The Load Capability Dependence on Characteristics of Driven Disks in a Lockup Assembly of an Overload Hydrodynamic Coupling

A V Koperchuk, A V Murin, V V Filonov

Yurga Institute of Technology, TPU Affiliate
Tomsk Polytechnic University, 634050, Tomsk, Lenin ave. 30

E-mail: avkop@tpu.ru

Abstract. A new design of a lockup assembly in an overload hydrodynamic coupling is offered, possible design variants of driven disks in a lockup assembly are considered, and results of experimental research into the importance of driven disk parameters for the load capability of a lockup assembly are given.

1. Introduction

Hydrodynamic couplings are used in drives of all currently available machines (belt, chain, scraper and slat conveyors, fans, mixers etc. [1]), as well as in newly developed ones (geokhod is a new class of mining machinery designed for tunneling mine workings [2-7]). A significant drawback of hydrodynamic couplings is energy loss caused by various angular velocities of turbine and pump wheels in steady conditions. This shortcoming can be eliminated via using a lockup assembly. One can find results of research into overload hydraulic coupling with a lockup assembly made as a centrifugal ball clutch in papers [8-11] (Figure 1).
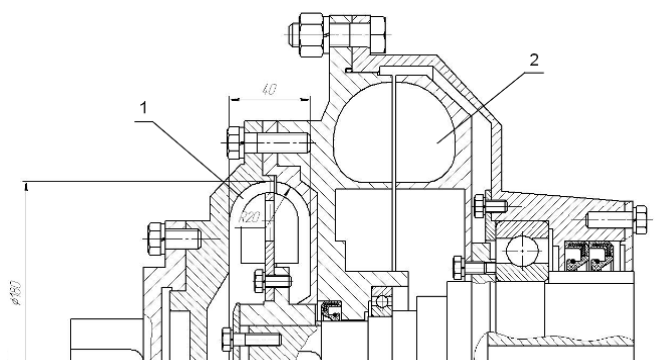
1 – lockup assembly
2 – overload hydrodynamic coupling
Figure 1. The structure of an overload hydrodynamic coupling with a lockup assembly
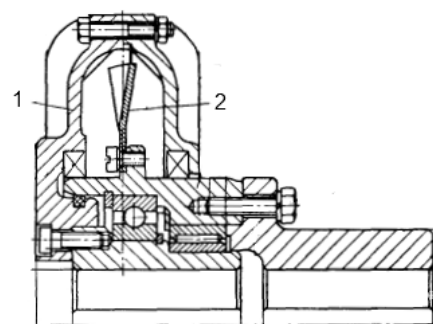
1 – case
2 – driven corrugated disk
Figure 2. Centrifugal ball clutch by Stromag

2. Results and discussions

In available structures of ball clutches with a semi-torus work space (Figure 2) [12] there are some peaks on the inner surface of a work space, which are intended to increase starting and maximal torques of a clutch. There are no peaks in a lockup assembly as it is a hydraulic coupling that provides smooth start of a driven shaft. Since the lower friction torque formed on walls of the work space via contacting with balls a possibility is considered to simplify the form and manufacturing technology of a driven disk, which is usually corrugated. It is proposed to use a flat driven disk with holes (Figure 3a) and a flat disk with peaks (Figure 3b).

The load capability of a solid flat disk in a lockup assembly is theoretically estimated. However, there is no data on using flat disks with holes or peaks in similar assemblies in literature.

We think, moment transferred by disk with holes can hardly be measured theoretically as it is formed not only by friction forces arising between balls and flat segments of the disk but due to tractive resistance of elements in the holes, which are the reason for peaks and hollows in these zones. As the consequence, the load capability of a lockup assembly with disks mentioned above was measured experimentally.

We fabricated disks 3 mm thick with 40 holes 8.5 mm in diameter, ones with 20 holes 17 mm in diameter, and ones with 10 holes 34 mm in diameter. The overall area of the holes was identical on all disks.

a)   b)
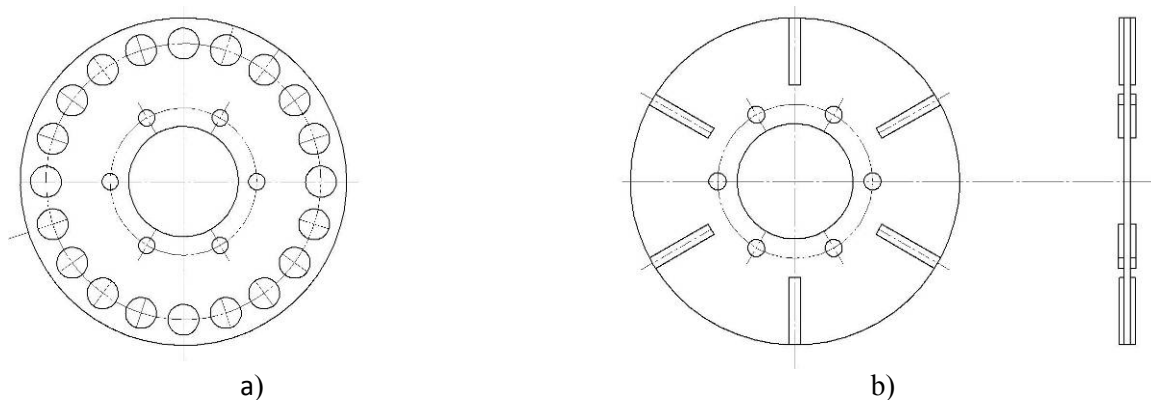
Figure 3. The structure of driven disks

Disks with radial peaks were designed the same way as corrugated ones, the data on their fabrication is provided in paper [13]. The height of a peak was accepted almost similar to the ball diameter (3.175 mm) and was equal to 3 mm in the first variant. The height of a peak in the second disk structure was assigned 12 mm under assumption slippage of granular material is impossible on the disk and a case-peak gap is ensured to provide free spreading of balls in the inner space. The length of peaks was similar (35 mm) and assigned with respect to the ring layer thickness of balls in a filled lockup assembly. The number of peaks was the same as that of flutes, i. d. 6 flutes on each side.

Geometrical parameters of the inner space in the lockup assembly (Figure 1):
- Maximal radius of inner space $R_0 = 0.09$ m;
- Radius of torus space $\rho = 0.02$ m.

Geometrical parameters of disks (Figure 3):
- Outer diameter of disks with holes 0.178 m;
- Outer diameter of disks with peaks 0.17 m (to support smooth spreading of filling material in inner space on both disk sides).

Hardened and planished steel bearing balls (steel ShH 15 GOST 801-78) 3.175 mm and 4.763 mm in diameter were used as filling material. It weighted $Q = 2.2$ kg. The case and disks were made of steel 20 GOST 1050-88 without thermal treatment.

The experiments have demonstrated unloaded driven shaft can't be accelerated without hydraulic liquid in a hydraulic coupling provided that the lockup assembly is filled with balls as specified. The starting torque of the assembly is insufficient to eliminate resistance in bearings, elastic coupling, belt transmission and electrical brake bearings of a test bench. To accelerate the driven section a hydraulic drive was filled up with 1 liter hydraulic fluid (I-20A GOST 20799-88), conforming to 28% of its filling level.

Figure 4 shows tests when accelerating and slowing down the hydraulic coupling filled 28 percent by a semi-torus ball lockup assembly 4.763 mm in diameter and 12 mm high peaks. The result of gauging the dynamometrical assembly is shown in the left section of the figure. The value of torque is given in Nm. Used symbols:

n_1 - rotation frequency of a driveshaft in a hydraulic coupling;

n_2 _ rotation frequency of a driven shaft in a hydraulic coupling;

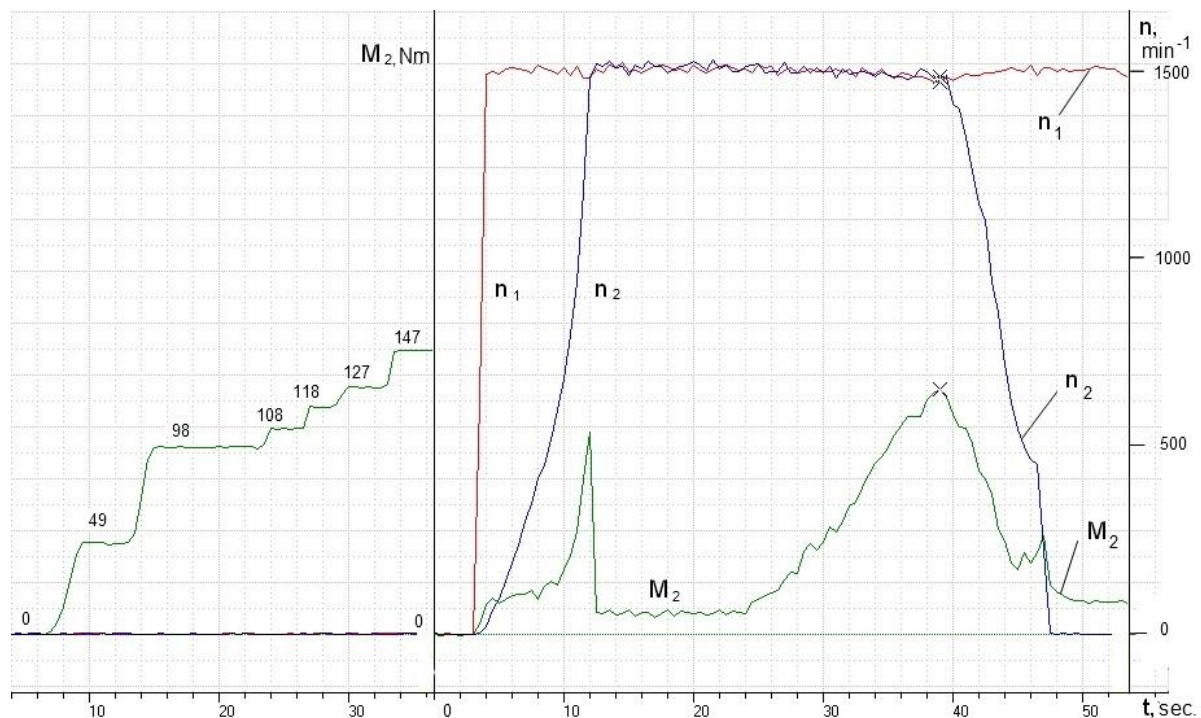M_2 – torque on the output shaft of a hydraulic coupling;

t - time.

Figure 4. Mechanical characteristics of a hydraulic coupling with a lockup assembly

As one can see from the analyzed experiment recordings:
- hydraulic coupling and lockup assembly running together can accelerate the driven shaft up to the frequency of the driveshaft;
- in these conditions there is no slippage because a hydraulic coupling is not warmed up;
- load is transferred by the lockup assembly only, since a hydraulic coupling can't function without relative movement of pump and turbine wheels.

The analysis of marks resulted from the contact of the lockup assembly with balls has revealed that granular material slips on the surface of 3 mm high disks with holes and peaks (Figure 5). If the peaks are 12 mm high, balls slip, as one has assumed, on the inner part of the lockup assembly case (Figure 6).

a)

b)

c)

d)

a)   a disk with holes 8.5 mm in diameter
b)   a disk with holes 20 mm in diameter
c)   a disk with holes 34 mm in diameter
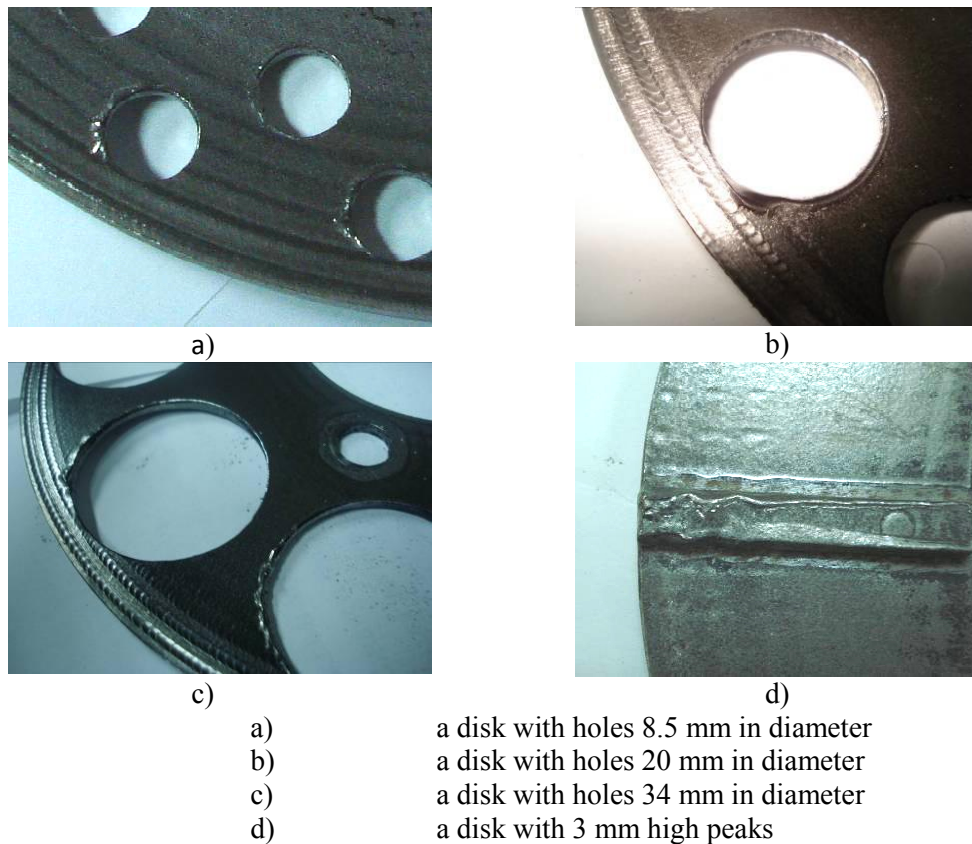d)   a disk with 3 mm high peaks

Figure 5. Driven disks with the marks of the contact

Figure 6. Inner surface of lockup assembly case with the marks of contact after using a driven disk with 12 mm high peaks

It should be noted, unhardened disks with holes and 3 mm high peaks are badly damaged under slipping of balls on their surface. If disks with 12 mm high peaks are used there are concentric hollows – result of contact with granular material – on the smooth surface of the case inner space, however, the depth of these hollows is constant for a long time.

Experiments made it possible to draw torque on the output shaft M_2 – slippage S (into lockup assembly) graph, which outlines mechanical statistical characteristics of lockup assembly with various disks (Figure 7). Curves are shown on the same graph for more convenience (Figure 8).
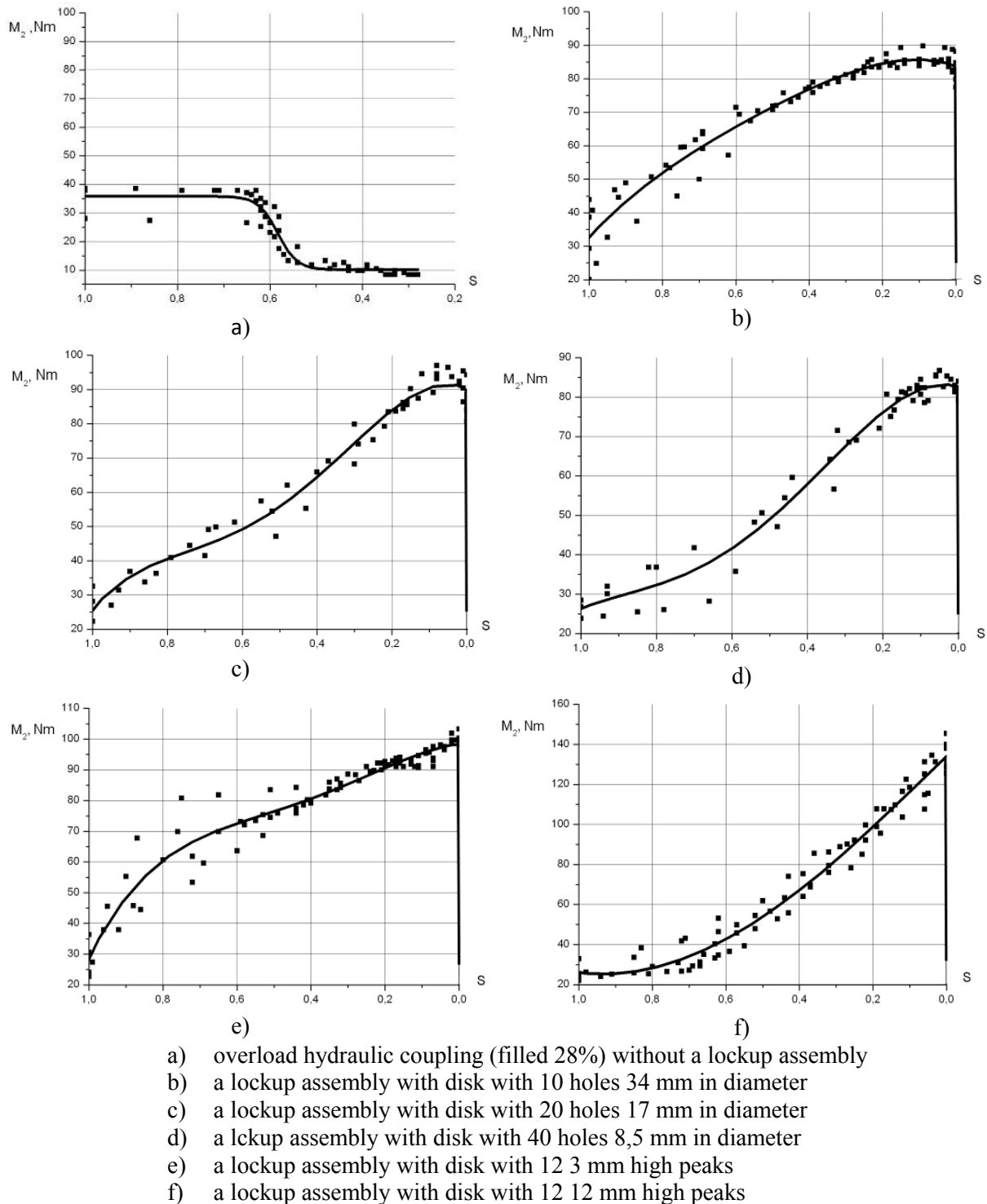
a)   overload hydraulic coupling (filled 28%) without a lockup assembly
b)   a lockup assembly with disk with 10 holes 34 mm in diameter
c)   a lockup assembly with disk with 20 holes 17 mm in diameter
d)   a lckup assembly with disk with 40 holes 8,5 mm in diameter
e)   a lockup assembly with disk with 12 3 mm high peaks
f)   a lockup assembly with disk with 12 12 mm high peaks

Figure 7. Mechanical characteristics of a lockup assembly with a semi-torus work space and various disks
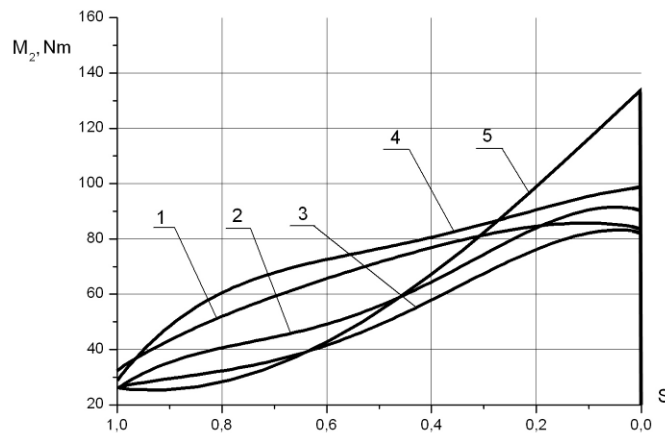
3. Conclusion

The following conclusions can be drawn on the base of analyzed graphs, experimental observations of the research and examination of the lockup assembly components after experiment:

   −   a lockup assembly with granular filling material has a low starting torque, which doesn't deteriorate starting properties of hydraulic couplings;

   −   granular filling material slips on the surface of disks with holes and 3 mm high peaks;

   −   disk with 12 mm high peaks supports the slippage of balls on the inner surface of the case; the loading capacity of a lockup assembly is 1.35 times higher under slippage of filling material on the surface of the case interior;

1 – disk with 10 holes 34 mm n diameter
2 – disk with 20 holes 17 mm in diameter
3 – disk with 40 holes 8.5 mm in diameter
4 – disk with 12 3 mm high peaks
5 – disk with 12 12 mm high peaks
Figure 8. Mechanical characteristics of a semi-torus lockup assembly with various disks

   −   disks supporting the slippage of balls on the case surface are recommended to be used in the lockup assembly of an overload hydraulic coupling as they provide higher loading capability and lower additional loads on the drive under slippage S over 0.65.

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