Development of a user application for optimizing the procedure of compressed air consumption calculation

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Abstract: *The procedure of reading and processing data from measuring devices or sensors is often difficult due to the need for manual recalculation of the obtained data on the computer. In this work, the consumption of compressed air was read from the "AirBox" measuring device. When transferring the read data to the computer, they are converted into a CSV file format. Up to now, the processing of that data on the computer involves manual recalculation of the consumption by the user using the entered expressions for the consumption of compressed air. In order to avoid manual calculation of compressed air consumption, a user application was developed which, based on the received CSV file, determines consumption and provides graphical and textual accompanying explanations. At the end, the validation of the work results was carried out. Possible errors and the time required for calculation are reduced.*

Key words: *Application development, Pneumatic systems, Energy efficiency, consumption of compressed air*

1. INTRODUCTION

Compressed air (CA) is a very widespread form of energy in industry. Accordingly, quality and rational consumption should be taken into because CA is an expensive source of energy. The cost of electricity for the production of CA can rise up to 20% of the cost of total electricity consumption in the industry (Blagojevic, 2020). The first step in reducing the consumption of CA is to measure current consumption.

Problems in pneumatic systems that lead to increased consumption as well as ways of saving are not easy to quantify. One of the reasons for this is that accurate and invasive measurements are necessary at the point of application of the compressed air system (CAS) (Eret, 2012). On the demand-side, the inefficiency of CA manifests itself in three ways: leakages, artificial demand and inappropriate uses, which can lead to the consumption of over 50% of the available CA (Abela, 2022). Among these losses, the most visible and significant sources of CA losses are leakages. CA leakage accounts for 20% to 40% of total CA losses (Dudic, 2012).

Determining possible sources of losses, as well as detecting faults in the CAS in the form of additional consumption of CA, leads to the selection of an adequate device for measuring indicators in the case of CA consumption. It is possible to use a wide range of devices, from gas detectors, ultrasonic detectors and thermal cameras, to portable devices and sensor stations. According to the mentioned ways of CA losses, the Air Box device, type GHDA-FQ-M-FDMJ-A, from Festo, was specifically selected.

The measured data from the Air Box must be transferred to the computer for further processing. The usual procedure according to the manufacturer's recommendation implies that the data is transferred to the computer using the manufacturer's specialized software through RS232 socket. The procedure for connecting the computer to the measuring device is shown in Figure 1. Doing so, files in CSV format are stored on the computer. The obtained files can be processed on the computer using software such as MATLAB, Excel, and the like. The CSV file also contains data that is not directly related to consumption calculation, such as date and time, file name etc. Concretely, when calculating the consumption of CA, it is necessary to manually select the rows and columns from the CSV file on the basis of which the software will calculate the consumption.

2. COMPRESSED AIR FLOW MEASUREMENT

In this work, the Air Box is used as a device to measure the flow of CA. On the basis of the collected data, the consumption of CA is calculated. Also, the Air Box measuring device can be used to determine air quality and to measure values such as pressure and temperature. Also, in this way, other indicators of CA losses in pneumatic systems can be reached. Functionality and proper use of Air Box can be found in the user manual of the device (Festo, 2006).

Figure 1: Connection of computer with Air Box measuring device

2.1 Compressed air consumption calculation

The current way of calculating CA consumption implies the appropriate selection of parameter values from the downloaded CSV file. An equation for the calculation of total CA consumption is:

$$Q = \sum_{i=1}^{n}(t_i - t_{i-1})\frac{(q_i + q_{i-1})}{2} \tag{1}$$

where:
Q – is total measured consumption [Nl]
t_i – is i^{th} time moment of flow measurement [s]
t_{i-1} – is i^{th-1} moment of flow measurement [s]
q_i – is flow measurement in the ith time moment [Nl/min]
q_{i-1} - is flow measurement in the i^{th-1} time moment [Nl/min].
The sum represents the digital equivalent of the CA flow integral, at discrete time instants.
The difference between (t_i - t_{i-1}) represents the selected period of time when the measurement with the Air Box was made. So, for the predetermined value of the selected period of time, this difference is constant and does not have to be calculated every time. Instead, a constant value t_p can be entered. Equation (1) is now simplified by extracting the constant terms in front of the sum:

$$Q = \frac{1}{2}t_p \sum_{i=1}^{n}(q_i + q_{i-1}) \tag{2}$$

where t_p [s] is the selected period of time, and represents the time that elapses between two consecutive CA flow measurements. The value of the selected period of time for measuring CA consumption within this work is 0.05 seconds and, in this case, depends on the Air Box device.

3. USER APPLICATION FOR AUTOMATIC CALCULATION OF CA CONSUMPTION

For automatic calculation of the total CA consumption, a desktop application was developed, and it is shown in Figure 2. It is adapted to the end user with a variety of different functions, which are shown below. The application was developed in the C# programming language within Microsoft Visual Studio and contains several buttons for control. There are two ways of displaying uploaded files, graphically and in the form of a table. The visibility of calculation results and the possibility of exporting them in a PDF file were one of the primary goals during developing the application. On the graph of CA consumption, it is possible to determine the time interval within which the consumption of CA is observed by moving left-right vertical lines (green and orange). These vertical lines are located on the left and right sides of the graph. This is very important because, in a visual way, it is easy to determine one complete working cycle of a pneumatic system with a start and end time point.
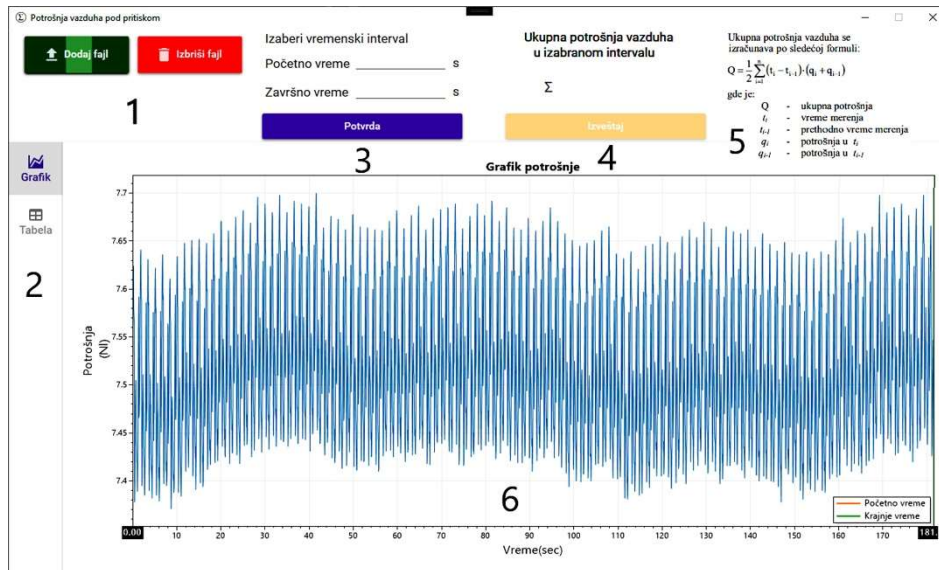
Figure 2: Application layout

The interactive panel given in Figure 2 consists of the following elements: (1) Button *Dodaj fajl* (the customized file with the measurement results from Air Box is inserted into the application, button *Izbriši fajl* serves to delete the inserted file (label 1)), (2) The *Grafik* and *Tabela* buttons (select the way of displaying the loaded data in the application itself (label 2)), (3) In the *Početno vreme* and *Završno vreme* (the desired interval is selected and after that, by pressing the *Potvrda* button, the application is informed to apply the formula to the given values (label 3)), (4) Field to display the results with the button *Izveštaj* below (pressing this button, a PDF file is created and by generating the report, data on the consumption of CA is obtained in graphic or table form, as well as the selected time interval and consumption of CA (label 4)), (5) Display of the formula (label 5) and (6) Display of graphics for the loaded file (label 6).

4. RESULTS AND DISCUSSION

By generating the report, data on CA consumption is obtained in graphic and/or table form, as well as the selected time interval. In order to validate the results, it is necessary to make sure that the created application accurately calculates CA consumption within the observed time interval. This can be checked by comparing the results obtained by the previous way of calculating the consumption of CA and the result given by the application. In this particular case, a file called Log2206.MSR was used for validation purposes. File names are automatically set in the measuring device. After uploading file Log2206.MSR into the application, the values that enable further manipulation are obtained. For one example, by choosing a time interval between 10 s and 60 s, the consumption of CA is 375.92 Nl/min, Figure 3, right.
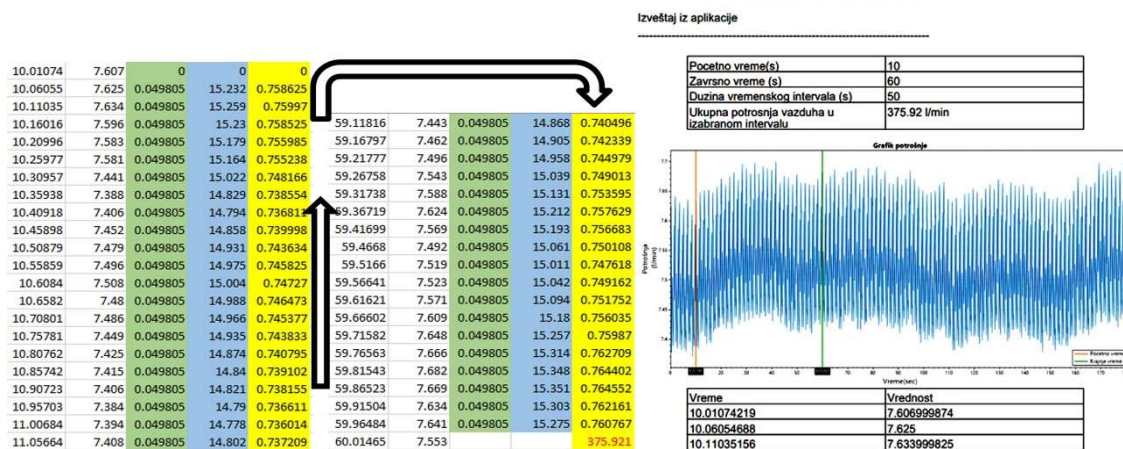

Figure 3: Excel table for manual calculation procedure (left), generated PDF report (right)

With the manual calculation of CA consumption, an Excel table was used with all necessary rows and columns obtained from the MSR file. Equation 1 was applied, for the calculation of CA consumption. The

obtained result of CA consumption is 375,921 Nl/min, which is identical to the result obtained automatically, using the developed application. The CA consumption results are provided for one, same period of time and are given in the Excel table in Figure 3, left.

5. CONCLUSION

In this paper, the need to facilitate obtaining measurement results from an appropriate measuring device was recognized. Namely, it is often necessary to adjust files with measurement results stored in the memory of the measuring device using additional software. Only customized files can be further processed on the computer in order to analyze the obtained data. Depending on the number of measurements, the process of transferring data from the measuring device to the computer may take some time. Additionally, if it is necessary to manually extract the types and columns with the required data from the downloaded files on the computer, then this procedure becomes more time-consuming. In this sense, this paper presents the idea of speeding up and facilitating this procedure with a single user application offering a universal solution for processing data obtained by measurement. Since the user does not have to manually select data fields, the possibility of error is reduced in this sense.

The advantages of the application are the display of measurement results for the selected time range in the form of a table and graph, as well as the generation of a report with measurement results in PDF format. The disadvantage of the current version of the developed application is the time that is needed for the conversion of the MSR file with data into a CSV file with data using the MSR software converter from the manufacturer. Also, after conversion, it is necessary to load the CSV file into the developed application. Future work will be to reduce the time and number of conversion steps and to directly load the file source (MSR format) obtained from the measuring device to the developed application. In this way, the mentioned shortcoming of the current version of the application would be eliminated.

7. REFERENCES

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