COMPARING THE PERFORMANCE OF DIFFERENT IMPELLERS IN MIXING VISCOPLASTIC FLUIDS: CFD, THEORY AND EXPERIMENT

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APPLICATIONS

➢Mechanically agitated vessels are widely used in a wide range of industries such as nuclear, pharmaceuticals, minerals, food processing, household and personal care products.

➢Complex fluids including viscoplastic (yield stress) fluids are frequently encountered in these processes.

CAVERNS

In the mixing of viscoplastic fluids, the impeller creates a 'cavern' within which liquid is in flow, but in the bulk where the shear stresses are below the apparent yield stress the fluid is stagnant, a phenomenon that can be disastrous for many mixing operations.

STATE OF ART

➢Such caverns were believed to be well mixed regions, but we recently showed that they are in fact generally poorly mixed.

➢Little work has been done, however, to understand which type of impeller is most effective in mixing such fluids by giving larger and better mixed caverns.

OBJECTIVES

- Study the mixing of a Herschel-Bulkley fluid agitated numerically using Ansys-CFX CFD software.
- Study the effect of mixer type on the characteristics of mixing for this type of complex fluids.
- Investigate cavern formation in different impellers (axial and radial impeller).

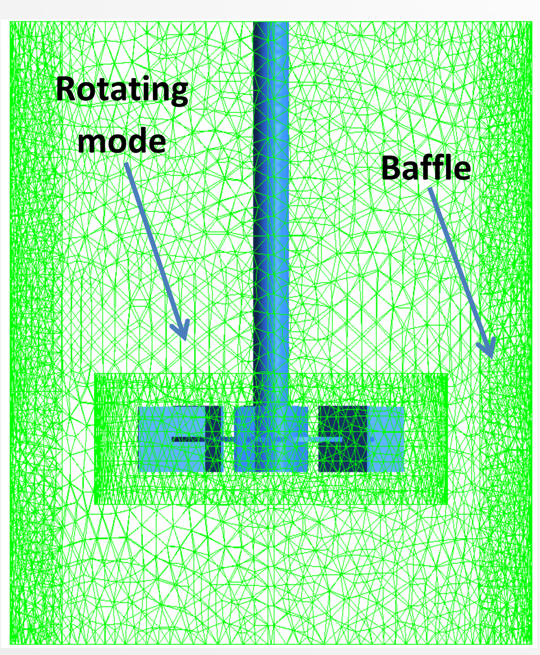
CFX Simulation and Validation

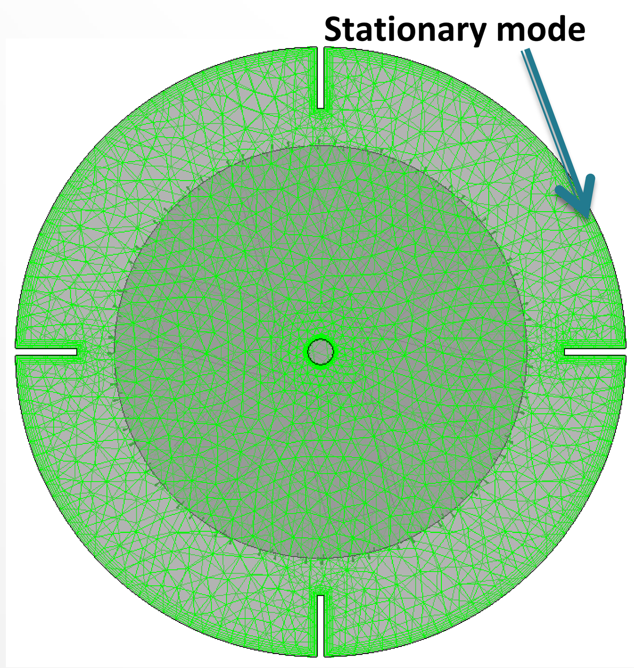
Software ➔ ANSYS CFX 14.5

Mesh ➔ **701,527** unstructured tetrahedral elements distributed non-uniformly

Method ➔ Multiple frame of reference (MFR)

Validation ➔ using ***photographic imaging*** where by caverns were visualised using methylene blue dye and measured on digital images taken during mixing of a Carbopol polymer solution..



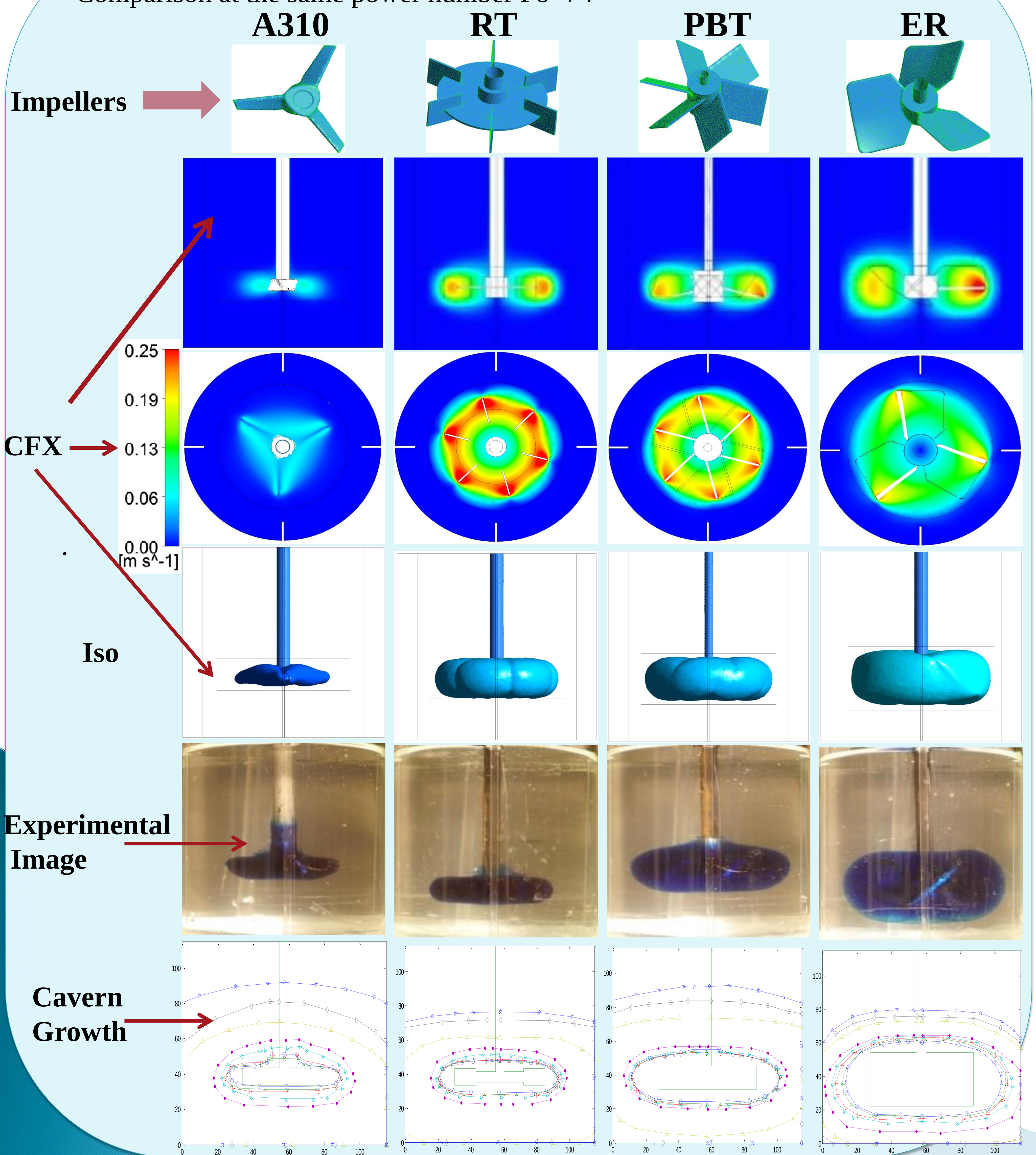


Conditions ➔ All the simulations were managed in the laminar and low transitional regimes

➔ To achieve an accurate prediction of cavern size, the simulation was operated to steady state with no initial conditions and maintain the simulation until the sum of all the normalized residuals were no more than **10^{-6}**.

RESULTS AND ANALYSIS

Comparison at the same power number Po=74



MODELLING

A number of mechanistic cavern models were tested and compared with experiment and CFD predictions. A modified toroidal model has been formulated which can be used for all these impellers

New Toroidal Model

$$\left(\frac{Dc}{D}\right)^2 = \frac{0.19}{\pi\left(\frac{Hc}{Dc}\right)\sqrt{\frac{1}{2}+2\left(\frac{Hc}{Dc}\right)^2}}\left(\frac{\rho N^2 D^2}{\tau_y}\right)\left[N_f^2+\left(\frac{4P_o}{3\pi}\right)^2\right]^{0.31}$$

CONCLUSION

Cavern size predicted from CFD predictions showed a good agreement with experimental measurements at low power number; at high power number, however, there is a significant divergence from experiment. At high power number the ER agitator generated the largest caverns, whilst at low power number the A310 agitator formed the largest caverns. Overall, however, the ER impeller was considered to be the most efficient impeller since, for a given power consumption, it also generated a well-mixed cavern compared to the other agitators. Results showed that for the PBT, A310 and ER, the up-pumping mode offered significant advantages over the down-pumping mode.

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