ECWS-9
2025
Conference
The 9th International Electronic Conference on Water Sciences
11–14 November 2025 | Online
MDPI

Transformer Linear Regression Algorithm for Predicting Maximum Air Pocket Pressure in Water Pipelines

Duban A. Paternina-Verona[1], Fernando J. Quintero-Vásquez[2], Oscar E. Coronado-Hernández[3], Helena M. Ramos[4]

[1]Research Group DEARTICA, Universidad del Sinú, Cartagena, Colombia; [2]School of Engineering, Architecture and Design, Universidad Tecnológica de Bolívar, Cartagena, Colombia; [3]Hydraulic and Sanitation Institute, Universidad de Cartagena, Cartagena, Colombia; [4]Civil Engineering Research and Innovation for Sustainability, Instituto Superior Técnico (IST), University of Lisbon, Lisbon, Portugal

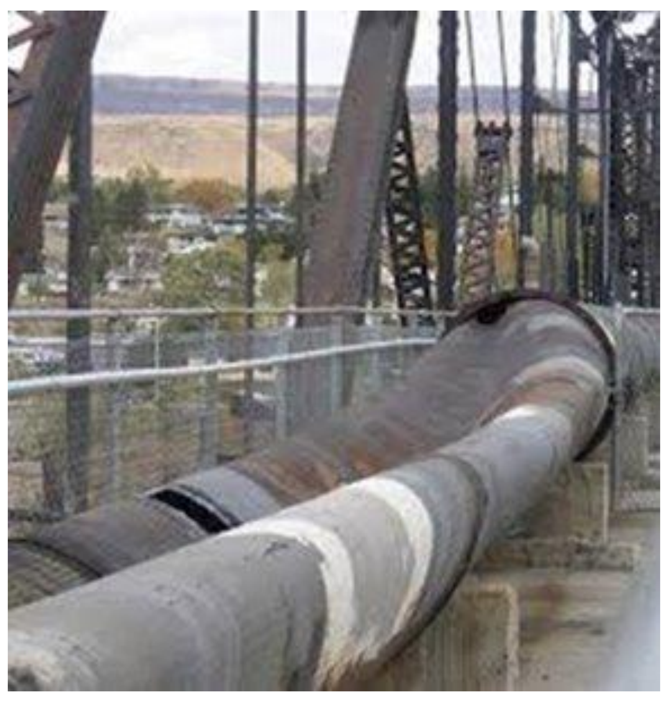
INTRODUCTION & AIM

Water distribution networks frequently experience transient events associated with trapped air during filling and emptying operations. These phenomena can lead to **over-pressures** or **vacuum conditions**, compromising the structural integrity of pipelines.

This study introduces a **Transformer Linear Regression (TLR)** model designed to **predict maximum and minimum air pocket pressures** in both experimental and large-scale systems.

The TLR model combines the **contextual learning of Transformer encoders** with the **interpretability of linear regression**, capturing both linear and nonlinear dependencies among hydraulic parameters. The main objective is to **develop a predictive tool** capable of anticipating extreme hydraulic pressures under different operating conditions.

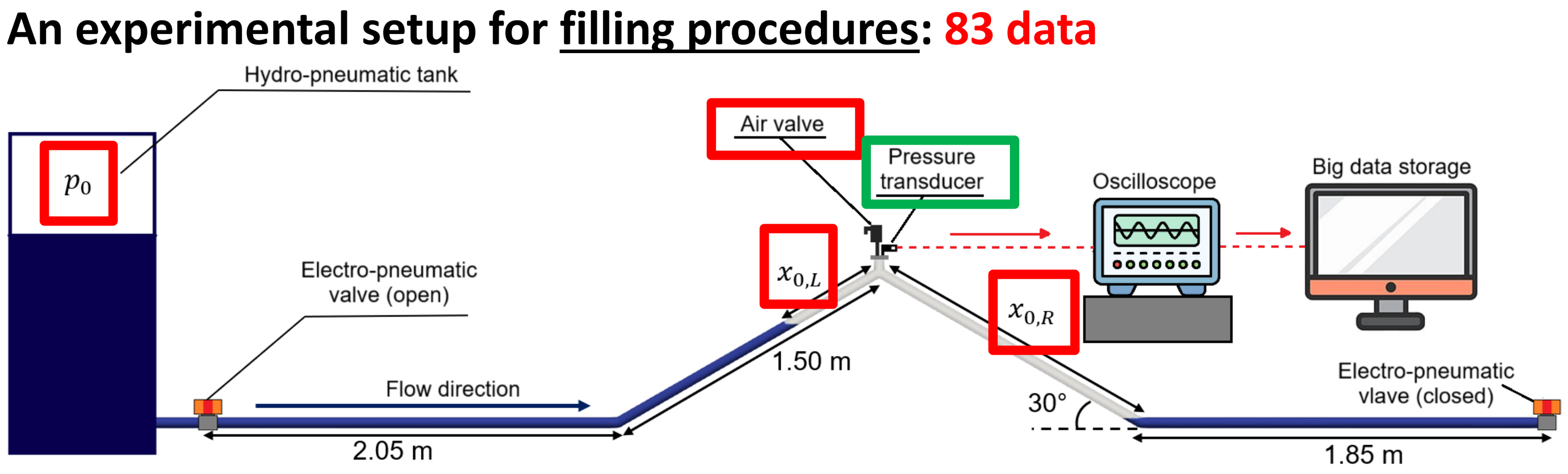
Failure due to overpressure



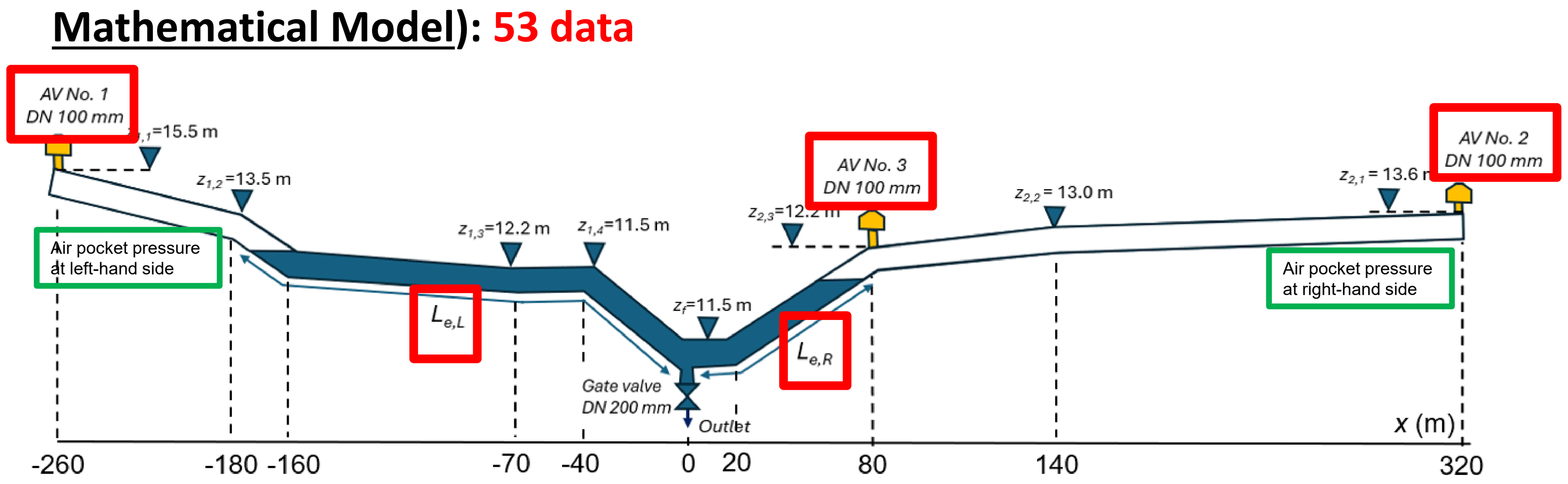
Failure due to vacuum pressure

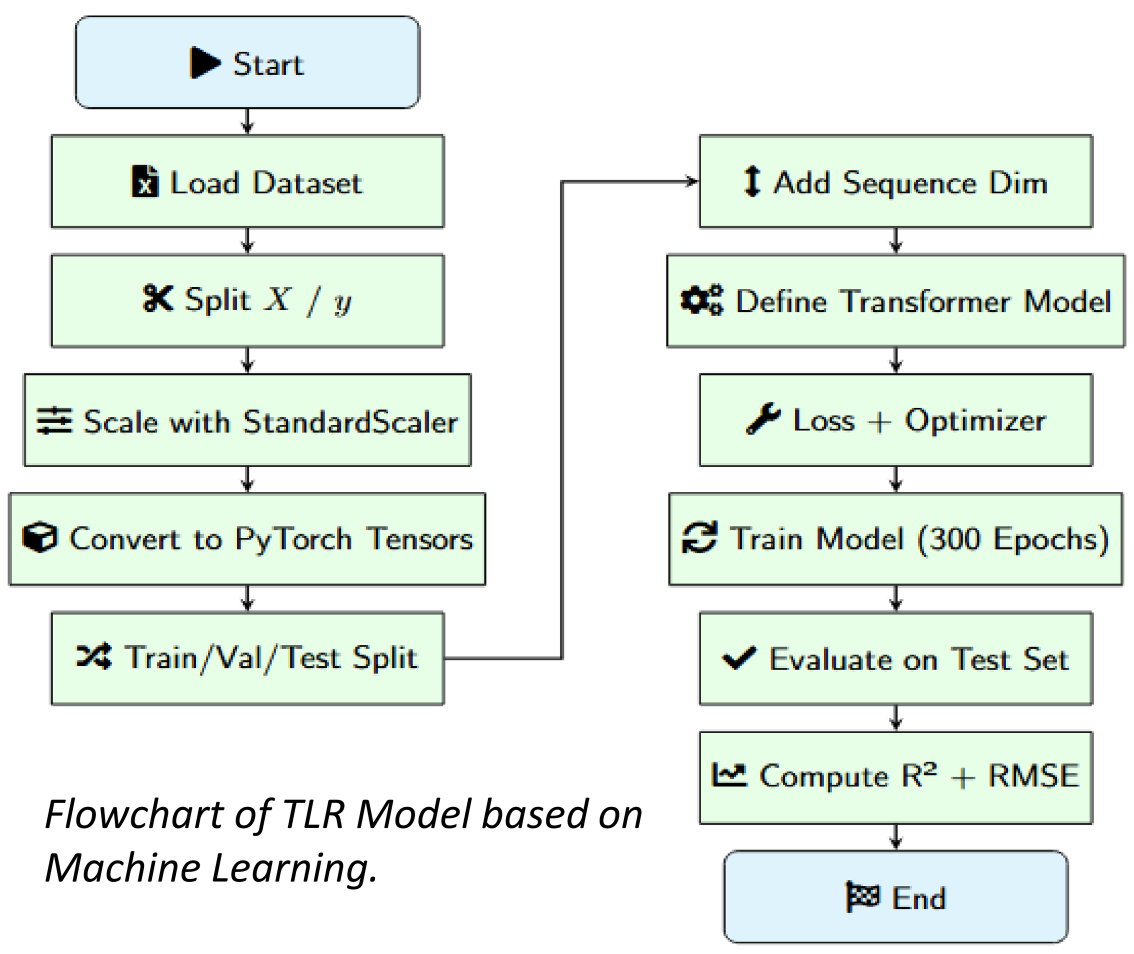
METHOD

An experimental setup for filling procedures: 83 data



A large-scale water pipeline for emptying procedures (based on Mathematical Model): 53 data





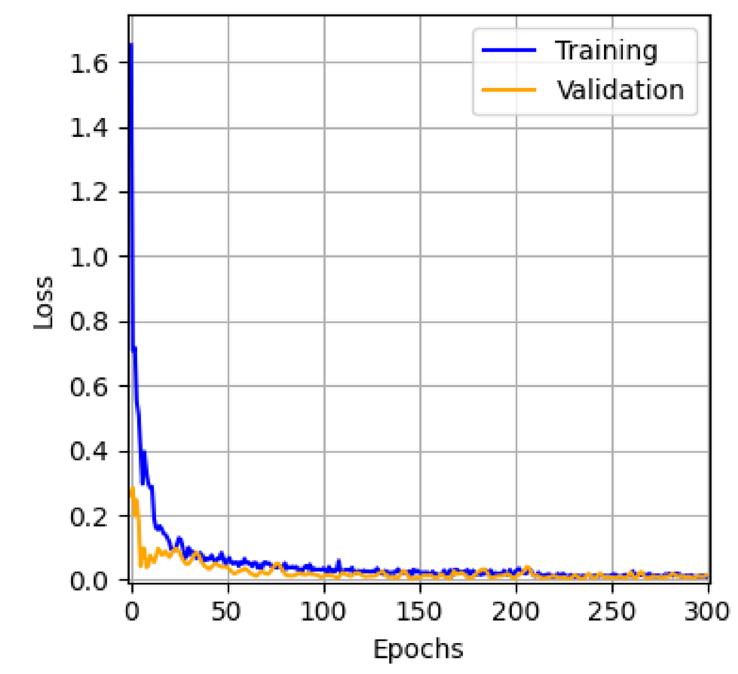
Flowchart of TLR Model based on Machine Learning.

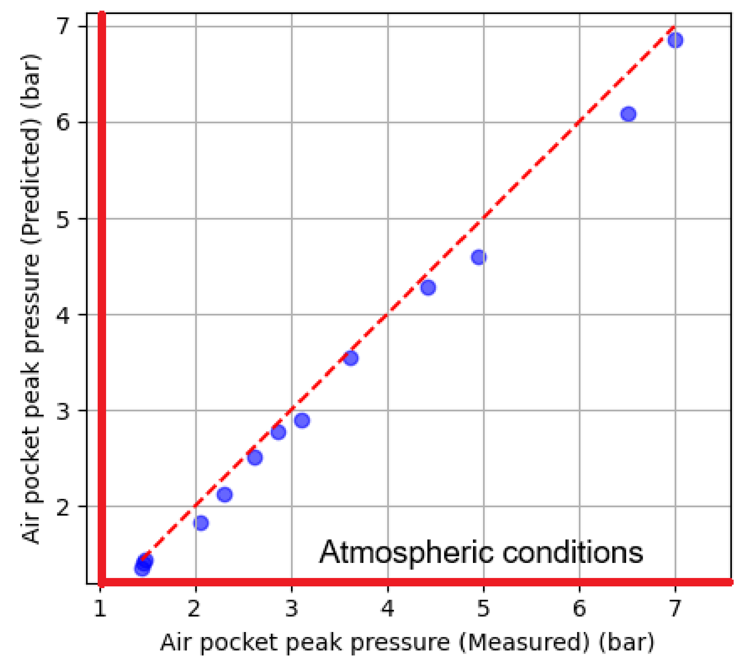
python™

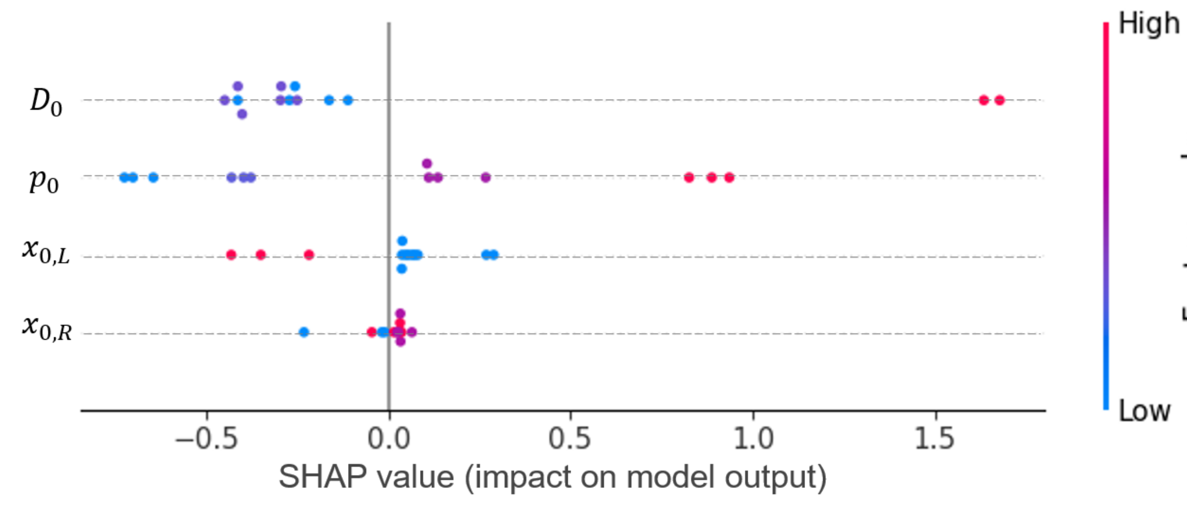
The **Pytorch** extension was used. This function is an open-source machine learning and deep learning framework.

RESULTS & DISCUSSION

An experimental setup for filling procedures: R^2 = 0.9951; RMSE: 0.1224 bar.
Data Splitting: Training: 70%; Validation: 30%

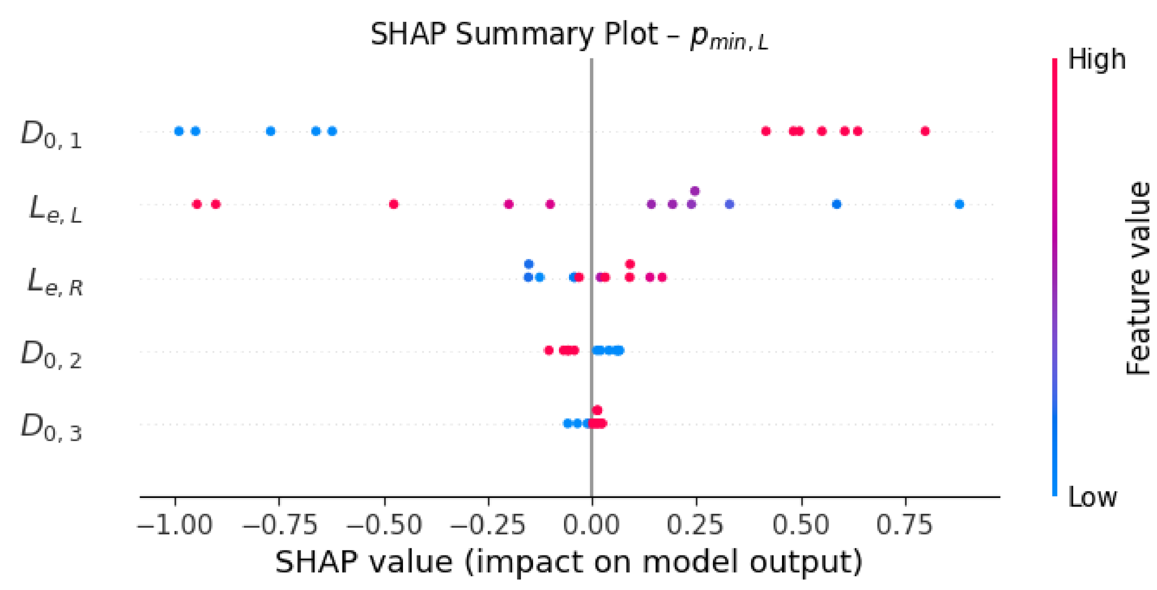


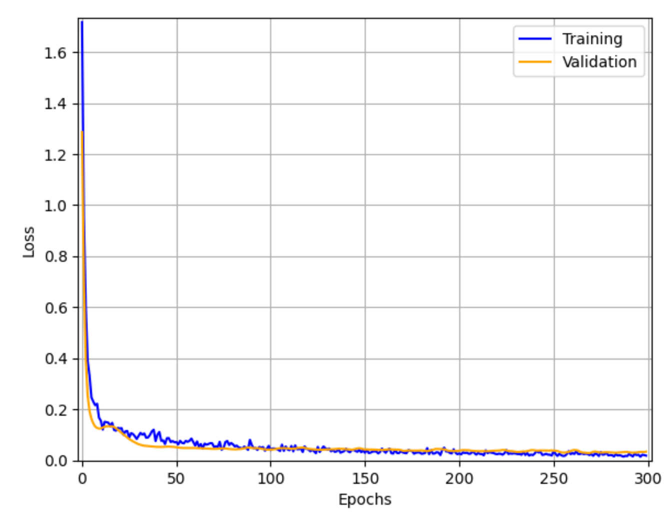


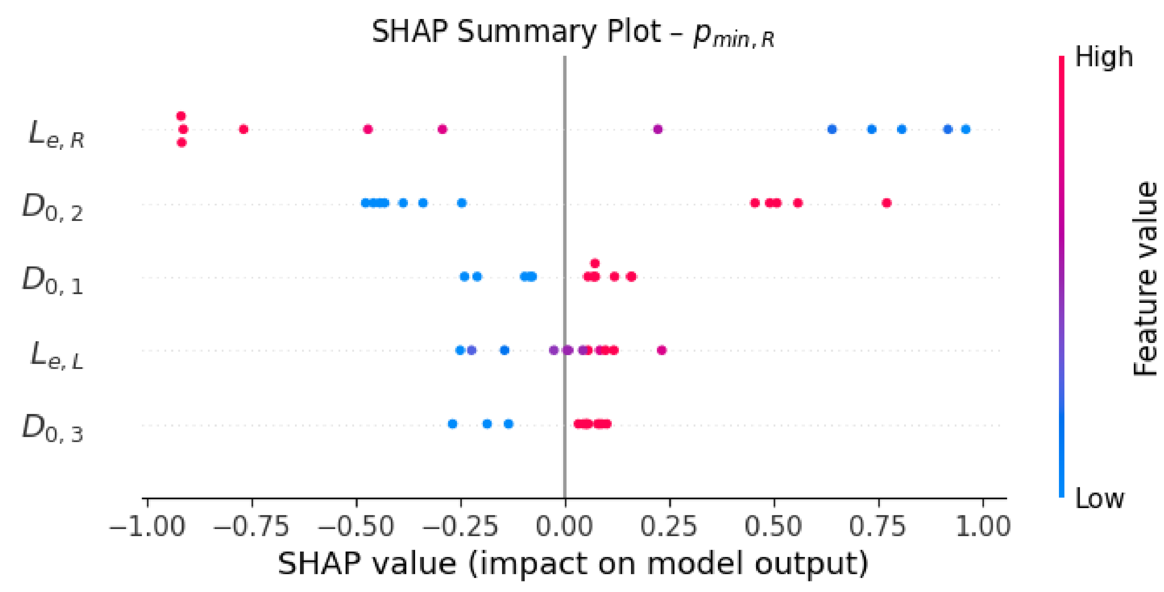


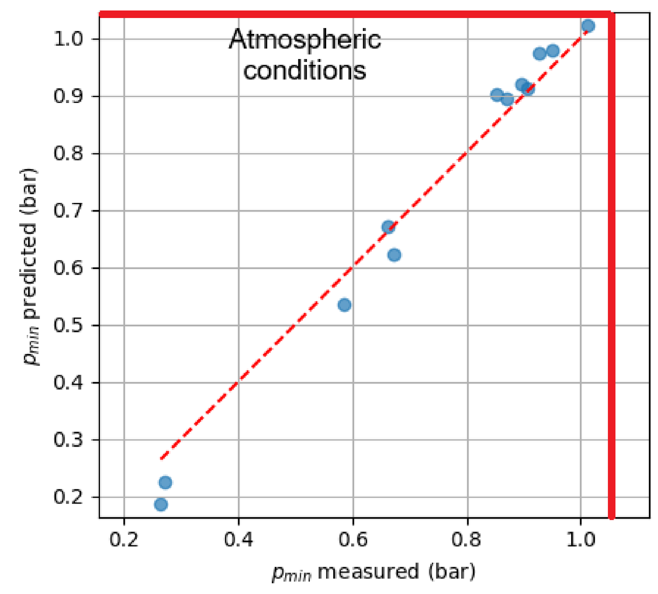
NOTE: SHAP values indicate the impact of each parameter has on the magnitude of the predicted values.

A large-scale water pipeline for emptying procedures: R^2 = 0.9750; RMSE: 0.36 bar. Data Splitting: Training: 70%; Validation: 30%









CONCLUSION

The proposed TLR model successfully predicts extreme pressures during filling and emptying of water pipelines with trapped air. The analysis highlights that:

- **Air valve diameter** and **tank pressure** are key variables in over-pressure.
- **Water column length** and **air valve operation** strongly affect vacuum pressures.
- The TLR model offers a **replicable and explainable AI-based tool** for supporting decision-making in hydraulic system management.

REFERENCES

- **Paternina-Verona, D. A., Coronado-Hernández, O. E., Espinoza-Román, H. G., Arrieta-Pastrana, A., Tasca, E., Fuertes-Miquel, V. S., & Ramos, H. M. (2024)** Attenuation of pipeline filling over-pressures through trapped air. *Urban Water Journal, 21*(6), 698–710.
- **Coronado-Hernández, O. E., Fuertes-Miquel, V. S., & Angulo-Hernández, F. N. (2017).** Emptying operation of wáter supply networks. *Water, 10*(1), 22.
- **Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., Kaiser, Ł., & Polosukhin, I. (2017).** Attention is all you need. *Advances in Neural Information Processing Systems, 30*, 5998–6008.