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Analyzing power consumption in a coaxial bioreactor using machine learning techniques with computational fluid dynamics

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INTRODUCTION & AIM

Agitated bioreactors are the subject of many studies regarding their design and scale-up to enhance productivity in various chemical and biochemical industries. In this regard, accurately predicting power consumption is very important because it influences the mass transfer rate and flow uniformity inside the bioreactor. A literature review revealed that no study has been conducted to investigate the performance of coaxial bioreactors in terms of power consumption using a machine learning method. In this study, both regressors and classifiers were applied to predict the torque obtained by the aerated coaxial mixer containing a non-Newtonian fluid.

METHOD

In this study, a computational fluid dynamics (CFD) model was developed and validated against experimental data. Subsequently, 500 simulations at different aeration rates (2 – 6 L/min), anchor impeller speeds (3.5 – 9.5 rpm), central impeller speeds (60 – 150 rpm), and rotating modes (co-rotating and counter-rotating) were conducted. CFD simulations were conducted based on the numerical model developed for a scaled-down model with a scale factor of 0.5. Therefore, the numerical results obtained from the full scale coaxial bioreactor was validated against the experimental results.

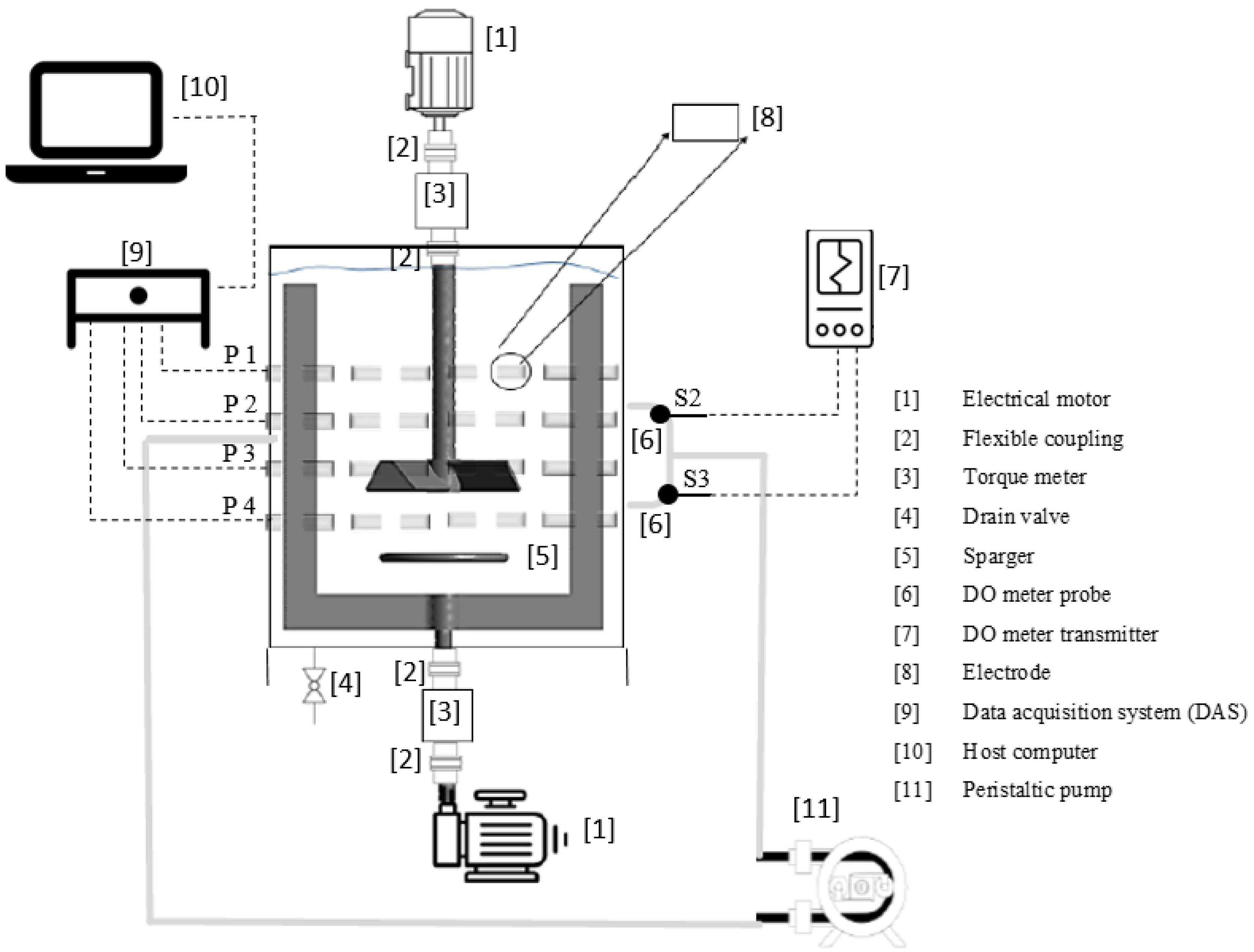

Fig 1. Experimental setup

For all machine learning models, the hyperparameter tuning, and cross validations were performed. To asses the performance of the regression models the mean squared error (MSE) was analyzed. In addition, accuracy was employed to examine the classifiers.

RESULTS & DISCUSSION

The data from CFD simulations were utilized to train and test various machine learning models. Initially, the *k*-nearest neighbor (KNN), and support vector machine (SVM) classification models were employed to categorize the coaxial bioreactors into different rotating modes. Both models showed satisfactory results. Interestingly, statistical analysis showed that by only considering the central impeller speed and torque generated by the coaxial bioreactor, the SVM model with a hard margin was able to categorize the rotating model with accuracy of 100%.

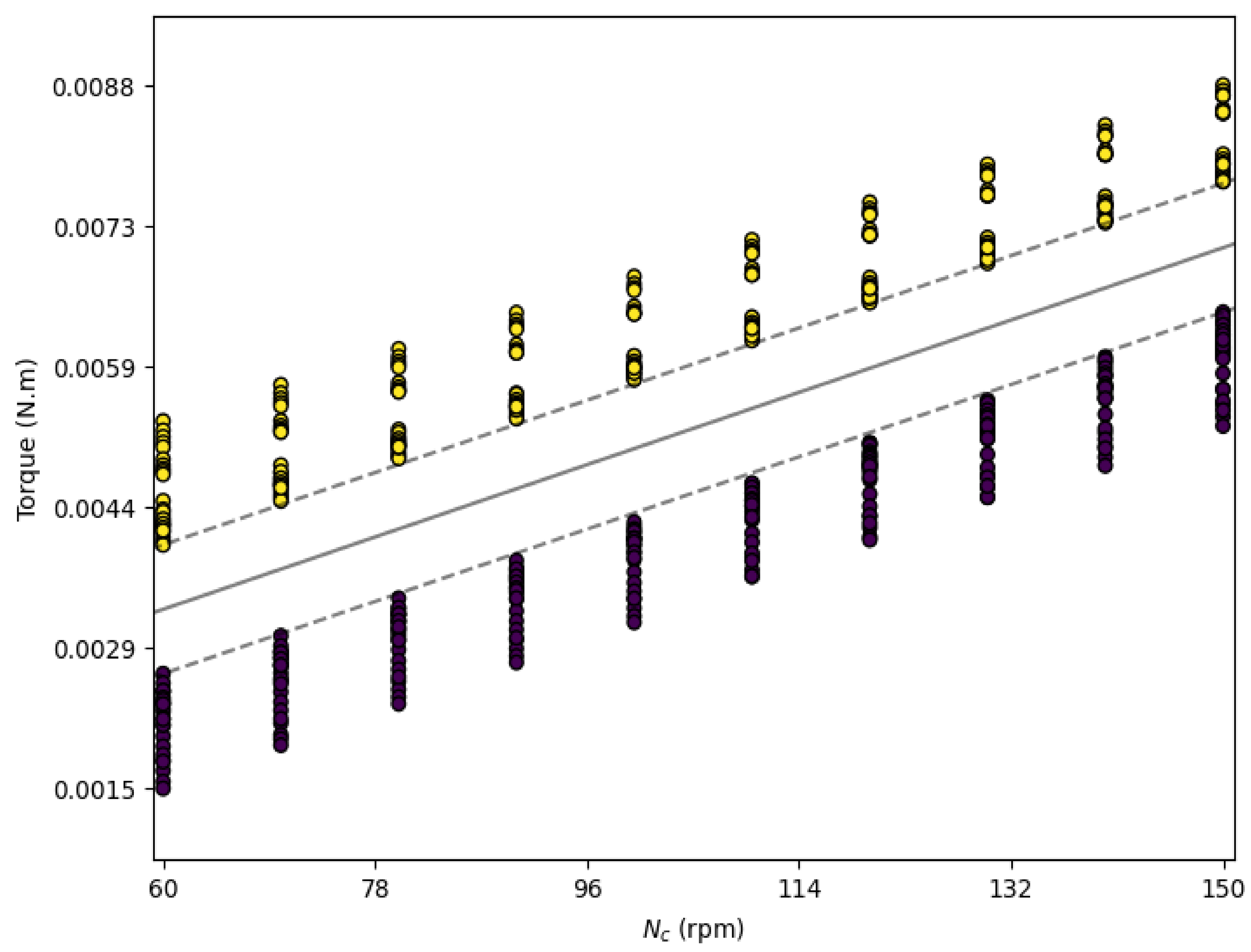

Fig 2. Support vector machine (SVM) classifier

KNN, artificial neural network, and random forest models were utilized to predict the torque generated by the coaxial bioreactor. In this case, rotating mode, central and anchor impellers speed, and aeration rate were considered as feature variables. The MSE results showed that only random forest model was able to predict the torque with a acceptable R squared of 0.999.

CONCLUSION

Various machine learning based classifiers and regressors were employed to asses the performance of the coaxial bioreactor in terms of the power consumption. The results of this can be used to determine the maximum amount of impeller speed and power dissipation inside the mixing bioreactor. These findings are significant specifically for gas dispersion inside a shear sensitive fluid.

ACKNOWLEDGMENT

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