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(54) **Limited slip differential gearing**

(57) A differential gear system of the type known as a limited slip differential, particularly but not exclusively for use in a motor vehicle, the differential gear system having a drive input (7), a pair of differential output elements (14, 15), each carrying respective gears (12, 13) transmitting torque between the differential output elements, the gears (12, 13) being arranged as a gear pump to pump liquid, which may be the lubricant of the differential gear system, the output of the gear pump including a restricted passageway (27) to provide a pressure differential between the gear pump input and output to hinder operation thereof and hence restrict the differential effect between the two output elements (14, 15).

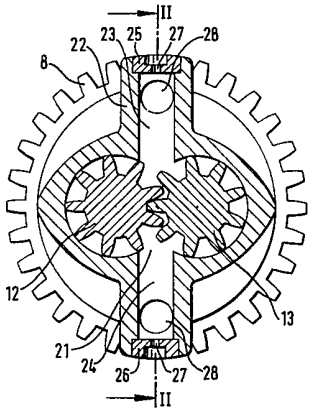
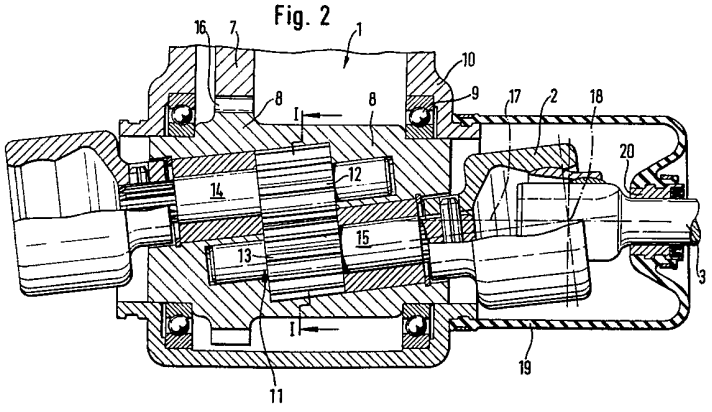


Fig. 3

Fig. 2



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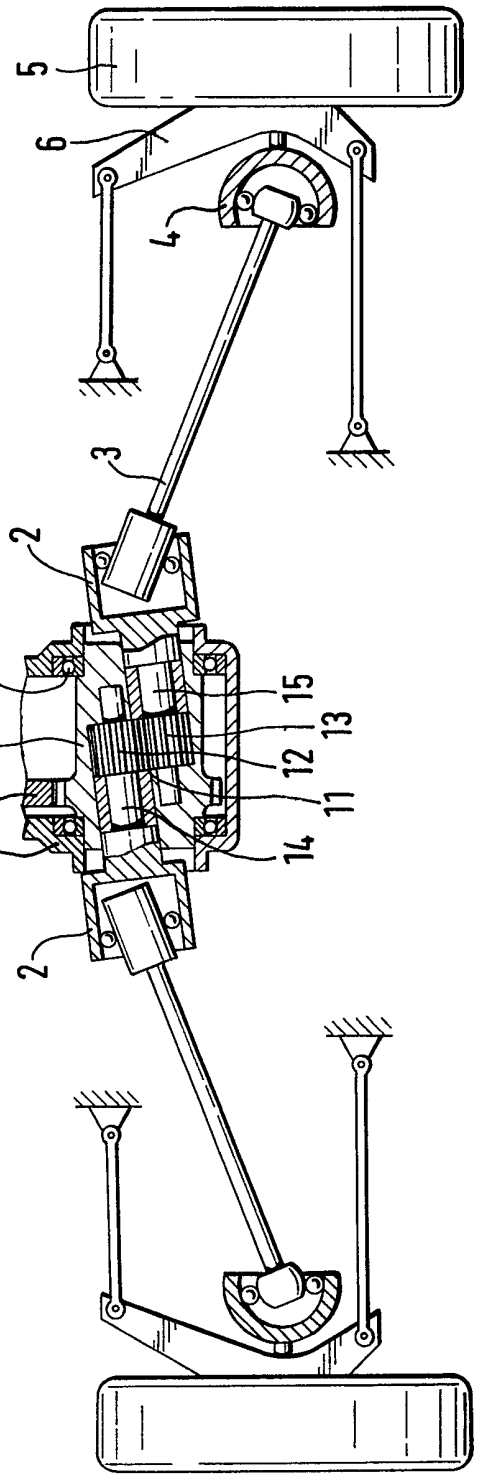

Fig. 1

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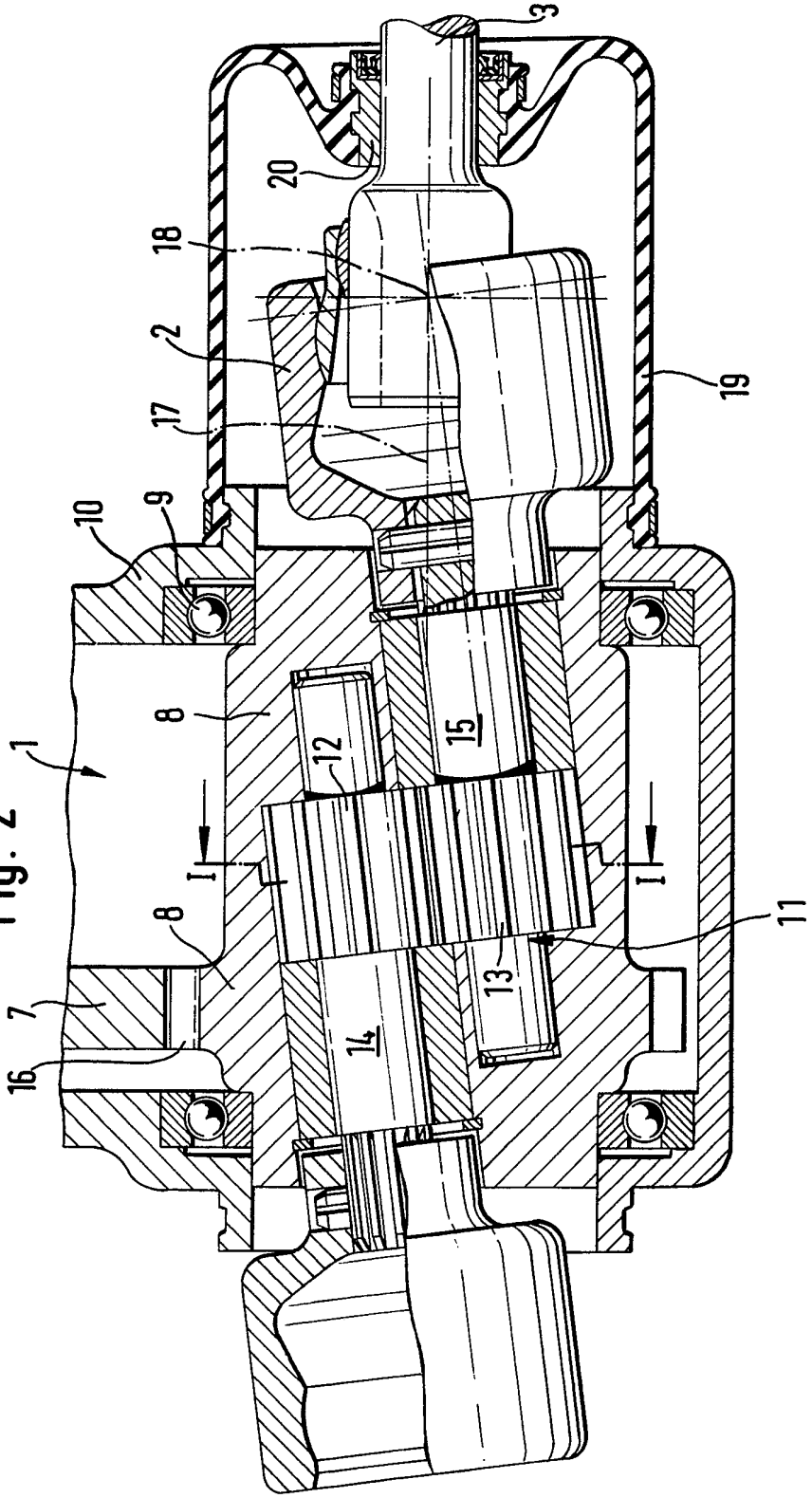

Fig. 2

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Fig. 5

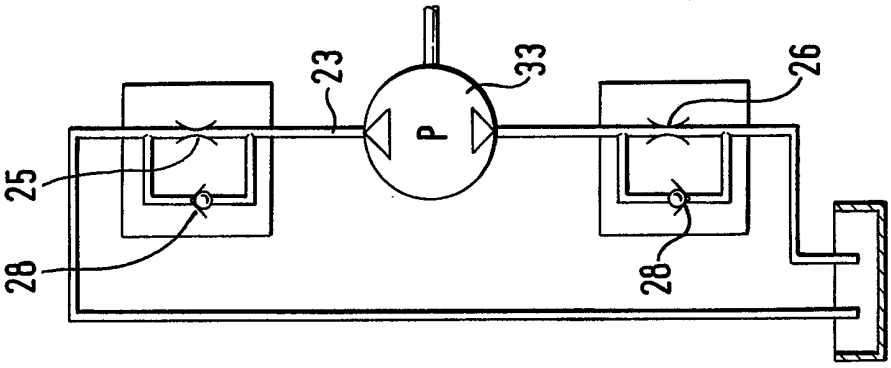


Fig. 4

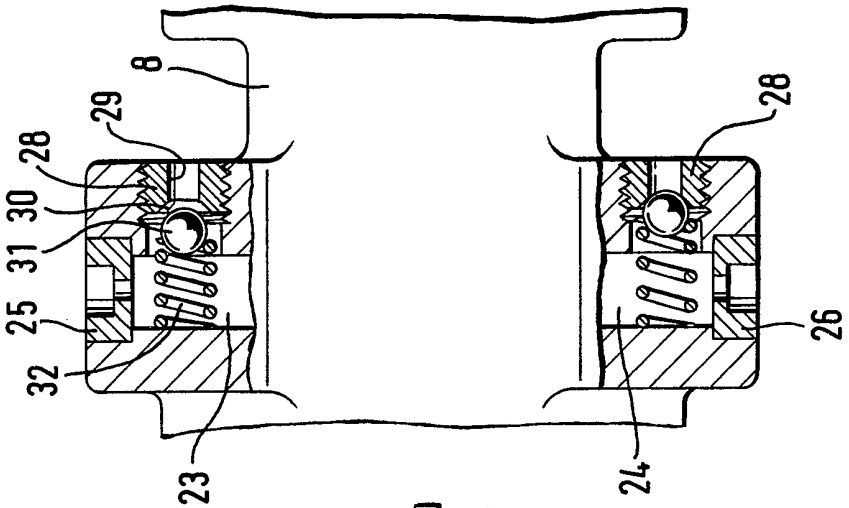
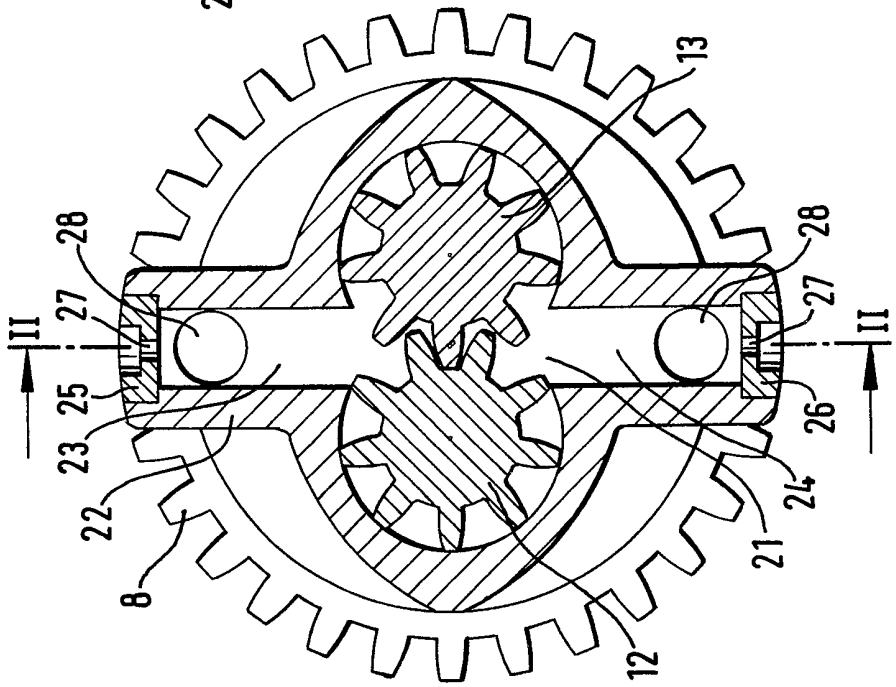


Fig. 3



SPECIFICATION

A differential gear system

The present invention relates to a differential gear system of the type commonly known as a 'limited slip differential' particularly, but not exclusively, for use in a motor vehicle, and which comprises a drive input and a pair of differential output elements.

British Patent Specification No. 1,187,798 describes a differential gear system in which the differential effect between the output shafts is effected by the insertion in the differential unit of a silicon polymer. This has the disadvantage that it entails the use of special material i.e. the silicon polymer.

It is an object of the present invention to provide a new or improved differential gear system in which the differential effect between the pair of differential output elements is limited.

According to the present invention we provide a differential gear system having a drive input and a pair of differential output elements wherein each of said output elements has a respective gear rotatable with the element, means is provided for supplying liquid to said gears, the gears being arranged to co-operate with each other to pump such liquid, and means is provided for restricting flow of liquid from the gears.

Preferably, the gear of each of the differential output elements, comprises torque transmitting means for transmitting torque between the two output elements.

According to another aspect of the invention we provide a differential gear system comprising a carrier part which carries a pair of differential output elements in the form of first and second rotatable elements, each rotatable element having a gear for transmitting torque between the said elements, the carrier part being rotatable about an axis to move at least one of the rotatable elements about an orbital path, the centre of which is spaced from the axis about which said rotatable element is itself rotatable, means for supplying liquid to said gears, said gears being arranged to co-operate with each other to pump said liquid and means for restricting flow of liquid from the gears.

Preferably, the liquid is a lubricant of a type that is normally provided for lubrication of a differential gear system.

In operation of the differential gear system, a pressure differential is present between the input and the output of the pump formed by the gears caused by the means for restricting flow from the gears which tends to hinder or restrain operation of the pump. Thus relative rotation between the differential elements is hindered and so they are constrained to rotate at speeds which do not vary from each other by a great extent.

In the case where the differential gear system is used on a vehicle, each of the two rotatable elements driving a respective wheel on a respective side of the vehicle, if there was a tendency for one wheel to rotate faster than the other, for example, in slippery conditions when one wheel may spin, then there will be a tendency for the differential gear system to 'lock-up' and thus maintain some drive to the wheel which is not spinning.

If a vehicle to which the differential gear system is fitted travels in a straight line, the differential output elements are not required to provide any differential in speed output and hence the pump provided by the gears will not operate. However, when the vehicle travels around a bend there will be a tendency for relative rotation to occur between the differential output elements which will commence operation of the gear pump which operation is met with resistance in view of the restricted output of the pump which will constrain relative rotation between the gears of the pump and provide limited slip to the differential.

In accordance with another aspect of the invention, the gears associated with each of the differential output elements are arranged to operate as a gear pump in either direction of rotation and means for restricting the output of the pump is provided in either direction of rotation of the gears.

Such an arrangement has the advantage that limited slip is effective in both directions of rotation which, when the system is fitted to a motor vehicle, is important since the direction of relative rotation between the differential output elements will depend on which wheel has a tendency to rotate faster than the other.

If restriction of pump output is provided in both relative directions of rotation, then the input to the pump in both directions of rotation should preferably be a good flow communication with the supply of liquid, for example the lubricant of the differential system.

According to another feature of the invention, the input to the gears in either direction of rotation is provided via one-way valves which enables good flow communication of liquid to the pump but which prevents flow of liquid from the pump. Such an arrangement enabling the pressure of the liquid at the input to the pump to be low compared with the pressure of the liquid at the output of the pump which provides the limited slip for the differential gear system.

The invention will now be described by way of example only, with reference to the accompanying drawings wherein:-

Figure 1 is a part-sectional view of a differential gear system arranged in a vehicle;

Figure 2 is a detailed part-sectional view of the differential gear system shown in Figure 1;

Figure 3 is a cross-sectional view along the line I-I shown in Figure 2;

Figure 4 is a sectional view taken on the line II-II shown in Figure 3;

Figure 5 is a schematic flow diagram showing the manner of operation of the gear pump of the differential gear system.

The arrangement shown in Figure 1 comprises a differential gear system 1 connected to constant velocity ratio universal joints 2 which drive car wheels 5 through drive shafts 3 and further universal joints 4. In this Figure, the wheel suspension 6 is schematically indicated.

The differential gear system 1 is connected to the motor vehicles engine by a spur-type driving gear 7 through a manual or automatic gearbox (not shown). From the driving gear 7 torque is transmitted to a carrier part in the form of a main gear 8. In the main gear 8 is arranged a bearing 9 provided within a housing 10. In a cavity 11, the main gear 8 are arranged first and second rotatable elements in the form of shafts 14 and 15 which are interconnected by spur gears 12 and 13 which intermesh with each other. The shafts 14 and 15 are provided with joints 2 at their outer ends.

Referring now to Figure 2, a differential gear system 1 is shown on an enlarged scale. The main gear 8 is mounted in bearings 9 provided in the housing 10. The main gear 8 is a spur gear having teeth 16 which mesh with the teeth of the driving gear 7. Differential gears 12 and 13, and their driven shafts 14 and 15, are so arranged in bores in the main gear 8 that their central axes extend at an angle relative to the axis of rotation 17 of the main gear 8. The joints 2 on each of the shafts 14 and 15 are arranged in such a manner that the joint centres 18 lie at the point of intersection of the axis of rotation 17 of the main gear 8 and the axis of rotation of the respective driven shaft 14 or 15.

As a result of this arrangement, joint 2 carries out a peripheral like motion so that the drive shaft 3 does not have to perform any additional kinematic based angular changes.

Suitable joints 2 are those in which the inner and outer joint members are able to move relative to each other, the joint centres remaining stationary relative to the drive shaft in the differential gear assembly, which in this case will be either the shaft 14 or 15.

The joint 2 is sealed from ingress or dirt etc. by a boot 19 which is fastened at one end to the differential assembly 10 and therefore does not rotate with the drive shaft 3 that is provided with the bearing 20, relative to which the drive shaft 3 is able to rotate.

The interior 11 of the main gear 8 has a chamber which is illustrated in detail in Figure 3

Figure 3 shows in detail the differential gears 12 and 13 which are arranged in a chamber 21. The wall 22 of the chamber 21 is formed by the main gear 8 itself. The chamber 21 in which the differential gears 12 and 13 are located, is provided with two ducts 23 and 24, each duct communicating with a constricted passageway 27 that is of a cross-section considerably smaller than the cross-section of either duct 23 or 24.

In order for the differential gears 12 and 13 to be lubricated during use of the differential gear assembly, lubricant is present in the chamber 21 and, the differential gears 12 and 13 will act as a gear pump.

If for example the differential gear 13 is rotating in a clockwise direction, lubricant will be pumped from the duct 24 to the duct 23 and out through the constricted passageway 27.

In order to provide a pressure differential between the input side and the output side of the gear pump formed by the differential gears 12 and 13, non-return valves 28 are provided in each of the ducts 23 and 24, the non-return valves 28 being operative to allow passage of lubricant from a supply through the non-return valve 28 into either of the ducts 23 or 24 but preventing flow of lubricant from either of the ducts 23 or 24 out of the non-return valve 28 located in that duct.

Figure 4 is a section taken along the line II-II in Figure 3 and shows the non-return valves in greater detail. Each non-return valve 28 is provided in a wall 22 of the chamber and is arranged perpendicularly relative to each of the ducts 23 and 24. The non-return valve 28 has a bore 29 including a tapered section 30 which provides a valve seat with which a valve member in the form of a ball 31 co-operates. A spring 32 acts on the ball 31 to maintain the non-return valve 28 in a normally closed position.

The manner of operation of lubricant flow will now be described in detail with additional reference to Figure 5.

When lubricant is pumped by the gear pumped formed by the differential gears 12 and 13 to the duct 23 and out of the constrictor 25, the non-return valve 28 located in the duct 23 will close, the non-return valve 28 and the duct 24 however will open, since the pressure within the duct 24, being on the input side of the pump, will be low and so lubricant will flow through the non-return valve 28 and the duct 24 and the constrictor 25 in the duct 24, through the duct 24 to the gear pump provided by the differential gears 12 and 13, into the duct 23.

The non-return valve 28 in the duct 23 is closed both by the spring 32 and the relatively high pressure present in the duct 23, thus all the lubricant pumped into the duct 23 will have to pass through the constricted passageway 27 of the constrictor 25, lubricant flowing through the through bore 27 in the throttle 25 then passes through a lubricant reservoir.

In view of the pressure differential created between the input and output sides of the pump formed by the differential gears 12 and 13, there will be considerable resistance to operation of the pump and hence resistance to relative rotation of the differential gears 12 and 13 thereby impeding the differential action of the gear assembly, thus providing a limiting slip feature to the differential gear assembly.

Since the arrangement of non-return valves 28 and constrictors 25 and 26 in each of the ducts 23 and 24 is identical, the limiting slip feature of the differential gear assembly will operate in an identical manner irrespective of which of the shafts 14 or 15 has a tendency to rotate faster than the other.

Whilst it is very convenient that the gear pump is provided by the differential gears 12 and 13 themselves, it is envisaged that each of the shafts 14 and 15 could each be provided with a separate gear, forming a gear pump connected to input and output ducts, together with the associated non-return valves and constrictors as aforedescribed.

CLAIMS

1. A differential gear system having a drive input and a pair of differential output elements wherein

each of said output elements has a respective gear rotatable with the element, means is provided for supplying liquid to said gears, the gears being arranged to co-operate with each other to pump such liquid, and means is provided for restricting flow of liquid from the gears.

2. A differential gear system as claimed in Claim 1 wherein said gears comprise torque transmitting means for transmitting torque between the two output elements.

3. A differential gear system comprising a carrier part which carries a pair of differential output elements in the form of first and second rotatable elements, each rotatable element having a gear for transmitting torque between said elements, the carrier part being rotatable about an axis to move at least one of the rotatable elements about an orbital path, the centre of which is spaced from the axis about which said rotatable element is itself rotatable, means for supplying liquid to said gears, said gears being arranged to co-operate with each other to pump said liquid, and means for restricting flow of liquid from the gears.

4. A differential gear system as claimed in any one of the preceding claims wherein said liquid is a lubricant of the type normally provided for lubrication of a differential gear system

5. A differential gear system as claimed in any one of the preceding claims wherein means are provided for restricting flow of liquid from the gears in both directions of relative rotation of the gears.

6. A differential gear system as claimed in any one of the preceding claims wherein the means for restricting flow of liquid from the gears comprises a passageway the cross-section of which is restricted relative to the means for supplying liquid to the gears.

7. A differential gear system as claimed in any one of the preceding claims wherein the means for supplying liquid to said gears comprises a flow path including a non-return valve which permits of supply of liquid to said gears but prevents flow of liquid from the gears therethrough.

8. A differential gear system substantially as hereinbefore described.

9. A differential gear system substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

10. A differential gear system including any novel feature or combination of features as described in the accompanying specification and/or illustrated in the accompanying drawings.

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