Removal of viscoplastic soiling layers by obliquely impinging water jets

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Objective
Liquid jets are widely used in CIP systems to remove residues from the walls of process vessels. Several systems employ rotating heads with several nozzles which move the jet over the surface, creating a dynamic cleaning pattern. Predicting the performance of these systems requires an accurate description of how the liquid is distributed when it impinges obliquely on the wall, and the associated rate of soil removal.
Methods
Series of experiments were performed to determine the flow distribution generated by 2 mm diameter coherent water jets impinging on vertical PMMA surfaces at different angles. Video analysis was used to estimate the flow rate from the initial location of the hydraulic jump and from the local cleaning rate of Nivea Soft, a viscoplastic emulsion. Both methods allowed the whole azimuthal range to be mapped.
The information combined with the jet cleaning model of Bhagat *et al*. (2017; Food & Bioproducts Processing, **102**, 31) in a Matlab ™ simulation of a rotating cleaning nozzle operating at a range of settings to predict its the cleaning effectiveness.
Results
The flow distribution functions obtained using the two methods showed good agreement. The amount of liquid flowing in the principal jet direction was smaller than predicted by the Hasson and Peck (1964; *AIChEJ*, **10**, 752) model. A one-parameter modification of this model gave good agreement with the data.
The observed rate of cleaning fitted the Bhagat et al. model reasonably well. Simulations reproduced the hatched pattern observed in practice for rotating nozzles. The fraction of surface cleaned increased very slowly in the final stage. The model does not include ageing of film drainage effects which would introduce time dependent removal kinetics, and this should be included in future work. The results allow the sustainability and effectiveness of different combinations to be compared.
Conclusions
The distribution of liquid generated from an impinging jet differs slightly from that predicted by geometric models. A good description of the flow function can be provided by a modified model, which, when incorporated in cleaning simulations, allows the performance of rotating nozzle systems to be assessed.