A novel Cleaning in Place (CIP) approach and CFD modeling of the removal of thin films from metal surfaces with rotating high speed jets

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Keywords: surface cleaning, surface activation, metal processing, film removal, CFD

Cleaning of surfaces prior to coating is an important process since it activates the surface resulting in a better adhesion of the applied coating [1]. Impinging jets are widely used in the surface preparation industry due to the environmental friendly process and effectiveness. Impinging jets can be classified into steady, unsteady jets mounted either on a static or a moving/rotating nozzle carrier head. In case of jets with a static nozzle carrier head, multiple nozzles have to be placed in order to ensure complete coverage of the area to be cleaned. Relative movement between the nozzle carrier and the substrate results in an impingement zone on the complete substrate, thus a better cleaning. This work involves the study of the effect of jets mounted on a rotating nozzle carrier designed in order to ensure the complete coverage of the area to be cleaned due to the elliptical nozzle groove path along with a relative nozzle and substrate movement as seen in figure 1.

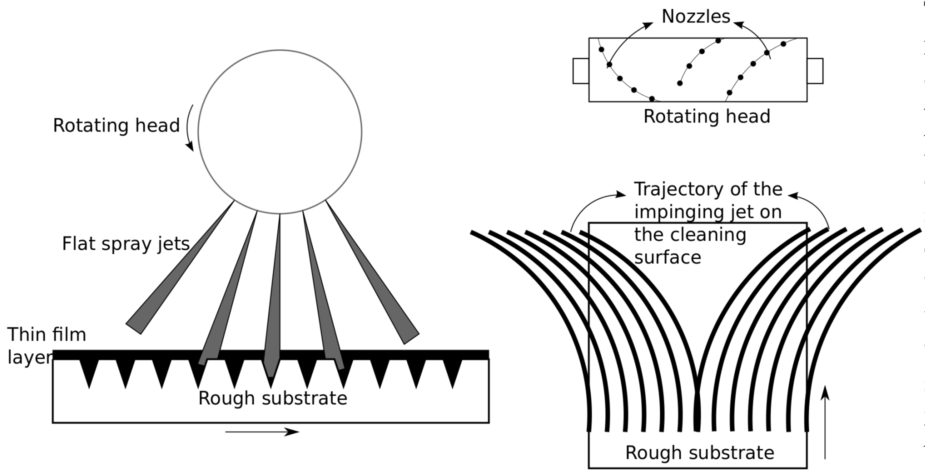

Fig 1:Rotating impinging jets for the removal of thin films from rough substrates

The force required for the removal of thin films increases with the decrease in the film height. When film height is of the same order of the roughness of the substrate, an initial force is required to overcome the frictional force and inertial force to remove the film from the pits in the substrate [2]. Hence, the idea is to use a rotating jet which impinges multiple times at a small angle while the substrate traverses under the nozzle carrier.

The interaction between the jets and the film layer is a complex phenomenon. The moving substrate poses further complexity. This work addresses the numerical modeling of the film removal process by using Computational Fluid Dynamics (CFD). The Volume Of Fluid (VOF) method, which is an interface tracking approach by acknowledging the presence of water, air and viscous layer, is used for multiphase modeling. Rotary impingement is achieved by implementing an inlet condition which transforms the jet by a time dependent rotational tensor. The rough substrate is geometrically modeled and the viscous layer is resolved by employing a fine grid. Arbitrarily Mesh Interface (AMI) between the substrate and the jet regions enables the movement of the substrate with a certain velocity in perpendicular direction of impingement. The model enables parametric analysis to study the effect of standoff distance, viscosity of the film layer, substrate roughness, substrate speed, frequency of rotation of the nozzle carrier and thus to optimize the cleaning downtime. An open-source code OpenFOAM® is used for CFD modeling and simulation.

References

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