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Research Article

Planetary Differential Speed Dependent on Engine

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Abstract

A dozer with a hydrostatic steering system and HSS brake is disclosed which is capable of performing effective steering; capable of effective control and various turning radius at different speeds ensuring higher productivity; and capable of performing pivot steering. To this end, a bulldozer with a hydrostatic steering system with HSS brake, wherein the power of a hydraulic motor driven by pressure oil fed from a hydraulic pump operated by an engine is transmitted to right and left crawler tracks through a differential steering means composed of planetary gear trains etc., is designed to have the differential speeds at left and right tracks.

Keywords: *Hydrostatic steering system etc.*

Introduction

The present invention relates to Hydrostatic steering system (HSS) with HSS brake for effective steering of bulldozers. Hydrostatic steering system is suitable for all low and medium class bulldozers for effective steering and improved productivity.

Background Art

A Bulldozer is a crawler (tracked tractor), equipped with a substantial metal plate (known as a blade), and used to push large quantities of soil, sand, rubble, coal, etc, during construction work, coal mines, etc. The power generated by engine is transmitted through a torque converter, a universal joint, a transmission, bevel gear set, steering clutches and then to final drive. The bevel gear shaft system meshes the bevel pinion and bevel gear and sends the power output from the transmission at right angles to the left and right. At the same time it also reduces the rotating speed. The steering clutches are interconnected with the bevel gear shaft at both ends by a spline. They act to connect and disconnect the power from the bevel gear shaft to the final drive to change the machine turning direction. The steering clutch is a wet type, multiple disc clutch, spring boosted type. It is actuated hydraulically by the pressurized oil from the steering valve, which is also interconnected with the brake. The steering brakes are interconnected with the left and right steering clutches. They carry out braking of the power from the steering clutch to the final drive and change the machine turning direction or brake the machine.

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In the above conventional bulldozer the steering is achieved by engagement or disengagement of both steering clutches and brakes controlled by steering control valve. During steering of the bulldozer power is transmitted only to one side of either clutches by engagement/disengagement of steering clutches/brakes causing the machine to steer in that particular direction respectively. Suppose if the left steering clutch is disengaged, power is transmitted only to the right steering clutch, so the left side track which is mounted on left final drive is held stationary causing the machine to turn left side. Similarly if the right steering clutch is disengaged, power is transmitted only to the left steering clutch, so the right side track which is mounted on right final drive is held stationary causing the machine to turn right side. Since the track is skidding on the ground while steering which causes following problems:

a. Shock loads are transmitted from ground to vehicle through tracks which causes vibrations.
b. Increased operator fatigue.
c. Less productivity.
d. More wear and tear of the track shoes which causes frequent replacement of track chain.
e. Constant turning radius.
f. Slow and sluggish.
g. Sharp turning is not possible.
h. Reduced life of undercarriage components.

The present invention is directed to overcome such problems and a prime object of the invention is therefore to provide hydrostatic steering system with HSS brake in bulldozers capable of performing efficient and sharp turning.

Planetary Differential

The above object can be accomplished by Hydrostatic steering system with HSS brake on bulldozer equipped with a steering pump and motor units in which the power of the engine is transmitted to the right and left sprockets through a torque converter, a transmission, and a differential steering means composed of planetary gear trains etc., whereas the power of a steering motor driven by pressure oil from a steering pump operated by the engine is transmitted to the right and left sprockets through the differential steering means.

The bulldozer comprising

Hydrostatic steering system equipped with steering pump and motor where power of the motor driven by pressure oil from steering pump operated by engine is transmitted to differential steering means composed of planetary gear trains and then to right and left sprockets.

HSS brake mounted on the steering motor driven shaft for perfect control of the vehicle.

Steering controls valve for optimum control of the main brake and HSS brake during straight, normal steering and pivot steering operations. According to the invention, effective steering is possible by giving differential speeds to both tracks by means of steering pump and motor which makes both tracks to rotate at different speeds during steering. HSS brake provides better control over the machine while machine is traveling straight.

A bulldozers with a hydrostatic steering system and HSS brake in which the power of an engine is transmitted to right and left drive wheels through at least a torque converter and differential steering means, whereas the power of a hydraulic motor, which is driven by pressure oil from a hydraulic pump operated by the engine, is transmitted to said right and left drive wheels through said differential steering means, said work vehicle comprising: speed ratio computing means for computing a speed ratio of the torque converter; and pump absorption torque controlling means for controlling torque absorbed by the hydraulic pump based on the speed ratio computed by the speed ratio computing means.

The work vehicle with a hydrostatic steering system according to claim , wherein said hydraulic pump is a variable displacement hydraulic pump whose discharge rate varies according to changes in its swash plate angle; which further includes a regulator for controlling the swash plate angle of the variable displacement hydraulic pump, a control valve for controlling the operation of said regulator in response to a supply of a control current, and an engine speed sensor for detecting the actual engine speed of said engine; and wherein said pump absorption torque controlling means includes a first control unit and a second control unit, the first control unit performing operation in which an absorption torque value indicating the amount of torque which said hydraulic pump should absorb is obtained by looking up data on the relationship between engine speed and absorption torque values indicating the amounts of torque which said hydraulic pump should absorb with an actual engine speed detected by said engine speed sensor, said data being prestored in accordance with the speed ratio of said torque converter, and the obtained absorption torque value is output as a pump absorption torque command value; and the second control unit performing operation in which a control current value for said control valve is obtained by looking up pre stored data on the relationship between pump absorption torque command values and control current values with a pump absorption torque command value sent from the first control unit, and a control current matching with the obtained control current value is output to said control valve.

Planetary Differential

FIG. 1 is 3D -Layout diagram of a bulldozer with a hydrostatic steering system with HSS brake according to one embodiment of the invention.

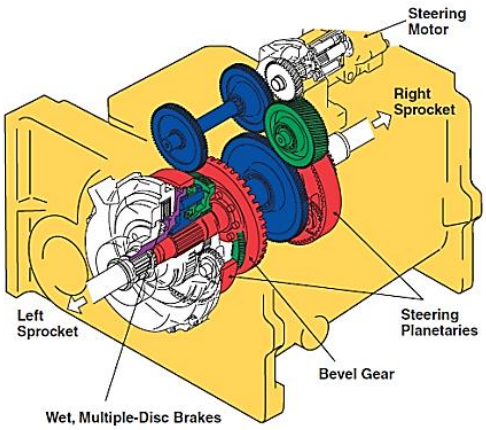

Fig 1: 3D Layout

Description of the HSS

With reference to the accompanying drawings, a bulldozer with a hydrostatic steering system and HSS brake will be concretely described according to a preferred embodiment of the invention.

Fig. 2 shows a powe rflow of a bulldozer with hydrostatic steering system and HSS brake constructed according to one embodiment of the invention.

As shown in FIG. 2, the rotary driving force of an engine is transmitted through damper and universal joint to a torque converter and then to a transmission from the output shaft of the torque converter . The force is then transmitted from the output shaft of the transmission to a transverse shaft through a bevel gear set . The rotary driving force of the engine is also transmitted to a variable displacement steering pump through a PTO .

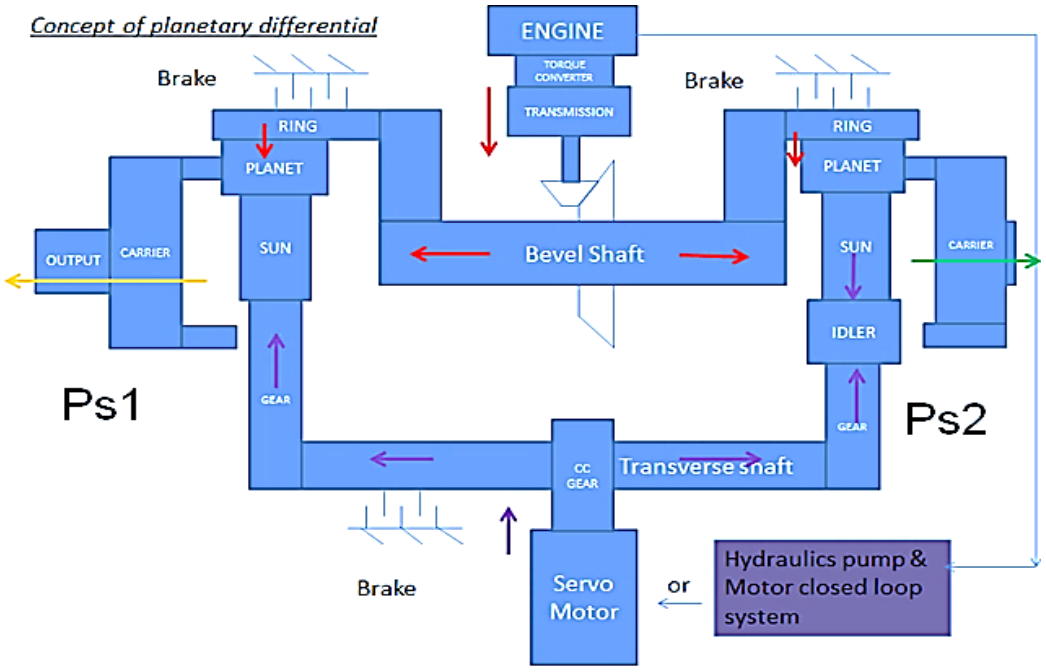

Fig.2: Power Flow

Coupled to the transverse shaft are brake units and planetary gear trains (corresponding to "the differential steering means" of the invention). An output shaft secured to a planetary carrier of the left planetary gear train is coupled to a left sprocket (left drive wheel) through a final drive reduction gears, whereas an output shaft secured to a planetary carrier of the right planetary gear train is coupled to a right sprocket (right drive wheel) through a final drive reduction gears. The left and right sprockets mesh with crawler tracks, respectively, arranged at the left and right sides of the vehicle body. The rotary driving forces which have been transmitted from the transverse shaft to the respective ring gears of the left and right planetary gear trains are then transmitted from the respective planetary carriers of the left and right planetary gear train to the sprockets respectively through the final reduction gears so that the crawler tracks are driven by the sprockets respectively.

A gear integrally secured to the sun gear of the left planetary gear train and a gear secured to the sun gear of the right planetary gear train mesh with gears secured to the output shaft of a steering motor through transfer gear box coupled with HSS brake (corresponding to "the HSS brake unit" of the invention) and power transmission mechanisms each consisting of a desired gear train. The rotary driving forces of the steering motor are transmitted from the respective sun gears of the left and right planetary gear trains to the left and right sprockets through the respective planetary carriers and final reduction gears whereby the revolution speeds of the left and right sprockets are made different from each other, thereby turning the vehicle to the right or left.

An operator's cab (not shown) includes a travel/turn operating unit for performing traveling and turning of the vehicle and an implement operating unit for operating an implement such as a blade (not shown). Herein, the travel/turn operating unit includes a travel/turn operating joystick for outputting a travel command or turn command and a pilot pressure oil outputting means (pressure reducing valve or the like) for outputting desired pilot pressure oil in response to the travel or turn command from the travel/turn operating joystick. The implement operating unit includes an implement operating joystick for outputting an implement operation command and a pilot pressure oil outputting means (pressure reducing valve or the like) for outputting desired pilot pressure oil in response to the implement operation command from the implement operating joystick.

Formed between the steering pump and the steering motor is a steering switching valve for feeding and discharging pressure oil discharged from the steering pump to and from the steering motor. With the pilot pressure oil output from the pilot pressure oil outputting means in response to the turn command from the travel/turn operating joystick, desired oil path switching operation of the steering switching valve is performed, which changes the rotating direction of the output shaft of the steering motor so that the vehicle is switched between left turning and right turning.

Formed between various hydraulic cylinders for actuating the implement and the hydraulic pump is an implement operating valve for feeding and discharging the pressure oil discharged from the hydraulic pump to and from the various hydraulic cylinders. Herein, the hydraulic cylinders refer to hydraulic cylinders for a lift, angle and tilt which are parts constitute the implement of the bulldozer. With the pilot pressure oil

output from the pilot pressure oil outputting means in response to the implement operation command from the implement operating joystick, desired oil path switching operation of the implement operating valve is performed, thereby allowing the implement to perform desired operation.

The steering pump and steering motor are formed in a closed loop load sensing system such that pumps swash plate angle is controlled by a discharge pipeline of the steering pump. An operating section of the servo valve is connected by a servo piston. A servo valve is for feeding and discharging control pressure oil to and from the servo piston is connected to discharge pipeline of the steering pump.

The transmission provides four speeds in both forward and reverse drive ranges and is composed of forward and reverse drive gears and first to fourth speed gears which consist of a stacked planetary gear sets. The reverse drive gear is provided with a reverse drive gear hydraulic clutch for connecting and disconnecting power to and from the reverse drive gear. The forward drive gear is provided with a forward drive gear hydraulic clutch for connecting and disconnecting power to and from the forward drive gear. The first speed gear is provided with a first speed gear hydraulic clutch for connection and disconnection of power with respect to the first speed gear; the second speed gear is provided with a second speed gear hydraulic clutch for connection and disconnection of power with respect to the second speed gear; and the third speed gear is provided with a third speed gear hydraulic clutch for connection and disconnection of power with respect to the third speed gear, and the fourth speed gear is provided with a fourth speed gear hydraulic clutch for connection and disconnection of power with respect to the fourth speed gear. In addition, the transmission includes a transmission operating valve containing Electronic Controlled Modulation Valves (ECMV) associated with the reverse drive gear hydraulic clutch.

The transmission operating valve functions to feed and discharge operating pressure oil to and from the reverse drive gear hydraulic clutch thereby switching it between a connected state and a disconnected state. In the transmission, the forward drive gear hydraulic clutch , the first speed gear hydraulic clutch, the second speed gear hydraulic clutch, the third speed gear hydraulic clutch and the fourth speed gear hydraulic clutch, are each provided with the transmission operating value .

The transmission operating valve containing ECMV associated with the reverse drive gear hydraulic clutch is equipped with a clutch operation detector (e.g., a pressure sensor, hydraulic switch, micro-switch, etc.). This clutch operation detector has the function of detecting that the transmission operating valve is in a state where operating pressure oil is allowed to be introduced into the reverse drive gear hydraulic clutch to engage the clutch , and outputting the result of the detection in the form of a clutch operation signal. The transmission operating valves for the forward drive gear hydraulic clutch , the first speed gear hydraulic clutch , the second speed gear hydraulic clutch, the third speed gear hydraulic clutch and the fourth speed gear hydraulic clutch respectively include a similar clutch operation detector .

The bulldozer of this embodiment has a controller serving as the main controlling means. The controller has, a drive/speed gear identifying unit, a speed ratio operation unit (speed ratio computing means), a first control unit and a second control unit.

Input to the drive/speed gear identifying unit are clutch operation signals respectively issued from the clutch operation detectors. The drive/speed gear identifying unit determines, based on the clutch operation signals, which of the drive and speed gears is presently selected and outputs the result of the determination to the speed ratio operation unit as drive/speed gear data.

Input to the speed ratio operation unit are drive/speed gear data from the drive/speed gear identifying unit; an engine speed signal from an engine speed sensor for detecting the actual engine speed of the engine; a transmission input shaft speed signal from a transmission input shaft speed sensor and a transmission output shaft speed signal from a transmission output shaft speed sensor for detecting the actual revolution speed of the input shaft and output shaft of the transmission. In the speed ratio operation unit, the present reduction ratio of the transmission is calculated based on the drive/speed gear data from the drive/speed gear identifying unit, and the speed ratio of the torque converter is calculated and send the result of the calculation to the first control unit and to the second control unit as torque converter speed ratio data.

Calculation: Table

Planetary Differential Speed calculation						
aA +sS = c(A+S)						
			Ps1		Ps2	
A	No of teeth	Ring	98		98	
S	No of teeth	Sun	46		46	
P	No of teeth	Planet	26		26	
	No of teeth	Idler	26		26	
Engine speed		2000	rpm		2000	rpm
TM & Bevel reduction		4			4	
a	Ring speed	500	rpm		500	rpm
s	sun speed	100	rpm		-100	rpm
c	carrier speed	372.2222	rpm		308.3333	rpm

The hydrostatic steering system with HSS brake as shown in the FIG. 1 provides three different operations namely, a) parking b) straight travel c) steering d) pivot steering. For each operation hydrostatic steering system operates differently which has been explained in detail as follows:

a) Parking

During parking, the operating joystick in operator's cabin is in neutral position. Pressurized oil from

transmission pump driven by PTO is not passed through operating valve to the main brakes and HSS brake. Hence main brakes and HSS brake are engaged ensuring perfect parking of the vehicle.

b) straight travel

c)

During straight travel, the operating joystick in operator's cabin is in either forward or reverse position to move the dozer in that particular direction respectively. Since steering of dozer is not required hence no signal is sent to the steering switching valve, therefore Pressurized oil from the steering pump is not transmitted to the steering motor and hence there is no power transmission from steering motor to transfer box . At the same time Pressurized oil from transmission pump driven by PTO is passed through operating valve to the main brakes and HSS brake. As shown in the FIG. 2 the operating valve contains two switching valves operated by three solenoids S1, S2 and S3. The controller gives the signal to the operating valve and actuates the solenoid S1 of switching valve allowing pressurized oil to main brakes clutches to disengage the main brakes mounted on transverse shaft and HSS brake is in engaged position. Power from the transmission is transmitted to the ring gear of the planetary gear trains, through the transverse shaft . Since HSS brake is engaged sun gears of the planetary gear trains are held stationary. The designed speed ratio of the planetary gear trains is same and hence same amount of output torque in the same direction from the planetary gear trains is transmitted through the carriers to the final drive gear system, left and right sprockets and to crawler tracks making the vehicle to travel in straight either forward or reverse direction.

d) Steering

During steering, the operating joystick in operator's cabin, in addition to the forward or reverse position is moved either left or right to move and turn the dozer in that particular direction respectively. When the operating joystick is moved towards left, electrical signal is sent to the controller which in turn gives the signal to the operating valve and actuates solenoids S2 and S3 of switching valves allowing pressurized oil to main brakes clutches and HSS brake clutch to disengage the main brakes and HSS brake mounted on transverse shaft and transfer gear box shaft respectively. At same time another electric signal is sent to the controller which in turn operates the steering switching valve allowing pressurized oil from steering pump to drive the steering motor. The torque from the steering motor drives the power transmission mechanism through transfer box which in turn drives the sun gears of the planetary gear trains. As shown in FIG. 2 the sun gear of left side planetary train is getting drive through an idler from the transfer gear box. Whereas the sun gear of right side planetary gear train is getting drive directly from the transfer gear box . This arrangement drives the sun gears of left and right planetary gear units in equal amount of torque and in opposite direction relatively. Power from the transmission is transmitted to the ring gears of the left and right planetary gear trains through the transverse shaft . Since sun gears and ring gears of left and right planetary gear units, are driven with unequal amount of torque a torque barrier is created which gives the differential output to the left and right tracks through planetary carriers, final drive gear system and left and right sprockets. Therefore left side track will rotate at lower speed compared to the right side track which makes the dozer to steer towards the left side.

Similarly when the operating joystick is moved towards right, electrical signal is sent to the controller which in turn gives the signal to the operating valve and actuates solenoids S2 and S3 of switching valves allowing pressurized oil to main brakes clutches and HSS brake clutch to disengage the main brakes and HSS brake mounted on transverse shaft and transfer gear box shaft respectively. At same time another electric signal is sent to the controller which in turn operates the steering switching valve allowing pressurized oil from steering pump to drive the steering motor in opposite direction. The torque which is opposite direction from the steering motor drives the power transmission mechanism through transfer box which in turn drives the sun gears of the planetary gear trains Power from the transmission is transmitted to the ring gears of the left and right planetary gear trains through the transverse shaft. Since sun gears and ring gears of left and right planetary gear units are driven with unequal amount of torque a torque barrier is created which gives the differential output to the left and right tracks through planetary carriers, final drive gear system and left and right sprockets. Therefore right side track will rotate at lower speed compared to the left side track 1 which makes the dozer to steer towards the right side.

e) Pivot steering

During pivot steering, the operating joystick in operator's cabin is moved either left or right to turn the dozer about the center of gravity in that particular direction respectively. Transmission is kept in neutral position hence no power transfer is transmitted to the transverse shaft. Main brake pedal inside the operator's cabin (not shown) is pressed which gives the signal to the controller which in turn gives the signal to the operating valve and actuates solenoid S2 of the switching valve allowing pressurized oil only to the HSS brake clutch to disengage the HSS brake couple with transfer gear box and main brakes are engaged. When the operating joystick is moved towards left, electric signal is sent to the controller which in turn operates the steering switching valve allowing pressurized oil from steering pump to drive the steering motor. The torque from the steering motor drives the power transmission mechanism through transfer box which in turn drives the sun gears of the planetary gear trains in opposite direction due to idler on the left side planetary gear train. Since the main

brakes mounted on transverse shaft are applied hence ring gears are held stationary. An equal and opposite torque is transmitted to the sun gears of planetary gear trains through power transmission mechanism and transfer box from the steering motor giving an equal and opposite torque output through the planetary carriers to the left and right tracks through final drive system and left and right sprockets. Since both tracks rotate with equal and opposite speed the vehicle steers towards left about the center of gravity which is known as "Pivot steering on left side".

Similarly when the operating joystick is moved towards right, electric signal is sent to the controller which in turn operates the steering switching valve allowing pressurized oil from steering pump to drive the steering motor in opposite direction. The torque which is in opposite direction from the steering motor drives the power transmission mechanism through transfer box which in turn drives the sun gears of the planetary gear trains in opposite direction due to idler on the left side planetary gear train. Since the main brakes mounted on transverse shaft 8 are applied hence ring gears are held stationary. An equal and opposite torque is transmitted to the sun gears of planetary gear trains through power transmission mechanism and transfer box from the steering motor giving an equal and opposite torque output through the planetary carriers to the left and right tracks through final drive system and left and right sprockets. Since both tracks rotate with equal and opposite speed the vehicle steers towards right about the center of gravity which is known as "Pivot steering on right side".

Conclusion

Engine power (Speed & torque) is transmitted to Bevel pinion to Planetary Ring

Engine connected –Hydraulic system-to Sun (Speed & torque),

In nutshell two input to planetary & Single output

- Differential speed
- One side we assist to increase speed
- Other side we reduce the speed by *giving counter rotation as input*

We get the following advantages

- We can reduce variant by it suits different variants
- We can have control on differential speed
- Better cornering control-Small turning radius

Reference

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