Proposal of a Speed Control System for PIG's using the Arduino Board

Victor Carvalho Galvão de Freitas
Gustavo Fernandes de Lima
Ralyson Rayala Gonçalves de Oliveira
Andres Ortiz Salazar
André Laurindo Maitelli
Francisco de Assis Oliveira Fontes

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Introduction

Common problems in pipelines

- Accumulation of compounds from the product transported
    - Flow capacity of the pipeline can be drastically reduced

- Interaction between compounds and duct can cause corrosion, leading to the disruption of its walls

Common problems in pipelines

Possible solution: **PIG (Pipeline Inspection Gauge)**

- Cleaning PIG - pipeline cleaning
- Smart PIG - inspection of pipeline integrity

Cleaning PIG

Able to remove the compounds accumulation inside the duct

(Source: http://www.smartpigs.net/pigging-products.html)

Smart PIG

Able to detect problems in the inspected duct through various sensors

(Source: http://www.gaznat.ch/)

Smart PIG

Requirement: for proper operation of the sensors, the speed must be maintained between **1 e 5 m/s**

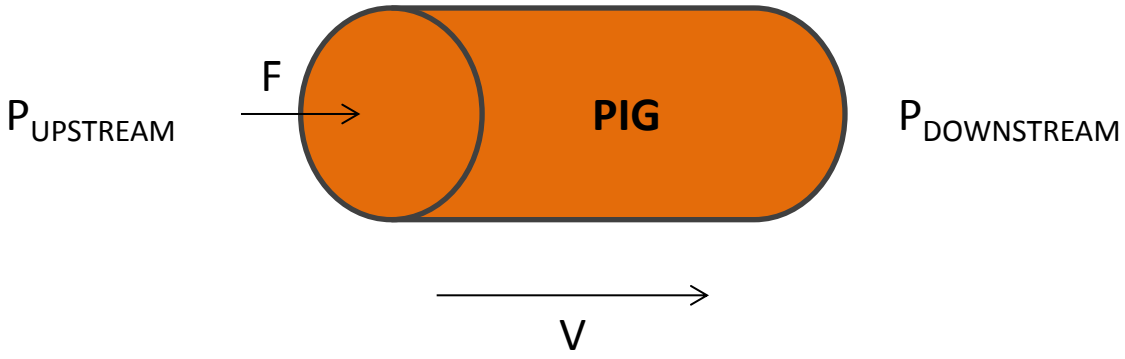
(Source: http://www.gaznat.ch/)

Speed control

- Therefore, it is necessary to use a speed control system for the PIG

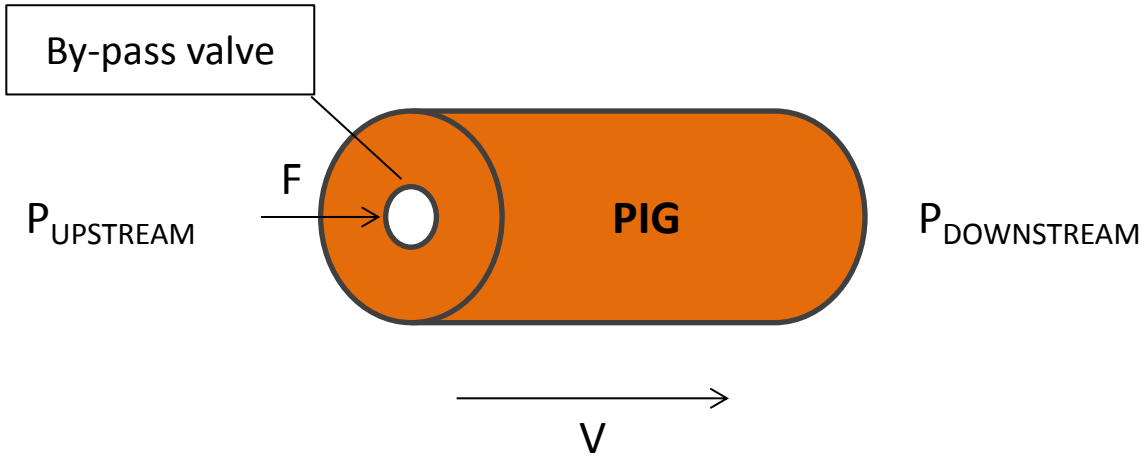
Speed control

- Speed can be controlled by controlling the **pressure difference** between upstream and downstream of the PIG



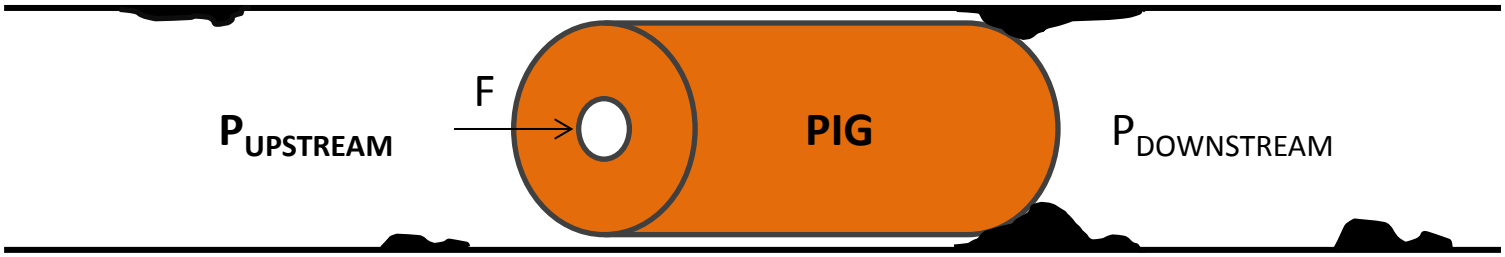
Speed control

- By-pass valve was developed
- When by-pass valve opens
  - ΔP decreases, speed decreases



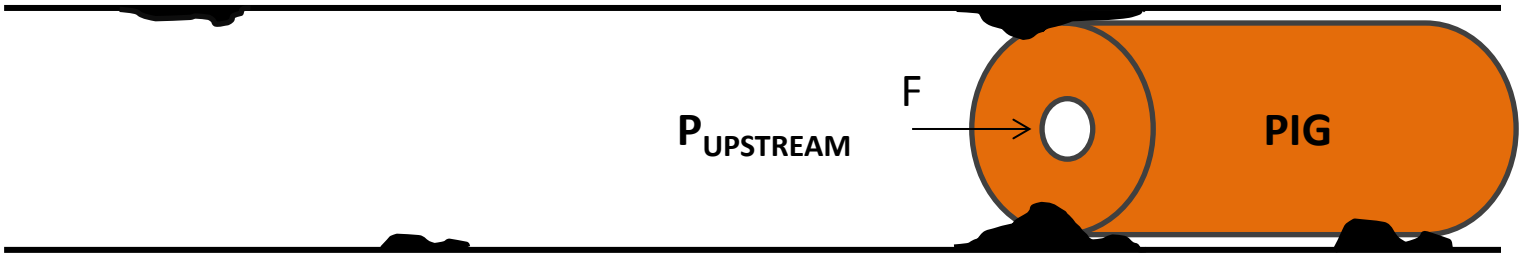
Special case: speed excursion

- When there's an obstruction in the duct, PIG stops and its upstream pressure increases until it overcomes the obstruction



Special case: speed excursion

- At this moment, a speed excursion (high speed) occurs: large pressure differential leads to high speed



Special case: speed excursion

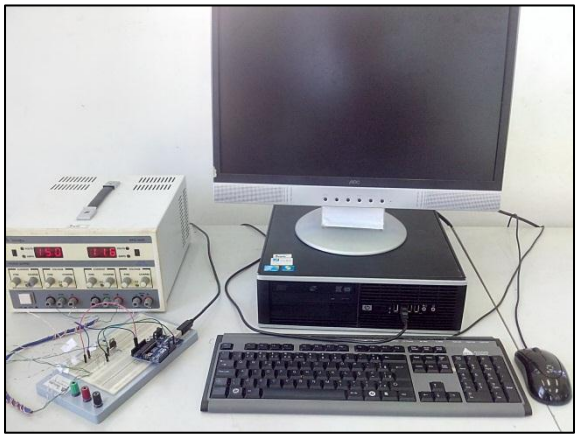
Problem: sensors do not work properly during the speed excursion

Minimize the speed excursion is the focus of our system

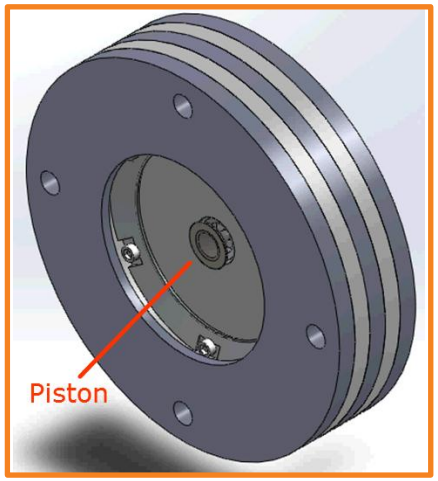
Tools and methodology

Test bench

- Constructed to simulate **speed excursions** situations;
- Galvanized steel, diameter 4”, length 2 m;
- Manometers and pressure transducers;
- V_T: speed excursion valve;
- V_{BP}: by-pass valve.

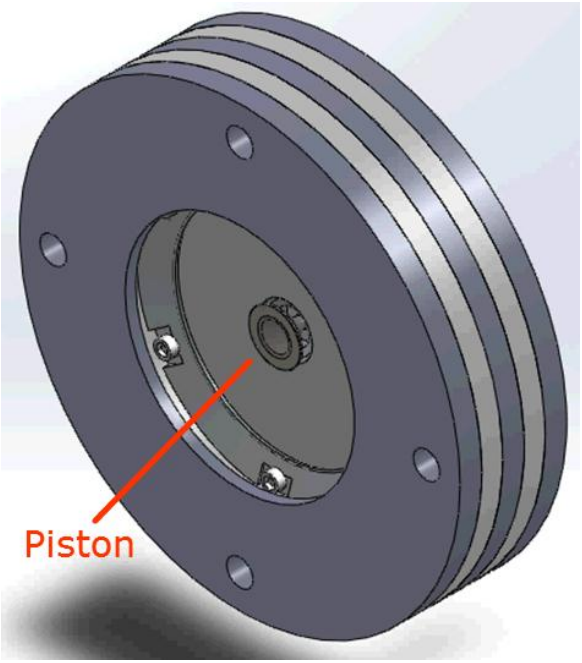


Test bench



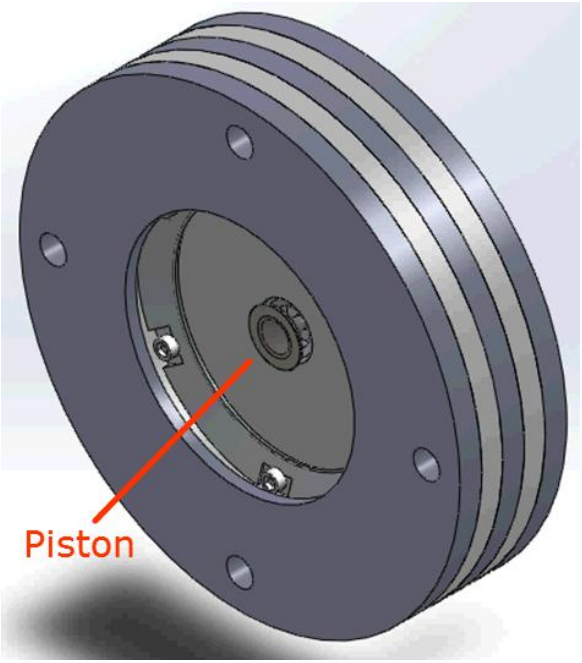
By-pass valve

- Controls the flow passing through the PIG and thus regulates the pressure difference between upstream and downstream

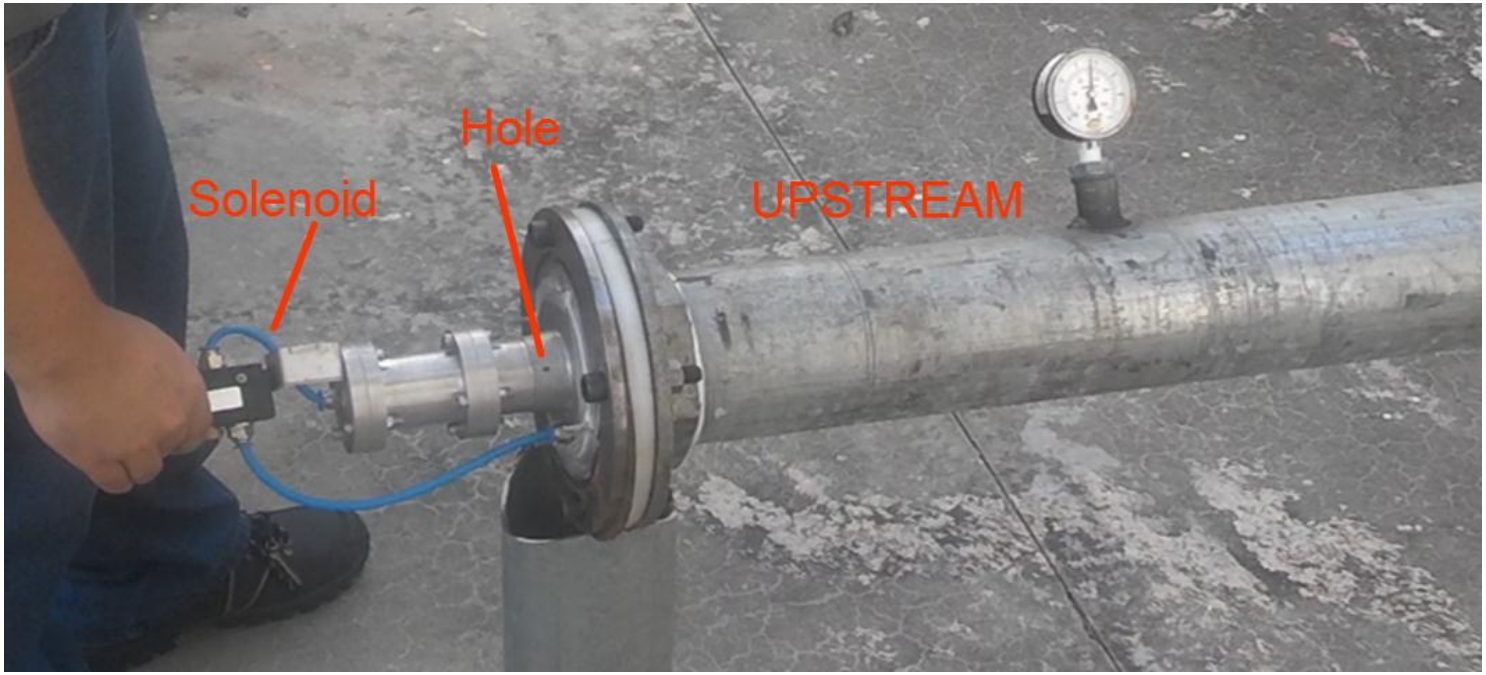


By-pass valve

- This pressure in the duct itself is used to push the piston
- Solenoid valve is used to control opening and closing of the piston

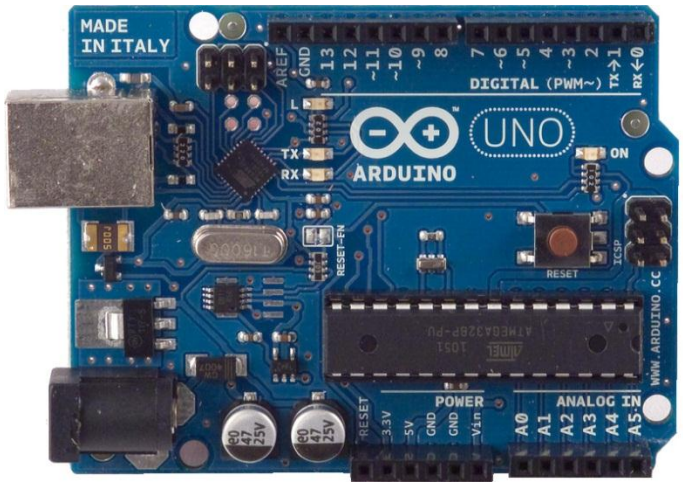


By-pass valve



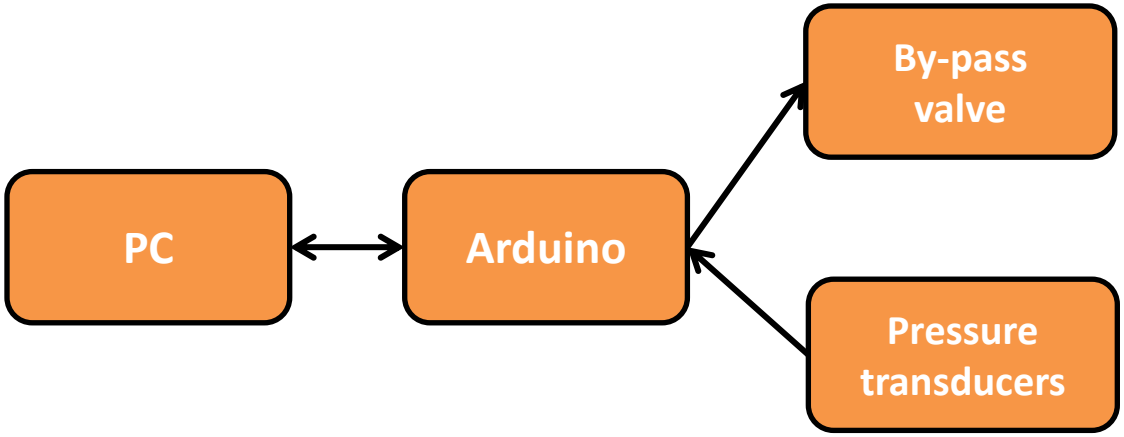
Arduino

- Arduino Uno
- Microcontroller + USB interface
- Low co$t and easy programming



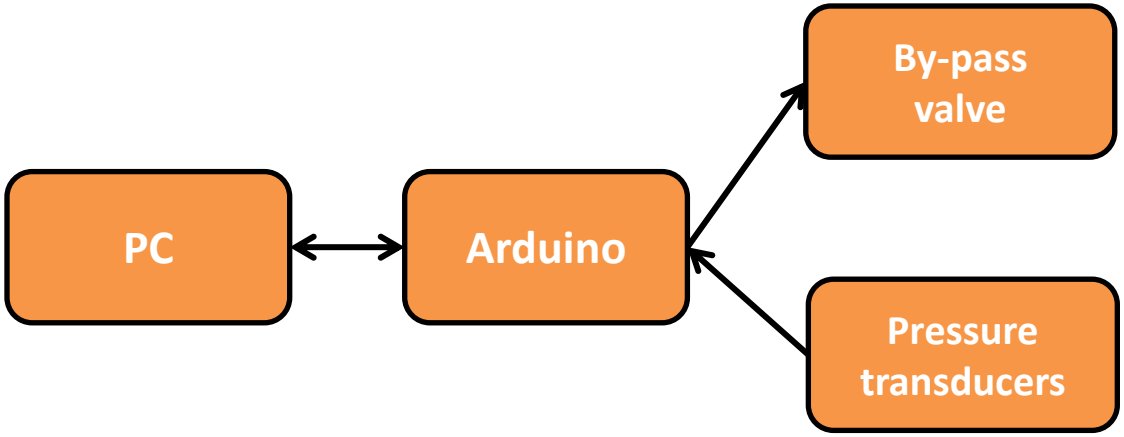
Communication

- The Arduino performs the interface between the bench and a PC
  - Reads transducers voltage (0-5V) and sends it to PC via USB
  - Also responsible for activating the bypass valve



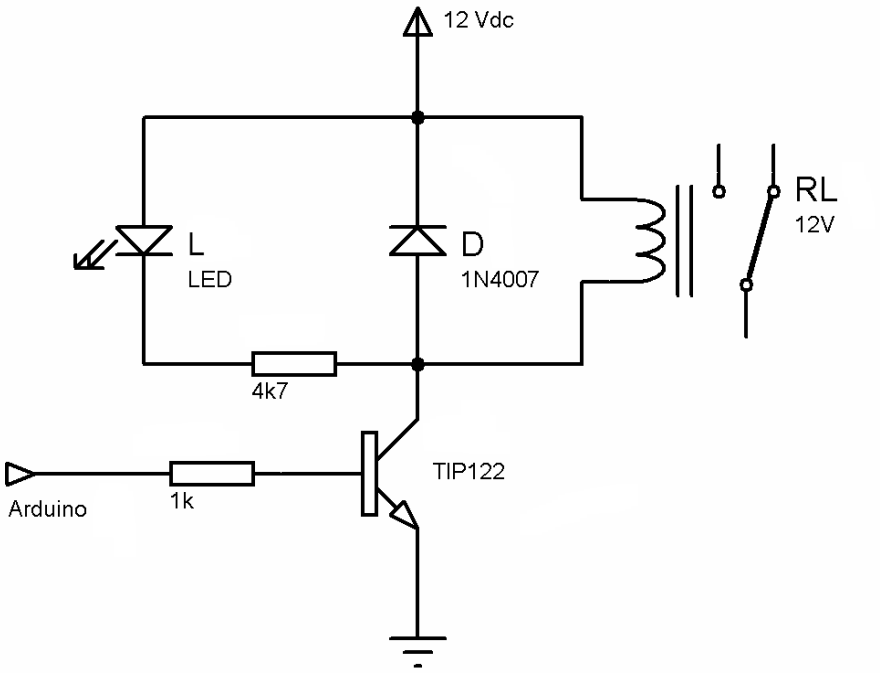
Communication

- The control algorithm is implemented in Arduino
- PC is used to plot signals using Matlab



Driver circuit

- Circuit used to activate solenoid



Control strategy

- ON/OFF Control of the bypass valve, to obtain a modulation in the output: similar to PWM
  - Average value of the output depends on how long the signal stays ON (valve open)

- **Objective: to minimize a large pressure differential quickly**

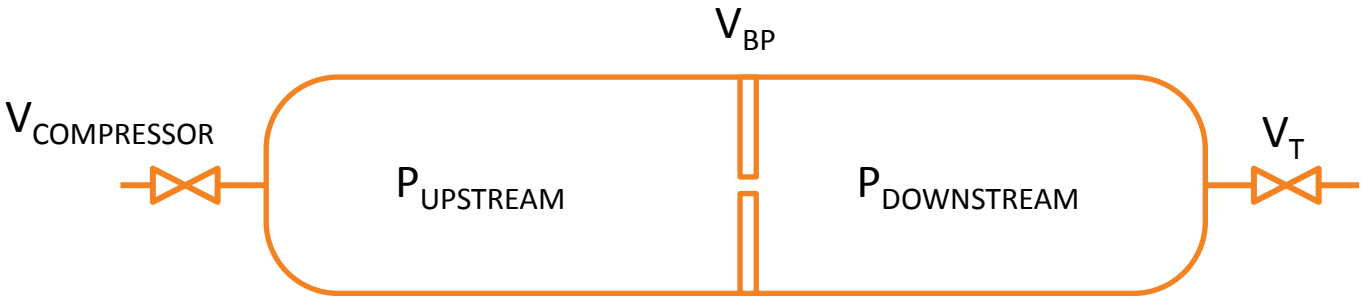
Control strategy

- The controller activates the valve opening based on the value of the pressure difference
- The higher ΔP, the longer V_{BP} is open

ΔP (PSI)	V_{BP} opening (%)
$\Delta P > 1{,}5\ \Delta P_{REF}$	100
$1{,}2\ \Delta P_{REF} < \Delta P < 1{,}5\ \Delta P_{REF}$	50
$1{,}1\ \Delta P_{REF} < \Delta P < 1{,}2\ \Delta P_{REF}$	20
$\Delta P_{REF} < \Delta P < 1{,}1\ \Delta P_{REF}$	10

Experimental procedure

- Speed excursion simulation

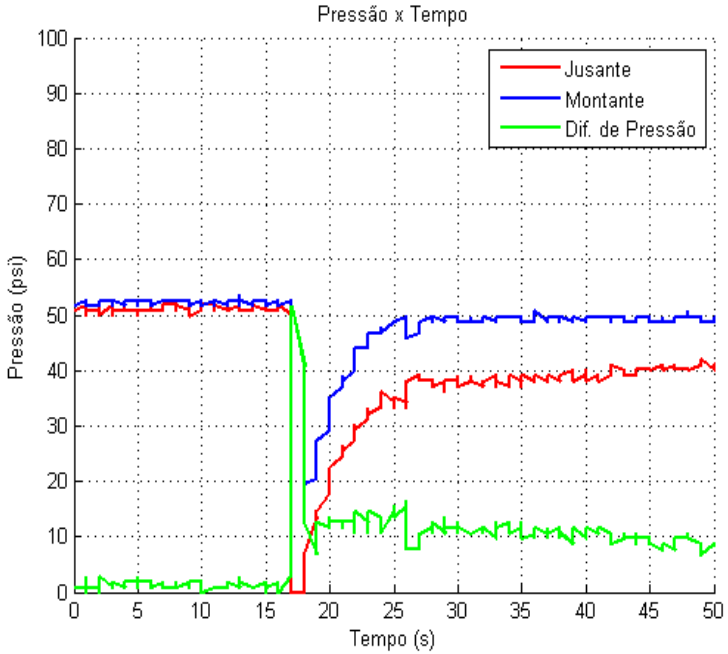


$P_{UPSTREAM}$ = 50 PSI
V_T opens at time = 15 s
ΔP_{REF} = 10 PSI

Results

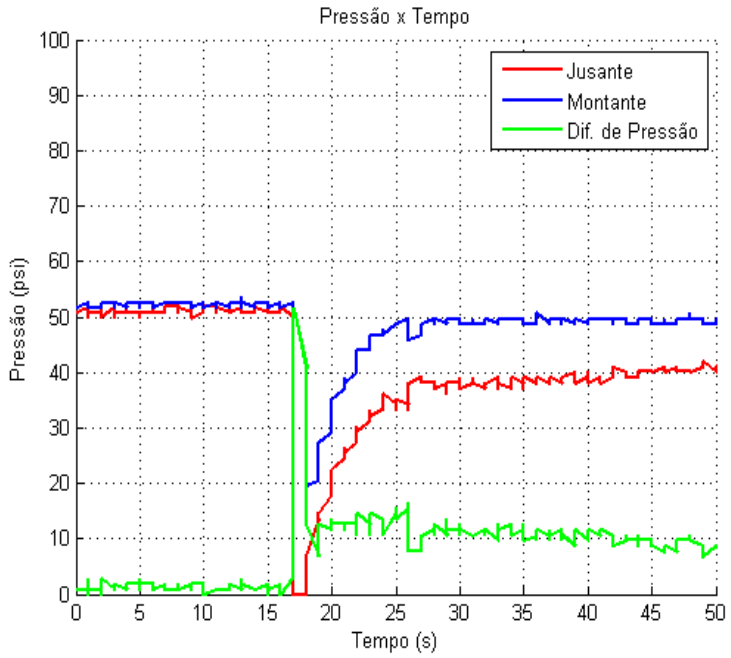
Results

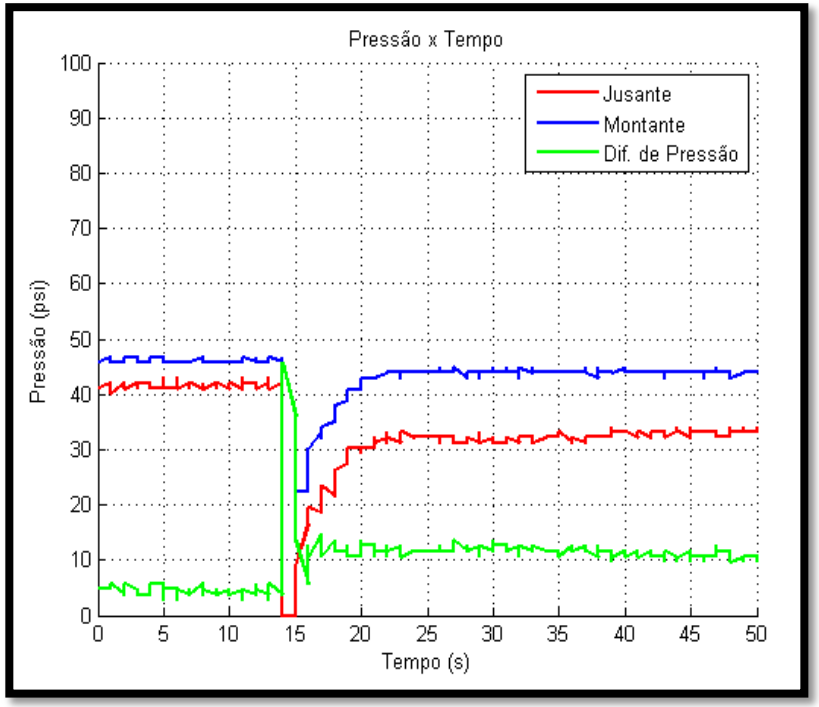
- Sudden increase in pressure differential when speed excursion occurs and controller action seeking to maintain the desired pressure differential value



Results

- In this case, **faster response**





Conclusions

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- Bench test suitable for the simulation of speed excursions;
- Arduino use for signal acquisition and controller implementation allows low cost;
- By-pass valve developed uses energy from the duct itself for its operation
  - Driver by low power solenoid (4,8W)

Conclusions

- The results indicate the possibility of controlling the PIG speed by controlling the pressure difference

- Future: replace the current controller for a Fuzzy controller and perform control in more general situations (not limited to pig excursion)

Thank you