Development of a vacuum pump with a double-circuit lubrication system for milking machines

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Abstract. The efficiency of milking dairy farm animals depends on the reliability of the milking equipment. Domestic milking machines are equipped with UVU 45/60 with a rotary vacuum pump that has an extremely limited service life, which is mainly due to imperfection of the lubrication system for its working bodies. In addition, oil loss along with the exhaust air leads to high lubricant consumption and environmental pollution. Analysis of modern designs of foreign rotary vacuum pumps shows that their operational reliability and service life are increased at the expense of maximum reduction of friction in the working body due to the improvement of the lubrication system, increased productivity, and elimination of oil loss and environmental pollution. One of the technical solutions to solve these problems is to equip the vacuum installation with a device that provides circulating lubrication of the pump working bodies without emitting oil into the atmosphere. The team of authors substantiated the design of the oil trap for the pump lubrication system with the efficiency of separating oil from the exhaust air up to 95 %. Experimental vacuum installations with single-circuit and double-circuit lubrication systems have been developed. Production tests of vacuum installations performed at a number of farms in Stavropol Territory confirmed high efficiency of the proposed engineering solution. The operational reliability of the pump due to the circulating lubrication of its working bodies in terms of the prolonged overhaul period increased by 65–70 %. Irrecoverable oil losses and environmental pollution are almost excluded. The payback period for additional capital investments in the vacuum installation design does not exceed 1.2–1.5 years.

1. Introduction

The efficiency of milking machines largely depends on the perfection of the vacuum system and, first of all, on the excess power of the vacuum pump in terms of productivity and operational reliability. Violation of the vacuum regime reduces productivity of dairy farm animals, increases incidence of udder infection, inhibits milk return reflex, and causes disturbances in the operation of milking machines [1]. In this regard, the issue of increasing the reliability of the vacuum system components, as one of the main reserves for growing productivity, and reducing downtime of milking and dairy equipment due to the elimination of technical and technological failures, is becoming increasingly acute [2, 3].

The majority of domestic milking machines (DAS-2B; AD-100A; UDM-200; UDA-8 Tandem; UDA-16 Yolochka, etc.) are equipped with UVU 60/45 (Fig. 1) with a rotary vacuum pump. The operating parameters and the efficiency of the installation depend on the vacuum pump design, which is the main executive unit [4, 5].
Long-term observations and studies of the operational reliability of such installations at dairy farms in Stavropol Territory have revealed a number of significant shortcomings, which include:

1. The applied lubrication system does not provide high-quality lubrication, which leads to increased wear of the blades and stator, and to overheating of the vacuum pump and its decreased efficiency.

2. Emission of the exhaust air through the muffler into the atmosphere leads to high oil consumption and environmental pollution.

3. A small volume of oil in the lubricator leads to dry friction of the working parts that causes wedging (breakage) of the plates.

4. Liquid may enter the pump together with the sucked air.

According to the data obtained, 85% of cases of pump failure is precisely due to insufficient lubrication of its working bodies [6].

Analysis of modern designs of foreign rotary vacuum pumps shows that their operational reliability is increased at the expense of:

- maximum reduction of the negative effect of friction between the plates and the pump due to the improved lubrication system;
- increased productivity;
- elimination of oil losses and environmental pollution [7].

One of the technical solutions to solve these problems is to equip the vacuum installation with a device that provides circulating lubrication of the pump working bodies without emitting oil into the atmosphere.

Figure 2 presents the scheme of the proposed installation. The installation is characterized by a tank included in the circuit, which acts as an oil trap and receiver. The oil circulates in a closed circuit, it is then separated from air in the oil trap and sent to lubricate the pump working parts; the air purified from oil is emitted into the atmosphere.
The circulating lubrication system can be single- and double-circuit (Fig. 3). A distinctive feature of the double-circuit system is the presence of an oil collector between the oil trap and the pump.

2. Materials and methods
To develop the most efficient design of the oil trap, an experimental setup was created. Figure 4 shows the general view and diagram of the setup and Figure 5 presents six prototypes of oil traps.
Brass tubes 3 mm in diameter and 10 mm in length (Fig. 5.1) and glass strips 10×150 mm in size (Fig. 5.2) were used as fillers. In a meshy oil trap, a metal mesh with a cell of 0.5×0.5 mm was used (Fig. 5.3).

The efficiency of oil trapping by the oil trap was estimated by the ratio of the amount of oil deposited in the trap ($O_{\text{deposited}}$) to the amount of oil consumed from the oil tank ($O_{\text{consumed}}$):
The amount of oil trapped by the oil trap was determined by weighing it before and after the experiment. The oil control was taken equal to 50 g.

3. Results and discussion
The efficiency of separating oil from air in the studied oil traps are presented in Table 1.

| Oil trap type                  | Efficiency of oil trapping, % |
|-------------------------------|-------------------------------|
| 1. With filler (tube)         | 69                            |
| 2. With filler (glass)        | 56                            |
| 3. Meshy                      | 66                            |
| 4. Gravitational              | 48                            |
| 5. One-sided disk-shaped      | 91                            |
| 6. Double-sided disk-shaped   | 88                            |

The most efficient way to ensure the separation of oil from air is a one-sided disc-shaped oil trap. This can be explained by the repeated swirling of air in the oil trap body, which contributes to the intensive enlargement of oil droplets and their separation from air when they contact with the surfaces of the plates and the body.

Vacuum installations with single- and double-circuit lubrication systems for the pump working parts have been developed at the Department of Machines and Technologies of the Agro-industrial Complex, Stavropol State Agrarian University (Fig. 6) [8].

Laboratory and production tests of the developed vacuum installations carried out at a number of farms in Stavropol Territory confirmed high efficiency of the proposed engineering solution. The operational reliability of the pump due to the circulating lubrication of its working bodies in terms of the prolonged overhaul period increased by 65–70 %. The most important resource-saving indicator is the saving of expensive lubricants and environmental safety.

It should be noted that in a single-circuit lubrication system, foamed oil is supplied to the pump from the oil trap, which decreases the pump efficiency. In a double-circuit system, oil is settled in the oil collector, which is an important advantage of this system over a single-circuit one. The proposed...
scheme is recommended for the modernization of series-produced vacuum installations with a rotary vacuum pump.

The technical and economic calculations performed on the basis of the data of the laboratory and production tests showed that the payback period for additional capital investments in the vacuum installation design does not exceed 1.2–1.5 years [9].

4. Conclusion

The investigations and production tests performed have shown that a two-circuit lubrication system with a one-sided disk-shaped oil trap most effectively separates oil from air and eliminates its loss. At the same time, the supply of settled oil from the oil collector without foaming increases operational reliability and reduces the adverse effect of friction between the plates and the body of the pump. The proposed scheme is recommended for the modernization of series-produced vacuum installations with a rotary vacuum pump.

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