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PRESSURE DROP DETERMINATION ON SAND CONTROL EQUIPMENTS BY EXPERIMENTAL APPROACH

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Abstract. Several devices are used in the completion of oil wells, including sand control devices, which aim to prevent the passage of particulate solids from the reservoir to the producing well. However, the use of these equipments can provide a high pressure drop, due the design of these devices. Little is known about the fluid dynamic behavior of sand control devices applied to the petroleum industry. Therefore, this experimental study aims to understand the fluid dynamics in sand control screens by performing experiments to determine the pressure drop in sand retention components applied to oil wells in turbulent or transition flow regimes. The experimental tests were performed on an instrumented and controlled experimental bench. With the supervisory system it was possible to control the flow tested and compute the measurements regarding the pressure transducers and the flow meter. It is shown that the pressure drop in sand control screens presents a nonlinear behavior with the increase of the flow rate, increasing sharply for high flows rates. When evaluating different methodologies for determining the pressure drop, the two-point methodology proved to be more advantageous, considering that it depends on fewer pressure measurements and consequently shorter testing time, without loss of precision.

Keywords: Sand control screen, pressure drop, experimental approach.

1. INTRODUCTION

The production of formation sand into a well is a worldwide problem in oil and gas reservoirs due to its adverse effects (Mahmud et al., 2019). In this way, the control of sand in oil wells is a completion technique used not only in the Brazilian wells but also all over the world. This method is used due to the complexity inherent to the exploration of offshore production wells, usually horizontal, where unconsolidated rock formations are found, such as friable sandstone reservoirs (Magalhães et al., 2006).

The most difficult problem of the low consolidation of the sedimentary rocks is the production of particulate solids that can be carried along with the produced oil and can reach the well equipment. These particulates can cause the impairment or failure of downhole and surface equipments due erosion and abrasion wear, obstruction of the flow passage, work-overtime and expenses to service the well, collapse of the production coating and wellbore instability (Ahad et al., 2020).

For sand control, it is necessary to choose a technique among the main ones used in the oil industry, such as cased hole gravel packs, high-rate water packs, frac pack, open hole gravel packs or stand-alone screens (Armentor et al., 2007). The stand-alone screen technique is widely used due the simplicity of installation, its effectiveness in formations with moderately selected grain size and also because they constitute a low cost alternative when compared to gravel pack and frac pack methods (Santos, 2007; Pessoa, 2011). Fig. 1 shows the configuration of a *premium* screen, used in the stand-alone screen technique.

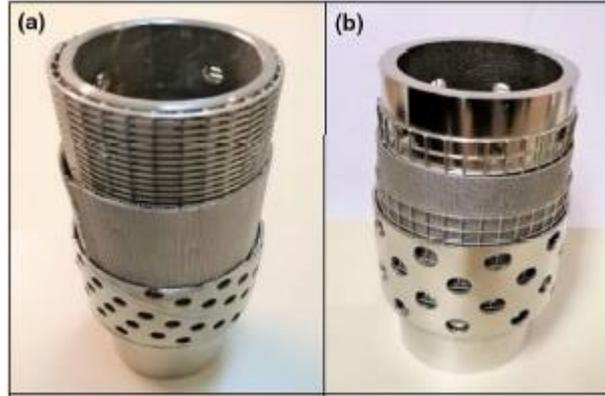


Figure 1. different types of *premium* stand-alone screens. Adapted from Ahad et al. (2020).

Once the sand control screen is installed and the oil production begin, the collapse of the formation inevitably occurs on the screen, filling the annular space of the production column with sand of the formation. Therefore, the amount of particles produced should be retained in order to avoid the risks of erosion and decreased productivity of the well due to the obstruction.

One of the main problems related to the use of sand control screens is the high pressure drop that occurs in the equipment, depending on the flow regime. The flow regime can be verified by the Reynolds number, that is the relation between the inertial and viscous forces (Reynolds, 1889), calculated by:

$$Re = \frac{8\rho\bar{u}^2}{\tau_w}, \quad (1)$$

where ρ is the fluid density, \bar{u} is the characteristic velocity and τ_w is the wall shear stress, which to a flow through a pipe, can be calculated by:

$$\tau_w = \frac{8\mu\bar{u}}{D}. \quad (2)$$

μ is the dynamic viscosity and D is the inlet pipe diameter. Relating Equations 1 and 2, the Reynolds number can also be calculated as a function of the flow rate ($Q = 4u/\pi d^2$), therefore:

$$Re = \frac{4\rho Q}{\pi\mu D}, \quad (3)$$

where Q is the flow rate. To the present study, the flow rate ranged from 150 L/h to 576 L/h, since these values correspond approximately to the actual oil production flow speeds (Procyk et al., 2015). This flow rate range corresponds to Reynolds numbers in the range from 2500 to 9700 Reynolds, therefore the flow regime evaluated was transitional and turbulent flow.

This paper aims to verify the behavior of the pressure drop in sand control screens, since knowing this dynamic behavior becomes important for the development of models that predict the physical behavior of flow in sand control devices.

2. METHODOLOGY

For the experiments, an experimental bench was used. It was necessary to construct a coupling for the samples of sand control screens, as highlighted in Fig. 2.

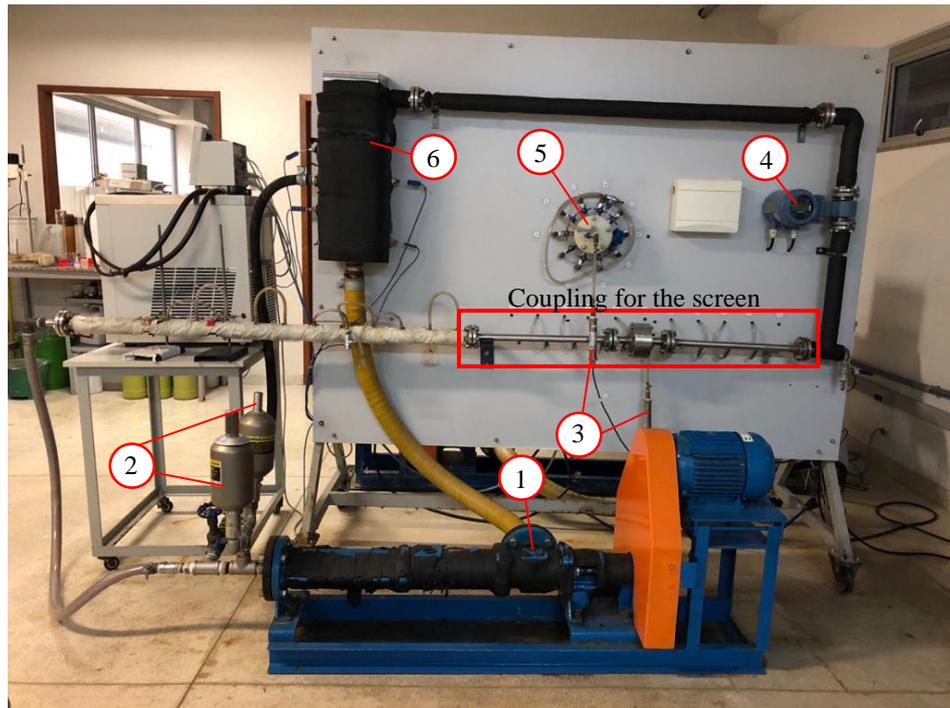


Figure 2. Configuration of the experimental bench.

The experimental apparatus, shown in Figure 2, is composed by a positive displacement pump (1); flow dampeners (2); pressure transducers (3); electromagnetic flow meter (4); manifold (5) and a reservoir (6). The measuring instruments were connected to a supervisory, allowing the measurement of pressure and flow data with a graphical interface on the computer. In addition, the coupling proposal is to ensure that the control screen is positioned perpendicular to the flow and the design was made in order to minimize the pressure drop on the coupling. Figure 3 presents an expanded view of the sand control screen coupling.

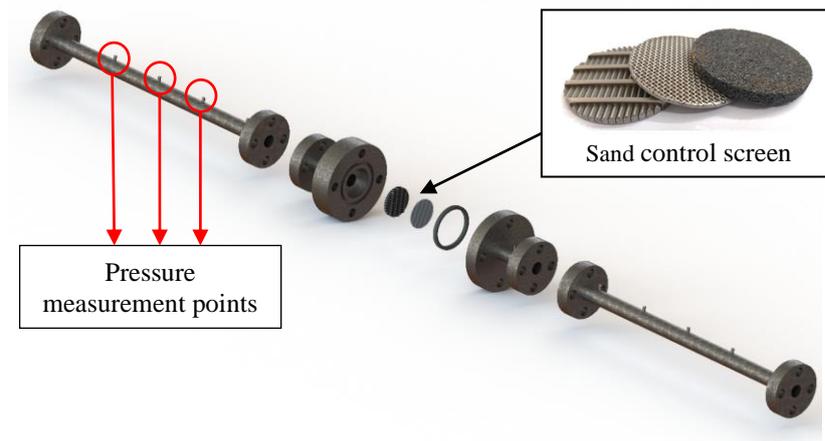


Figure 3. Coupling of the experimental bench.

For the experiments, the hydraulic circuit shown in Fig. 4 was proposed. The water contained in the reservoir (6) when driven by the pump (1), passes through flow dampeners (2) to attenuates the flow oscillations generated by the positive displacement pump. Then, the flow is directed to the test zone, having to overcome the pressure loss offered by the screen to return to the reservoir. In this way, the pressure transducers (3) convert the values from the pressure measurement points into electrical signals, which are sent to the supervisory system (Fig. 4). The electromagnetic flow meter (4) also communicates with the supervisory to measure the flow rate. In addition, the experimental bench also has a *bypass* (7), which is responsible for redirecting the flow in case of overpressure in the test zone of the screen.

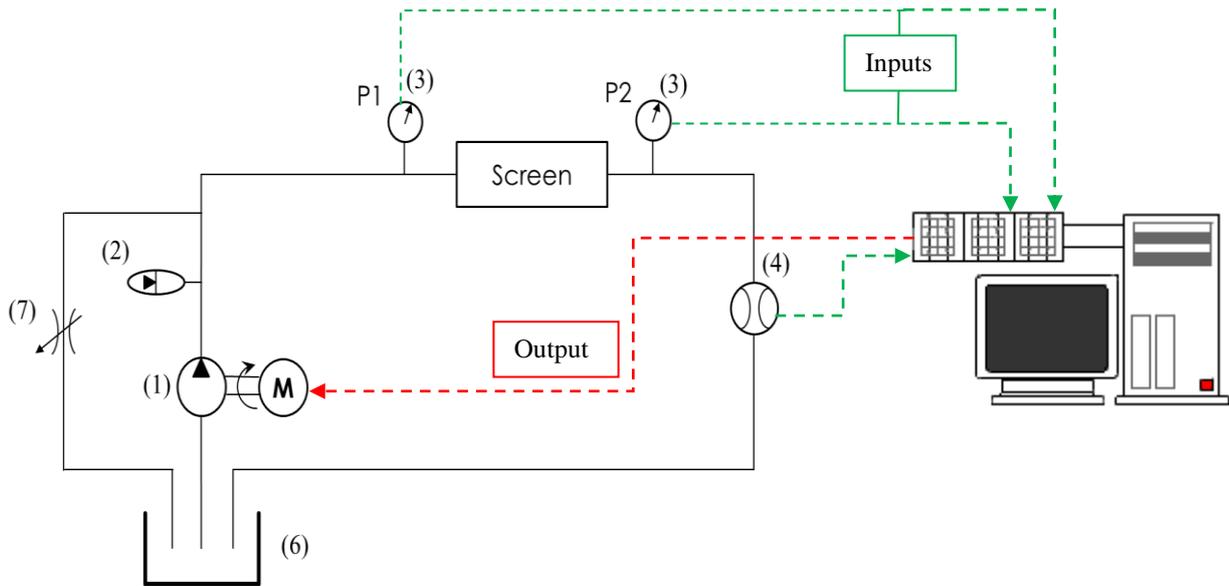


Figure 4. hydraulic cycle of the experimental bench and supervisory system.

With the supervisory system it was also possible to control the flow rate through the frequency of rotation of the pump, as shown in Fig.4. For this, a linearization curve of the discharge flow was plotted as a function of the pump rotation (Fig. 5). As can be seen in Fig. 5, the linearization represented the flow behavior as a function of the pump rotation with satisfactory adjustment coefficients. Therefore, calibration curve allowed the flow rate control. It is worth mentioning that the discharge flow rate of the pump remained constant through the experimental bench during each test, as it was set by the operator.

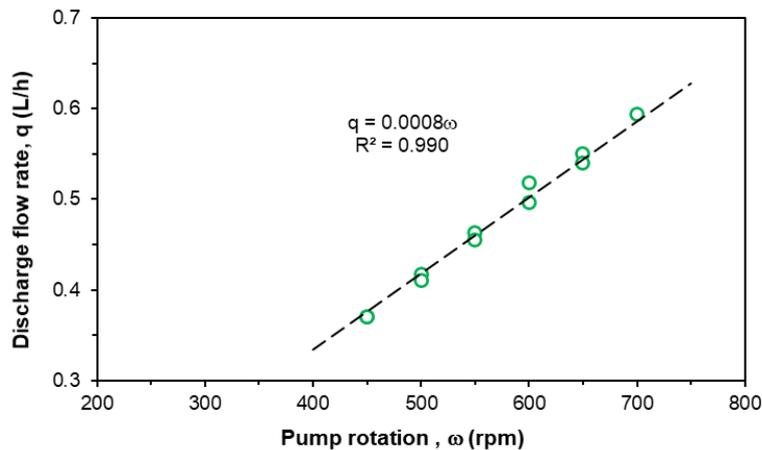


Figure 5. Flow rate linearization by pump rotation.

For each flow rate, the pressure transducers measure 2 values in one second at the pressure measurement points. The supervisory system receives these data, performs an arithmetic average with the time elapsed to obtain greater accuracy in the measurements and then computes the calculated value. For example, Fig. 6 shows the values regarding to the pressure drop over time, for specific Reynolds numbers, and also the average pressure drop value calculated by the supervisory system. Fig. 6 refers to the two-point methodology, which is used to determine the pressure drop on the screen and will be explained soon.

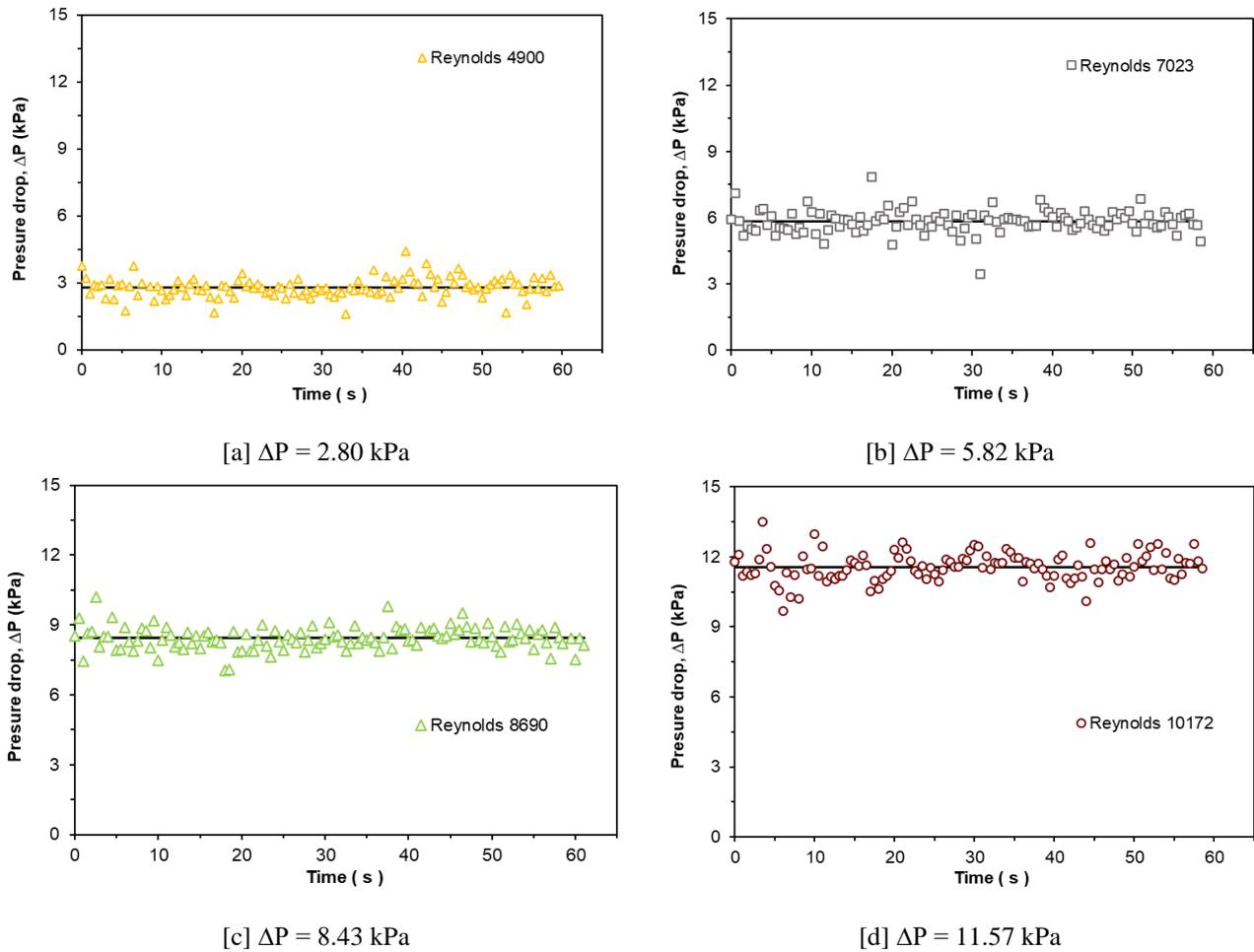


Figure 6 - Pressure drop values on the screen measured over time.

To determinate the pressure drop across the screen, two different methodologies were used. The methodology used by Kfuri et al. (2016) consist of determining the pressure at several points along the pipe before and after the screen in order to have the pressure behavior along the pipe. With the pressure behavior, two linear curves are fitted to the measured points in order to determine the pressure drop at the screen (Fig. 7). It is worth mentioning that due to the complex flow pattern close to the screen, the methodology mentioned by Kfuri et al. (2016) was also used to certify that the pressure drop has been correctly measured.

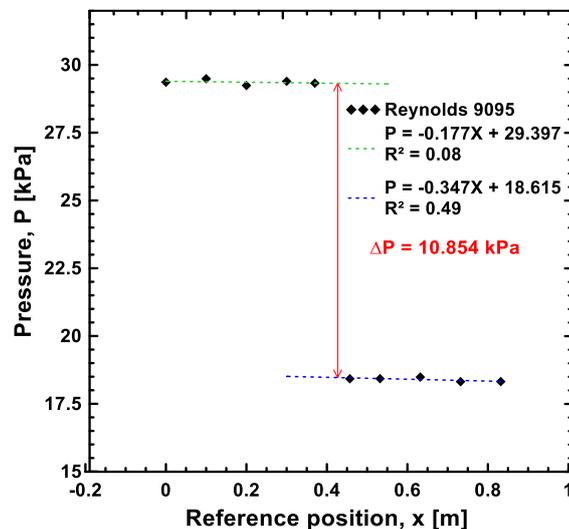


Figure 7. Determination of the pressure drop by the methodology used by Kfuri et al. (2016).

The second methodology used to determinate the pressure drop was the two-point methodology. This method consists of measuring the pressure before and after the screen and the pressure drop is obtained by the difference between the pressure measured at both points.

3. RESULTS AND DISCUSSIONS

For each methodology applied, the flow rate was controlled by the pump frequency, changing the flow rate and also the Reynolds number. The rotational speed of the pump was in the range from 450 to 700 rpm. The measurements were made in order to start at one rotational speed and after the measurement, the rotation was increased to a value corresponding to the subsequent point. After that, the tests were made again, decreasing the rotation to verify the reproducibility of the experiment.

For the method used by Kfuri et al. (2016), the pressure drop measured in each experiment (as exemplified on Fig. 7) represent one point on the pressure drop vs Reynolds number (Fig. 8).

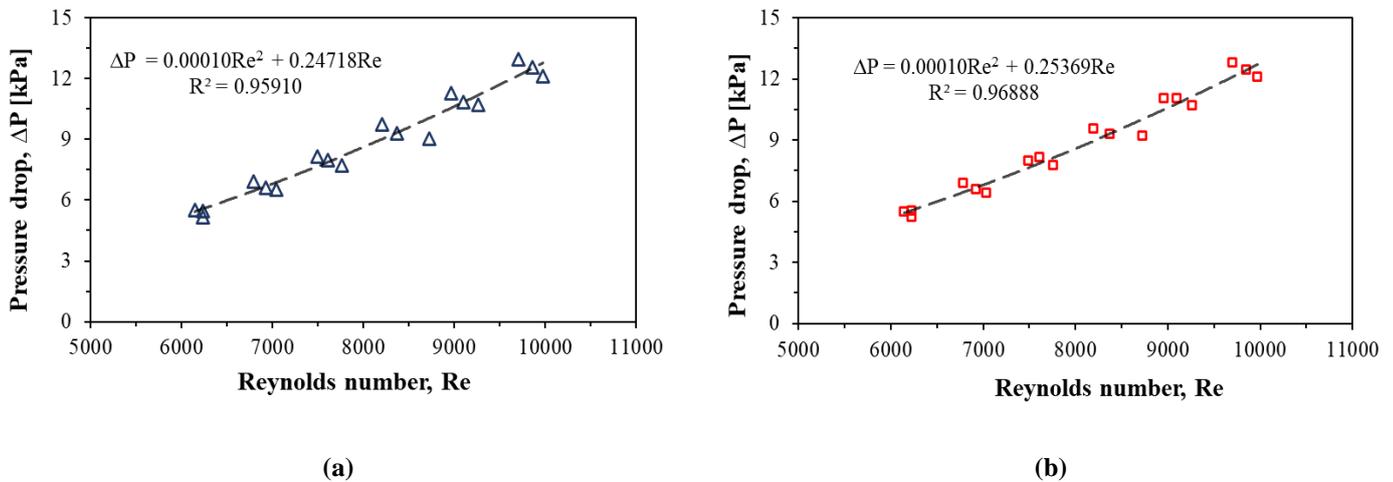


Figure 8. Pressure drop [a] method used by Kfuri et al. (2016) and [b] two-point method.

As show in Fig. 8, the experiments present a great reproductibility. It is noted that, controlling the rotational speed of the pump, the Reynolds number varied for the same set rotation, but always becomes near a average value.

The pressure drop behavior with the range Reynolds number fit well with a quadratic curve, shown in Fig. 8, indicating that the pressure drop increase more intensively at higher flow rates. This behavior can be associated with the inertial effects of the fluid passage through the screen. On the turbulent flow, the viscous effects are not dominant on the flow, making the pressure drop to increase faster while the inertial effects increase. To a laminar flow, it is expected that only the viscous effects be dominant, and the pressure drop presents a linear behavior with the increase of Reynolds number. With the verification of the pressure behavior, the linear coefficient of the fitted equations can be associated with the viscous effects, and the quadratic term of the fitted equation can be incorporated by the inertial effects.

It is noted that the two point methodology presents almost the same adjusted coefficients of the method used by Kfuri et al. (2016), but the two-point method require less time to perform the tests. The little difference between the methods occurs because the pressure drop on the sand control screens is too high. So, the distributed pressure drop are negligible when compared with the local pressure drops.

Experiments were also performed with a larger range of Reynolds to investigate the reproducibility of the experimental bench, using the two-point method, since it requires less time to perform the tests (Fig. 9).

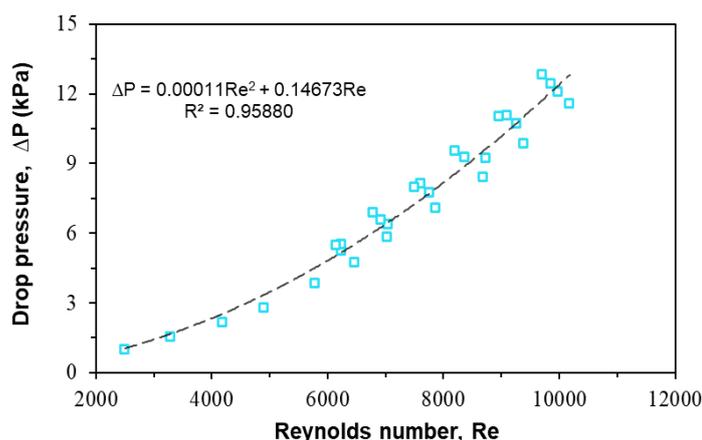


Figure 9. pressure drop with greater Reynolds number range.

As shown in Fig. 9, the quadratic behavior of the pressure drop as a function of Reynolds number showed satisfactory adjustment coefficients, ensuring the reproducibility of the experimental bench. However, there was a noticeable difference between the quadratic and linear coefficients in Fig. 9 when compared to Fig. 8. This can be justified by the influence of the flow regime on the pressure drop, since in Figure 8 the flow regime was turbulent, while in Fig. 9 it was transitional and turbulent.

4. CONCLUSIONS

For the experimental conditions that were investigated, the pressure drop in the sand control screens was successfully measured using two different methodologies and represented a quadratic behavior as a function of the flow rate. Future studies are focused on new measurements in order to evaluate how the deposition of particles on the screen surface can affect this behavior, in order to achieve a better control of the process.

5. ACKNOWLEDGEMENTS

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