Feb. 24, 1970 H. R. ASK 3,497,014

AUTOMATIC BLADE BITE CONTROL

Filed May 1, 1967 3 Sheets-Sheet 1

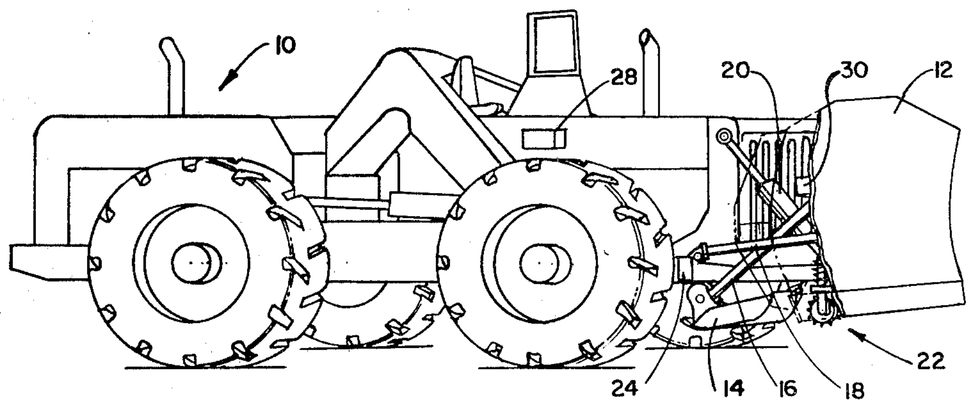

FIG. 1

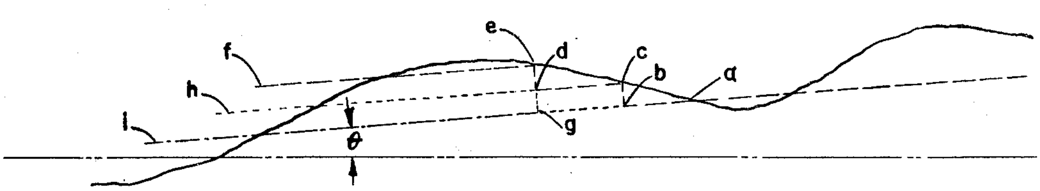

FIG. 5

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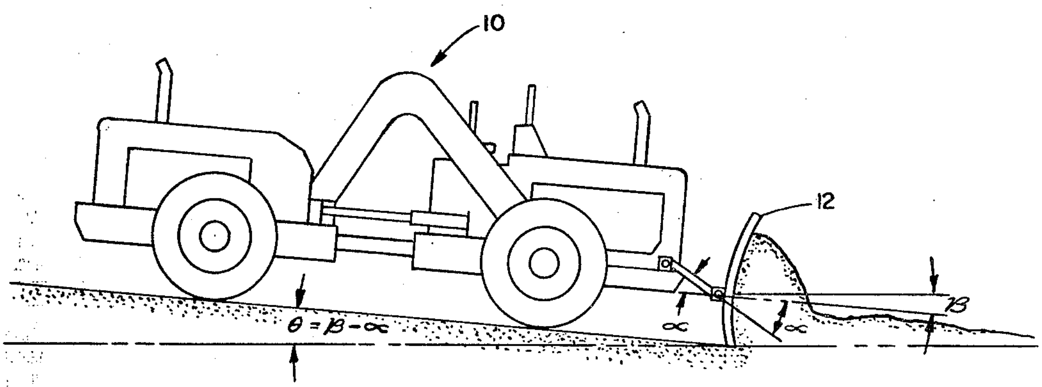

FIG. 2

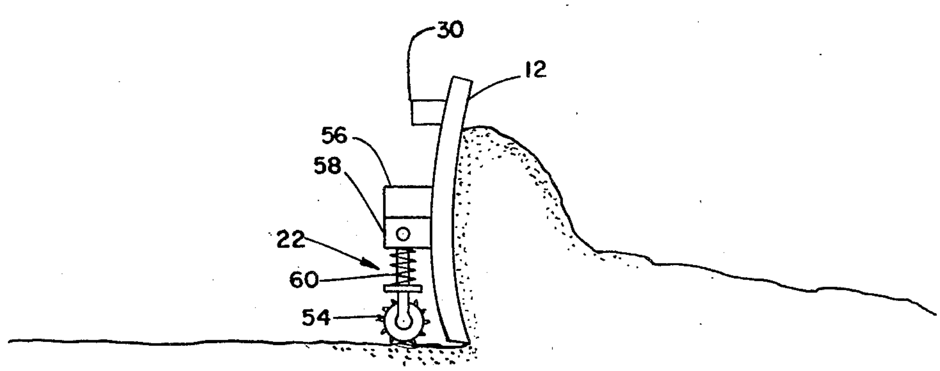

FIG. 4

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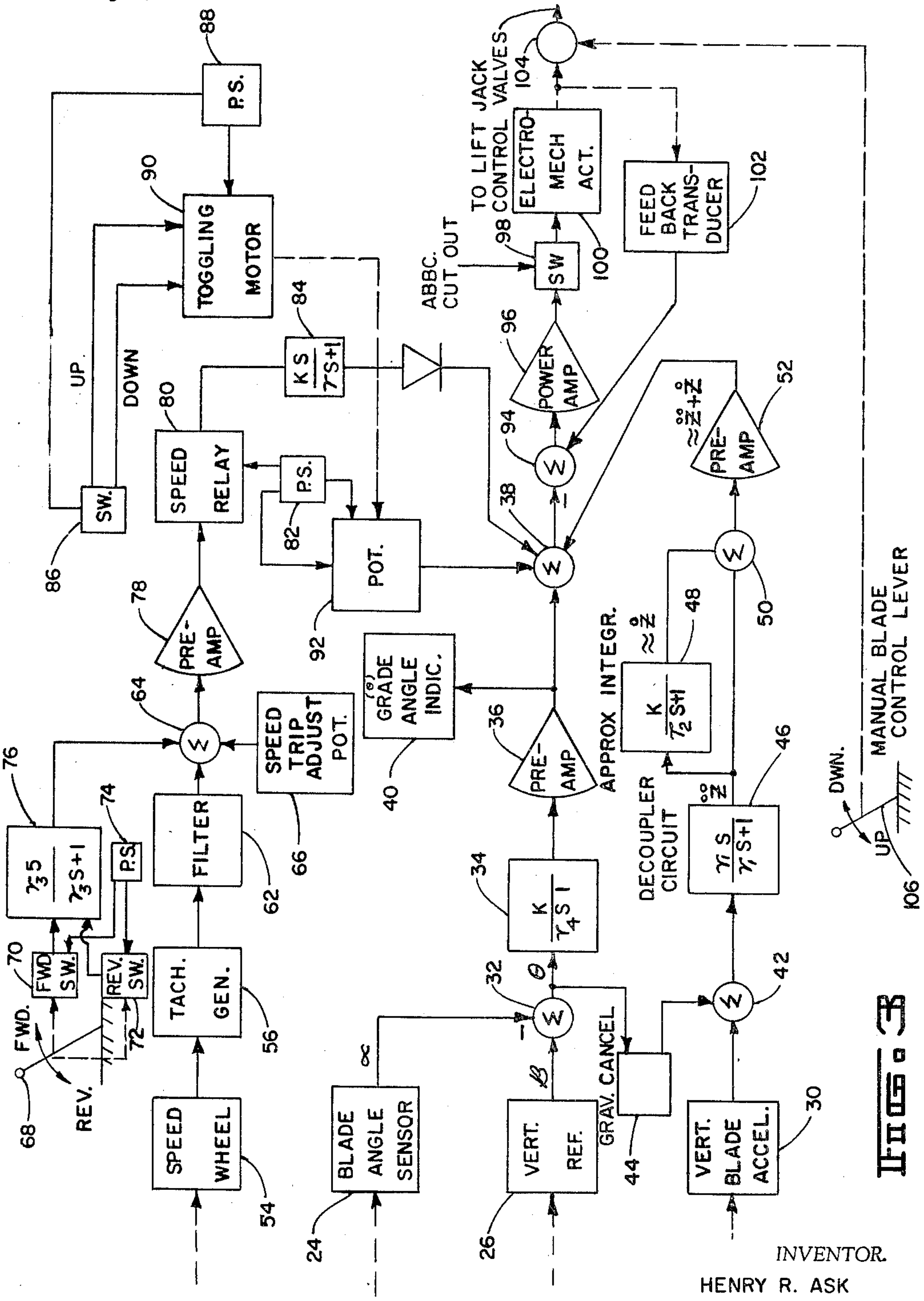
AUTOMATIC BLADE BITE CONTROL

Filed May 1, 1967 3 Sheets-Sheet 3



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United States Patent Office

3,497,014
Patented Feb. 24, 1970

3,497,014

AUTOMATIC BLADE BITE CONTROL

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Filed May 1, 1967, Ser. No. 635,102
Int. Cl. E02f *3/76, 3/86*
U.S. Cl. 172—4.5 **12 Claims**

ABSTRACT OF THE DISCLOSURE

An automatic blade bite control for high speed earth contouring machinery; the control including a blade assembly mounted vertical accelerometer and associated circuitry for generating signals commensurate with short term vertical movements of the earth working blade, such signals being applied to the blade actuators to thereby isolate the blade from vertical movements of the machinery caused by irregularities in the terrain being worked. The control also includes means for comparing the actual fore and aft blade assembly angle with the desired blade assembly angle and providing a corrective signal in the case of discrepancies therebetween and means for sensing the actual forward speed of the machinery and generating a transient overload compensation signal.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to the control of earth working machinery. More particularly, the present invention is directed to the automatic control of machinery employed to work irregular terrain to a preselected grade. Accordingly, the general objects of the present invention are to provide new and improved methods and apparatus of such character.

Description of the prior art

While not limited thereto in its utility, the present invention is particularly well suited for use on equipments, known generally in the art as dozers, which dislodge and move material by means of an adjustable, front mounted blade. By controlling blade assembly angle, it is possible to cut and/or fill in the establishment of a desired grade or contour. For many applications, there is a trend in the earth working machinery art to replace the conventional and relatively slow moving tracked equipment; commonly known as the bulldozer; with large, high speed, rubber tired apparatus. That is, for many jobs, it has been found to be more efficient to perform grading operations with the high speed, rubber tired dozers even though the blade bite of such equipment is generally less than that of the slower moving tracked equipment. Among the reasons for this trend are the improved maneuverability of rubber tired equipment and their increased versatility since the speed of operation of the equipment may be matched to the job requirements.

In the prior art, a grading operation has typically been performed with a slow speed, tracked vehicle making a rough cut and in the course thereof, removing or burying obstacles such as large rocks. Thereafter, in order to

grade to the desired contour, scraper type equipment depth by some object. Further, since the finished grade Due to the slow speed and relatively stiff suspension systems on the tracked dozers, it has previously been deemed unnecessary to provide compensation for short term vertical blade movements in the control systems for such equipment. Restated, due to the slow forward speed of the prior art tracked dozers, the operator thereof could easily manually compensate for the situation where the vehicle and thus the blade was deflected from the desired cut depth by some object. Further, since the finished grade was generally produced by additional equipment brought to the construction site it was previously not deemed necessary to provide the dozer with automatic controls having the necessary sensing devices to provide compensation for such vertical movements.

However, automatic blade bite control equipment has been designed and occasionally utilized on earth working machinery to facilitate grading operations. Such control equipment is generally quite complex and thus both expensive and often lacking in reliability. Even more important, the prior art control schemes are not suitable for employment upon the high speed, rubber tired equipment. That is, the foregoing comments regarding the lack of compensation for vertical movements are true even in the case of relatively sophisticated dozer controls which provided for the maintaining of a pre-selected blade bite or grade angle. Such controls were capable of sensing the deviation from the desired grade and generating blade actuator control signals which would cause proper adjustment of the blade relative to the tractor so as to return to the desired grade. However, as a result of the relatively slow working speed of the tracked equipment, it was unnecessary to provide means to isolate the blade from short term vertical movements of the tractor. This, of course, is not true in the case of the high speed, rubber tired dozer. When one of the wheels of the latter equipment strikes an object at the normal or medium working speed, the blade will be deflected from the desired grade. In addition the rubber tire suspension causes an oscillatory pitching response in the vehicle not found in slow tracked vehicles. These responses are sensed as blade accelerations and largely taken out by this invention.

In addition to the above discussed deficiency of prior art blade controls, it should be noted that, while some of these prior art controls provided for maintaining of a pre-selected grade angle, the controls did not provide for automatic stepping of the equipment to a second elevation while continuing to grade at the desired grade angle. In a grading operation, it often happens that the dozer or other earth working machine will lose forward speed due to an excessive load of material ahead of the blade. In the prior art, when this situation occurred, the control system would oppose the equipment's attempt to climb out of the cut and resume grading along the same angle but at a different level. Restated, in the prior art, when the earth working machine lost speed, it was necessary for the operator to disengage the automatic control and take over manual operation of the machine until a set of conditions was achieved where the automatic control could be reactivated.

SUMMARY OF THE INVENTION

The present invention comprises an automatic blade bite control for earth moving machinery which overcomes the above-discussed disadvantages of the prior art and thus constitutes an improvement thereover. This improvement is precipitated by a control which employs means for sensing the onset of short term vertical accelerations of the earth working blade and for generating signals commensurate with such short term accelerations. Through suitable control circuitry, the signals commensurate with short term vertical blade accelerations are applied to the blade actuating mechanism thereby isolating the blade from short term vertical and rotational movements of the vehicle upon which it is mounted. The present invention also includes means for comparing the actual blade assembly angle with the desired blade assembly angle and for generating corrective signals for application to the blade actuators when the actual angle departs from the desired angle. The angle comparing means thus aids the operator in maintenance of a preselected grade slope. The present invention further comprises means for sensing the forward speed of the blade relative to the earth and for generating a signal which causes application of a transient blade up bias signal to the blade actuators when the forward speed of the blade drops below a pre-selected level. When the vehicle climbs out of the initial cut and begins moving forward on a different level, the disabling signal will automatically decay and the blade assembly angle will revert back to the commanded value.

BRIEF DESCRIPTION OF THE DRAWING

The present invention may be better understood and its numerous advantages will become apparent to those skilled in the art by reference to the accompanying drawing wherein like reference numerals refer to like elements in the various figures and in which:

FIGURE 1 depicts a high speed, rubber tired, earth moving machine incorporating the present invention; the earth working blade of the apparatus of FIGURE 1 being partially broken away to show the placement of the sensors in a preferred embodiment of the present invention.

FIGURE 2 is a schematic representation of the earth moving apparatus of FIGURE 1 indicating the various angles which must be sensed and maintained during operation of the equipment.

FIGURE 3 consists of a block diagram of a preferred embodiment of the present invention.

FIGURE 4 represents a speed sensor of a type which may be employed on the present invention.

FIGURE 5 is an elevation view of terrain which depicts the operation of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIGURE 1, a rubber-tired earth moving vehicle (dozer) is indicated generally at **10**. Dozer **10** has an earth working or moving blade assembly **12** mounted, by means of skids **14** and arms **16** and **18**, from its front end. The angle of the blade assembly relative to the dozer will be controlled by a pair of hydraulic lift jacks **20**, only one of which is shown. The lift jacks **20** will extend between opposite sides of blade **12** and the frame of dozer **10**. Through control of the hydraulic lift jacks **20**, the angle (bite) of blade **12** relative to the fore and aft axis of the vehicle may be adjusted thereby adjusting the finish grade angle of the terrain being worked. Dozer **10** is characterized by high maneuverability and the ability to operate at a relatively high speed while a cut is being made with blade **12**.

The automatic blade bite control of the present invention includes a plurality of sensors which, with the exception to be described below, may be mounted on the apparatus at positions which, through trial and error, place the sensors where they are least susceptible to damage. In FIGURE 1, blade **12** has been partially broken away to show a plurality of these sensors.

A speed sensor, indicated generally at **22**, is mounted behind blade **12** and preferably includes fifth wheel means, which contacts the terrain, and an associated tach-

ometer generator, which provides a signal commensurate with the speed of rotation of the fifth wheel means and thus with the actual forward velocity of the dozer **10**. A fifth or speed wheel which is in actual contact with the surface of the terrain over which dozer **10** is moving is necessary in order to measure the forward velocity of the apparatus. An ordinary speedometer connected to one of the wheels of dozer **10** would not provide an accurate measure of actual forward speed relative to the earth since the wheels of dozer **10** are generally all driven and always experience various amounts of slippage when blade **12** is loaded.

An angle sensing means **24** is shown in FIGURE 1 as mounted on a suitable bracket between blade **12** and the front end of dozer **10**. Angle sensor **24** comprises means for sensing the angle α between the blade **12** and dozer **10**.

It is also necessary to sense the angle β of the vehicle with respect to the earth. The angle β is known as the vertical deviation angle and is measured by a sensor **26** which includes a vertical reference generator (see FIGURE 3) conveniently located in or near the control box **28**.

A linear accelerometer **30** is mounted on the rear of blade **12**, as shown, with its sensitive axis aligned to sense local vertical motions of the blade. In accordance with the present invention, accelerometer **30** must be mounted on blade **12**. While there is some flexibility, the primary consideration in the mounting of accelerometer **30** is, of course, that it be protected against damage from debris which falls or is otherwise forced between blade **12** and the front of dozer **10**.

Considering briefly FIGURE 2, the three angles of interest in the operation of the present invention, as employed to cut and fill terrain to a desired grade angle, are shown. The angle α comprises the angle between the blade assembly and the fore-aft axis of the dozer. The angle β is the angle of the vehicle with respect to earth. That is, angle β is the angular deviation of dozer **10** with respect to earth or, restated, the fore and aft pitch angle of the dozer. The angle θ is the desired grade angle in the direction of vehicle travel. In the normal control mode, the algebraic sum of the vertical deviation β and the blade assembly angle α is equivalent to the desired grade angle θ.

Referring now to FIGURE 3, a preferred embodiment of the control of the present invention is shown in block form. The means for computing the actual grade angle comprises, in the preferred embodiment, blade angle sensor **24** and vertical deviation angle sensor **26**. The vertical deviation β angle sensor **26** may comprise a gyro slaved to the earth or a damped pendulum. The output of sensor **26** is, as previously noted, a signal commensurate with the angular deviation β of the dozer **10** with respect to the earth (the fore and aft pitching angle). The blade assembly angle sensor **24**, which provides a signal commensurate with the angular rotation of the blade assembly with respect to dozer **10**, will comprise a transducer mounted in such a manner as to pick off said angular rotation.

The α and β signals, respectively from the blade angle transducer **24** and vertical position sensor **26**, are applied to a summing circuit **32**. Summing circuit **32** provides an output signal proportional to the algebraic sum of the vertical deviation β and the blade assembly angle α. As noted above, this sum is a signal proportional to the angle θ between the blade reference axis and the earth which is, in the normal control mode, equivalent to the desired grade angle in the direction of vehicle travel. The θ or grade angle signal from summing circuit **32** is passed through a lag or integrating circuit **34** to raise its low frequency gain level and hence improve its steady state position accuracy. The output signal from lag circuit **34** is amplified in a preamplifier **36** and applied to both a summing circuit **38** and a grade angle indicator **40**.

A signal commensurate with vertical blade acceleration is generated by accelerometer **30**. The acceleration signal from accelerometer **30** is summed with a gravity compensation signal in a summing circuit **42**. The gravity compensation signal is obtained from the net blade assembly angle signal by passing the output signal from summing circuit **32** through a compensation circuit **44**. Circuit **44** generates a signal commensurate with the magnitude of the θ signal for application to summing circuit **42**. The compensated vertical blade acceleration signals from summing circuit **42** are passed through a decoupler cihcuit **46** which eliminates steady state signal components due to imperfect gravity cancellation and/or null shifts in sensor **30**. The output signals from decoupler circuit **46** are fed along two paths, being integrated in one path in approximate form by an integrator **48** to provide a short term velocity signal. The short term velocity and acceleration signals,

$$\dot{Z} \text{ and } \ddot{Z}$$

respectively, are summed in an addition circuit **50** and the sum is amplified by a preamplifier **52**. The acceleration plus short term velocity (transient blade angle stabilization) signals from preamplifier **52** are applied directly to summing circuit **38**.

As noted above in the discussion of FIGURE 1, the preferred embodiment of the present invention being described also includes means for sensing the forward speed of the dozer relative to the earth. While shown in FIGURES 1 and 4 as being mounted from the rear of blade **12**, speed sensor **22** may be mounted from any suitable point on the apparatus. As may be seen most clearly from FIGURE 4, the speed sensing means **22** preferably comprises a speed wheel **54** and a tachometer generator **56**. The speed sensor **22** is typically mounted from a bracket **58** on the rear of blade **12** and the speed wheel is urged into contact with the terrain being worked by a spring **60**. The mechanical connection between speed wheel **54** and tachometer generator **56** will pass within the strut by which the speed wheel is suspended from the bracket. Raising of blade assembly **12** will lift speed wheel **54** out of contact with the earth.

The output of tachometer generator **56** is a signal commensurate with the actual speed of dozer **10**. This speed signal is filtered in a filter circuit **62** to remove short term transients and is thereafter applied to a summing circuit **64**. Also applied to summing circuit **64** is a speed trip adjustment signal commensurate with the desired minimum forward speed of dozer **10**. The speed trip adjustment is made as required via a potentiometer **66** which will be physically located in the cab area of dozer **10**.

Also added at summing circuit **64** is the forward-reverse lever lagged rate signal. The forward-reverse lever **68** actuates either forward switch **70** or reverse switch **72** depending upon its position. Switches **70** and **72** apply a fixed voltage of the proper polarity from power supply **74** to a derivative-lag circuit **76**. When the operator moves the forward-reverse lever **68** from the forward to the reverse position, or vice-versa, one of switches **70** and **72** will be closed applying a steady state voltage to derivative-lag circuit **76**. Upon the removal and then reapplication of a steady state signal thereto, circuit **76** generates a transient artificial over-speed signal which is applied to summing circuit **64**. This transient over-speed signal will, in the manner to be described below, prevent the blade assembly from raising when the operator changes the direction of vehicle travel. It is to be noted that the decay time of the transient over-speed signal generated by derivative-lag circuit **76** is commensurate with the time it takes for the dozer to come up to or resume speed upon start up or direction change under normal working conditions.

Under normal operating conditions, that is when the operator has not ordered a change in direction of travel, the actual speed signal from filter circuit **62** and the desired speed trip adjustment signal from potentiometer **66** are summed in summing circuit **64** to provide a speed error signal. The speed error signal from summing circuit **64** is applied to a preamplifier **78**. The output of preamplifier **78** is applied to a speed relay **80**. Preamplifier **78** will normally provide an output signal of sufficient magnitude to hold relay **80** "in." With relay **80** held "in," its contacts will be in the normally open position and no signal will appear at the output of the speed relay. However, when the forward speed of dozer **10** drops below a preselected value, such value being commensurate with the preselected speed trip adjustment signal, the speed error signal will increase in the proper direction to cause a reduction of the speed relay current supplied by preamplifier **78**. When the signal from preamplifier **78** becomes insufficient to hold "in" relay **80**, the relay will be unlatched, its contacts closed and a blade up bias signal from bias power supply **82** will be applied, through a decoupling circuit **84**, to summing circuit **38**. Decoupling circuit **84**, in response to the application of a signal thereto from power supply **82** via the contacts of relay **80**, generates a transient blade up signal. This transient blade up signal operates in the manner to be described below so as to cause the blade assembly to first rise and then, as the signal decays, to return to its original position and reengage the speed wheel. The decay time is sufficient to allow the dozer to climb out of the cut and regain speed.

The blade assembly angle is initially set by the operator by means of adjusting the blade while observing grade angle indicator **54**. The blade is adjusted by periodically closing a switch **86** to the up or down position. Each time the operator closes switch **86** in either direction, current of the proper polarity from a power supply **88** is delivered to a toggling motor **90**. The output shaft of toggling motor **90** is connected through a gear reduction to the movable arm of a potentiometer **92** which is connected across power supply **82**. The output signal as derived from the movable arm of potentiometer **92** will thus be a signal commensurate with the desired blade assembly angle. This blade assembly angle signal is applied to summing circuit **38**.

During normal operation, after the speed trip potential at summing circuit **64** has been adjusted and the desired grade angle selected, the only signals applied to summing circuit **38** will be the desired grade angle signal from potentiometer **92**, the actual grade angle θ signal from preamplifier **36** and the transient stabilizing signals from preamplifier **52**. When there is a discrepancy between the actual and desired grade angle signals or when a blade assembly vertical acceleration is sensed, a grade angle error signal will appear at the output of summing circuit **38**. This grade angle error signal will be applied to a summing circuit **94** and thence to a power amplifier **96**. The output of amplifier **96** is passed, via the normally closed contacts of a master automatic blade bite control cutout switch **98**, to an actuator **100**. Actuator **100** may be any well known electromechanical or electrohydraulic servo device which will control the operation of the lift jacks **20** on dozer **10** by means of regulating valves or other devices associated with the supply of motive power for the lift jacks. Movements of the output shaft of servo actuator **100** are sensed by a feedback transducer **102** which generates signals commensurate with such movements for application to summing circuit **94**. Thus, the grade angle command signals from summing circuit **38** and blade actuator feedback signals are summed and the error signals feed a minor position loop; the minor feedback loop consisting of amplifier **96**, servo actuator **100** and feedback transducer **102**. As previously noted, the output of servo actuator **100** is mechanically coupled to the lift jack regulating means which are indicated schematically at **104**.

Master cutout switch **98** may be controlled by the operator and is used when it is desired to disconnect the automatic blade bite control system of the present invention from the blade bite position controlling means on dozer **10**. Regardless of the position of switch **98**, the blade assembly may be manually adjusted by the operator through the operation of a control lever **106** located in the cab area. Control lever **106** is directly linked to regulating means **104**.

In operation, through the manipulation of two-way switch **86**, a signal commensurate with the desired grade angle is set into the system. During the setting of the desired grade angle signal, blade angle sensor **24** and vertical reference signal generator **26** will be operative to provide an actual grade angle signal to blade angle indicator **40**. Thus, by watching indicator **40** and manipulating switch **86**, the operator can ascertain when the proper blade angle for achieving the desired grade angle has been obtained. During the initial setting of the blade and thereafter during operation, the grade angle error signal provided by summing circuit **38** will control the operation of a feedback control system including a servo actuator **100** which positions the blade assembly lift jack regulating means. The desired speed trip point signal is also initially set into the system by adjusting potentiometer **66**.

Once the desired grade angle and speed trip adjustment points have been set, the operator engages the forward-reverse lever **68** and the dozer begins to move forward. During the time that the dozer is coming up to speed, a transient simulated over-speed signal from lag circuit **76** is applied to speed relay preamplifier **78**. This over-speed signal results in the holding "in" of the speed relay **80** and allows the blade assembly to assume the required angle even though the output from tachometer **56** is insufficient to null out the speed trip signal from potentiometer **66**.

Once the dozer has come up to speed, the speed sensing system comprising speed wheel **54** and tachometer generator **56** will provide an output signal which will oppose the desired speed signal established by speed trip adjustment potentiometer **66** and the speed error signal will be nulled. Speed relay **80** will accordingly be held "in" when the transient simulated over-speed signal from lag circuit **76** falls to zero. Operation of the dozer will continue with grade angle error signals being generated by summing circuit **38** and applied to the control loop. Should the dozer encounter an irregularity which results in vertical movement of dozer **10** and/or the blade assembly **12**, vertical blade accelerometer **30** will sense such motion and; through the action of decoupler **46**, integrator **48**, summing circuit **50** and preamplifier **52**; will provide a large amplitude output signal. This transient

$$\ddot{Z}+\dot{Z}$$

signal will be applied to summing circuit **38** and thence to the control loop. The acceleration signals and their integrated (velocity) values as applied to summing circuit **38** from preamplifier **52** will cause the servo actuator **100** to operate the blade lift jacks **20** in a direction opposite to the sensed motion of the blade. The response of the system is quite rapid and thus the blade assembly is effectively isolated from short term vertical movements of the dozer.

As grading continues, a load of material may build up in front of the blade **12** of dozer **10**. This load of material will cause the dozer to slow down to a point where a speed error signal of sufficient magnitude to cause the dropping out of speed relay **80** will be generated. When this happens, a transient blade up bias signal will be applied to the control loop via decoupling circuit **84**. The blade will then be raised, the dozer will proceed forward and will climb out of the cut while gaining speed, the transient blade up bias signal will decay to zero and the blade will be returned to the preset angle through the nulling of the grade angle error signal. Grading will then resume at a new initial elevation point and will proceed at the proper grade angle.

The above described operation may be more clearly seen from a consideration of FIGURE 5. In FIGURE 5, it is presumed that, starting at point *a*, the dozer is to grade the terrain to provide a grade at an angle θ from point *a* to point *i*. The grade angle is set into the system by adjusting potentiometer **92** via control switch **86** and toggling motor **90**. The throttle is then advanced, the forward-reverse lever engaged and the dozer proceeds forward (in a downhill direction) to point *b*. At point *b*, the load on the blade has become so great that the dozer loses speed. A transient blade up bias signal is thus applied to the system, the blade raised and the dozer again begins to proceed forward. As the dozer climbs out of the cut made by the blade between points *a* and *b*, it resumes speed, the blade up bias signal decays, the blade lowers and cutting is resumed. A new cut will thus be made at a different level but on the same angle θ between point *c* and *d*. At point *d*, the blade is again loaded, the dozer slows down, the blade is raised, the dozer proceeds forward again and the blade is lowered thus grading along a third level but again at the same angle θ between points *e* and *f*. The dozer will then be returned to point *b* and the operation will be repeated with the first cut being from point *b* to *g*, the blade then being raised and a second cut being from point *d* to point *h*. The dozer then is returned to point *g* and finishes the grade to point *i*. The three passes required to contour the terrain to the grade angle θ, since they are performed with a piece of equipment operating at a relatively high speed and under automatic control, takes considerably less time than would be required using prior art equipment and techniques. Thus, the entire operation is speeded up thereby achieving higher equipment and manpower utilization. In addition, as a by-product of the automatic control, the level of skill required by the operator to bring an excavation to grade and/or to bring the excavation to grade more accurately using rough grading equipment is considerably reduced. This, in turn, reduces the job of finished grading where necessary. Operator fatigue is also reduced through the automatic control of equipment engaged in repetitious and/or ordinary rough grading and excavating operations.

To summarize the results achieved through use of the present invention, the automatic blade bite control described above maintains a constant long term blade position with respect to earth. Because the dozer cuts its own path while maintaining a constant blade assembly angle, a constant grade slope results as long as material is available or as long as the bite does not cause the vehicle to significantly slow down. The acceleration and velocity feedback paths for the signal sensed by the blade vertical accelerometer (vertical deviations of the blade due either to blade and/or vehicle rotation and vertical translation of the entire vehicle) isolate the blade of the dozer from vehicle motions. By using an override signal to raise the dozer blade when the vehicle speed falls to near zero due to blade loading, the operator is released from making continuing blade adjustments due to blade resistance.

While a preferred embodiment has been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the present invention. Accordingly, it is to be understood that the present invention has been described by way of illustration rather than limitation.

What is claimed is:

1. An automatic blade control system for a vehicle having mounted thereon an adjustable blade, said vehicle being employed for moving material by means of said blade, the control system comprising:

an accelerometer mounted on the blade, said accelerometer comprising means for providing signals commensurate with short-term vertical motions of the blade relative to the vehicle and to the earth;

means for generating a signal commensurate with the desired blade attitude;

means for sensing the actual blade attitude and for generating a signal commensurate therewith;

means responsive to said desired and actual blade attitude signals and to said signals commensurate with vertical blade motions for generating blade adjustment control signals when the actual blade attitude deviates from the desired blade attitude and when a short-term vertical blade motion signal is present; and

means for applying said blade adjustment control signals to the blade positioning actuators on the vehicle whereby the desired blade attitude may be maintained and the blade isolated from short-term vertical motions of the vehicle.

2. The apparatus of claim **1** wherein said means for sensing the actual blade attitude comprises:

means for sensing the angle of the blade with respect to the fore-aft axis of the vehicle and for generating a signal commensurate with said blade angle;

means for sensing the fore-aft pitch angle of the vehicle and for generating a signal commensurate with said pitch angle; and

summing means responsive to said signals commensurate with blade and pitch angle for providing a signal commensurate with the actual angular position of the blade.

3. The apparatus of claim **1** further comprising:

means for sensing the forward velocity of the vehicle and for generating a signal commensurate therewith;

means responsive to said vehicle velocity signal for generating a blade up bias signal when the vehicle velocity falls below a preselected level; and

means applying said blade up bias signal to said means for generating blade adjustment control signals whereby said blade will be raised when the load thereon causes the forward speed of the vehicle to fall below the preselected level.

4. The apparatus of claim **3** wherein said means for generating a blade up bias signal comprises:

means for generating a signal commensurate with a preselected minimum velocity;

means responsive to said signals commensurate with forward velocity and minimum velocity for generating a speed error signal; and

means responsive to said speed error signal for generating a transient blade up bias signal.

5. The apparatus of claim **4** wherein said means for generating a transient blade up bias signal comprises:

a source of steady state potential;

a decoupling circuit for generating a transient bias signal upon the application of a steady state signal thereto; and

means responsive to said speed error signal for applying a steady state signal from said potential source to said decoupling circuit.

6. The apparatus of claim **3** wherein said means for sensing the actual blade attitude comprises:

means for sensing the angle of the blade with respect to the fore-aft axis of the vehicle and for generating a signal commensurate with said blade angle;

means for sensing the fore-aft pitch angle of the vehicle and for generating a signal commensurate with said pitch angle; and

summing means responsive to said signals commensurate with blade and pitch angle for providing a signal commensurate with the actual angular position of the blade.

7. An automatic blade control system for a vehicle having mounted thereon an adjustable blade, said vehicle being employed for moving material by means of said blade, the control system comprising means for sensing vertical motions of the blade and for generating signals commensurate therewith;

means for generating a signal commensurate with the desired blade attitude;

means for sensing the actual blade attitude and for generating a signal commensurate therewith;

means for sensing the actual forward velocity of the vehicle and for generating a signal commensurate with therewith;

means for generating a signal commensurate with a preselected minimum forward velocity;

means responsive to said signal commensurate with actual and minimum forward velocity for generating a speed error signal;

means responsive to said speed error signal for generating a transient blade up bias signal;

means responsive to said desired and actual blade attitude signals and to said signals commensurate with said vertical blade motions for generating blade adjustment control signals when the actual blade attitude deviates from the desired blade attitude and when a vertical blade motion signal is present, said blade adjustment control signal generating means also being responsive to said transient blade up bias signals and generating blade adjustment control signals commensurate therewith; and

means for applying said blade adjustment control signals to the blade positioning actuators on the vehicle whereby the desired blade position may be maintained, the blade isolated from vertical movements of the vehicle and the blade momentarily unloaded in response to an unrequested decrease in vehicle speed greater than a preselected value.

8. The apparatus of claim **7** wherein said means for sensing vertical motions of the blade comprises:

an accelerometer mounted on the blade, said accelerometer providing signals commensurate with short term vertical motions of the blade relative to the vehicle and to the earth.

9. The apparatus of claim **7** wherein said means for generating a transient blade up bias signal comprises:

a source of steady-state potential;

a decoupling circuit for generating a transient bias signal upon the application of the steady-state signal thereto; and

means responsive to said speed error signal for applying a steady-state signal from said potential source to said decoupling circuit.

10. The apparatus of claim **9** wherein said means for sensing vertical motions of the blade comprises:

an accelerometer mounted on the blade, said accelerometer providing signals commensurate with short term vertical motions of the blade relative to the vehicle and to the earth.

11. The apparatus of claim **10** wherein said means for sensing the actual blade attitude comprises:

means for sensing the angle of the blade with respect to the fore-aft axis of the vehicle and for generating a signal commensurate with said blade angle;

means for sensing the fore-aft pitch angle of the vehicle and for generating a signal commensurate with said pitch angle; and summing means responsive to said signals commensurate with blade and pitch angle for providing a signal commensurate with the actual angular position of the blade.

12. The apparatus of claim **11** further comprising:

means for generating a transient artificial over-speed signal in response to vehicle direction of motion change commands; and

means applying said transient over-speed signal to said speed error signal generating means whereby blade up bias signals will not be applied to said control signal generating means during start up or when the direction of movement of the vehicle is reversed.

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