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# A CONTRIBUTION TO THE DEVELOPMENT OF DEVICE FOR TRANSFERRING HIGH VISCOSITY MEDIA

# DOPRINOS RAZVOJU UREĐAJA ZA PREPUMPAVANJE VISOKOVISKOZNIH MEDIJA

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Preliminary communication

***Abstract:*** *In the processing industry high viscosity media are transferred by using very expensive worm-drive pumps whose form and characteristics are adapted to the standardized packaging of the media. A significantly cheaper and simpler device with a worm coil has been designed for the purpose of transporting media of various viscosities. Experimental transferring was carried out on a limited number of media samples of various viscosities. The functionality of the device was confirmed. The results of the experiment during the operation of the device with two versions of worm coils (1 and 2) were compared. Guidelines for further research and possible development of an applicable device were proposed.*

***Key words:*** *high viscosity media, worm coil, experimental device.*

Prethodno priopćenje

***Sažetak:*** *U prerađivačkoj industriji se za pretakanje visokoviskoznih medija koriste veoma skupe zavojne pumpe oblikom i karakteristikama prilagođene standardiziranoj ambalaži medija. Osmišljen je znatno jeftiniji i jednostavniji uređaj s pužnom zavojnicom za transport medija različite viskoznosti. Provedena su pokusna ispitivanja pretakanja na ograničenom broju uzoraka dostupnih medija različite viskoznosti. Utvrđena je funkcionalnost uređaja. Uspoređeni su rezultati ispitivanja pri radu uređaja sa dvije izvedbe pužne zavojnice (1 i 2). Predložene su smjernice daljnjeg istraživanja i mogućeg razvoja primjenjivog uređaja.*

***Ključne riječi:*** *visokoviskozni mediji, pužna zavojnica, pokusni uređaj.*

## 1. INTRODUCTION

In the processing industry (food industry, pharmaceutical industry, chemical industry,…) very expensive worm-drive pumps [1, 2, 3, 4] are usually used for transferring high viscosity media (glycerol, liquid paraffin, sorbitol, various types of liquid sweeteners, additives etc.). Media of viscosity from 1 Pa s to around 30 Pa s are transferred from thin-wall metal cylindrical containers of volume ranging from 0.2 $m^3$ to 0.3 $m^3$ into smaller plastic containers of volume ranging from 10 l to 20 l that can be transported easily and be used for utilizing media in technological processes. The stator tube with the drive shaft and propeller of the worm-drive pumps is vertically immersed in a medium through the opening on the upper side of the cylindrical container with the standard ∅ 50 mm. A drive electric motor with a modifiable number of rotations is positioned on the axle from the upper side of the pump, outside the container. The penetration depth of the cylindrical part of the pump with the propeller on the top of the drive shaft depends on the amount of viscous medium, but it maximally reaches the bottom of the container. The respective worm-drive pumps are from the constructional and functional perspective adapted to the opening diameter and the size and form of the container [3, 4]. By means of a flexible pipeline connected to the pressure side of the pump a viscous medium is transported (transferred) on short distances (a few meters) into smaller plastic containers. A practical example of transferring viscous media is shown in Figure 1.

For the purpose of easier and more suitable manipulation, part replacement and maintenance as well as significantly simpler and cheaper implementation, an experimental device was designed. Furthermore, experimental measuring in transferring media of various viscosities was carried out.

## 2. EXPERIMENTAL DEVICE

A worm coil with a drive shaft that is centrally leant against the lower and upper bearing [5, 6, 7] is integrated in the cylindrical casing with the inner diameter amounting to ∅ 35 mm, wall thickness amounting to 2.5 mm and the overall length amounting to 526 mm.

**Figure 1**. A practical example of transferring viscous media

By placing the device in the vertical position, the medium inlet is located on the bottom side, and the outlet is vertically aligned to the coil at the top of the device. By the use of reduction and coupling, a PVC flexible tube with the inner diameter amounting to ∅ 30 mm is connected to the inlet (pressure) side and is used for transporting a viscous medium into the smaller plastic container. The selected material of the experimental device is adapted to its usage in food, pharmaceutical and chemical industry. The drive shaft of the drive device, the worm coil and the cylindrical casing are made of stainless steel (NIROSTAL 4541). The casing with a bearing and the shaft collar are made of bronze (GBZ 14) [7]. Other device elements are made of hard PVC material. Two worm coils tightly screwed to the shaft with the diameter amounting to ∅ 10 mm were made for the purpose of experimental measuring. The external diameter of coil 1 amounted to $D_1$ = 24 mm, coil pitch amounted to $s_1$ = 29 mm. The external diameter of coil 2 amounted to $D_2$ = 34 mm, whereas the coil pitch amounted $s_2$ = 14 mm (Figure 2).

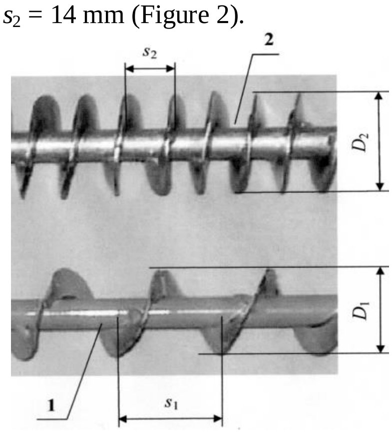



**Figure 2.** Coil diameter and pitch 1 and 2

The inclination angle of coil 1 amounted to $\gamma_1$ = 15 °, and the inclination angle of coil 2 amounted to $\gamma_2$ = 30 °. The coils are shown in Figure 3 and the longitudinal cross-section of the experimental device is shown in Figure 4a. The external appearance of the experimental device is shown in Figure 4b.

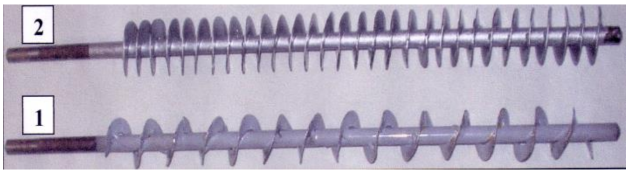
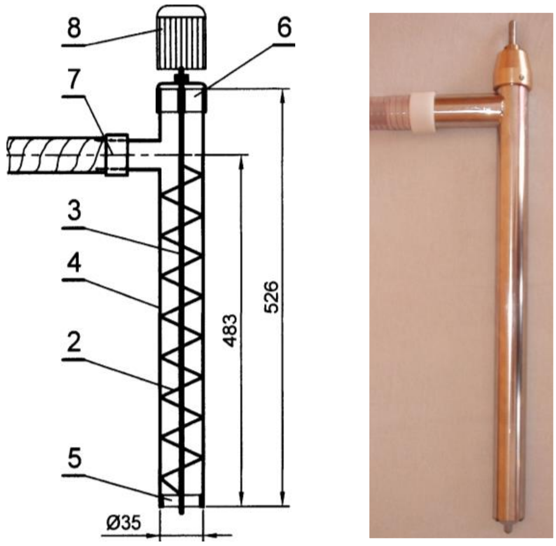



**Figure 3**. Worm coil 1 and 2

A drive electric motor with a modifiable number of rotations $n_{max.}$ = 3000 min$^{-1}$ and maximum power amounting to $P$ = 1000 W was mounted on the shaft of the experimental device. During the experiment the number of rotations of the electric motor amounted to $n$ = 2700 min$^{-1}$, and the electric energy $P_e$ was measured by an integrated electronic device for measuring the electric energy consumption. Time of transferring selected media of various viscosities $t$ was measured by a digital stopwatch. The mass $m_{P(1,2)}$ of empty plastic containers P1 and P2, i.e. containers with a medium $m_{PM(1,2)}$ was measured before and after the transfer by digital scales.

The mass of each of the experimental media at the temperature amounting to 20 °C was determined based on the following relation:

$$m_M = m_{PM(1,2)} - m_{P(1,2)} \quad \text{kg.} \tag{1}$$




a b

2. Coil 2, 3. Shaft, 4. Tube (stator)
5. Sliding bearing, 6. Ball bearing with a shaft collar
7. Coupling with reduction, 8. Electric motor

**Figure 4**. Experimental device for transferring viscous media

Due to relatively high price of media of various viscosities, an available amount adapted to purchase possibilities and experiment conditions was used. Mass flux of a medium was determined according to the following expression:

$$\bar{m} = \frac{m_M}{t} \quad \text{kg/s.} \tag{2}$$

## 3. EXPERIMENTAL MEASURING

### 3.1. The first experimental measuring

It was carried out by positioning plastic containers P1 and P2 on a horizontal surface one next to another, as shown in Figure 5.

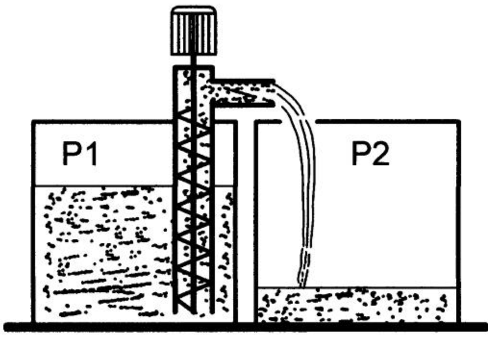



**Figure 5.** The scheme of the first experiment

Transferring media of various viscosities was carried out by using an experimental device with the worm coil 1, and then with the worm coil 2, without a flexible tube being connected to the outlet (pressure) opening of the device. The results of the first experimental measuring $(t, m, \bar{m}, P_e)$ at $n$ = 2700 min$^{-1}$ of the drive electric motor of the experimental device are shown in table 1.

**Table 1**. Results of the first experimental measuring

| Medium | μ Pa s | $t$ s | $m$ kg | $\bar{m}$ kg/s | $P_e$ W s |
|---|---|---|---|---|---|
| | Coil 1 | | | | |
| Glycerol | 1.49 | 27 | 9.4 | 0.35 | 480 |
| Sorbitol | 0.210 | 46 | 10 | 0.22 | 450 |
| Liquid paraffin | 0.189 | 50 | 6.1 | 0.12 | 441 |
| Water | 0.001 | 254 | 7.4 | 0.03 | 415 |
| | Coil 2 | | | | |
| Glycerol | 1.49 | 19 | 9.6 | 0.50 | 780 |
| Sorbitol | 0.210 | 42 | 9.8 | 0.23 | 644 |
| Liquid paraffin | 0.189 | 43 | 6.3 | 0.19 | 650 |
| Water | 0.001 | 65 | 7.7 | 0.05 | 490 |

### 3.2. The second experimental measuring

The distance between plastic containers P1and P2 of equal volumes amounts to the length of the flexible pipeline $l$ = 1.3 m with the inner diameter amounting to ∅ 30 mm, as shown in Figure 6.

This distance is often applied in practice when media are transferred from one into another container, both of which are placed on a flat surface. The results of the second experimental measuring $(t, m, \bar{m}, P_e)$ at $n$ = 2700 min$^{-1}$ of the drive electric motor of the experimental device are shown in table 2.

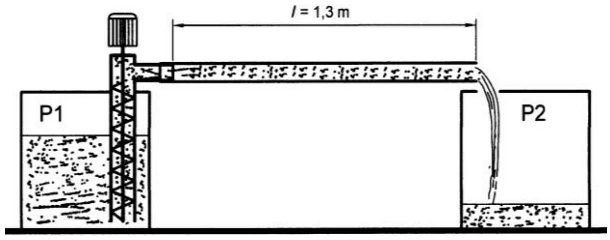



**Figure 6**. The scheme of the second experiment

**Table 2.** Results of the second experimental measuring

| Medium | μ Pa s | $t$ s | $m$ kg | $\bar{m}$ kg/s | $P_e$ W s |
|---|---|---|---|---|---|
| | Coil 1 | | | | |
| Glycerol | 1.49 | 30 | 9.1 | 0.30 | 489 |
| Sorbitol | 0.210 | 49 | 9.7 | 0.21 | 455 |
| Liquid paraffin | 0.189 | 54 | 5.9 | 0.11 | 448 |
| Water | 0.001 | 296 | 7.1 | 0.02 | 419 |
| | Coil 2 | | | | |
| Glycerol | 1.49 | 23 | 9.3 | 0.40 | 780 |
| Sorbitol | 0.210 | 45 | 9.4 | 0.21 | 650 |
| Liquid paraffin | 0.189 | 46 | 5.8 | 0.11 | 648 |
| Water | 0.001 | 71 | 7.0 | 0.1 | 419 |

### 3.3. The third experimental measuring

Exceptions from usual practice sometimes refer to transferring media from container P1 into container P2 that is located at a height greater than container P1. For the length of the PVC pipeline $l$ = 1.3 m the maximum inclination angle between the horizontal surface at the location of the pressure connection with the experimental device and a flat sloped pipeline amounts to α = 70 ° (Figure 7).

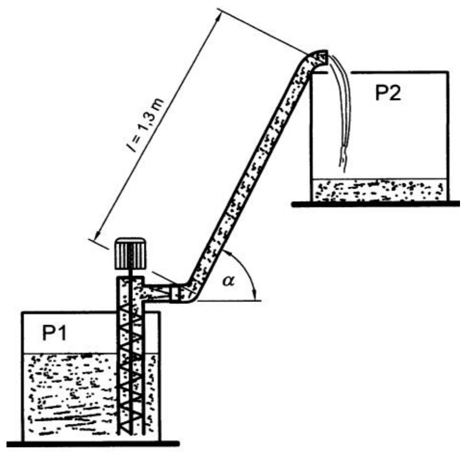



**Figure 7**. The scheme of the third experiment

Quantified values of the third experimental measuring $(t, m, \bar{m}, P_e)$ at $n$ = 2700 min$^{-1}$ of the drive electric motor of the experimental device are shown in table 3.

**Table 3.** Results of the third experimental measuring

| Medium | μ Pa s | t s | m kg | $\bar{m}$ kg/s | $P_e$ W s |
|---|---|---|---|---|---|
| | Coil 1 | | | | |
| Glycerol | 1.49 | 36 | 9.0 | 0.25 | 489 |
| Sorbitol | 0.210 | 56 | 9.3 | 0.16 | 457 |
| Liquid paraffin | 0.189 | 58 | 6.0 | 0.10 | 449 |
| Water | 0.001 | --- | --- | --- | --- |
| | Coil 2 | | | | |
| Glycerol | 1.49 | 28 | 9.1 | 0.33 | 788 |
| Sorbitol | 0.210 | 51 | 9.2 | 0.18 | 673 |
| Liquid paraffin | 0.189 | 53 | 5.9 | 0.10 | 655 |
| Water | 0.001 | 79 | 7.1 | 0.09 | 476 |

## 3.4. The fourth experimental measuring

For the purpose of checking the maximum transport height of tested media by using the experimental device (immersed in the container P1) with coil 1 and coil 2, a flat PVC pipeline with the length amounting to 7.5 m and inner diameter amounting to ∅ 30 mm was connected to its outlet side, as shown in Figure 8. Pipeline slope in relation to the horizontal surface amounted to α = 70 °.

By turning the electric motor of the drive device on at a constant number of rotations $n$ = 2700 min$^{-1}$ and after time $t$ = 60 s had expired, during the usage of glycerol (1), sorbitol (2) and liquid paraffin (3), i.e. $t$ = 240 s during the usage of water (4), pipeline lengths $l$(1), $l$(2), $l$(3) and $l$(4) on which the medium level had stabilized were measured. The height $h_{max}$ (1, 2, 3, 4) was determined according to the following:

$$h_{max}(1,2,3,4) = l(1,2,3,4)\cdot\sin\alpha \quad \text{m}. \tag{3}$$

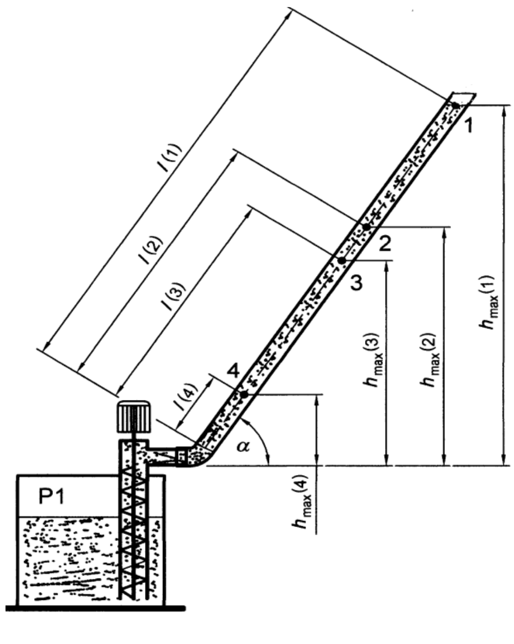



**Figure 8.** The scheme of the fourth experiment

Measurement results [$l$(1,2,3,4), $P_e$] and calculated values of $h_{max}$(1,2,3,4) are shown in table 4.

**Table 4.** Results of the fourth experimental measuring at $n$ = 2700 min$^{-1}$ of the drive electric motor of the experimental device

| Medium | μ Pa s | l m | $h_{max}$ m | $P_e$ W s |
|---|---|---|---|---|
| | Coil 1 | | | |
| Glycerol (1) | 1.49 | 2.13 | 2 | 487 |
| Sorbitol (2) | 0.210 | 1.7 | 1.6 | 458 |
| Liquid paraffin (3) | 0.189 | 1.49 | 1.4 | 454 |
| Water (4) | 0.001 | | 0.5 | 403 |
| | Coil 2 | | | |
| Glycerol (1) | 1.49 | 7.45 | 7 | 687 |
| Sorbitol (2) | 0.210 | 4.8 | 4.5 | 600 |
| Liquid paraffin (3) | 0.189 | 4.26 | 4.0 | 554 |
| Water (4) | 0.001 | 1.6 | 1.5 | 465 |

## 4. RESULTS ANALYSIS

By experimental transferring of available media of various viscosities the functionality of the experimental device with worm coils 1 and 2 was proven. Experiments were carried out at $n$ = 2700 min$^{-1}$ of the drive electric motor of the experimental device. The pitch and inclination angle values of coil 2 are twice as high the ones referring to coil 1. The free cross-section between the stator (casing) of the experimental device and coil 1 amounts to 53%, whereas between the stator and coil 2 it amounts to 5.6% of the overall cross-section. At atmosphere pressure and temperature amounting to 20 °C water viscosity is significantly lower (between 189 and 1490 times) than the viscosity of media used in experimental measuring.

During the transferring of media of higher viscosity (liquid paraffin, sorbitol, glycerol) using coil 2 in the experimental device, the consumption of electric energy is higher by about 30% to 38% in comparison to transferring the same media using the experimental device with coil 1. For approximately equal medium mass in somewhat shorter intervals, the mass flux of glycerol was increased by around 25% to 30% by using the experimental device with coil 2, regardless of the position of the container P2. The transport of water from container P1 to container P2 is negligible and the experimental device cannot be used for transferring media of very low viscosity. With the increase of medium viscosity the transport height $h_{max}$ increases around 2.6 – 3.5 times during the medium transfer using the experimental device with coil 2 in comparison to the one with coil 1. The consumption of electric energy is higher by around 25% to 30% at driving the experimental device with coil 2.

## 5. CONCLUSION

Due to high costs and complex construction of pumps for transferring very expensive media of various (often high) viscosities, a significantly cheaper and simpler experimental device was designed and experimentally tested using available media of various viscosities. The experiments confirmed its functionality and maximum transport height. In experimental conditions and approximately equal time intervals the following was determined: the transported mass of media of various viscosities, mass flux and consumed electric energy of the device with worm coil 1 and 2. The height $h_{max}$ is significantly affected by the free space between the stator (casing) and the coil. Better results were achieved by using coil 2. Further research should aim at optimizing the geometrical shape of the worm coil, maximal reducing the free space depending on the transfer rate and medium viscosity. Furthermore, mathematical models with experimental checkup of transferring media of higher to maximally possible viscosity up to the limit of technical applicability and cost-effectiveness of the device are to be developed.

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