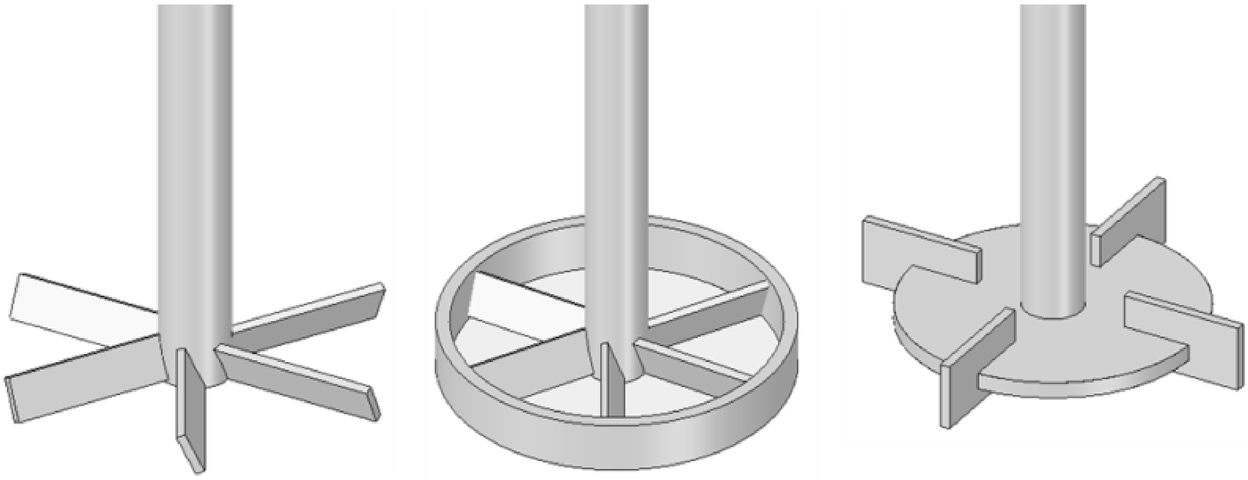
Computational fluid dynamics in metallurgy

Stirrer design optimization for improving efficiency of a lead refinery



Summary

Lead refinery processes typically occur in heated kettles, in which stirrers ensure a proper mixing of the liquid lead bullion. The processes have a typical duration of several hours. As a result, improvements in the kinetics, reducing the process batch time, can significantly increase the productivity of the refinery.

Improving mixing is a straightforward strategy to increase the kinetics (process speed) without modifying temperature or chemistry.

The mixing efficiency is a result of the kettle and stirrer design. The effect of modifications can be calculated using computational fluid dynamics (CFD).

The efficiency of the stirrer set-up can be evaluated by different approaches, depending on the process requirements:

- Classically, mixing efficiency is evaluated by calculating the mixing time, i.e. the time it takes to reach a homogeneous mixture.
- When gas is injected in the process, a valuable measure is the gas residence time in the metal melt.
- To guarantee the quick uptake of additions, the vortex shape can be relevant as well.

Challenges

From the modelling perspective, a lead refinery kettle is very similar to a mixing tank, for which many solutions and examples exist. However, set-ups for water or viscous liquids are not appropriate for the heavy, low viscosity liquid lead metal. Also, whereas the presence of a vortex is typically not a sign of efficient mixing, it may be desired by lead refiners.

Theoretically, many aspects of the stirrer design can be varied: number and angle of the blades, addition of a reinforcement ring, use of several impellers, etc. In practice, redesigning a lead refinery stirrer requires dealing with constraints on size and weight, complexity of the assembly, and especially on the available power of the motor. An experienced engineer will set-up targeted calculations in order to find an improved or even optimal design within these constraints.

Technology used

- Geometry preparation and parametrization: ANSYS Spaceclaim
- Mesh preparation: ANSYS Meshing
- Computational Fluid Dynamics (CFD) software: ANSYS Fluent

Engineering Solution

- Appropriate turbulence models and structured wall meshes are used to account for turbulent flow and boundary layers at the wall.
- Steady-state mixing regimes can be calculated using the Multiple Reference Framework, which allows to compare many cases quickly.
- The geometry is parametrized in order to automate design optimization.
- Mixing times are evaluated by virtually adding a tracer element at a certain location, and monitoring the tracer concentration at different locations (Figure 2).
- Gas bubble trajectories (Figure 3) and residence times (Figure 4) are evaluated using the Discrete Phase Method (DPM). This approach can also be applied for solid precipitates or additions.
- The vortex size can be estimated from flow patterns, or can be calculated directly using multiphase models when desired.

Benefits

- **Mixing times and gas residence times are calculated for several stirrer designs.**
- **Particularities of the lead refinery process and plant requirements are taken into account.**
- **Modelling allows to avoid standard designs and to find the optimal stirrer for available power, kettle shape, and constraints in the plant.**
- **Location and parameters of gas injection, or addition of solid reactants, can be optimized.**

Sander Arnout, PhD
Modelling expert
InsPyro NV
Leuven, Belgium

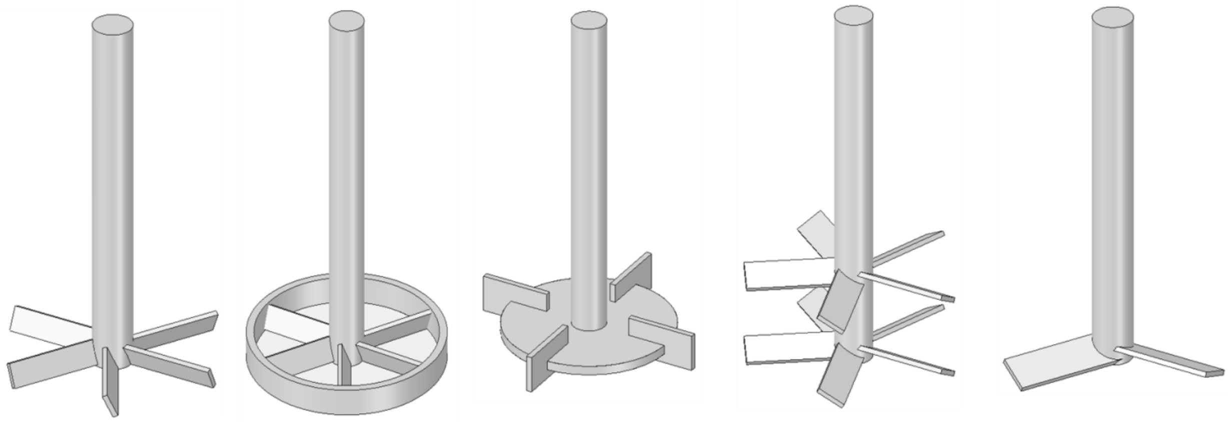


Figure 1: Examples of typical stirrer layouts and design modifications*

*Hypothetical designs are used throughout this article.

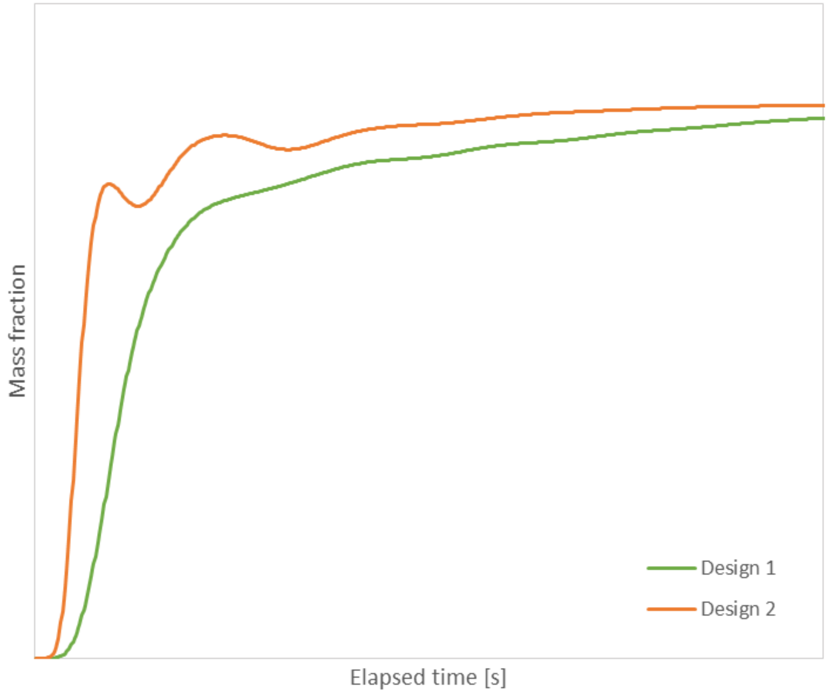


Figure 2: Tracer concentration as a function of time after addition, to assess mixing times for two different set-ups

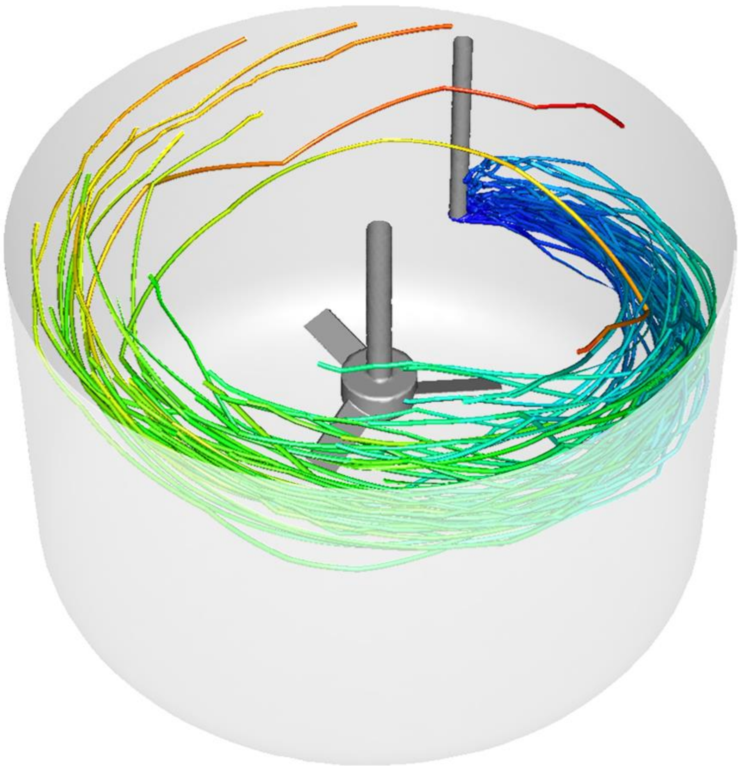


Figure 3: Flow of injected gas in a lead refining kettle

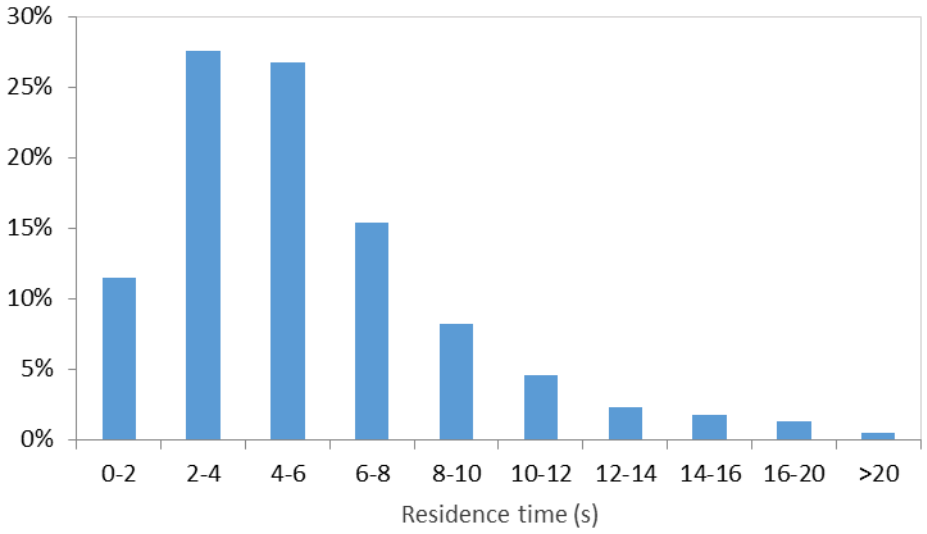


Figure 4: Residence time distribution of injected gas bubbles