SUCCESS STORY

K1-MET SusMet4Planet
Competence Center of Sustainable Digitalized Metallurgy for a Climate Neutral and Resource Efficient Planet

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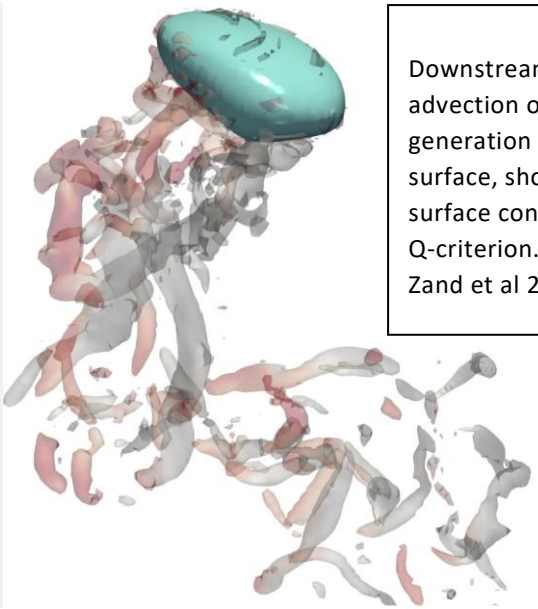
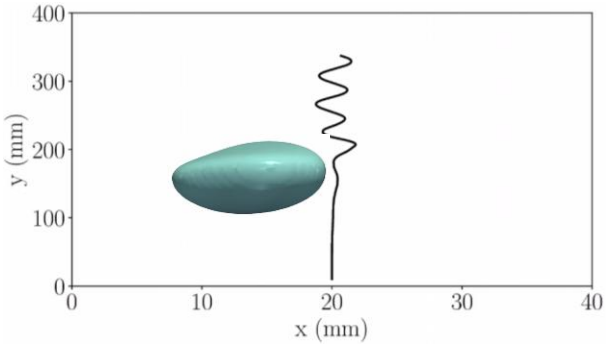


Downstream advection of vorticity generation on bubble surface, showing iso surface contours of Q-criterion. (M.K. Zand et al 2025).

ON THE INTERACTION OF BUBBLE AND VORTICITY

UNRAVELING BUBBLE LIFT FORCE EMERGENCE USING GENERAL VORTICITY TRANSPORT EQUATION

The lateral distribution and flowing regime of bubbles in bubble plumes, which are used in various industrial applications like converter steelmaking or continuous casting in steel production, is influenced by the lift force acting on them. This lift force arises from vorticity, which is characterized by a rotation happening in the fluid flow. Here, we have explored how bubble deformation and surface tension forces contribute to vorticity generation near the bubble surface and ultimately give rise to the lift force, which causes the lateral motion of the bubbles rising in liquids.



Onset of bubble lateral movements initiated by bubble shape deformation. An instantaneous snapshot of bubble shape is brought in the picture. (M.K. Zand et al 2025).

Through simulations of individual, freely rising bubbles of varying sizes in different liquid environments —spanning a broad spectrum of fluid flow conditions and properties — using the interface-resolved volume of fluid (VOF) method, we observe a strong correlation between vorticity generation from surface tension forces, which influence the bubble shape deformation and the lateral force experienced by the bubble.

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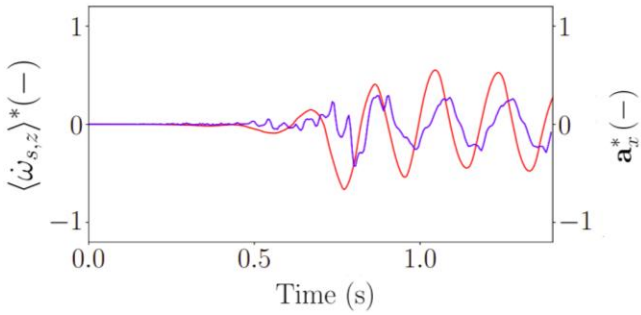
Impact and effects

The results show similarities in the trends of bubble lateral acceleration and the patterns of bubble vorticity generation, which is a representation of the lateral forces imposed on the bubble, namely the bubble lift force. In addition, it is evident from the plots that vorticity is generated first, then bubble lateral acceleration follows the same pattern of vorticity generation rate. A zero generation of vorticity by the bubble results in zero lateral acceleration, but a positive (negative) vorticity generation rate results in positive (negative) acceleration rate.

These findings of the present work provide a new point of view to investigate the lift force phenomenon, which has previously been neglected in this research field. This novel perspective suggests a fundamental link between vorticity generation due to bubble deformation and bubble lift force and offers a promising pathway to develop a new lift force model, which could be used for modeling the bubble dynamics with better accuracy in complex multiphase scenarios such as gas injection into metal melts.



Comparison of bubble lateral acceleration (blue line) and vorticity generation (red line). (M.K. Zand et al 2025).

Project coordination (Story)
Mohammad Karimi Zand
PhD Student, Researcher
K1-MET GmbH
T +43 732 2468 6714
mohammad.zand@k1-met.com

K1-MET GmbH
Stahlstraße 14
4020 Linz
T +43 (0) 732 6989 75607
office@k1-met.com
www.k1-met.com

Project partners

- Johannes Kepler University Linz, AT
- Montanuniversität Leoben, AT
- SWERIM AB, SWE
- Primetals Technologies Austria GmbH, AT
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- voestalpine Stahl Donawitz GmbH, AT

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Federal Ministry
Innovation, Mobility
and Infrastructure
Republic of Austria

Federal Ministry
Economy, Energy
and Tourism
Republic of Austria

Austrian Research Promotion Agency
Sensengasse 1, A-1090 Vienna
P +43 (0) 5 77 55 - 0
office@ffg.at
www.ffg.at