PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : F16H 1/45, 1/44 — **A1**

(11) International Publication Number: **WO 92/19888**

(43) International Publication Date: 12 November 1992 (12.11.92)

(21) International Application Number: PCT/AU92/00208

(22) International Filing Date: 7 May 1992 (07.05.92)

(30) Priority data:
PK 6041 8 May 1991 (08.05.91) AU

(71) Applicant *(for all designated States except US):* BTR ENGINEERING (AUSTRALIA) LIMITED [AU/AU]; A.C.N. 000 019 536, 77 Seville Street, Fairfield, NSW 2165 (AU).

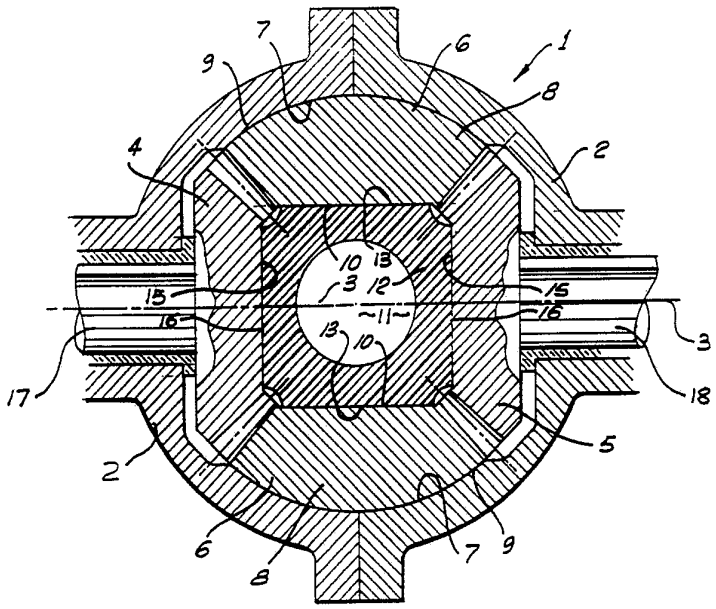
(72) Inventors; and
(75) Inventors/Applicants *(for US only) :* JOACHIM, Clifford, Anthony [AU/AU]; 4 Meehan Place, Baulkham Hills, NSW 2153 (AU). SPRYZYNSKY,Stanislaw [AU/AU]; 6, Enfield Colse, Cabramatta, NSW 2166 (AU).

(74) Agent: SHELSTON WATERS; 55 Clarence Street, Sydney, NSW 2000 (AU).

(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CI (OAPI patent), CM (OAPI patent), CS, DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GN (OAPI patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC (European patent), MG, ML (OAPI patent), MN, MR (OAPI patent), MW, NL, NL (European patent), NO, PL, RO, RU, SD, SE, SE (European patent), SN (OAPI patent), TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.
With amended claims.

(54) Title: LIMITED SLIP DIFFERENTIAL INCORPORATING BEVEL PINIONS



(57) Abstract

A differential mechanism (1) includes a carrier housing (2) adapted to be rotatably driven about a longitudinal axis (3). A pair of independent coaxial parallel side gears (4, 5) are supported for rotation about the axis (3). The carrier housing (2) includes two inner peripherally spaced part-spherical recessed pinion cavities (6) defining respective inwardly directed housing thrust surfaces (7). Two floating bevel pinions (8), each in a meshing engagement with the side gears (4, 5), have respective pinion outer and inner thrust surfaces (9, 10). The outer thrust surfaces (9) are adapted for frictional rotation within the recess cavities (6). A cubic thrust block (12) is supported generally within the carrier housing (2) by a cross shaft (11) and defines four outwardly directed thrust directed thrust surfaces (13, 16).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**FI**	Finland	**ML**	Mali
AU	Australia	**FR**	France	**MN**	Mongolia
BB	Barbados	**GA**	Gabon	**MR**	Mauritania
BE	Belgium	**GB**	United Kingdom	**MW**	Malawi
BF	Burkina Faso	**GN**	Guinea	**NL**	Netherlands
BG	Bulgaria	**GR**	Greece	**NO**	Norway
BJ	Benin	**HU**	Hungary	**PL**	Poland
BR	Brazil	**IE**	Ireland	**RO**	Romania
CA	Canada	**IT**	Italy	**RU**	Russian Federation
CF	Central African Republic	**JP**	Japan	**SD**	Sudan
CG	Congo	**KP**	Democratic People's Republic of Korea	**SE**	Sweden
CH	Switzerland			**SN**	Senegal
CI	Côte d'Ivoire	**KR**	Republic of Korea	**SU**	Soviet Union
CM	Cameroon	**LI**	Liechtenstein	**TD**	Chad
CS	Czechoslovakia	**LK**	Sri Lanka	**TG**	Togo
DE	Germany	**LU**	Luxembourg	**US**	United States of America
DK	Denmark	**MC**	Monaco		
ES	Spain	**MG**	Madagascar		

Title: "LIMITED SLIP DIFFERENTIAL INCORPORATING BEVEL PINIONS"

TECHNICAL FIELD

The present invention relates to differential mechanisms and in particular to a torque proportioning or "limited slip" differential having inherent frictional torque bias.

The invention has been developed primarily for use in automotive applications, and will be described hereinafter with reference to this application. However, it will be appreciated that the invention is not limited to this particular field of use.

BACKGROUND ART

When a vehicle is cornering, the outside wheel rotates with higher angular velocity than the inside wheel. The conventional differential mechanism accommodates this difference in angular velocity while, in the case of a differential having 100% efficiency, transmitting equal torque to both driving wheels at all

times.

However, if one driving wheel loses traction, for example on a slippery surface, this wheel will spin freely and support little or no torque and therefore the conventional differential mechanism will transmit little or no driving torque to the wheel with traction and the vehicle will remain motionless.

One solution to this problem is to provide a torque proportioning or "limited slip" differential whereby torque is biased or transferred to the wheel with the most traction to control loss of drive. The resultant ratio of torques is known as torque bias and is defined in the following equation:

$$\text{Torque bias} = \frac{\text{torque on high torque side}}{\text{torque on low torque side}}$$

Torque proportioning differentials are known. However, many of these known differentials do not provide sufficient range of torque bias for all design applications. These limitations are particularly significant in heavy vehicles. Other known torque proportioning differentials have employed preloading springs and frictional clutches as a means of increasing the torque bias. However, these designs have limited operational life due to excessive clutch wear which occurs whenever there is differential motion as a result of the inherent frictional preload which is applied to the

clutches. Furthermore, the inherent friction preload in the clutches resists relative wheel rotation during normal turning manoeuvres thereby adversely affecting vehicle handling under normal driving conditions and giving rise to a further problem of increased tyre wear. These problems are particularly significant in front wheel drive vehicular applications.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to provide a relatively simple torque proportioning differential which overcomes or substantially ameliorates at least some of these disadvantages of the prior art.

According to one aspect of the invention there is provided a torque proportioning differential mechanism having inherent frictional torque bias, said differential mechanism including a carrier housing adapted to be rotatably driven about a longitudinal axis and having a plurality of inner peripherally spaced pinion locating formations defining respective inwardly directed housing thrust surfaces, a pair of independent coaxial bevel side gears supported for rotation about an axis fixed with respect to said carrier housing, a plurality of floating bevel pinions in meshing engagement with said side gears and having complementary pinion outer thrust surfaces respectively adapted for frictional rotation with respect to said locating formations and disposed such that when unequal unidirectional torques apply at said side gears, a

radial separating force tends to displace said pinions with respect to said pinion locating formations thereby creating frictional drag which enables unequal torque to be supported at each side gear.

Preferably the pinion locating formations are recessed cavities.

In a preferred embodiment, the differential mechanism includes a centrally spaced thrust block supported by the housing and defining outwardly directed substantially flat thrust block surfaces.

The floating bevel pinions advantageously define substantially flat pinion inner thrust surfaces respectively adapted for frictional rotation with respect to said thrust block surfaces such that when unequal unidirectional torques apply at the side gears, relative rotation of the pinions with respect to the housing results in bearing friction between the thrust block surfaces and the pinion inner thrust surfaces.

In one embodiment, the inwardly directed housing thrust surfaces and the complementary pinion outer thrust surfaces are spherical.

In alternative embodiment, the differential mechanism includes a centrally disposed spider having recessed conical sockets to rotatingly receive and locate complementary conical pinion protrusions. In this embodiment, it is preferred that three floating bevel pinions each having mutually opposed outwardly depending

conical protrusions defining inner and outer pinion thrust surfaces are uniformly circumferentially spaced around the side gears.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a partly sectioned front elevation of a two pinion torque proportioning differential mechanism having a centrally spaced thrust block according to a first embodiment of the invention;

Figure 2 is a partly sectioned side elevation of a three pinion torque proportioning differential mechanism having a centrally disposed spider rigidly mounted to the housing according to a second embodiment of the invention;

Figure 3 is a partly sectioned side elevation of a three pinion torque proportioning differential similar to that shown in figure 2 but wherein the central spider is free floating, according to a third embodiment of the invention;

Figure 4 is a partly sectioned side elevation of a three pinion torque proportioning differential mechanism similar to that shown in figure 2 and having spherical thrust surfaces; and

Figure 5 is a partly sectioned side elevation of a three pinion torque proportioning differential mechanism similar to that shown in figure 4, but wherein the central

spider is free floating.

MODES FOR CARRYING OUT THE INVENTION

Referring to figure 1 of the drawings, a differential mechanism 1 includes a carrier housing 2 adapted to be rotatably driven about a longitudinal axis 3. A pair of independent coaxial parallel side gears 4 and 5 are supported for rotation about the axis 3. The carrier housing 2 includes two inner peripherally spaced part-spherical recessed pinion cavities 6 defining respective inwardly directed housing thrust surfaces 7.

Two floating bevel pinions 8, each in meshing engagement with the side gears 4 and 5, have respective pinion outer and inner thrust surfaces 9 and 10. The outer thrust surfaces 9 are adapted for frictional rotation within the recessed cavities 6.

A cubic thrust block 12 is supported centrally within the carrier housing 2 by a cross shaft 11 and defines four outwardly directed thrust surfaces.

The inner thrust surfaces 10 of the two pinions 8 are adapted for frictional rotation relative to two respective thrust block surfaces 13. The thrust block surfaces 16 locate the side gears in position with respect to the housing.

Turning now to figures 2 and 3 showing alternative embodiments of the invention wherein corresponding features are denoted by corresponding reference numerals, the differential mechanism 1 includes a centrally spaced

spider 20. The spider 20 may be fixed to the carrier housing by radial arms 21 (as shown in figure 2) or free floating within the housing as shown in figure 3 and located and maintained in position by the thrust forces on the pinions within their respective cavities.

Three floating bevel pinions 22 each have mutually opposed conical protrusions 23 and 24 defining inner 25 and outer 26 pinion thrust surfaces respectively.

The housing 2 includes three uniformly circumferentially spaced conical sockets 27 to receive complementary conical pinion protrusions 24, thereby locating the pinions with respect to the housing. The conical sockets 27 define respective inwardly directed housing thrust surfaces 28 to engage respective complementary pinion outer thrust surfaces 26 with frictional sliding.

Similarly, the spider 20 includes three uniformly spaced radially directed outwardly diverging conical sockets 29 to receive complementary conical pinion protrusions 23. The conical sockets 29 define respective outwardly directed spider thrust surfaces 30 to engage respective complementary pinion inner thrust surfaces 25 with frictional sliding.

Referring to figures 4 and 5, where corresponding features are denoted by corresponding reference numerals, three floating bevel pinions 31 each have mutually opposed spherical protrusions 32 and 33 defining inner 34 and

outer 35 pinion thrust surfaces respectively.

The housing 2 includes three uniformly circumferentially spaced spherical sockets 36 to receive complementary spherical pinion protrusions 33, thereby locating the pinions with respect to the housing. The spherical sockets 36 define respective inwardly directed housing thrust surfaces 37 to engage respective complementary pinion outer thrust surfaces 35 with frictional sliding.

Similarly, the spider 20 includes three uniformly spaced radially directed outwardly diverging spherical sockets 38 to receive complementary spherical pinion protrusions 32. The spherical sockets 36 define respective outwardly directed spider thrust surfaces 39 to engage respective complementary pinion inner thrust surfaces 34 with frictional sliding.

These embodiments allow relative motion between the side gears to take place either during a normal turning manoeuvre or under conditions of wheel slip when one wheel loses traction and spins. The pinions are disposed such that relative rotation of the side gears causes a corresponding rotation of the pinions.

During turning manoeuvres torques in opposite directions apply at each side gear, whereas under conditions of wheel slip when one wheel loses traction, unidirectional torques (torques of the same direction) apply at each side gear.

When opposite torques act on the side gears during the execution of a turn, the floating pinions rotate freely without a build up of opposing reaction forces. The forces which produce rotation of the pinions under these conditions are small in magnitude, and the reaction forces at the points of contact are proportionately small giving rise to little or no frictional drag so the pinions rotate freely within their respective cavities.

Under conditions of wheel slip, radially directed forces urge the pinions into frictional engagement with their respective pinion cavities. The resultant bearing friction, arising from the relatively high internal reaction forces, creates an "inefficiency" in the form of high frictional drag which enables unequal unidirectional torques to be supported at the respective side gears.

It will be appreciated that this differential mechanism permits relative motion of the pinions either with low resistance for turning manoeuvres, or with high resistance under conditions of wheel slip. This is a distinct advantage of the present invention over preloaded clutch type torque proportioning differentials of the prior art, which resist relative gear motion under all operating conditions, thereby adversely affecting vehicle handling under normal driving conditions, reducing the service life of the differential and causing unnecessary tyre wear. Furthermore, the torque bias actually achieved by these clutch type and other known differentials has

sometimes proven inadequate.

It will be apparent that the central spider of the embodiment shown in figures 2 and 3 provides a more positive location for the pinions than the embodiment of figure 1, thereby resulting in a mechanism with less differential backlash.

Furthermore, the configuration shown in figure 3 having a free floating spider will have a greater degree of differential backlash than the embodiment of figure 2, wherein the spider is rigidly supported by the housing.

The configuration of figure 3 is a lower cost option that may be used effectively in applications less sensitive to differential backlash.

Turning now to describe the operation of the differential in an automotive application, the carrier housing 2 is driven about the axis 3 by means of an input drive shaft (not shown). The input drive axis is subsequently diverted through 90° by a bevel pinion meshingly engaging a complementary bevel crown wheel fixed with respect to the carrier. The side gears 4 and 5 are integral with or fixed with respect to a pair of coaxial mutually opposed, outwardly depending half shafts 17 and 18 which in turn are connected to the driving wheels of the vehicle.

Under normal driving conditions both wheels (and hence both side gears) rotate with approximately equal angular velocity and support approximately equal torque.

When the vehicle makes a turn, the torques on each side gear apply in opposite directions and under these conditions the pinions rotate freely as in a conventional differential gear mechanism.

However, if one wheel loses traction, unequal torques (in the same direction) apply at each side gear giving rise to high internal reaction forces which are supported by the differential gear train, as radially directed separating force components tend to displace the pinions radially with respect to the pinion cavities. The pinions tend to become wedged into their respective cavities thereby creating frictional drag to provide a locking action which impedes differential rotation of the side gears and enables unequal unidirectional torques to be transmitted to the driving wheels.

It will be appreciated that any number of pinions may be uniformly circumferentially spaced around the side gears 4 and 5 to provide improved dynamic balance and more uniform transmission of gear tooth load, in which case the thrust block or spider would have a complementary configuration. These alternative configurations also provide greater flexibility for designing torque proportioning differentials with a wide range of torque bias ratios for different applications.

Furthermore, it will be appreciated that the thrust surface geometries of the pinions need not be spherical, conical or flat, but could be in the form of any other

suitable geometrical shapes such as cylinders, or a series of concentric grooves and ridges to maximise surface contact.

The torque bias of the differential mechanism of the present invention is a function of:

1. The type of bevel gears used (e.g. straight or spiral).
2. The pressure angle of the gears which affects the radial separating force therebetween.
3. The pitch diameter of the pinions.
4. The geometry of the pinion and housing thrust surfaces.
5. The coefficient of friction between the pinions and the housing, which varies with surface finish of the thrust surfaces and with the nature of the lubricant used.
6. The number of pinions used.
7. The configuration of the central thrust block or spider.

The configurations of pinions shown in the drawings achieve a torque bias ratio of the order of 6.0 which is particularly suitable for use with road vehicles.

This invention provides an improved, relatively simple torque proportioning differential mechanism which can provide a wide range of torque bias ratios for a wide range of design applications without the need for springs or clutches. Furthermore, the differential of the present

invention does not resist differential rotation of the side gears during normal turning manoeuvres, and so provides increased differential service life, and improved handling and tyre wear in vehicular applications.

Although the invention has been described with reference to specific examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms.

CLAIMS:-

1. A torque proportioning differential mechanism having inherent frictional torque bias, said differential mechanism including a carrier housing adapted to be rotatably driven about a longitudinal axis and having a plurality of inner peripherally spaced pinion locating formations defining respective inwardly directed housing thrust surfaces, a pair of independent coaxial bevels side gears supported for rotation about an axis fixed with respect to said carrier housing, a plurality of floating bevel pinions in meshing engagement with said side gears and having complimentary pinion outer thrust surface respectively adapted for frictional rotation with respect to said locating formations and disposed such that when unequal unidirectional torques apply at said side gears, a radially separating force tends to displace said pinions with respect to said pinion locating formations thereby creating frictional drag which enables unequal torque to be supported at each side gear.

2. A differential mechanism according to claim 1 wherein said pinion locating formations are recessed cavities.

3. A differential mechanism according to claim 1 including a centrally spaced thrust block supported by said housing and defining outwardly directed substantially flat thrust block surfaces.

4. A differential mechanism according to claim 1

wherein said floating bevel pinions define substantially flat pinion inner thrust surfaces respectively adapted for frictional rotation with respect to said thrust block surfaces such that when unequal unidirectional torques apply at said side gears, relative rotation of said pinions with respect to said housing results in bearing friction between said thrust block surfaces and said pinion inner thrust surfaces.

5. A differential mechanism according to claim 1 wherein said inwardly directed housing thrust surfaces and said complimentary pinion outer thrust surfaces are spherical.

6. A differential mechanism according to claim 1 including a centrally disposed spider having recessed sockets to rotatingly receive and locate complimentary pinion protrusions.

7. A differential mechanism according to claim 6 wherein said recessed sockets are conical.

8. A differential mechanism according to claim 6 wherein said recessed sockets are spherical.

9. A differential mechanism according to claim 6 including three floating bevel pinions each having mutually opposed outwardly depending protrusions defining inner and outer pinion thrust surfaces uniformly circumferentially spaced around said side gears.

AMENDED CLAIMS

[received by the International Bureau on 13 October 1992 (13.10.92);
original claim 1 amended;
remaining claims unchanged (1 page)]

1. [AMENDED] A torque proportioning differential mechanism having inherent frictional torque bias, said differential including a carrier adapted to be rotatably driven about a first axis and having a plurality of inner peripherally spaced pinion locating formations defining respective inwardly directed thrust surfaces, a pair of substantially coaxial spaced apart bevel side gears supported for rotation about a common axis fixed with respect to said carrier, a plurality of peripherally spaced floating shaftless bevel pinions each in meshing engagement with both said side gears and having an outer thrust surface in nesting engagement with a respective one of said locating formations, said pinions being rotatably supported by said locating formations such that when unequal torques apply at said side gears a separating force tends to urge the pinions outwardly into engagement with the respective locating formations so as to create frictional force components resisting rotation of the pinions relative to the carrier thereby providing torque bias between said side gears.

2. A differential mechanism according to claim 1 wherein said pinion locating formations are recessed cavities.

3. A differential mechanism according to claim 1 including a centrally spaced thrust block supported by said housing and defining outwardly directed substantially flat thrust block surfaces.

4. A differential mechanism according to claim 1

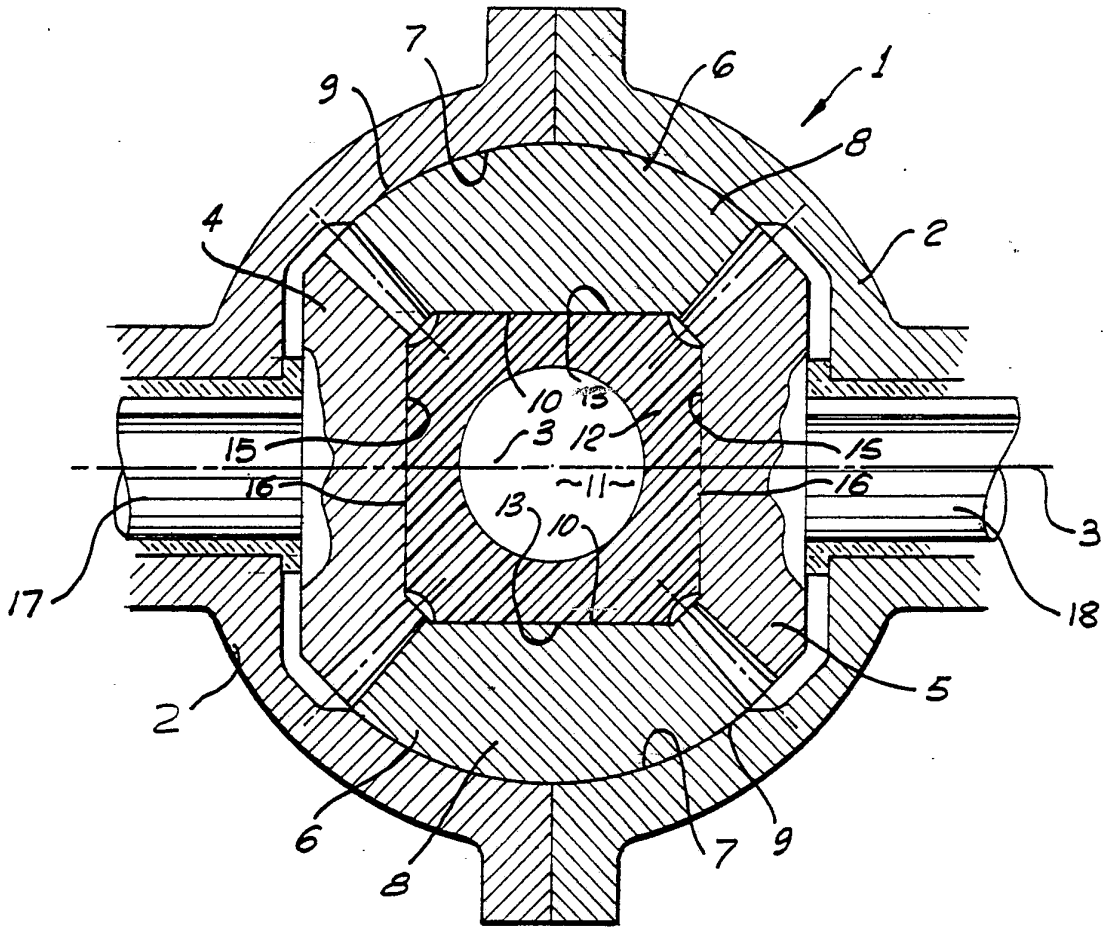


FIG. 1

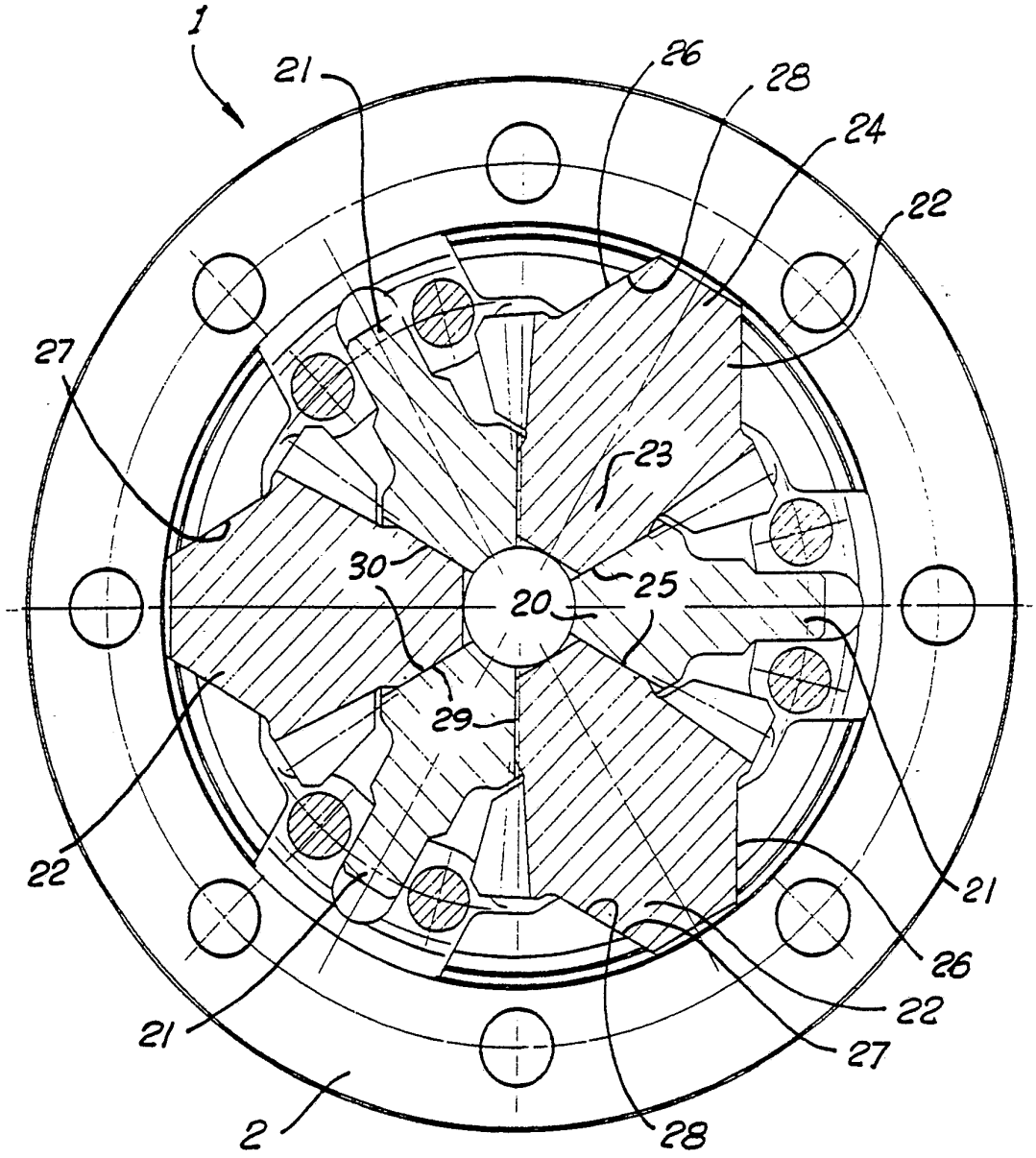


FIG. 2

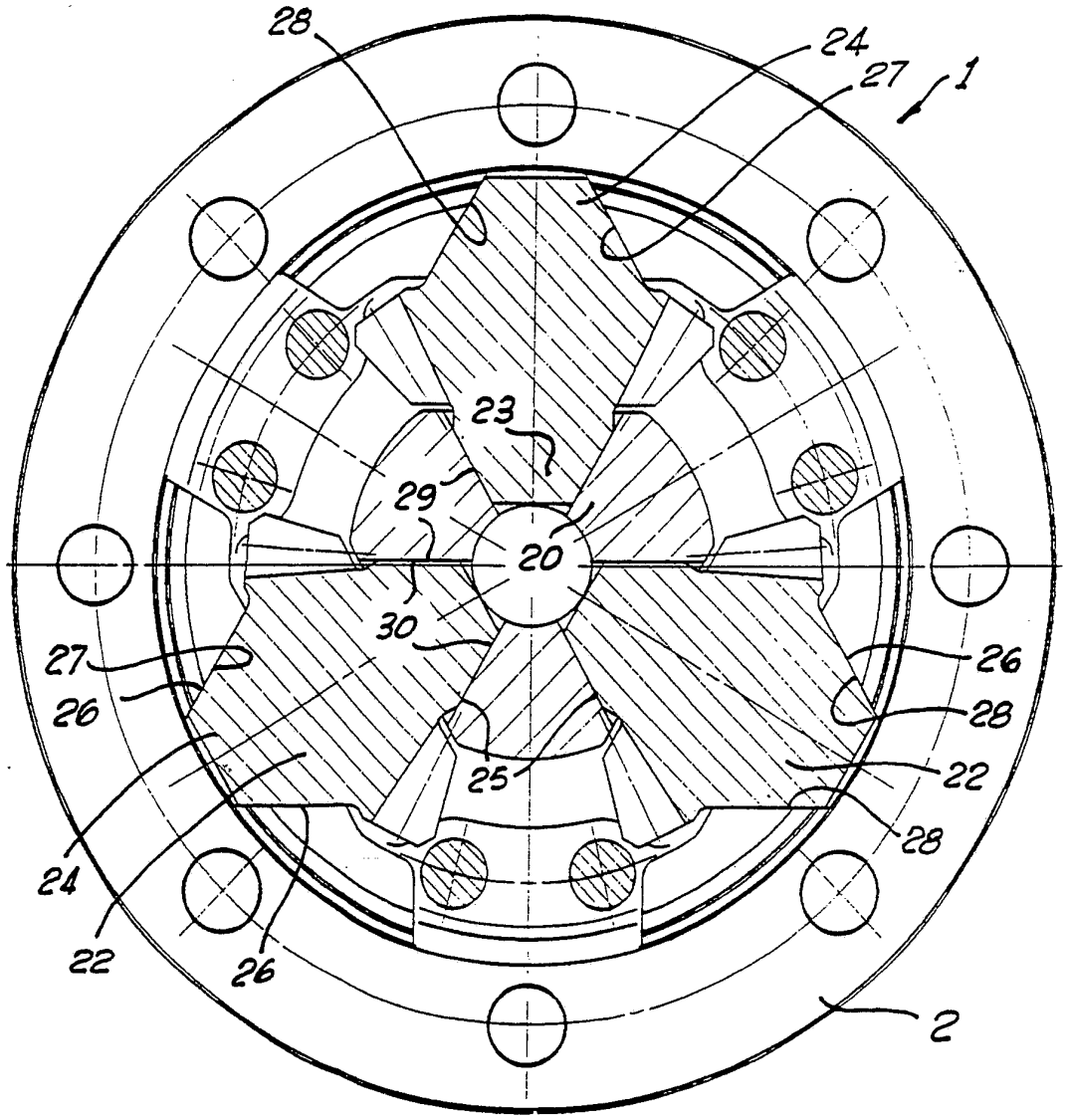


FIG. 3

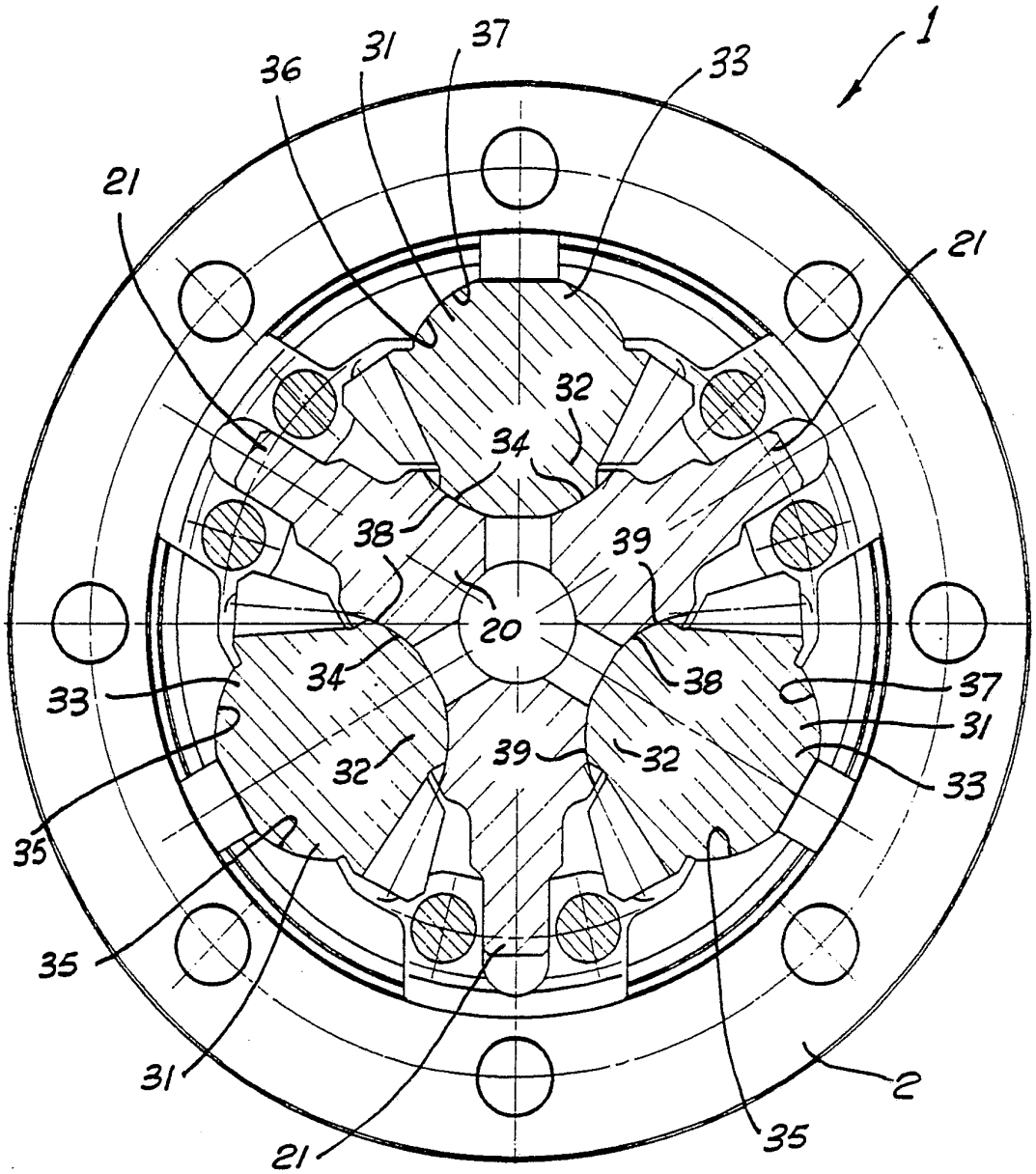

1
2
20
21
21
21
31
31
31
32
32
32
33
33
33
34
34
35
35
35
36
37
37
38
38
39
39

FIG. 4

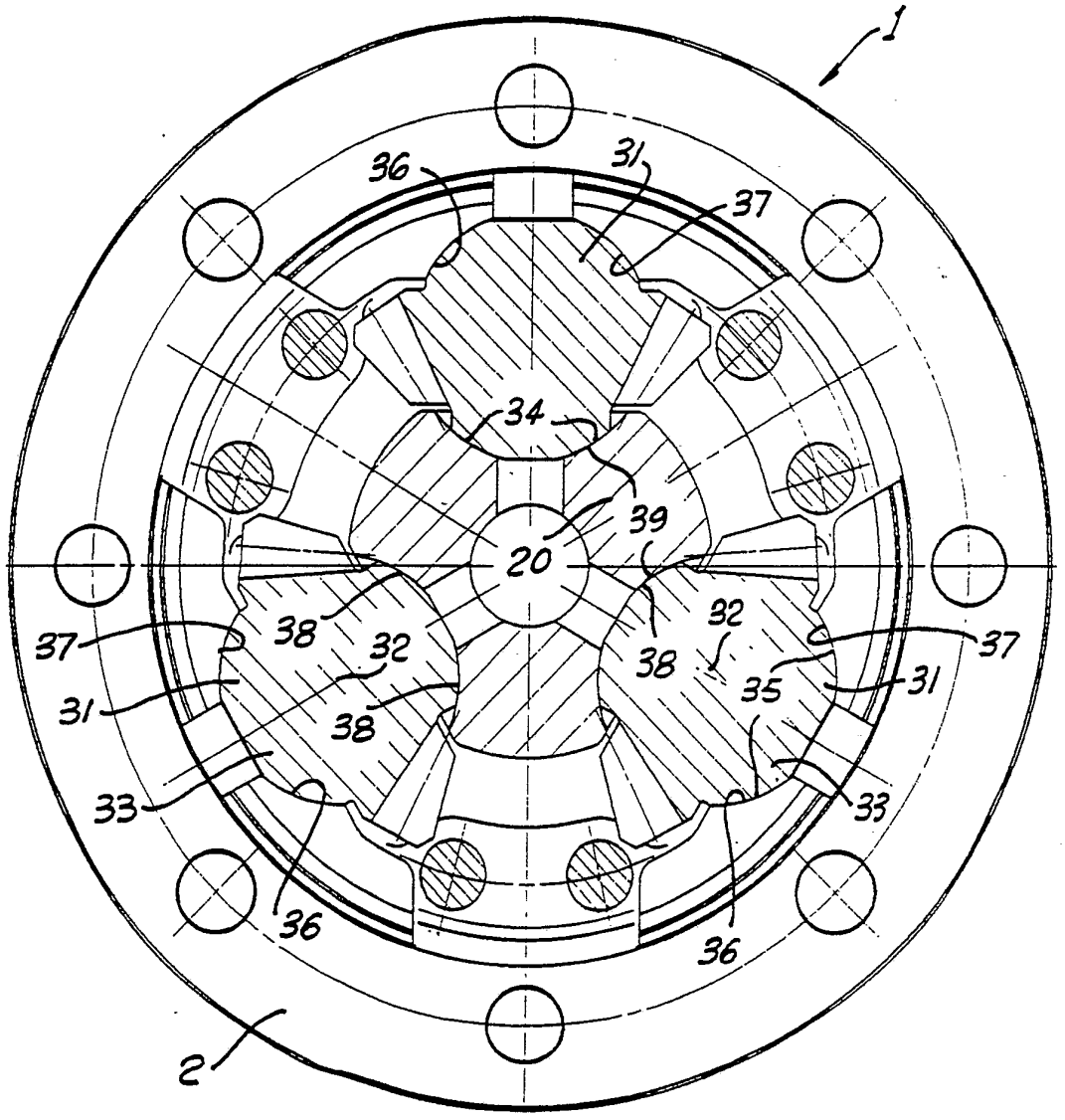


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU92/00208

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.[5] F16H 1/45, 1/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC F16H 1/45, 1/44

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)

DERWENT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X Y	US,A,3930424 (MYERS, Sr.) 6 January 1976 (06.01.76) column 3, line 26 - column 4, line 39	1-2,5 3
Y	US,A,3097545 (IMMEL) 16 July 1963 (16.07.63) column 2, lines 31-56	3
X	US,A,2850922 (WELSH) 9 September 1958 (09.09.58) column 2, line 40 - column 4, line 36	1-2

[X] Further documents are listed in the continuation of Box C.

[ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 August 1992 (10.08.92)	18 Aug 1992 (18.08.92)

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200
WODEN ACT 2606
AUSTRALIA

Facsimile No. 06 2811841

Authorized officer

C.M. WYATT

Telephone No. (06) 2832538

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	**Citation of document, with indication, where appropriate of the relevant passages**	**Relevant to Claim No.**
X	US,A,1431535 (MACDONALD) 10 October 1922 (10.10.22) page 2, lines 6-59	1-2
X	GB,A,606782 (R.G. LETOURNEAU, INC.) 19 August 1948 (19.08.48) page 2, lines 1-49	1
X,P	US,A,5055095 (OSENBAUGH et al) 8 October 1991 (08.10.91) column 2, line 48 - column 3, line 48	1-2,5
A	US,A,2354214 (LOCKWOOD) 25 July 1944 (25.07.44)	
A	US,A,2490146 (MILLER, Jr.) 6 December 1949 (06.12.49)	
A	US,A,3964346 (MYERS, Sr.) 22 June 1976 (22.06.76)	