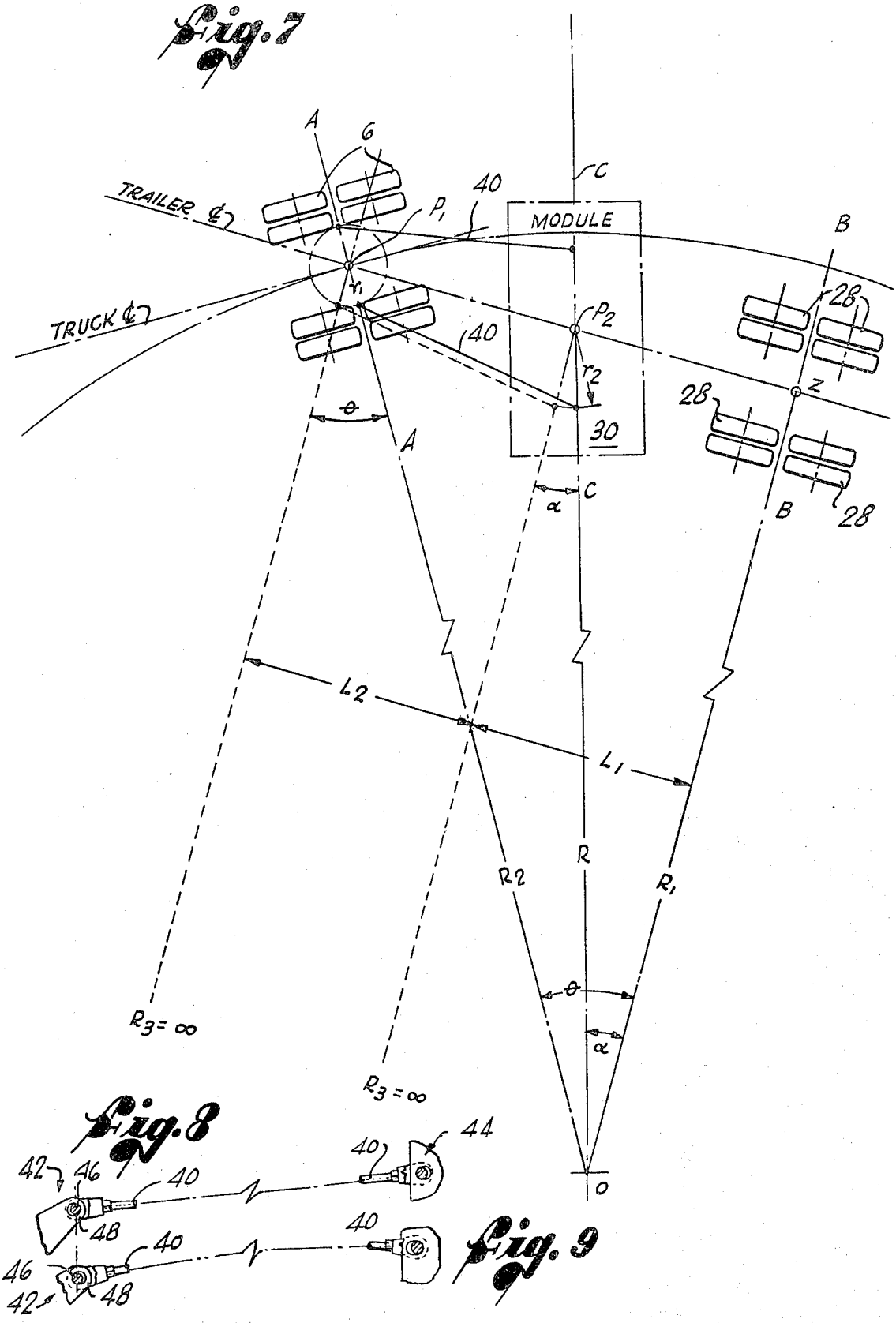


Fig. 8

Fig. 9

PAVEMENT GROOVING MACHINE INCLUDING A CUTTING BLADE GUIDANCE SYSTEM

RELATED APPLICATIONS

This application is a continuation-in-part of applicant's copending application for a "Pavement Grooving Machine," U.S. Ser. No. 261,360, filed June 9, 1972.

BACKGROUND OF THE INVENTION

This invention relates to a pavement grooving machine of the type including a cutting assembly having a plurality of spaced rotary cutting blades mounted on a drive shaft, which engage the pavement surface to cut parallel grooves therein. In particular, the grooving machine is provided with a blade guidance system which enables the cutting blades to remain in parallel relation to a curve in the pavement surface as the grooving machine travels around the curve.

To improve the traction of vehicle wheels on rain-soaked pavements, such as roads and aircraft runways, it is known to cut shallow, parallel grooves in the pavement to promote escape of water between the pavement surface and the vehicle wheels traveling thereon. Grooving of the pavement is commonly performed by specialized pavement grooving machines. One such pavement grooving machine disclosed in applicant's above-identified earlier patent application includes a truck having front and rear wheels pulling a trailer connected for articulated motion about a axis pivot saxis relative to the truck. The trailer includes a yoke extending between the truck and a pair of rear wheels at the end of the trailer. The yoke carries a module, mounted for rotation about a second vertical axis which supports at least one cutting assembly. In its operating condition the cutting assembly extends in a direction which is perpendicular to the longitudinal axis of the trailer.

When an articulated grooving machine is required to move around a curve in the road, the truck portion of the unit tends to move to the outside of the curve while the rear wheels of the trailer tend to be positioned relatively closer to the inside of the curve. As a result, the trailer travels around the curve at a slight inclination relative to its forward direction of travel. If the cutting blades continue to extend perpendicularly to the trailer, the blades would not be disposed in parallel relation to the curvature of the road due to the inclination of the trailer to the direction of travel. Such a non-parallel relationship between the blades and road curvature could be very damaging to the blades by imposing components of side force on them due to the inclination at which the blades would be to their direction of forward motion. As a result, excessive blade wear and blade failure could occur. In addition, the grooves themselves might be unnecessarily widened due to the inclination of the blade to the forward direction of its travel.

SUMMARY OF THE INVENTION

A pavement grooving machine according to the present invention, enables the cutting blades of the assembly to maintain parallel relationship to a curve in the pavement around which the machine is traveling. As a result, imposition of forces on the side faces of the blades is avoided and blade wear and overheating and breaking of blades are substantially minimized. In addition, the grooves produced in the pavement surface are of uniform width corresponding to the width of each blade and are oriented in accurate, parallel relation to the curve in the pavement.

More particularly, a pavement grooving machine according to the invention includes a truck having steerable front wheels and a set of rear wheels located adjacent a rear transverse axis of the truck. A trailer is connected to the truck for articulated motion about a vertical first pivot axis intersecting the rear axis of the truck. The truck includes a set of rear wheels located adjacent a rear transverse axis of the trailer, spaced rearwardly of the rear axis of the truck. The trailer supports a module for rotational motion about a vertical second pivot axis positioned between the rear axes of the truck and the trailer. The module carries at least one assembly of spaced, rotary cutting blades mounted on a horizontal drive shaft with the shaft extending in a generally transverse direction relative to the trailer. A guidance system maintains the cutting blades in substantially parallel relation to a curve in the pavement when the machine travels around the curve. The guidance system includes a linkage which rotates the module relative to the trailer during relative turning motion between the trailer and the truck in such relation that the drive shaft and the rear transverse axes of the truck and the trailer are all substantially aligned with a common turning center.

Because the cutting blades turn about a common center with the path of the rear wheels of the truck and trailer, imposition of side forces on the blades is avoided. As a result, the earlier described harmful effects associated with side loading the blades are substantially avoided.

It is also necessary that the machine's center of turn should coincide substantially with the center of curvature of the pavement being grooved. A positioning system to achieve this function includes at least one arm pivotally connected with the module for horizontal swinging motion. The arm is adapted to be visually aligned in overlying relation to a guideline which extends concentrically around the curve in the pavement. When the arm is aligned with the guideline, the blade drive shaft is in radial alignment with the center of the curve.

The arm is connected by a flexible line to a hub member connected with the adjacent one of the front wheels of the truck. As the machine rounds the curve, steering motion of the front wheel is transmitted by the flexible line to the arm. Deviation of the truck front wheel from a correct inclination to maintain the blade drive shaft in radial alignment with the curve moves the arm out of overlying alignment with the guideline. By observing the change, the driver can make the appropriate steering correction to return the front wheel to the correct position to align the blade drive shaft radially with the curve.

Summarizing, the linkage mechanism insures that the blade drive shaft and of the rear axes of the truck and trailer turn about a common center, while the positioning system insures that the common center of turn coincides with the center of the curve around which the machine is traveling.

The foregoing and other advantages of the invention are set forth more fully in detailed description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

A pavement grooving machine according to the invention is illustrated in the accompanying drawings in which:

FIG. 1 is a side view of a pavement grooving machine constructed in accordance with the preferred embodiment of the invention, with the machine shown in a transit condition in which a cutting assembly forming a part of the invention is in a raised, inoperative condition elevated from the pavement, to permit the machine to travel rapidly to a jobsite;

FIG. 2 is a side view of the pavement grooving machine shown in FIG. 1 but with the cutting assembly shown in a lowered, working condition to groove the pavement at the jobsite;

FIG. 3 is a simplified plan view of the pavement grooving machine as it travels around a curve in the pavement;

FIG. 4 is a fragmentary side view of an indicating arm forming a part of the pavement grooving machine shown in FIG. 1;

FIG. 5 is a cross-sectional view of a portion of the indicating arm shown in FIG. 4 taken along the lines 5—5 therein;

FIG. 6 is a fragmentary side view of a supporting latch utilized when the pavement grooving machine is in the transit condition;

FIG. 7 is a simplified, geometrical drawing on a deliberately exaggerated scale of a linkage mechanism utilized to guide the cutting assembly as the machine travels around the curve;

FIG. 8 is an enlarged view of an active link forming part of the linkage system, during a turn; and

FIG. 9 is an enlarged view of a passive link forming part of the linkage system, during a turn.

DETAILED DESCRIPTION

Referring to FIG. 1 of the drawings, a pavement grooving machine according to the preferred embodiment of the invention is there shown. The machine includes a conventional truck 2 having steerable front wheels 4 and two sets of compound rear wheels 6 positioned on opposite sides of a rear transverse axis A—A (FIG. 3) of the truck. The truck 2 also includes the usual engine for driving the truck, a driver's cab from which the truck may be steered and driven, and a conventional fifth wheel mounting structure 10 positioned between the truck rear wheels.

The truck pulls a trailer 12 of generally rectangular, open framework construction. The trailer 12 includes a horizontal, transversely extending, forward base support 15 (FIG. 1) which is connected at its transverse midpoint to the fifth wheel mounting structure 10 on the truck for pivoting motion about a vertical first pivot axis P_1, enabling the trailer to be pulled by the truck while remaining capable of articulated motion relative to the truck. The first pivot axis P_1 intersects the rear transverse axis A—A of the truck at a point where the centerlines of the truck and the trailer intersect, as shown in FIG. 3.

The transverse support member 14 carries an upwardly projecting, stationary forward piston 16 (FIG. 1) at its transverse midpoint, aligned with the first pivot axis P_1. Slidably mounted on the piston 16 is a hydraulic jack cylinder 18 (FIG. 3) which is mounted at its upper end at the midpoint of a forward portion of a rectangular rigid superstructure 20. Two similar hydraulic jack cylinders 22 are mounted at the rear corners of the superstructure 20 and extend slidably onto two upwardly projecting, stationary pistons 24 mounted on the opposed transverse extremities of a rear base support 26. The rear base 26 is rigidly connected to two sets of rear wheels 28 of the trailer. The rear wheels 28 are positioned at equal transverse distances on opposite sides of the centerline of the trailer and are mounted for rotation about transverse axes spaced on opposite sides of, and parallel to, a rear transverse axis B—B (FIG. 3) of the trailer.

The superstructure 20 of the trailer supports a module 30, of generally rectangular configuration, for rotation about a vertical second pivot axis P_2 positioned on the centerline of the trailer at approximately its midpoint. In the working position shown in FIG. 3, the module 30 is positioned with its longer horizontal dimension extending generally transversely of the trailer. The longer dimension of the module, in the preferred embodiment, is approximately twelve feet to enable the grooving machine to groove a twelve foot wide lane of the highway in a single pass.

The module 30 carries four cutting assemblies 32 (FIG. 3), each of which comprises a plurality of spaced parallel rotary cutting blades 34 mounted on a drive shaft 36 (FIG. 2). The cutting blades are rotated by belt-drive driven by a conventional motor mounted within the interior of the module 30. The four cutting assemblies 32 are disposed in two banks of two spaced with their drive shafts in parallel relation to, and on opposite sides of a horizontal transverse axis C—C (FIG. 3) of the module intersecting the second pivot axis P_2. The cutting assemblies are arranged in alternately overlapped relation extending across the width of the path to be cut so that the full width of one lane can be grooved in a single pass. The overlapping relation between the ends of adjacent assemblies is such that the space between the outermost rotary cutting blades in the assemblies is equal to the spacing between the individual blades in each cutting assembly, thereby ensuring that the spacing between the grooves cut in the pavement is uniform across the width of the lane.

In the working condition, no hydraulic pressure is applied to the jack cylinders 18 and 22 so that the superstructure 20 is in a lowered condition (FIG. 2) in which the cutting assemblies are in contact with the pavement to be grooved. For precise control of groove depth, the cutting assemblies are mounted for limited, controlled vertical motion relative to the module 30 and are biased downwardly against the pavement.

By directing hydraulic fluid under pressure to the hydraulic jack cylinders 18 and 22, the superstructure 20 can be elevated on the pistons 16 and 24 to raise the cutting assemblies from the pavement. In a fully elevated condition (FIG. 1) the cutting assemblies are spaced an ample distance above the pavement to facilitate transit from one job site to the next. The shorter horizontal dimension of the module 30 is approximately equal to the width of the superstructure 20 of the trailer so that the module 30 may be rotated through 90° to align the module with the trailer in the transit condition (FIG. 1) thereby reducing the overall road width of the vehicle sufficiently to enable it to be driven along a public highway, as described hereafter.

A significant feature of the present invention resides in structure which is intended to ensure that when the

pavement grooving machine travels around a curve during grooving operations, the rotary cutting blades travel in a path which is parallel to the curve. Such structure avoids the imposition of side loads on the cutting blades. As a result blade wear, overheating and the occurrence of blade failure, are greatly reduced. In addition the grooves cut are less subject to changes in width in regions where the pavement curves.

The relevant structure comprises two principal portions, firstly, a linkage to align the drive shafts of the cutting assemblies with substantially a common center of turn with the rear transverse rear axes of the truck and the trailer, and, secondly, a positioning system to position the foregoing common center of turn in coincidence with the center of the curve in the pavement.

The linkage includes two rod-like connecting links **40** (FIGS. **2** and **3**) positioned on opposite sides of the centerlines of the truck and trailer. At their forward ends, the links **40** are connected by releasable pivotal connections **42** to the truck. The pivotal connections **42** are positioned symmetrically on opposite sides of the truck centerline, spaced forwardly of the rear transverse axis A—A and are pitched at equal radii r_1 from the first pivot axis P_1. The rear ends of the links **40** are connected by pivotal connections **44** to the forward end of the module. The pivotal connections **44** are located at positions spaced symmetrically on opposite sides of the module centerline, spaced forwardly of the module transverse axis C—C and are pitched at equal radii r_2 from the second pivot axis P_2.

The operation of the linkage is explained with reference to FIG. **7**, which illustrates in a simplified manner with exaggerated angular deflections, the truck, trailer and module transverse axes intersecting at a common center of turn O as the machine travels around a curve. As shown, the pivot axis P_2 of the module travels around a curve of radius R while the rear wheels of the truck and trailer are at greater and lesser radial distances R_2 and R_1, respectively, from the center of turn O. To steer the vehicle around the curve, it has been necessary to turn the truck relative to the trailer so that the truck rear axis A—A has been deflected through angle θ, relative to the position it would occupy in the straight ahead position. The corresponding amount by which the module transverse axis C—C has been deflected by the action of the link **40** is indicated by the angle α on FIG. **7**. In FIG. **7** the pivot points **42** and **44** have been shown as coinciding with the transverse axes A—A and C—C to simplify the discussion. Actually, as earlier described, the pivot points are pitched forwardly of the axes. However the distance by which the pivot points are pitched forwardly is so insignificant in comparison to the relative magnitudes of the radius R that the effect of the forward pitching is not considered to alter the operation described in the following paragraphs, significantly.

In the ensuing discussion, it is necessary to appreciate that, unlike the deliberately exaggerated showing in FIG. **7**, the angles of deflection at which the machine actually operates are very small, and within the range in which the sine of an angle is equal to the value of the angle in radians (under 8° approximately). Utilizing the preferred embodiment of the invention, which functions with a 25-foot trailer, representative values of the dimensions and angles shown in FIG. **7** are tabulated in the following Example.

EXAMPLE

Utilizing a trailer having a 25-foot length between the rear transverse axes A—A of the truck and B—B of the trailer with the pivot axis P_2 situated at the midpoint, the following dimensions shown on FIG. **7** apply for curves of 300 foot and and 2,000 foot radius respectively.

R	R_1	R_2	$\alpha°$	$\theta°$
300	299.74	300.78	2°23′	4°46′
2000	1,999.965	2000.15	0°21′	0°43′

Within this narrow angular range, it can be assumed as a first approximation that the limited arcuate distances travelled by the ends of the link **40** as it moves the module relative to the trailer, are essentially linear and equal, leading to the following relation

$$r_2 \cdot \alpha = r_1 \cdot \theta$$

$$\therefore \frac{r_2}{r_1} = \frac{\theta}{\alpha}$$

Also within this range (as less than approximately 8°) each angle in radians is equal to its sine, thus

$$\frac{r_2}{r_1} = \frac{\sin \theta}{\sin \alpha}$$

As can be seen from FIG. **7**

$$\sin \alpha = \frac{L_1}{R} \text{ and } \sin \theta \; \frac{L_1 + L_2}{R_2}$$

Within the angular range considered R_2 is substantially equal to R, leading to the following result,

$$\frac{r_2}{r_1} = \frac{L_1 + L_2}{L_1}$$

Thus, in the preferred embodiment where the module is positioned at the midpoint of the trailer and L_1 equals L_2, the ratio $r_2{:}r_1$ is two to one.

Because the drive shafts **36** of the cutting assemblies **32** are parallel to and closely adjacent the transverse C—C of the module, alignment of the module axis C—C with the center of turn O substantially aligns each drive shaft **32** with the center of the turn. As a result the cutting blades travel in parallel relation to the curved path in which they are carried by the tractor and trailer and therefore are substantially free from side forces acting on the blades.

The preferred embodiment utilizes two of the links **40**, as previously described. During each turn operation, the link on the outside of the turn is in tension and functions as the active link (FIG. **8**) for turning the module transverse axis C—C into alignment with the center of turn O. Because it is necessary that the operation of the active link should not be prevented by counter-reaction from the passive link (FIG. **9**) on the inside of the turn, provision is made for limited movement of the passive link. This movement is provided for in two ways. Firstly, the pivotal connections **42** and **44** com-

prise pins **46** riding in loose, or slightly oversized bores **48** which provides for limited linear shifting of position of the passive link as the pins move to the opposite sides of the bores (FIG. **9**). In addition, the links **40** are sufficiently slender to permit them to bow resiliently under compression. The passive link can therefore move sufficiently (FIG. **9**) so that it does not prevent the active link from turning the module in the desired relationship.

When the pavement grooving machine is in transit with the module in the position shown in FIG. **1**, the links **40** are released from the truck and are swung upwardly to connect to adjacent portions of the superstructure **20**.

During a turn, it is also necessary to locate the common center of turn O so that it coincides with the center of the curve in the pavement. To do so, the pavement grooving machine includes a positioning system which cooperates with a guideline **49** (FIG. **3**) marked on the pavement concentric with the curve. In grooving a highway the guideline will usually be the the marked traffic lanes on the highway centerline. On an unmarked pavement a temporary guideline, such as a wire marker supported on pegs, can be employed.

The positioning system (FIGS. **2** and **3**) includes two indicator arms **50** pivotally connected to the forward end of the module **30** adjacent its transverse ends. Each indicating arm **50** can swing transversely in the horizontal plane in either direction from a neutral position in which the indicator arm has its longitudinal axis inclined in generally perpendicular relation to the transverse axis C—C of the module.

The indicator arms **50** are spring-biased to turn in a direction outwardly from the module and the bias forces are opposed by two flexible lines **52** (FIG. **3**) connected to one of the indicator arms adjacent its midpoint.

The flexible line **52** connect their associated indicator arms **50** to the ends of two hub members **54** mounted in concentric relation on the axles supporting the front wheels **4** of the truck **2**. Each hub member **54** includes a non-rotating stub projecting axially from the wheel axle and having a rearwardly extending flat plate at its outer end to which the associated line **52** is secured. Each hub member **54** is turned from side to side during steering motion of the front wheel on which it is mounted.

Three pairs of pulleys **56, 58** and **60** guide the lines **52** in their paths between the hub members and the indicator arms. Each of the pulleys **56** is secured to the truck **2** adjacent the rear outer corner of the cab and guides the adjacent line **52** from the hub member towards the rear, center of the truck. The two pulleys **58** are spaced closely apart on opposite sides of the truck centerline at a short distance forwardly of the first pivot axis P_1. The pulleys **58** guide the lines **52** from the pulleys **56** towards the third pulleys **60**. The third pulleys **60** are spaced closely apart on opposite sides of the midpoint of the forward edge of the module **30**. The flexible lines **52** pass around the pulleys **60** and extend outwardly to their points of connection to the indicator arms **50**.

During a grooving operation, the operator must be able to see the indicator arms **50** as he drives and steers the machine in order to keep the common center of turn of the transverse axes of the truck, trailer and module coincident with the center of the curve, utilizing the indicator arms **50**. As this would not be possible from the driving position in the truck cab, a second driving position is provided at the rear end of the truck. The second driving position includes a control console **62** (FIG. **2**) provided with a steering wheel and all other driving controls necessary to drive and steer the truck **2**. The console **62** is carried by the superstructure **20** in a central location overlying the rear wheels of the truck. In conjunction with the console **62** the second driving position includes a platform **64** connected to the rear end of the truck. The operator, standing on the platform **64** and controlling the truck from the console **62**, is in a position to observe the indicator arms **50**. When not in use, the platform **64** can be hinged upwardly out of the way (FIG. **1**).

To calibrate the machine, it is operated with the truck and trailer in the straight ahead position with the axes of the blade shafts **36** between and perpendicular to two straight parallel guidelines. The lengths of the lines **52** are then adjusted until the indicating arms are both aligned in overlying relation to the guidelines, at which time the indicating arms will be in the neutral position in perpendicular relation to the axes of the blade shafts **36**.

In operation as the grooving machine travels around a curve in the pavement, the operator steers the vehicle so as to locate one of the indicator arms **50** in aligned, overlying relation to the guideline **49**. In that configuration the drive shafts **36** of the cutting assemblies **32** are aligned radially with a center of turn which coincides with the center of curvature of the guideline and the cutting blades are traveling in a path parallel to the curve in the pavement.

If the operator should over-steer the truck in a direction inwardly of the curve, the outer front wheel will tighten the outer flexible line **52**, thereby moving the outer one of the indicator arms **50** in a direction inwardly of the curve. At the same time, the inner one of the front wheels **4** slackens the flexible line **52** connected to the indicator arm on the inside of the curve which is moved inwardly of the curve by its biasing spring. The operator will then observe that whichever of the indicator arms **50** was formerly aligned with the guideline **49** has moved out of alignment and is now inclined relative to the guideline in a direction inward of the curve. On observing this condition, the operator can take the appropriate action to steer the wheels outwardly again by the correct amount to restore the indicator arm to alignment with the guideline.

Conversely, if the operator oversteers in a direction outwardly of the curve, the indicator arms will be deflected in a direction outwardly of the curve so that the operator is provided with an indication to correct in the opposite direction.

The positioning system thus described enables the operator to steer the vehicle around the curve so that the cutting blades maintain continuous parallel alignment with the curve in the pavement without the imposition of side forces on the cutting blades. As a result, blade wear, blade overheating and blade failure are all substantially avoided. In addition, the grooving machine avoids the possibility of cutting grooves with the blades inclined at an angle to their forward direction, thereby leading to an enlarged groove width in the region in which the pavement is curved.

Each of the previously mentioned indicator arms **50** (FIG. **4**) comprises a slender tube having a round, flat

indicator plate 68 secured to its forward free end. At its rear end, the arm 50 is connected to a horizontal transversely, extending axle 70 (FIG. 5) mounted for rotation about a transverse axis in a vertical, rectangular frame 72. The lower part of the frame 72 extends in a longitudinal direction in underlying relation to the rear end portions of the arm (FIG. 4) and is provided with a set screw 74 movable upwardly in the frame 72 to contact the arm 50 to support the arm at a slight downward droop which can be varied by altering the setting of the screw 74. The upper end of the frame 72 is fixedly secured to a vertical shaft 76 which extends rotatably through the horizontal arms of a U-shaped supporting bracket 80 which has its vertical side fixedly secured to the forward edge of the module 30. A torsion spring 81 connected between the bracket 80 and a fixed collar 82 connected to the shaft 76, applies torque in a direction to bias the arm 50 in an outward transverse direction from the module.

During transit between jobsites the arms 50 are hinged upwardly about the axles 70 and secured to the module 30. The hub members 54 and flexible lines 52 are also disconnected from the front wheels during transit.

During transit the superstructure 20 is elevated, as previously described, to raise the cutting assemblies from the ground. To provide a positive mechanical system for holding the superstructure in the raised position, each of the pistons 16 and 24 is provided with a mechanical latch 80 (FIG. 6). Each latch 80 is of T-cross section, comprising a flat web 83 abutting the adjacent end of the pistons 16 and 24 with a central spine 84 extending vertically along the centerline of the web 83. The lower end of each spine 84 is connected by a radially offset hinge 86 to adjacent portions of the base regions 14 and 26 of the trailer, for swinging motion about a horizontal axis. The horizontal upper end 83' of the web 83 of each latch extends in flat, abutting relation to the horizontal lower rim of the adjacent one of the jack cylinders 18 and 22, which rests on the web in abutting relation so that the latch supports the jack cylinder against downward motion. Significantly, the offset positioning of the hinge 86 causes the upper end of the latch 80 to be positioned in an overcenter relationship with respect to the jack cylinder. As a result the latch cannot inadvertently be swung to the unlatched condition out of contact with the jack cylinder without first raising the jack cylinder by the application of a hydraulic pressure to elevate the same. Consequently, the possibility that the latches 80 could be released during transit by passage over bumps or other severe road vibration, is substantially eliminated.

The rotary mounting used to support the module 30 beneath the superstructure 20 for rotation about the axis P_2 includes a circular boss 90 (FIG. 1) fixedly secured to the upper horizontal surface of the module, centrally thereof. The boss 90 is provided with a plurality of trunnion bearings 92 which extend radially outward and ride in an annular track 100 in the superstructure 20. The trunnions 92 rest on an underlying circular ring 94 secured to the superstructure and are spaced equally around the boss 90 to provide distributed support. Three or more horizontal rollers 96 connected to the underside of the superstructure rotatably contact the circular, vertical edge of the boss 90 to center the module for rotation about the previously described vertical axis P_2. In the preferred embodiment the module can be rotated manually about the axis P_2 using the bearing structure described.

In the working position heretofore described, the blades of the cutting assemblies have been shown in contact with the pavement, without specific description of their direction of rotation. It is possible to perform grooving operations in either an up-cutting mode in which the leading edges of the blades in the direction of linear motion are moving upwardly from the pavement, or a down-cutting mode in which the leading edges of the blades are moving downwardly into contact with the pavement. The mounting assembly shown in FIG. 11 enables cutting to be performed in either an up-cutting mode or a down-cutting mode, as may be desired for the particular grooving operation being performed, by simply rotating the module through 180° from one working position to an opposite working position to change the cutting mode.

To move the module to the transit position, the module is rotated 90° from either of the two working positions described. A locking bolt or other conventional structure (not shown) is utilized to lock the module in each of its opposite working positions and in the transit position.

Although the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that many deletions, additions, substitutions, modifications and other changes may be made which will fall within the spirit of the invention.

I claim:

1. In a pavement grooving machine including a truck provided with steerable front wheels and at least one set of rear wheels located adjacent a horizontal rear transverse axis of the truck; a trailer connected to the truck for articulated motion about a vertical first pivot axis intersecting the rear transverse axis of the truck, the trailer having at least one set of rear wheels located adjacent a horizontal rear transverse axis of the trailer spaced rearwardly from the rear transverse axis of the truck; and at least one assembly of spaced, rotary cutting blades mounted on a generally horizontal drive shaft; a blade guidance system operable during movement of the pavement grooving machine around a curve in the pavement to maintain the cutting blades in substantially parallel relation to the curve, the guidance system comprising:

a module mounted on the trailer for rotational motion about a vertical second pivot axis positioned between the rear wheels of the truck and the rear wheels of the trailer, said module supporting the cutting assembly with the blades in cutting engagement with the pavement and with the drive shaft extending in a generally transverse direction relative to the trailer; and

linkage means connecting the truck with said module for rotating said module relative to the trailer during relative turning motion between the trailer and the truck in such relation that the drive shaft and the rear transverse axes of the truck and the trailer are all substantially aligned with a common turning center.

2. A guidance system as defined in claim 1, wherein the truck and the trailer have longitudinal centerlines, the first pivot axis being intersected by the longitudinal centerlines of both the truck and the trailer, the second pivot axis being positioned on the longitudinal center-

line of the trailer at longitudinal distances L_1 and L_2 from the first pivot axis and from the rear transverse axis of the trailer, respectively; and wherein said linkage means comprises:

at least one longitudinally extending link spaced on one side of said centerlines, said link at its forward and rearward ends being connected by pivotal connections to the truck and to said module at radii r_1 and r_2 from said first and second pivot axis, respectively, said radii having approximately the following ratio,

$$\frac{r_2}{r_1} = \frac{L_1 + L_2}{L_1}.$$

3. A guidance system as defined in claim 2, further including two of said links positioned symmetrically on opposite sides of the centerlines of the truck and trailer, said links having sufficient resilient flexibility and sufficient looseness in their pivotal connections to the truck and module to enable turning of said module relative to said trailer without binding or permanently deforming said links over a predetermined range of angular motion of the module relative to a neutral position which said module occupies when the centerlines of the truck and trailer are in alignment.

4. A guidance system as defined in claim 3, wherein the predetermined range of angular motion of said module comprises approximately 8° in either direction from the neutral position.

5. In a pavement grooving machine including a truck provided with steerable front wheels and at least one set of rear wheels located adjacent a horizontal rear transverse axis of the truck; a trailer connected to the trailer for articulated motion about a vertical first pivot axis intersecting the rear transverse axis of the truck, the trailer having at least one set of rear wheels located adjacent a horizontal rear transverse axis of the trailer spaced rearwardly from the rear transverse axis of the truck; and at least one assembly of spaced, rotary cutting blades mounted on a generally horizontal drive shaft; a blade guidance system operable during movement of the pavement grooving machine around a curve in the pavement following a correspondingly curved guideline therealong, to maintain the cutting blades in substantially parallel relation to the curve, the guidance system comprising:

a module mounted on the trailer for rotational motion about a second vertical pivot axis positioned between the rear wheels of the truck and the rear wheels of the trailer, said module supporting the cutting assembly with the blades in cutting engagement with the pavement and with the drive shaft extending in a generally transverse direction relative to the trailer;

linkage means connecting the truck with said module for rotating said module relative to the trailer during relative turning motion between the trailer and the truck in such relation that the drive shaft and the rear transverse axes of the truck and the trailer are all substantially aligned with a common turning center; and

positioning means alignable with the guideline connected with said module and with at least one of the front wheels of the truck for enabling the truck to be steered around the curve in such relation that said common turning center coincides substantially with the center of the curve in the pavement.

6. A guidance system as defined in claim 5, wherein said positioning means comprises:

at least one arm pivotally connected with said module, said arm in a neutral position relative to said module extending in a direction generally perpendicular to the drive shaft, said arm adapted to be visually aligned in overlying relation to the guideline whereby the drive shaft is positioned substantially in radial alignment to the cruve when said arm is in the neutral position thereof;

at least one hub member connected with one of the truck front wheels movable angularly therewith in response to steering motion of the one front wheel; and

connecting said hub member with said arm for causing motion thereof from its neutral position in directions inwardly and outwardly of the curve in response to steering motion of the one front wheel of the truck in directions inwardly and outwardly of the curve, respectively, whereby deviation of the one front wheel from a correct inclination to maintain the drive shaft in radial alignment to the curve causes said arm to move out of aligned, overlying relation to the guideline.

7. A guidance system as defined in claim 6, wherein the guidance system further includes:

driving and steering means connected with one of the truck and trailer for driving and steering the truck; and

an operator supporting platform connected with one of the trailer and the truck on which an operator may be positioned to operate said driving and steering means, said driving position being located in a position from which the operator can visually align said arm with the guideline.

8. A guidance system as defined in claim 6, wherein the truck and the trailer have longitudinal centerlines, the first pivot axis being intersected by the longitudinal centerlines of both the truck and the trailer, the second pivot axis being positioned on the longitudinal centerline of the trailer at longitudinal distances L_1 and L_2 from the first pivot axis and from the rear transverse axis of the trailer, respectively; and wherein said linkage means comprises:

at least one longitudinally extending link spaced on one side of said centerlines, said link at its forward and rearward ends being connected by pivotal connection to the truck and to said module at radii r_1 and r_2 from said first and second pivot axis, respectively, said radii having approximately the following ratio,

$$\frac{r_2}{r_1} = \frac{L_1 + L_2}{L_1}.$$

9. A pavement grooving machine comprising:

a truck having steerable front wheels and at least one set of rear wheels located adjacent a horizontal rear transverse axis of said truck;

a trailer connected to said truck for articulated motion about a vertical first pivot axis intersecting the rear axis of said truck, the trailer including at least one set of rear wheels located adjacent a horizontal, rear transverse axis of said trailer spaced rearwardly from the rear axis of said truck;

a module mounted on said trailer for rotational motion about a vertical second pivot axis positioned between said rear wheels of said truck and said rear wheels of said trailer;

at least one assembly of spaced, rotary cutting blades mounted on a generally horizontal drive shaft, said module supporting said cutting assembly with said blades in cutting engagement with the pavement and said drive shaft extending in a generally transverse direction relative to said trailer; and

a guidance system operable during movement of the pavement grooving machine around a curve in the pavement to maintain said cutting blades in substantially parallel relation to the curve, the guidance system including,

linkage means connecting said truck with said module for rotating said module relative to said trailer during relative turning motion between said trailer and said truck in such relation that said drive shaft and the rear transverse axes of said truck and said trailer are all substantially aligned with a common turning center.

10. A pavement grooving machine as defined in claim **9**, wherein said truck and said trailer have longitudinal centerlines, the first pivot axis being intersected by the longitudinal centerlines of both said truck and said trailer, the second pivot axis being positioned on the longitudinal centerline of said trailer at longitudinal distances L_1 and L_2 from the first pivot axis and from the rear transverse axis of said trailer, respectively; and wherein said linkage means comprises:

at least one longitudinally extending link spaced on one side of said centerlines, said link at its forward and rearward ends being connected by pivotal connections to said truck and to said module at radii r_1 and r_2 from said first and second pivot axis, respectively, said radii having approximately the following ratio,

$$\frac{r_2}{r_1} = \frac{L_1 + L_2}{L_1}.$$

11. A pavement grooving machine as defined in claim **10**, further including two of said links positioned symmetrically on opposite sides of the centerlines of said truck and trailer, said links having sufficient flexibility and sufficient looseness in their pivotal connections to said truck and said module to enable turning of said module relative to said trailer without binding or permanently distorting said links over a predetermined range of angular motion of the module relative to a neutral position which said module occupies when the centerlines of said truck and said trailer are in alignment.

12. A guidance system as defined in claim **11**, wherein the predetermined range of angular motion of said module comprises approximately **8** degrees in either direction from the neutral position.

13. A pavement grooving machine as defined in claim **9**, wherein said trailer further includes:

forward and rear base portions connected with said truck and with said rear wheels of said trailer, respectively;

a longitudinal superstructure connected to said base portions for vertical motion relative thereto, said module being attached to said superstructure; and

means for selectively raising and lowering said superstructure relative to said base portions of said trailer.

14. A pavement grooving machine as defined in claim **13**, wherein said means for raising and lowering said superstructure includes at least one hydraulic jack, said hydraulic jack including:

a stationary piston member secured to one of said base portions of said frame;

a jack cylinder slidably movable along said jack piston, said jack cylinder being fixedly secured to said superstructure to raise and lower the same as hydraulic fluid is admitted and exhausted from the jack cylinder;

the pavement machine further including,

a latch extending axially along the lower end of the jack piston and secured thereto for vertical swinging motion about a horizontal axis between an upright position against the jack piston and an inclined position spaced away therefrom, said latch in the upright position having a horizontal, upwardly facing, end face abuttingly engaging an end face of the jack cylinder to support the same against downward movement.

15. A pavement grooving machine comprising:

a truck having steerable front wheels and at least one set of rear wheels located adjacent a horizontal rear transverse axis of said truck;

a trailer connected to said truck for articulated motion about a vertical first pivot axis intersecting the rear axis of said truck, the trailer including at least one set of rear wheels located adjacent a horizontal, rear transverse axis of said trailer spaced rearwardly from the rear axis of said truck;

a module mounted on said trailer for rotational motion about a vertical second pivot axis positioned between said rear wheels of said truck and said rear wheels of said trailer;

at least one assembly of spaced, rotary cutting blades mounted on a generally horizontal drive shaft, said module supporting said cutting assembly with said blades in cutting engagement with the pavement and said drive shaft extending in a generally transverse direction relative to said trailer; and

a guidance system operable during movement of the pavement grooving machine around a curve in the pavement following a correspondingly curved guideline therealong, to maintain said cutting blades in substantially parallel relation to the curve, the guidance system including,

linkage means connecting said truck with said module for rotating said module relative to said trailer during relative turning motion between said trailer and said truck in such relation that said drive shaft and the rear transverse axes of said truck and said trailer are all substantially aligned with a common turning center; and

positioning means alignable with the guideline connected with said module and with at least one of the front wheels of said truck for enabling said truck to be steered around the curve in such relation that said common turning center coincides substantially with the center of the curve in the pavement.

16. A pavement grooving machine as defined in claim **15**, wherein said positioning means includes:

at least one arm pivotally connected with said module, said arm in a neutral position relative to said module extending in a direction generally perpendicular to said drive shaft, said arm adapted to be visually aligned in overlying relation to the guideline whereby said drive shaft is positioned substantially in radial alignment to the curve when said arm is in the neutral position thereof;

at least one hub member connected with one of said truck front wheels movable angularly therewith in response to steering motion of said one front wheel; and

means connecting said hub member with said arm for causing motion thereof from its neutral position in directions inwardly and outwardly of the curve in response to steering motion of said one front wheel of said truck in directions inwardly and outwardly of the curve, respectively, whereby deviation of said front wheel from a correct inclination to maintain said drive shaft in radial alignment to the curve causes said arm to move out of aligned, overlying relation to the guideline.

17. A pavement grooving machine as defined in claim **16,** wherein said means connecting said hub member with said arm includes:

spring means connected with said arm and with said module for resiliently biasing said arm in one transverse direction;

a flexible line extending between said arm and said hub member; and

pulley means configuring the path of the line such that said line exerts a pull on said arm in an opposite transverse direction to the action of said spring means.

18. A pavement grooving machine as defined in claim **16,** further including:

two of said arms positioned at opposite transverse ends of said module extending forwardly therefrom;

two of said hub members, said hub members connected with said front wheels projecting concentrically and sidewardly therefrom in opposite directions; and

two of said connecting means for connecting each of said hub members with the adjacent one of said arms.

19. A pavement grooving machine as defined in claim **16,** wherein said guidance system further includes:

driving and steering means connected with one of said truck and said trailer for driving and steering said truck; and

an operator supporting platform connected with one of said trailer and said truck on which an operator may be positioned to operate said driving and steering means, said driving position being located in a position from which the operator can visually align said arm with the guideline.

20. A pavement grooving machine as defined in claim **15,** wherein said truck and said trailer have longitudinal centerlines, the first pivot axis being intersected by the longitudinal centerlines of both said truck and said trailer, the second pivot axis being positioned on the longitudinal centerline of said trailer at longitudinal distances L_1 and L_2 from the first pivot axis and from the rear transverse axis of said trailer, respectively; and wherein said linkage means comprises:

at least one longitudinally extending link spaced on one side of said centerlines, said link at its forward and rearward ends being connected by pivotal connections to said truck and to said module at radii r_1 and r_2 from said first and second pivot axis, respectively, said radii having approximately the following ratio,

$$\frac{r_2}{r_1} = \frac{L_1 + L_2}{L_1}.$$

21. A pavement grooving machine as defined in claim **20,** further including two of said links positioned symmetrically on opposite sides of the centerlines of said truck and said trailer, said links having sufficient resilient flexibility and sufficient looseness in their pivotal connections to said truck and said module to enable turning of said module relative to said trailer without binding or permanently deforming said links over a predetermined range of angular motion of the module relative to a neutral position which said module occupies when the centerlines of said truck and said trailer are in alignment.

22. A pavement grooving machine as defined in claim **21,** wherein the effective working range of angular motion of said module relative to said trailer comprises approximately 8° in either direction from the neutral position.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,896,989
DATED : August 5, 1975
INVENTOR(S) : Stafford M. Ellis

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 11, line 36, delete the word "trailer" and substitute --truck--.

Column 12, line 11, delete the word "cruve" and substitute --curve--.

Column 12, line 17, before "connecting" insert the word --means--.

Signed and Sealed this

Tenth Day of May 1977

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks