May 7, 1957 A. F. BOHNHOFF ET AL 2,791,185

HYDRAULIC ROTARY TRANSMISSION DEVICE

Filed July 19, 1954 2 Sheets-Sheet 1

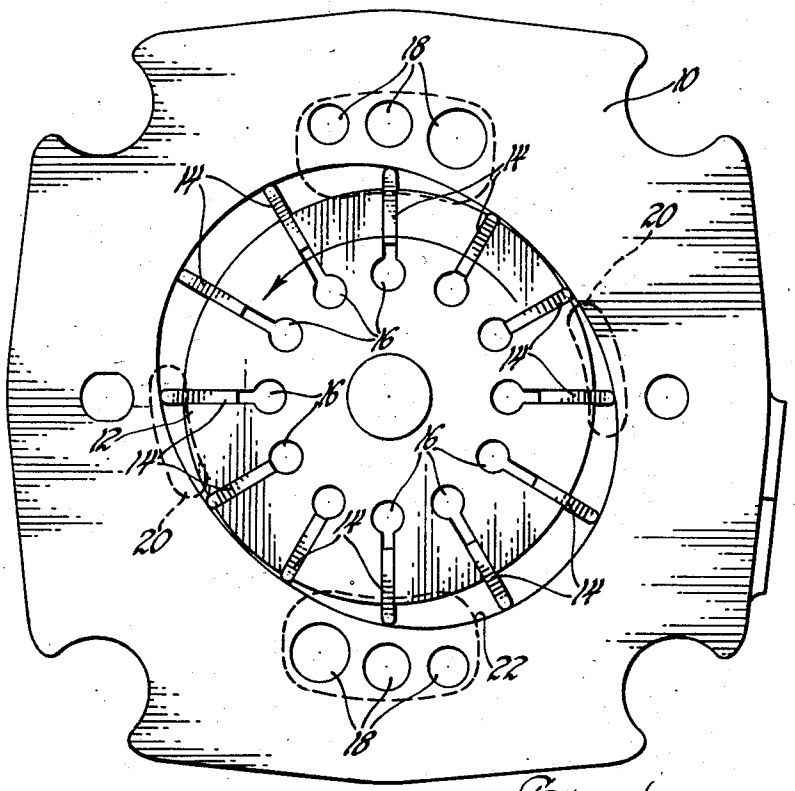


Fig. 1

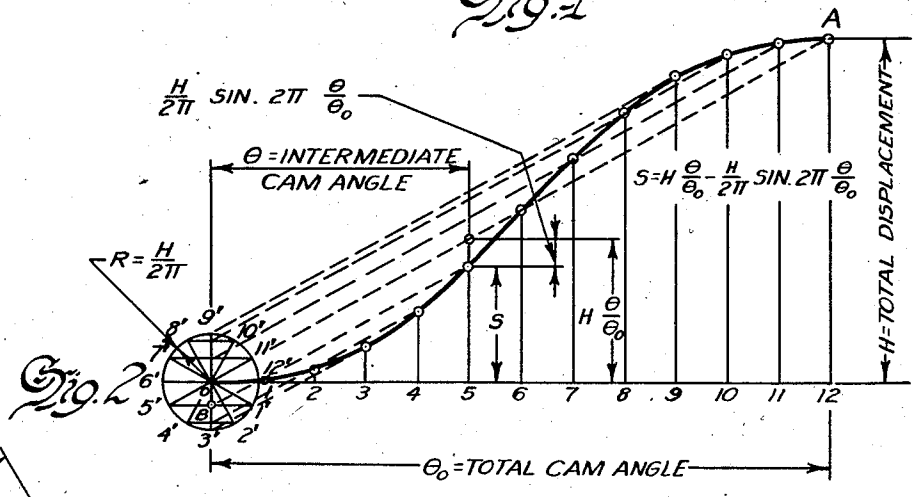


Fig. 2

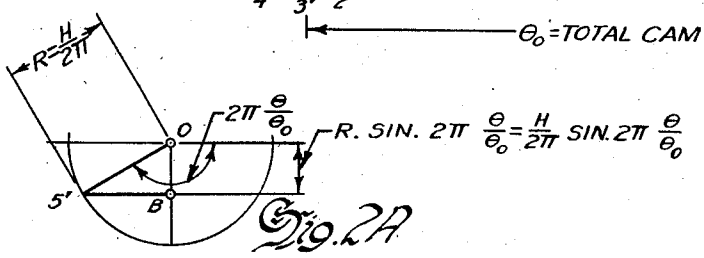


Fig. 2A

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HYDRAULIC ROTARY TRANSMISSION DEVICE

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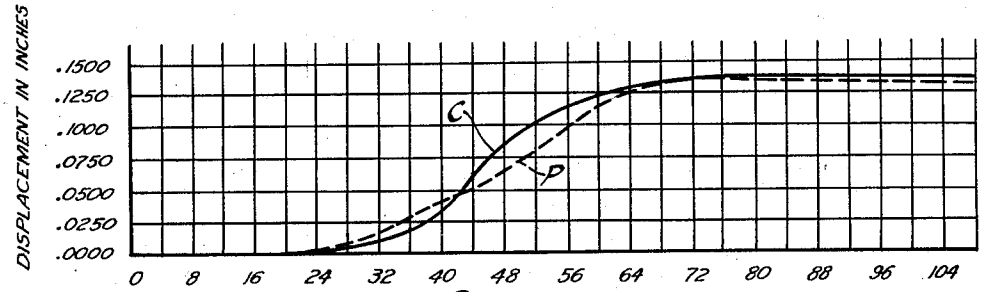


Fig. 3

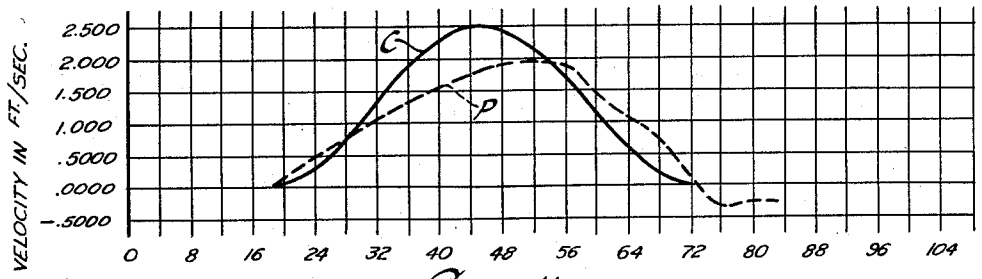


Fig. 4

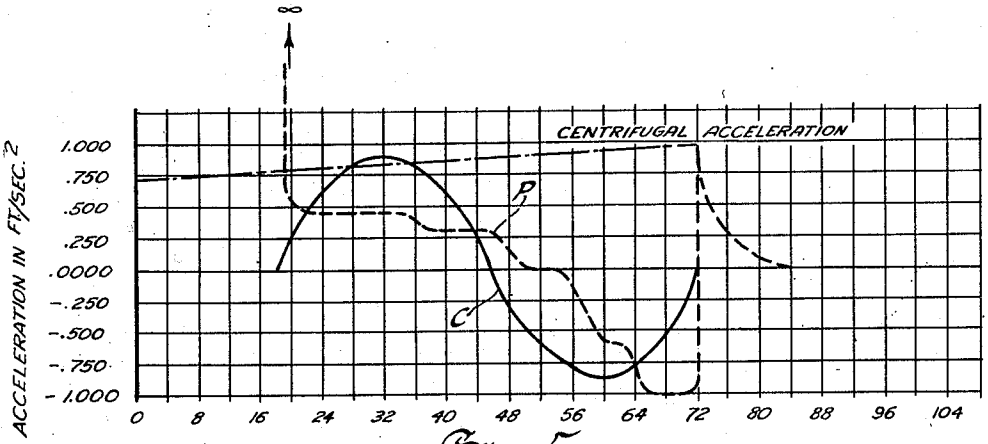


Fig. 5

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HYDRAULIC ROTARY TRANSMISSION DEVICE

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2 Claims. (Cl. 103—136)

This invention relates to hydraulic rotary transmission devices and more particularly pertains to rotary pumps and motors of the type comprising a circular rotor adapted to turn within a ring engaged by the outer ends of a plurality of radially movable vanes carried by the rotor, the inner contour of the ring being shaped to induce radial movement of the vanes.

Hydraulic pumps of the indicated design are used for a variety of purposes and in most cases, especially where they are operated at low speed, apparently perform quite well. However, as applied in the hydraulic power steering of automotive vehicles, for instance (see for example Davis Patent 2,213,271) they have been found to be lacking in the necessary wearing qualities. As would be expected, the wearing is most pronounced about the inner surface of the ring in which the rotor turns, a condition which in time is bound to be reflected in the operating efficiency of the pump.

The present invention is based on the discovery that the wearing qualities of the pump ring are determined by the internal contouring thereof. More specifically, we have found that the pump ring wear in the case of the previous designs owes to the fact that the vanes do not contact the ring in the essentially even and uniform manner supposed. Rather, the contact (especially at high speeds) is marked in certain areas by high frequency impingement of the vanes against the ring surfaces and in other areas by variations in the load applied against the ring surfaces by the vanes.

Considering the foregoing, it should be clear that ring wear is a function of shock and that the degree of shock relates to the radial acceleration characteristics of the vanes as set by the ring contour. Obviously the shock will be greater the greater the value of "(F)" in the formula "$(F)=Ma$," where M equals the mass of the vane and a its radial acceleration.

The principal object of our invention is implicit from the foregoing, i. e., our main purpose is to reduce ring wear, thereby to lengthen the life of the pump or other device and render it maximally efficient over a longer period. A further and more specific object is to provide a ring for rotary vane hydraulic transmission devices in which the inner contouring is such as to avoid high frequency impingement of the vanes and to substantially lessen variations in the load imposed thereby. A corollary object is the provision of a ring contour whereby

(a) Centrifugal force alone will be nearly sufficient to maintain vane contact at the speeds contemplated.

(b) Vane acceleration is zero at the beginning and at the end of rise.

(c) Though retaining features (a) and (b), displacement in the intake areas is greater than in the case of conventional devices of similar design.

Still another object of the invention is to provide such a contour which is easily and accurately reproduced and which is based on a curve capable of definition by an algebraic equation to the end that for any given application the radial velocity and acceleration of the vanes and the physical dimensions and properties of the contour can be readily determined, regardless of the amount of rise and the travel used to achieve it.

In the accompanying drawings which will be referred to in the further description:

Fig. 1 is a side view of a pump conforming to the invention, the pump cover being removed to show the principal parts;

Figs. 2 and 2A show the development of the equation definitive of the cycloidal curve on which the internal contour of the pump ring is based; and

Figs. 3–5 are graphs affording a comparison of the performance of the pump with that of a prior art pump heretofore used for the particular purpose, namely, power steering. The velocity and acceleration curves (Figs. 4 and 5) are for $n=1000$ R. P. M.

Referring first to Fig. 1, it will be seen that the illustrated pump is of the general type disclosed, for instance, in U. S. Patent 2,544,987 to Gardiner et al. Thus, the principal parts are the ring **10**, the rotor **12** and the vanes **14**, the outer ends of which are maintained against the inner surfaces of the ring by centrifugal force plus a hydraulic force developed at **16**, these chambers **16**, with the pump in operation, being filled with fluid under discharge pressure. As well understood, on turning of the rotor **12** counterclockwise (clockwise rotation may be provided for by means of the expedient of an interchangeable cover piece altering the porting as required) the inner vane chambers become filled with oil in the vicinity of the inlet ports **18** and discharge oil in the vicinity of the outlet ports **20**, the vanes **14** moving in or out as determined by the ring contour **22**.

It should be evident that the construction shown is adapted for use as a hydraulic motor as well as a pump. When so applied, the pressure fluid, supplied from a pump, accumulator or other source, may enter the system through either the ports **18** or **20**. The rotary motion of the rotor shaft induced by the impact of the fluid against the vanes may be translated by known means into any other type of motion which may be desired.

We have brought out in the forepart hereof the importance of the inner contour **22** of the ring **10**. In accordance with our invention, we base this contour on a cycloidally formed curve. Such a curve as illustrated by Figures 2 and 2A and as indicated in Figure 2, may be expressed algebrically as:

$$S=H\frac{\theta}{\theta_0}-\frac{H}{2\pi}\text{ sine }2\pi\frac{\theta}{\theta_0}$$

From the figure and formula, it is apparent that vertical (or radial) displacement (S) for an angular travel (θ) along the contour is equal to the vertical (or radial) displacement

$$\left(H\frac{\theta}{\theta_0}\right)$$

of a point on the straight line (or spiral) "OA" minus the displacement

$$\left(\frac{H}{2\pi}\text{ sine }2\pi\frac{\theta}{\theta_0}\right)$$

of a point on the circumference of the generating circle of radius

$$\frac{H}{2\pi}$$

whose center moves along the line (or spiral) "OA" while it rotates through the angle

$$2\pi\frac{\theta}{\theta_0}$$

The inner contour of the ring member **10** comprises two rise portions and two fall portions connected by dwell portions of a predetermined length calculated as desirable. Such contour may be defined as based on a curve representing an algebraic summation of an Archimedes spiral and a sine curve having its generating radius equal to the total rise divided by 2π.

The advantage of the cycloidal curve as a basis for the inner contour of the ring **10** is demonstrated graphically by Figures 3–5 wherein the symbol P refers to the old contour, and the symbol C to the contour **22**. Figure 3 shows the displacement, i. e., the linear distance, expressed in inches, between the contour **22** and the base circle for each degree of rotation of the latter through the arc indicated by the arrow (Fig. 1). The figure demonstrates that the C contour provides for the displacement of substantially more fluid in the filling area than the P contour (note the spread between the curves through the distance 42°—72°), a substantial advantage in many applications.

It is to be noted from Fig. 4 that curve P, unlike curve C, is irregular or non-symmetrical, particularly as it pursues its downward path. Such irregularity causes variations in the load imposed by the vanes resulting in localized wearing, representing a major fault of the prior pump.

Figure 5 has relation to the vane acceleration required to maintain contact between the vanes and ring. From the figure it will be observed that whereas centrifugal force alone, unaided by hydraulic pressure, is substantially sufficient to maintain contact between the vanes and ring in the instance of curve C, an infinite acceleration is demanded in the case of curve P to effect the contact at the beginning of the rise. As a consequence, using curve P, there is no contact on initiation of the rise and when contact does occur it is so abrupt as to cause deformation of the ring surfaces. Similar contact with similar effects, occurs (curve P) at the end of the rise, on the abrupt reversal in the direction of radial movement of the vanes without a dwell. In other words, this sharp reversal results in momentary loss of contact, followed by a quick, hard rebound of the vanes against the ring, spelling obvious adverse effects on the ring surfaces involved. Continuing with reference to curve P, it should be clear that the stepping of this curve between the rise and fall reflects changes in acceleration which are also adverse from a wear standpoint, even though vane contact may be maintained through the area. In practical effect the symmetry of curve C means that such wearing

of the ring surfaces as may occur is substantially uniform, without pitting or indentation. Significantly the vanes have zero acceleration both at the beginning and at the end of the rise.

Having thus described and illustrated our invention what we claim is:

1. A hydraulic transmission device of the type including a rotor mounting radially movable vane means and a ring member surrounding and contacting the vane means so as to determine the radial positioning of the latter for each increment of rotation of the rotor, the inner contour of said ring member comprising two rise portions and two fall portions connected by dwell portions of predetermined length, the contour of said rise and fall portions being substantially set by application of the following equation:

$$S=H\frac{\theta}{\theta_0}-\frac{H}{2\pi}\sin 2\pi\frac{\theta}{\theta_0}$$

wherein:

S=radial displacement of a point on the contour from the base circle (or base line)

θ=angular distance from start of contour to point "A" (Figure 2)

θ_0=total angular distance from start to end of contour

H=total rise (or fall) of contour in angular distance θ_0, the units of linear measurement as to S and H being the same, the units of angular measurement as to θ and θ_0 likewise being the same.

2. A hydraulic transmission device of the type including a rotor mounting radially movable vane and a ring member surrounding and contacting the vane means so as to determine the radial positioning of the latter for each increment of rotation of the rotor, the inner contour of said ring member comprising two rise portions and two fall portions connected by dwell portions of predetermined length, said inner contour being based on a curve representing an algebraic summation of an Archimedes spiral and a sine curve having its generating radius equal to the total rise divided by 2π.

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