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POWER SPLIT DRIVE TECHNOLOGY - TRENDS & REQUIREMENTS

1. Introduction

Developments in car industry as well as in mobile machines are shaped by a strong demand to reduce the fuel consumption. One can say that in general more environmental friendly system solutions and the reduction of operating costs play an increasing role today. In the area of power transmissions this has lead to various alternative new solutions. The paper analysis these trends and summerizes the requirements in the field of hydrostatic transmissions following from this actual development.

The principle of power split drive is known over more than four decades. Due to the combination of a planetary mechanical gear with a continuously variable transmission the power split drive combines the stepless control of driving speed with simultaneous high efficiency as known from mechanical gears. There are three basic alternative solutions to realize a power split drive:
- combination of planetary gear with a continuous variable mechanical gear,
- combination of planetary gear with hydrodynamic transmission,
- combination of planetary gear with a hydrostatic transmission.

On one side the market requires a wide speed range, high efficiency level, an excellent controllability of speed, compactness, high reliability and long life and on the other side it demands the lowest possible price. Due to this the third basic principle - a combination of planetary gear with a hydrostatic transmission - has a good chance to be applied in a lot of different machines and cars.

2. Power Split Drive Based on Hydrostatic Transmission

Figure 1 demonstrates the principle structure of a power split drive using a hydrostatic transmission for continuous variable speed control. The hydrostatic transmission with a variable unit A and a fixed dis-placement unit B is connected with two shafts of the three-shaft planetary gear. In accordance with the chosen system design only a part of the transmitted power is transferred via the hydrostatic transmission. The amount of hydrostatically transferred power can be controlled by the variable displacement unit. In case of a zero adjusted displacement volume the whole power is transferred mechanically. Both displace-ment units can exchange their function, i.e. unit A runs as motor and unit B as pump. This allows to reduce the speed of the output shaft accordingly.

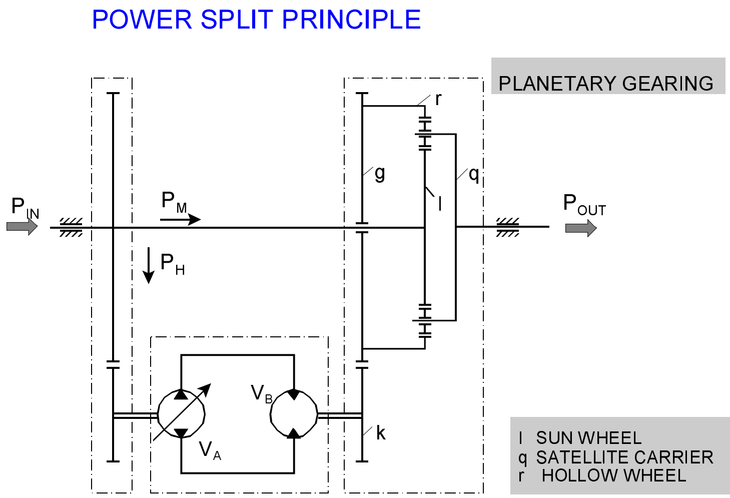

Fig. 1. Power split drive with hydrostatic transmission - basic structure

The different arrangement of the satellite carrier and flexible structure of the hydrostatic transmission (two, three or more units) allows a lot of different solutions of this kind of transmission, which can be divided into two basic groups:

I. Transmissions with high ratio of hydrostatically transmitted power

II. Transmission with low ratio of hydrostatically transmitted power

Figure 2 shows an example for a power split transmission according to the defined class I. A possible solution for a transmission of class II is demonstrated in Figure 3. Both basic principles require a high efficiency of the hydrostatic transmission. In this matter ways for efficiency improvements of displacement machines are very important. The displacement pumps and motors, which are currently on the market, usually achieve a relatively long life and sufficient reliability, but very often they have a low efficiency and a too high noise emission. Values for the maximum total efficiency below 0.85 are not seldom for most of today's designs. In this matter we can notice a strong demand to reach higher efficiency levels of pumps and motors especially if we think about the use of pumps or motors applied in power split drive technol-ogy. The achievable improvements of efficiency of today's displacement machines lie in a range between some tenth and some hundredth. It follows from this that the assessment of improvements requires a very high accuracy of efficiency measurements including the determination of the derived capacity.

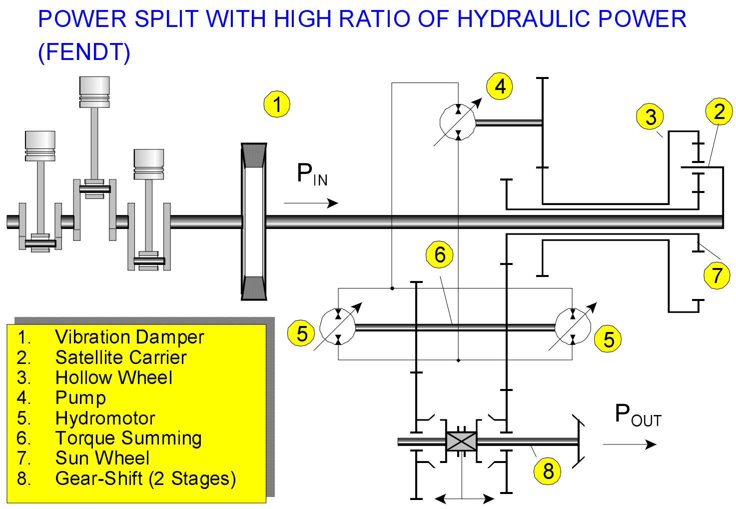

Fig. 2. Power Split drive with high ratio of hydraulically transferred power

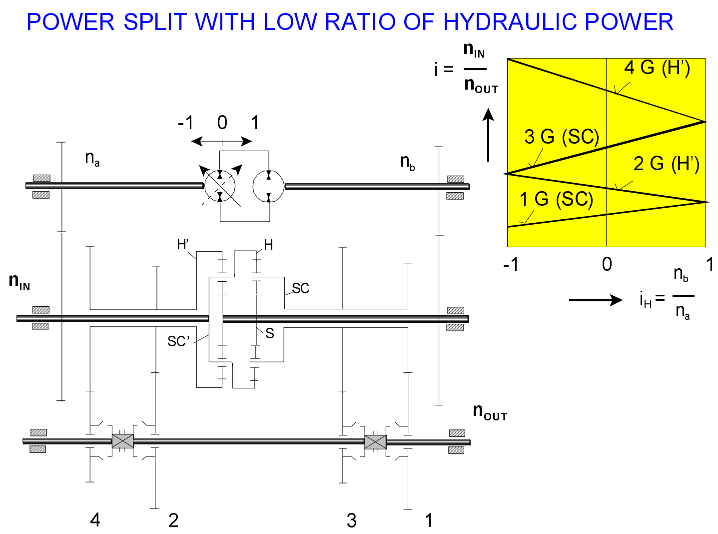

Fig. 3. Power split drive with low ratio of hydraulically transferred power

Based on a short analysis of the loss behaviour of modern displacement machines a new method for the determination of losses including an analytical description is introduced in this paper.

In all types of displacement machines one can find lubricating gaps between the parts moving relatively to each other. The lubricating gap, which very often serves as a sliding bearing and accomplishes addition-ally a sealing function represents one of the main sources of energy losses. A part of the input energy of the displacement machine is dissipated due to the gap flow. The gap flow simulation allows the prediction of volumetric losses. The advantages as well as the current limits of this new approach will be explained in the paper.

Due to the complex behaviour of hydraulic-mechanical losses, which are mainly caused by different types of friction as well as through the impulse change of the fluid flowing through several hydraulic resistance within the displacement machine the determination of losses of a real displacement machine can be only done by measurements. The international standard ISO-4409 define the test procedures, conditions and required measurement accuracy for the determination of steady state performance of displacement ma-chines. For the calculation of volumetric losses QS and torque losses MS the determination of the derived displacement volume Vi, which is also termed as derived capacity, is necessary. There are several methods applied in practice. One of the methods is defined in the international standard ISO 8426. Another method was developed by Toet. It can be shown that both methods are not quite exact. The method according to ISO gives different values for the derived displacement volume for different pressure differences and with the Toet method the Vi - values obtained for different speeds differ from each other. Based on comparison of gap flow simulation results and steady state performance measurements a new method for determination of volumetric and torque losses was developed.

The application of computer aided design methods for fluid power systems requires an analytical descrip-tion of the loss behaviour of all components, but especially of the displacement machines. The prediction of losses of fluid power systems by system simulation and the design of systems with a minimum of power losses require a very high accuracy of steady state models. In the past a number of different mathematical models for the description of loss behaviour of displacement machines were developed. Nearly all available models are based on measurements, but different methods are applied to obtain an analytical description. Following the classical models developed by Wilson and Schlösser for example Bavendiek has tried to describe all the individual sources of losses in an axial piston pump as a function of operational parameters and the viscosity of the fluid with simplified equations, which can be solved analytically. It can be shown that the use of some polynomial fittings allow a higher accuracy of the model. The paper includes a comparison of different approaches and shows the results which can be achieved with the new model POLYMOD. The gap flow simulation programme CASPAR, which was presented on the 6th SICFP'99 in Tampere, allows an exact computation of volumetric losses. Due to this fact a comparison of volumetric losses and theirs dependence on operation parameters given by measurement and the measurement based steady state model POLYMOD with the computation results of the gap flow simulation programme can be presented and discussed in this paper.

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