# STUDY OF THE ENERGY EFFICIENCY OF THE UDS 214 EXCAVATOR HYDRAULIC SYSTEM

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The paper deals with the comparison of the energy consumption of hydraulic systems for controlling the moves of the UDS 214 telescopic excavator. To compare energy losses in the hydraulic circuits for controlling the UDS 214 excavator moves, the flow rates of hydraulic oil were measured with a Hydrotechnik MultiSystem 5060 digital meter in these hydraulic circuits. Firstly, for the state of the UDS 214 excavator before the hydraulic system upgrade and then for the state of the excavator after the hydraulic system innovation. For the each hydraulic circuit, the hydraulic oil flow rates between the Bosch Rexroth A8VO107 double axial piston pump and the Bosch Rexroth 7M8-22 manifold were measured firstly and subsequently between the manifold and the appliance. The total power losses of the individual hydraulic circuits were then determined from the values measured in this way and applying a number of calculations. From these calculated power losses, the efficiency of individual hydraulic circuits was evaluated in the excavator state before and after the hydraulic system innovation.

**KEYWORDS**

hydraulic, excavator, efficiency, energy, pressure loss, power loss

## 1 INTRODUCTION

The paper is directly related to the authors' previous study Influence of the Excavator Hydraulic System Efficiency on the Productivity, which was after the reviewing process recommended for publication in a scientific journal Research in Agricultural Engineering. This study describes hydraulic systems of the telescopic excavator UDS 214 in the original state from manufacturer. Testing methods using combined meters in hydraulic circuits for controlling the working movements of the UDS 214 telescopic excavator tool was the same as described below in this contribution. From the measured values of the hydraulic oil flow rate, the total power losses and the overall efficiencies of the hydraulic circuits were also calculated as in this paper, but as already mentioned, this evaluation was made for the original state of the hydraulic system.

With regard to the calculated power losses of the hydraulic circuits and their calculated and measured efficiencies and taking into account the percentage of average time when the hydraulic circuit participated on the measured total operating time of the UDS 214 telescopic excavator, a hydraulic circuit of turning the swing body was chosen as a suitable hydraulic circuit for innovation. This finding and identification of a suitable hydraulic system for innovation was also the main goal of the mentioned previous study. The aim of this paper is to calculate the total power losses for individual hydraulic circuits controlling the working movements of the telescopic excavator tool from the measured values of hydraulic oil flow rates. However, the main goal of this paper is to compare the total power losses and measured and calculated efficiencies of individual hydraulic circuits in the state before and after the innovation of the excavator's hydraulic system. Another goal is to answer the question of whether and how much this innovation of the hydraulic system is advantageous in terms of reducing power loss and increasing the average efficiency of individual hydraulic circuits for controlling the working movements of the UDS 214 telescopic excavator tool.

The energy losses, mentioned in the paper, do not represent an absolute energy loss, but an undesirable conversion of the hydraulic energy according to the principle of the energy conservation.

## 2 MATERIAL AND METHODS

### 2.1 Description of the Telescopic Excavator UDS 214

The UDS 214 telescopic excavator on a three-axle Tatra 815 truck chassis is designed for finishing earthworks and, with the use of suitable additional equipment for excavation and other earthworks (excavation of foundation trenches, canals, construction and maintenance of utility networks) [CSM Industry s.r.o. 2020]. At present, the UDS 214 telescopic excavator is used for the mining of soil of the I. and II. classes according to the standard ČSN 73 6133 [ČSN 73 6133 2010]. The excavator is also suitable for dealing with the consequences of emergencies such as floods, landslides, and also statically disturbed buildings. The UDS 214 telescopic excavator is used both in the private sector and in the armed forces and fire brigades, for example in the Czech and Slovak Republics. The machine can also be equipped with a microtravel [Juza et al. 2020].

This means that the operator can drive the excavator around the construction site with the help of the John Deere 4045 excavator engine and the hydraulic system without the help of the combustion engine of the Tatra chassis. The operator can also control the direction of travel of the Tatra 815 chassis, control the parking brake, extend and retract the stabilizer supports of the excavator, all from the operator's cab of the UDS 214 excavator.

The power unit of the UDS 214 telescopic excavator is an inline four-stroke liquid-cooled four-cylinder John Deere 4045 diesel engine with direct fuel injection. The power of this engine, in the state before the hydraulic system innovation, is 94 kW at 2200 $min^{-1}$. After the hydraulic system innovation, the engine power has to be increased to the upper limit of the power range for this engine to 129 kW at 2200 $min^{-1}$ [Deere & Company 2022].

The engine drives axial piston pumps, which supplies the pressurized hydraulic oil to the hydraulic circuits of the excavator's working movements allowing the UDS 214 telescopic excavator to perform the five basic movements of the working tool:

- extending and retracting the inner telescopic boom,
- raising and lowering the telescopic boom,
- turning the working tool (using the swivel head),
- opening and closing the working tool,
- turning the swing body of the UDS 214 excavator [Juza et al. 2020].

The paper does not include schemes of individual hydraulic circuits of the UDS 214 excavator, due to the limited size of this text. Particular schemes of hydraulic circuits for controlling the working moves of the excavator are available from authors on request.


**Figure 1.** Telescopic excavator UDS 214 on the Tatra 815 truck

**1** – boom; **2** – inner telescopic arm; **3** – rotating head; **4** – depth five-teeth bucket of the 0.63 m$^3$ volume; **5** – lower frame; **6** – telescopic excavator UDS 214; **7** – Tatra 815 truck (cabine).

Because the operator does not use the hydraulic circuit for turning the working tool during a soil usual mining, which is used only for special operations such as sloping, and this movement is not included in the standard scheme of the excavator work cycle. Therefore, the hydraulic system for turning the working tool was not tested in this paper [Juza et al. 2020].

### 2.2 *Hydraulic system of the UDS 214 telescopic excavator after the innovation*

In the state before the hydraulic system innovation of the UDS 214 telescopic excavator, the pressurized hydraulic oil for all five hydraulic circuits controlling the excavator's working movements is supplied only by the Bosch Rexroth A8VO107 double axial piston pump, which is distributed via a seven-section Bosch Rexroth 7M8-22 mono-bloc manifold to appliances [Bosch Rexroth AG 2021a].

After the hydraulic system has been innovated, this Bosch Rexroth A8VO107 axial piston double pump supplies hydraulic oil via the seven-section mono-bloc manifold Bosch Rexroth 7M8-22 to only four hydraulic circuits for controlling the working movements of the UDS 214 excavator, namely:

- into the linear hydraulic motor of the inner telescopic boom,
- into a pair of linear hydraulic motors for the boom stroke,
- into a pair of rotary hydraulic motors of the rotating head,
- and also into the linear hydraulic motor of the tool.

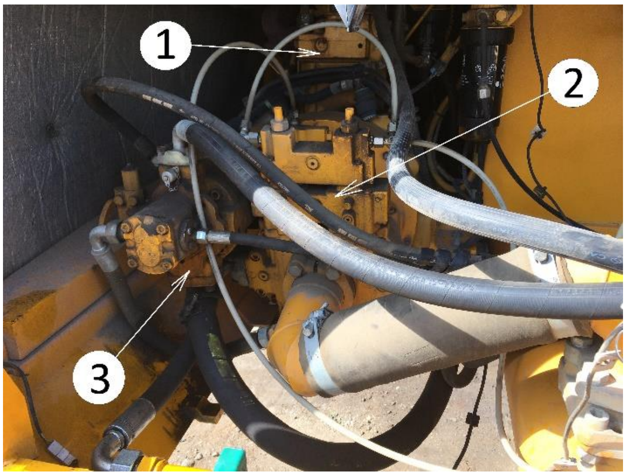


**Figure 2.** Side view of the UDS 214 telescopic excavator unit after the hydraulic system innovation

**1** – the engine John Deere 4045; **2** – the axial piston double pump Bosch Rexroth A8VO107; **3** – added axial piston pump Bosch Rexroth A10VO45 for the hydraulic circuit of swing body turning.

The innovation of the hydraulic system of the telescopic excavator UDS 214 consists in the separation of the hydraulic circuit of the excavator swinging body turning. This separation was achieved due to the addition of another axial piston pump, the Bosch Rexroth A10VO45, to the output drive from the Bosch Rexroth A8VO107 axial piston pump. This new axial piston pump supplies pressure hydraulic oil, via a single-section hydraulic manifold Bosch Rexroth 1MO-16, only to the rotary hydraulic motor of the body turning [Bosch Rexroth AG 2021d]. This single-section hydraulic distributor is also added compared to the state of the excavator before the hydraulic system was innovated.

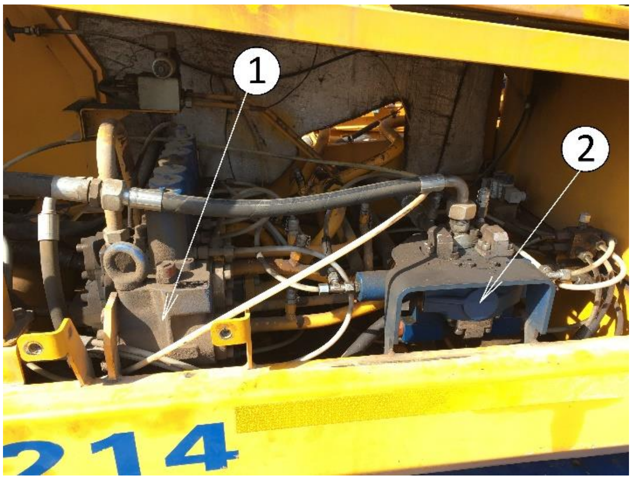


**Figure 3.** Hydraulic distributors of the UDS 214 telescopic excavator after the hydraulic system innovation

**1** – the seven-section Bosch Rexroth 7M8-22 mono-bloc manifold; **2** – added single-section hydraulic manifold Bosch Rexroth 1MO-16 for the hydraulic circuit of swing body turning.

### 2.3 *Methods of Measurement*

For each measured hydraulic circuit, the measurement was performed first between the axial piston pump and the hydraulic distributor. Subsequently, measurements were performed in the hydraulic line between the hydraulic manifold and the appliance. The term appliance refers to a hydraulic cylinder or a pair of hydraulic cylinders or also a rotary hydraulic motor.


**Figure 4.** Connection of the analog meter OTC H50 and the digital meter Hydrotechnik MultiSystem 5060 to the tested hydraulic circuit (measurement at the beginning of the hydraulic circuit of the excavator body turning)

Two combined meters were used in the measurement. One is digital from HYDROTECHNIK GmbH with the designation MultiSystem 5060 [Hydrotechnik GmbH 2012] and the other is analog from Owatonna Tool Company with the designation OTC H50 [Bosch Automotive Service Solutions INC. 2021]. Both combined meters allow to measure the pressure (0 – 40 MPa), the flow rate (0 – 200 $dm^3 \cdot s^{-1}$) and the temperature (0 – 120 °C) of the hydraulic oil in a given hydraulic circuit. After connecting the combined meters to the measured hydraulic circuit, the testing was performed as follows:

- Setting the John Deere 4045 combustion engine speed to 1600 rpm.
- Using the joystick in the cab to set the manifold slider to the working position for the appropriate movement of the given hydraulic motor.
- Loading the hydraulic circuit by the throttle valve on the analog meter OTC H50 to the predetermined pressure.
- Using the HYDROTECHNIK MultiSystem 5060 digital meter to record the values of the hydraulic oil pressure and flow rate to the meter's memory. Writing the current hydraulic oil temperature and the engine speed to the prepared tables.

**Figure 5.** Detail of the connection of the analog meter OTC H50 and the digital meter Hydrotechnik MultiSystem 5060 during the performed measurement

When measuring the hydraulic circuits between the pump and the hydraulic distributor, where the source of pressurized hydraulic oil is an axial piston double pump with the designation A8VO107, the value of the maximum hydraulic oil setting pressure was 27 MPa. For the hydraulic circuit of the body turning, where the source of pressure hydraulic oil is an axial piston pump marked A10VO45, the value of the maximum hydraulic oil setting pressure was 24.1 MPa, when measured between the pump and the distributor.

When measuring the hydraulic circuits between the hydraulic distributor and the appliance, the maximum value of the hydraulic oil setting pressure depended on the value to which the safety pressure valve was set for the given hydraulic circuit. This value was 26 MPa for hydraulic circuits where the source of hydraulic oil pressure is an axial piston double pump and 24 MPa for the hydraulic circuit of the body turning. For calculations of hydraulic circuits between the axial piston pump and the distributor, the hydraulic oil flow rate was assumed at 27 MPa for the axial piston double pump and for the axial piston pump of the body turning was assumed pressure 24.1 MPa. This assumption refers to the fact when measuring and simulating the load at the end of the hydraulic circuit at the maximum possible pressure, the hydraulic oil pressure at the outlet of the axial piston pump would increase.

### *2.4 Measurement of the Hydraulic Circuit between the Pump and the Distributor*

Measurements in hydraulic circuits where the source of pressure hydraulic oil is an axial piston double pump with the designation A8VO107 took place as follows. When measuring the hydraulic circuit of the telescopic boom extension, the supply hydraulic hose to both combined meters was connected to the discharge of the left side of the axial piston double pump. The output hydraulic hose from the analog meter OTC H50 was connected to the left inlet to the hydraulic manifold marked 7M8-22. When testing the hydraulic circuits of the boom stroke and the opening and closing of the tool, the hydraulic supply hose to both combined meters was connected to the discharge of the right side of the axial piston double pump. The output hydraulic hose from the analog meter OTC H50 was connected to the right inlet of the hydraulic manifold marked 7M8-22. When testing the hydraulic circuit of the body turning, the supply hydraulic hose to both combined gauges was connected to the discharge of the axial piston pump marked A10VO45. The output hydraulic hose from the analog meter OTC H50 was connected to the supply to a single-section hydraulic manifold marked 1MO-16. When performing these measurements, it is necessary to shift the control joystick for the appropriate movement of the excavator tool into the working position after starting the John Deere 4045 engine, so that the swash plate of the tested axial piston pump tilts and thus the maximum hydraulic oil supply is reached.

### 2.5 *Measurement of the Hydraulic Circuit between the Manifold and the Appliance*

When measuring in the hydraulic circuit between the hydraulic manifold and the appliance, the combined meters were connected to the hydraulic circuit instead of the appliance. Instead of linear or rotary hydraulic motors. The intake hose of the combined meters was connected with the intake line to the appliance and the output hydraulic hose from the analog meter was connected to the return line from the appliance.

### 2.6 *Specified values for the state of telescopic excavator UDS 214 after inovation of hydraulic system*

***Specified values of used hydraulic oil ISO VG 46***

| | |
|---|---|
| The density at 15 °C | $\rho = 866\ kg \cdot m^{-3}$ |
| The kinematic viscosity at 40 °C | $\upsilon = 45.92\ mm^2 \cdot s^{-1}$ |

***Specified values of axial piston double pump Bosch Rexroth A8VO107***

| | |
|---|---|
| The volumetric efficiency | $\eta_v = 0.94$ |
| The mechanical hydraulic efficiency | $\eta_{mh} = 0.89$ |
| The maximum geometric volume | $V_{gmax} = 2 \times 0.107\ dm^3$ |
| The double pump input power consumption | $P = 87\ kW$ |

[Bosch Rexroth AG 2021b]

***Specified values of axial piston pump Bosch Rexroth A10VO45***

| | |
|---|---|
| The volumetric efficiency | $\eta_v = 0.975$ |
| The mechanical hydraulic efficiency | $\eta_{mh} = 0.945$ |
| The maximum geometric volume | $V_{gmax} = 0.045\ dm^3$ |
| The axial piston pump input power consumption | $P = 28\ kW$ |

[Bosch Rexroth AG 2021c]

The volumetric efficiency and the mechanical-hydraulic efficiency of the Bosch Rexroth A10VO45 axial piston pump is higher compared to the Bosch Rexroth A8VO107 axial piston pump. This is due to the better ratio between the actual calculated geometric volume of this pump from the measured hydraulic oil flow rate at a given pressure in the given hydraulic circuit and the maximum geometric volume of this axial piston pump, which is stated by the manufacturer. [Bosch Rexroth AG 2021c].

### 2.7 *Calculations*

Calculation of the actual geometric volume of the axial piston pump. The calculation is performed for each tested hydraulic circuit and for the case of measurement at the beginning and at the end of the given hydraulic circuit [Zhang 2008].

$$V_g = \frac{1000 \cdot Q}{n \cdot \eta_v} \tag{1}$$

where: $V_g$ – the actual geometric volume of the axial piston pump Bosch Rexroth A8VO107 ($dm^3$); Q – the measured hydraulic oil flow rate with the Hydrotechnik MultiSystem 5060 digital meter ($dm^3 \cdot min^{-1}$); n – the measured speed of the internal combustion engine John Deere 4045 ($min^{-1}$); $\eta_v$ – the volumetric efficiency of the axial piston double pump Bosch Rexroth A8VO107 or axial piston pump Bosch Rexroth A10VO45 (-).

Calculation of the theoretical flow rate of the axial piston pump [Akers et al. 2006].

$$Q_{th} = V_g \cdot n \tag{2}$$

where: $Q_{th}$ – the theoretical flow rate of the axial piston pump ($dm^3 \cdot min^{-1}$).

Evaluation of the overall efficiency of the axial piston pump [Wood 2005].

$$\eta_t = \frac{Q}{Q_{th}} \cdot \eta_{mh} \tag{3}$$

where: $\eta_t$ – the overall efficiency of the axial piston pump (-); $\eta_{mh}$ – the mechanical hydraulic efficiency of the axial piston pump (-).

Calculation of power loss of the axial piston pump [Götz 1998].

$$P_{LP} = (1 - \eta_t) \cdot P \tag{4}$$

where: $P_{LP}$ – the power loss of the axial piston pump (W); P – axial piston pump input power consumption (W).

## 3 RESULTS AND DISCUSSION

During the calculations, it was at first necessary to measure all geometric dimensions of the hydraulic circuit (inner diameter of hoses, pipes and length of lines) on a given excavator UDS 214 with an innovated hydraulic system on which the measurement was performed. The individual elements arranged in series were determined from the hydraulic schemes of the individual hydraulic circuits and after studying the given hydraulic circuits directly on the UDS 214 excavator with the innovated hydraulic system on which the measurements took place. These elements have always been entered in a table belonging to a certain hydraulic circuit. Each table always shows the name of the element in the hydraulic circuit, the number of pieces, the calculated value of the pressure loss $p_L$ and finally the calculated power loss of the element $P_L$. It is necessary to determine the pressure losses of all elements in the hydraulic circuit except the pump. These pressure losses in the individual elements of the hydraulic circuit, multiplied by a given measured flow rate in a given section of the hydraulic circuit, mean the power loss of the element in the hydraulic circuit. It is necessary to calculate the power loss directly for the pump. After adding up these individual power losses, we get the total power loss of the hydraulic circuit. It was necessary to calculate the pressure losses in the direct line for hydraulic hoses and hydraulic pipes, according to the values of the measured hydraulic oil flow rates in the hydraulic circuits of the UDS 214 excavator with the innovated hydraulic system. It was also necessary to calculate the pressure losses in the local resistances of the hydraulic circuits. For example, fittings (hose and steel pipe coupling or manifold neck), a 90° elbow or a safety valve. For subsequent calculations of efficiencies of individual circuits, it was first necessary to determine the values of flow and mechanical-hydraulic efficiency, geometric volume and power input of axial piston pumps. Furthermore, it was necessary to determine the pressure losses of hydraulic distributors Bosch Rexroth 7M8-22 and Bosch Rexroth 1MO-16, which are listed by their manufacturers. The theoretical pump flow rates, the overall pump efficiencies and finally the pump power losses were calculated from the known values. The individual calculated or determined pressure losses of the elements that are used in the hydraulic circuits were multiplied by the measured flow rate of the pump to the manifold to determine the power losses of the elements. And the pressure losses of the elements behind the manifold were multiplied by the actual measured flow rate at the end of the hydraulic circuit. By this procedure, the total power loss was then determined in the prepared tables for each hydraulic circuit.

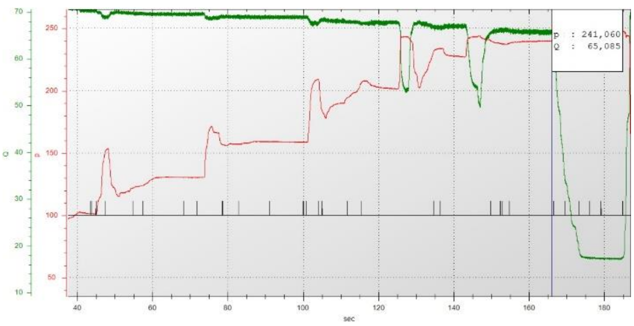

**Figure 6.** Time dependency graph of the flow rate (green line) and pressure (red line) of hydraulic oil in the hydraulic circuit for the swing body turning (measured on the axial piston pump Bosch Rexroth A10VO45) using the Hydrotechnik software

| p [MPa] | Q [$dm^3 \cdot min^{-1}$] | t [°C] | n [$min^{-1}$] |
|---|---|---|---|
| **0** | 73.2 | 35.4 | 1600 |
| **5** | 72 | 36.7 | 1596 |
| **10** | 70.7 | 38.5 | 1590 |
| **13** | 69.9 | 40.2 | 1585 |
| **16** | 69 | 41 | 1581 |
| **20** | 67.7 | 41.6 | 1578 |
| **23** | 67.2 | 42.5 | 1574 |
| **24.1** | 65 | 43.7 | 1570 |

**Table 1.** Measured data for the hydraulic circuit of the swing body turning (measured on the Bosch Rexroth A10VO45 axial piston pump)

Where: p – adjusted pressure of hydraulic oil by throttle valve of the analog meter OTC H50 (MPa); Q – measured hydraulic oil flow rate by the digital meter Hydrotechnik MultiSystem 5060 ($dm^3 \cdot min^{-1}$); t – measured hydraulic oil temperature by the digital meter Hydrotechnik MultiSystem 5060 (°C); n –measured speed of internal combustion engine John Deere 4045 by the digital tachometer in the operator's cabin ($min^{-1}$).

The actual geometric volumes of the axial piston pumps that supply the pressure hydraulic oil to the hydraulic circuits controlling the working movements of the telescopic excavator UDS 214 were calculated according to formula (1). In the specific case of the hydraulic circuit of the swing body turning where the source of pressure hydraulic oil is an axial piston pump with the designation A10VO45, the actual geometric volume of this pump, that, according to the measured hydraulic oil flow rate in this hydraulic circuit, was 0.0424 $dm^3$. Theoretical flow rates of axial piston pumps in the individual hydraulic circuits of the UDS 214 telescopic excavator with the innovated hydraulic system were calculated using formula (2). In the case of the already mentioned hydraulic circuit of the swing body turning, the theoretical flow rate of the axial piston pump was 1.11 $dm^3 \cdot s^{-1}$. The total efficiencies of the axial piston pumps in the individual hydraulic circuits of the UDS 214 telescopic excavator were calculated using formula (3). The efficiency of the axial piston pump was 0.922 for the hydraulic circuit of the swing body turning in the state after the performed innovation. Finally, the power loss of the axial piston pumps in the individual hydraulic circuits was calculated according to formula (4). The power loss of the axial piston pump marked A10VO45 in the hydraulic circuit of the swing body turning in the state after the innovation of the hydraulic system was 2.184 kW.

| **Hydraulic circuit of the turning the swing body - after innovation of hydraulic system of excavator UDS 214** | | | |
|---|---|---|---|
| **Element in the circuit** | **Number of elements** | **$p_L$ [kPa]** | **$P_L$ [W]** |
| **Axial piston pump Bosch Rexroth A10VO45** | 1 | | 2 184 |
| **90° elbow Ø 19 mm** | 1 | 8.34 | 9.03 |
| **Hose Ø 19 mm / 1160mm** | 1 | 18.56 | 20.10 |
| **Fitting Ø 20 mm** | 2 | 1.06 | 1.15 |
| **Hose Ø 20 mm / 180 mm** | 1 | 2.35 | 2.55 |
| **Fitting Ø 19 mm** | 1 | 0.66 | 0.71 |
| **Hose Ø 19 mm / 545 mm** | 1 | 8.72 | 9.44 |
| **90° elbow Ø 19 mm** | 1 | 8.34 | 9.03 |
| **Fitting Ø 19 mm** | 1 | 0.66 | 0.71 |
| **Open center control block Bosch Rexroth 1MO-16** | 1 | 67.22 | 72.8 |
| **90° elbow Ø 15 mm** | 1 | 13.99 | 12.23 |
| **Pipe Ø 15 mm / 70 mm** | 1 | 1.86 | 1.63 |
| **Fitting Ø 19 mm** | 1 | 0.43 | 0.38 |
| **Hose Ø 19 / 900 mm** | 1 | 11.63 | 10.17 |
| **90° elbow Ø 19 mm** | 1 | 5.44 | 4.76 |
| **Fitting Ø 19 mm** | 1 | 0.43 | 0.38 |
| **Total power loss $P_{LT}$ [W]** | | | **2 339.07** |

$Q_1 = 1.083\ dm^3 \cdot s^{-1}$ $Q_2 = 0.8744\ dm^3 \cdot s^{-1}$

**Table 2.** Results of calculation of the total power loss and overall efficiencies for the turning the swing body hydraulic circuit – after innovation of the hydraulic system of excavator UDS 214

Where: $p_L$ – calculated pressure loss of individual elements of the hydraulic circuit (kPa); $P_L$ – calculated energy loss of individual elements of the hydraulic circuit (W); $P_{LT}$ – total power loss of the given hydraulic circuit (W); $Q_1$ – measured hydraulic oil flow rate at Bosch Rexroth A10VO45 axial piston pump (at the beginning of the hydraulic circuit for turning the excavator swing body); $Q_2$ – measured hydraulic oil flow rate before the input of the rotary hydraulic motor (the end of the hydraulic circuit for turning the excavator swing body).

For each hydraulic circuit controlling the working movements of the telescopic excavator UDS 214 in the state before and after the innovation, such a table was prepared as shown in the example of Table 2. Final comparison of individual hydraulic circuits in the state before and after the innovation of the hydraulic system of the telescopic excavator UDS 214 with the stated total power losses of the individual hydraulic circuits and a comparison of the total calculated efficiencies can be seen in Table 3. The comparison of the power loss savings and the average efficiency increase for each hydraulic circuit is given in Table 4.

| Hydraulic circuit | Before innovation | | After innovation | |
|---|---|---|---|---|
| | Total power loss $P_{LT}$ [W] | Calculated $\eta_c$ [-] | Total power loss $P_{LT}$ [W] | Calculated $\eta_c$ [-] |
| Turning the swing body | 8605.20 | 0.802 | 2339.07 | 0.916 |
| Telescopic boom stroke | 8573.55 | 0.803 | 7630.98 | 0.825 |
| Opening and closing the working tool | 8695.57 | 0.800 | 7743.56 | 0.822 |
| Extending the telescopic boom | 9520.79 | 0.781 | 8212.47 | 0.811 |

**Table 3. Comparison of total power losses and total calculated efficiencies of individual hydraulic circuits in the state before and after the innovation of the hydraulic system of the UDS 214 excavator**

Where: $P_{LT}$ – total power loss of the given hydraulic circuit (W); $\eta_c$ – overall efficiency of hydraulic circuits obtained by calculation (-).

| Hydraulic circuit | Saving power loss [W] | Increase in efficiency of the hydraulic circuit by [-] |
|---|---|---|
| Turning the swing body | 6266.13 | 0.114 |
| Telescopic boom stroke | 942.57 | 0.022 |
| Opening and closing the working tool | 952.01 | 0.022 |
| Extending the telescopic boom | 1308.32 | 0.030 |

**Table 4. Comparison of savings in total power losses and increasing the total calculated efficiency of individual hydraulic circuits for controlling the working moves of the telescopic excavator UDS 214**

## 4 CONCLUSIONS

From Tables 3 and 4, it is clear that for all hydraulic circuits for controlling the working movements of the UDS 214 telescopic excavator tool, the total power loss of the hydraulic circuits decreased and the calculated total efficiency increased in the state of the hydraulic system after the innovation. In the hydraulic circuits of the telescopic boom stroke, the working tool opening and closing, and the telescopic boom extension, where the source of the hydraulic pressure oil is a Bosch Rexroth A8VO107 axial piston pump and this hydraulic pressure oil is distributed to the mentioned hydraulic circuits via a seven-section mono-bloc manifold Bosch Rexroth 7M8-22. Here, the average reduction in total power loss is by 1.067 kW in these hydraulic circuits. Concurrently, the average overall efficiency obtained by calculation increased by 0.024 in these hydraulic circuits. In the case of the hydraulic circuit of the UDS 214 swing body turning after the innovation, the source of the hydraulic pressure oil is the axial piston pump Bosch Rexroth A10VO45, which supplies this via the single-section manifold Bosch Rexroth 1MO-16 to the swing body hydraulic motor. Here, the power loss was reduced by 6.266 kW and concurrently the overall efficiency obtained by calculation of the hydraulic system was increased by 0.114.

I have a positive responses from owners and operators, who have three UDS 214 telescopic excavators with the innovated hydraulic system in their company fleet. According to their practical experience, the biggest advantage of the telescopic excavator with an innovated hydraulic system against the telescopic excavator with a hydraulic system in its original state is that they can concurrently use three hydraulic circuits to control the working movements of the tool at the same time. This is not possible with the UDS 214 telescopic excavator without the hydraulic system innovation. The UDS 214 telescopic excavator without innovated hydraulic system allows a maximum of two simultaneous movements of the working tool at the same time. An aspect of the issue, which is to quantify the actual operating performance of the telescopic excavator UDS 214 with an innovated hydraulic system and its comparison with the excavator in its original state from the manufacturer is the subject of the further research.


## ACKNOWLEDGMENTS

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