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Design of gearbox lubrication system

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Abstract: The basic task of lubrication is to reduce frictional forces, reduce wear and remove heat generated from the point of contact. The most common transmission lubrication system is wading lubrication. In this way, the lubrication of the gearbox in the rope drum drive on the pickling line is also solved. The lubrication of the bevel gear of this gearbox is insufficient and is manifested by the failure rate of the given gear. The paper describes a proposal for changes in the lubrication of a specific bevel gearbox to eliminate failures due to insufficient lubrication of the bevel gears.

Keywords: gear box, innovation, lubrication, circulatory lubrication.

1. INTRODUCTION

Gear lubrication aims to reduce wear on the sides of the teeth. At the same time increase the degree of efficiency due to reduced friction, better heat dissipation generated by friction [1-3]. Gear lubrication is a discontinuous process. This means that a new lubricating film must be formed between the tooth flanks each time the teeth are meshed. The geometric shape of the tooth flanks conditions the rolling and sliding movement, so the gears often work in the area of mixed friction. This results in damage to the gearboxes and an increase in the power loss of the gearbox [4 -7].

The most common lubrication of gearboxes is by wading. In this way, the lubrication of the examined gearbox in the pickling line drive was solved. Such lubrication is used for small and medium-sized gearboxes - reducers, which create an oil mist when rotating [8-13]. The oil that makes the filling of the gearbox and the gear wheels that wade in the oil fill push the oil into meshing. Such gearbox lubrication is used for peripheral speeds of $v \leq 12\ ms^{-1}$. It is specified that for high-speed wheels, the immersion depth must be less than twice the modulus value, but not less than 10 mm. During operation, the oil level drops, so the depth of immersion of the high-speed gear wheels at rest should be selected up to four times the modulus. At low peripheral speeds up to $1.5\ m.s^{-1}$, the immersion depth can be up to 1/6 of the pitch diameter of the gear wheel.

Forced circulatory lubrication - with central circulation lubrication is another possible way of lubricating gearboxes [14-20]. For this method of lubrication, the oil is fed to the lubrication areas and then discharged back into the tank. The lubricating oil circulates in the gear unit in this way [21-24]. Requirements for circulating lubrication are the reliability of the lubrication system and its parts, the possibility of selecting or regulating lubrication areas, the possibility of automation of operation and reliable control and operation of control elements.

2. ORIGINAL BEVEL HELICAL GEARBOX LUBRICATION SYSTEM

The reserve of the belt on the pickling line is formed by two loop carts, pulled horizontally by steel ropes. The parallel operation of both trolleys is performed on the tracks below each other and is enabled by a transfer rope drum. The rope drum is driven via a three-stage bevel gearbox (Fig. 1).

Fig. 1. Three-stage bevel helical gearbox

The first gear of the gearbox, formed by a bevel gear, shows a considerable degree of wear. Over the last 10 years, the input pinion with the counterpart has been changed three times and, in addition, the input pinion twice separately. The original lubrication is

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designed by spraying of the wading wheel in the oil filling. This method of lubrication is unsatisfactory at very low speeds (max. input speed approx. 200 rpm, most often speeds are from 0 - 100 rpm). It is a three-stage bevel gearbox with a gear ratio of 19.706, power of 500 kW. The first gear of the gearbox consists of a bevel gear with helical gearing. It is the lubrication of this gear that is insufficient. Therefore, the change described below was proposed.

3. DESIGN OF TRANSMISSION CIRCULATORY LUBRICATION SYSTEM

Currently designed bath lubrication is satisfactory only for the second and third gear of the mentioned three-stage bevel helical gearbox. The calculated circumferential speeds on these helical wheels were less than 12 ms^{-1}, which it can be concluded that it is an advantageous lubrication system. In this case, the larger second and third gear wheels are immersed in oil. The suitability of this lubrication is also substantiated by the fact that during the inspection of the gearbox after dismantling the cover at the time of its shutdown, the helical gears were coated with a continuous oil layer. During this inspection, the gearing did not show signs of progressive wear, which occurs at high loads and low relative speeds, when the conditions of elastohydrodynamic lubrication are not met during contact of the gear wheels.

The first gear formed by a bevel gearing showed signs of wear, as did the bearings of the first countershaft. Therefore, the circulatory lubrication system shown in Fig.2 was selected.

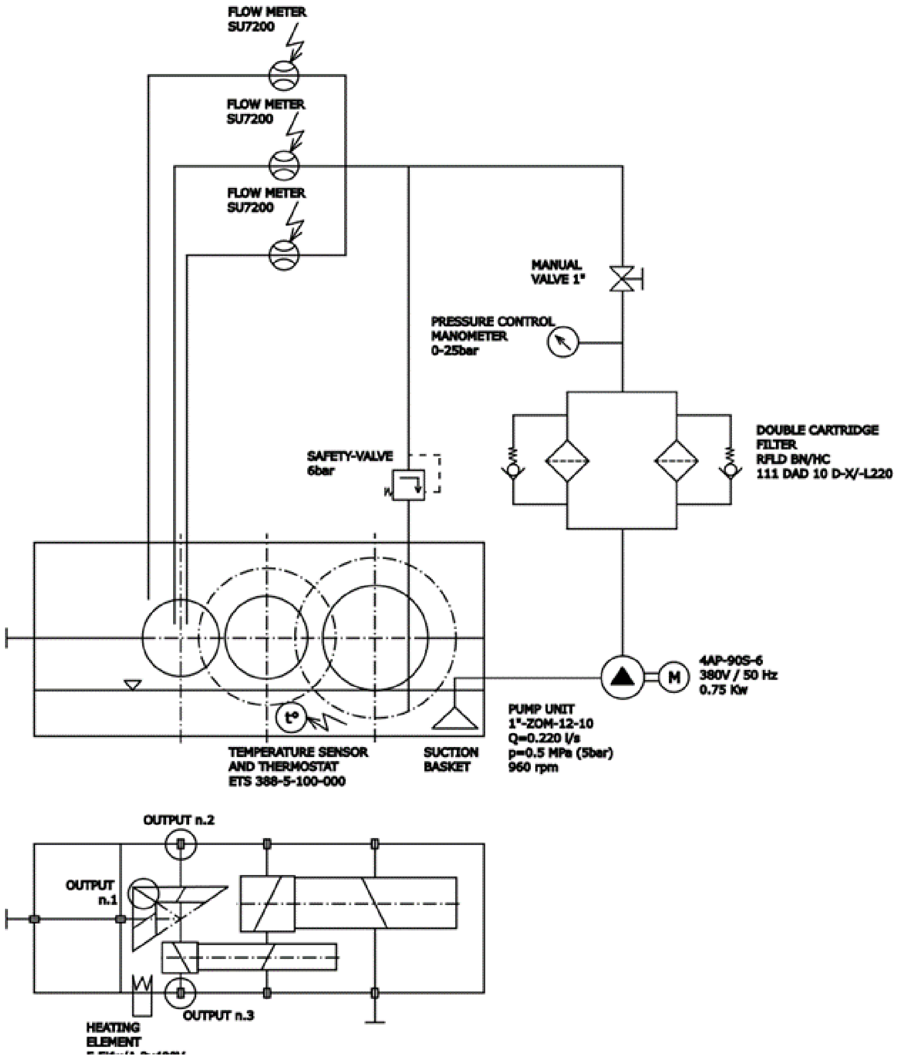
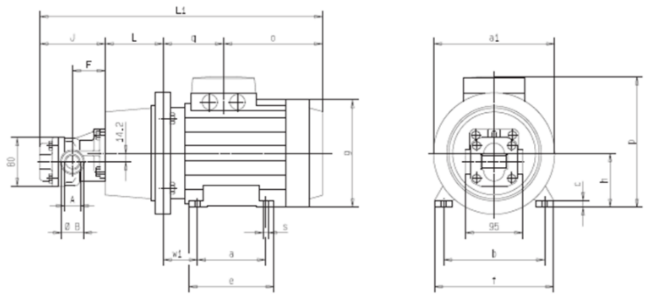


Fig. 2 Innovative gearbox lubrication design

This central circulatory lubrication consists of a pump unit, which consists of a geared monoblock low-pressure pump, which consists of a gear pump, a clutch and an electric motor (Fig. 3).

Another main component is a double cartridge switchable filter (Fig. 4). This filter is mounted on the output of the pump unit and has an electronic clogging indicator of the filter element.

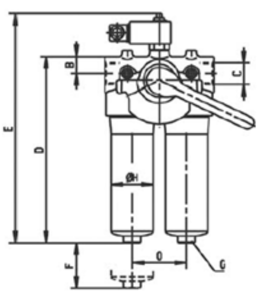
Before putting the device into operation (during a longer shutdown), it is necessary to activate the thermostat, which detects the temperature of the lubricating medium. If the temperature is below the required operating value, it is necessary to heat the lubricating medium up to the required temperature via a heating element (spiral). When the required lubricating oil temperature is reached, its heating is stopped, and the device (gearbox) is ready for start-up. The operating temperature of the lubricating medium is also monitored during the operation of the device, and in the event of a temperature drop below the set temperature, the heating is switched on by means of a heating element.



A	= G1"	a	= 100 mm	s	= 10 mm
ØB	= 42 mm	b	= 140 mm	L_1	= 488 mm
J	= 131 mm	e	= 125 mm	a_1	= 200 mm
F	= 63 mm	f	= 170 mm	o	= 134 mm
L	= 100 mm	w_1	= 56 mm	q	= 99mm

Fig. 3 Pump unit

When the device is put into operation i.e., when the required temperature of the lubricating medium is reached, it is possible to start the central circulatory lubrication by switching on the pump unit. The pump unit consists of a geared monobloc low-pressure pump, the speed of which is 960 min^{-1}, the flow pressure of the pump is 0.5 MPa (5 bar), max. viscosity of the pumped oil 228 mm^2.s^{-1} and flow rate is Q = 0.22 l.s^{-1} (13.2 l.min^{-1}).



A	= 78 mm
B	= 38 mm
C	G1"
D	= 200 mm
E	= 258 mm
ΦH	= 66 mm
I	= 139 mm
K	= 168 mm
L	M8x16
O	= 85 mm

Fig. 4 Double casket filter

The pump is driven by an electric motor (which is part of the pump unit) 4AP - 90S - 6 with an output of 0.75 kW (three - phase, asynchronous with a short - circuit rotor for direct connection to the grid, closed version with its own surface cooling for 380V, 50Hz). This pump unit pumps the lubricating medium from the gearbox oil bath through the suction basket (Fig. 5), the function of which is to prevent coarse impurities from entering the lubrication circulatory system and injecting the lubricating medium into the filter.

Fig. 5 Suction basket

Flow sensors (Fig. 6) with ultrasonic sensor and programmable two switching outputs. The first output is a control of the lubricant flow with a display of the flow rate in l.min^{-1} and signaling in case of insufficient (zero) flow. The second output can be used to measure the temperature of the lubricating medium in °C.

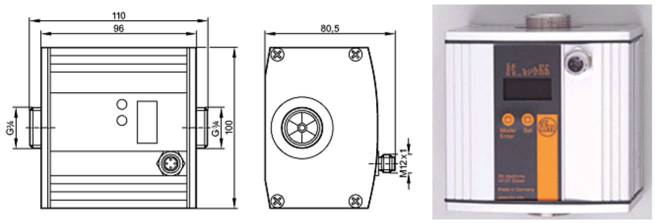


Fig. 6. Flow sensor

The end element on each branch is a spray nozzle. It is recommended to use spray nozzles with annular shape spray for the supply of lubricating medium to the bearings and a nozzle with a fan-shaped oil spray for the supply of lubricating medium to the meshing of the bevel gear. The oil returns to the gearbox, back into circulation.

The design of the amount of lubricating medium i.e., the flow for the lubrication of the bearings by the central circulatory system, was based on the outer diameter of the bearing used on the first template (from a diameter of 340 mm). Based on [3], a lubricant flow in the range from 0.1 l.min^{-1} to 10 l.min^{-1} is required for this case, with the note that higher flow values are used if the lubricant also serves as a cooling medium required for heat dissipation. Based on this requirement, a pump unit with a flow rate of Q = 0.22 l.s^{-1} (13.2 l.min^{-1}) was selected . The flow rate at which the lubrication areas are lubricated (bevel gearing meshing and bearings) is equal to one third of the pump unit flow i.e., 4.4 l.min^{-1}, which corresponds to the required amount of oil required to lubricate the bearings and also meets the required amount of lubricant for lubricating the bevel gearing meshing.

Due to the hydraulic resistances in the circulatory lubrication branches, the resulting flow rate will be even lower, as the flow rate is inversely proportional to the resistance to movement. It is important to fine-tune the lubrication system during operation.

4. CONCLUSION

Low mechanical losses, high durability as well as partial noise reduction and heat dissipation is ensured by perfect gear lubrication. Oil lubrication is often preferred over grease lubrication for better heat dissipation. Grease lubrication is used for gearbox bearing housings that cannot be sealed or can only be sealed at high construction costs.

The original lubrication of the three-tage bevel helical gearbox was solved by wading the wheels in oil. Such lubrication was not satisfactory, and the gearing was damaged. Upon requisition, a central circulatory lubrication of the first template bearings and the first countershaft bearings was designed. The task of lubrication systems is to supply and distribute the lubricant from one central source to all parts of the machine where unwanted friction occurs, in a precisely determined amount and time. The dripping oil flows back into the oil pan. With this lubrication method, the oil can be filtered and cooled to separate impurities and to dissipate heat.
It should also be noted that the design of the gearbox (dimensions, design of the shafts, etc.) is not designed and adapted to the required circulating lubrication. To solve the problem of lubrication by designing central circulatory lubrication, it is necessary to implement a modification in the body of the gearbox, which is possible on the basis of stiffness analysis, which requires precise parameters.

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