Novel Super-Pitch, Circular Rake, Cambered, Zero-Velocity-Sump Propeller Design Performance Evaluated as a Function of Number of Blades

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ABSTRACT

Propellers borrowed from the world of marine propulsion are not optimized for use with mixers. Marine props are optimized for a given inlet fluid flow and are designed to optimize thrust whereas mixer props must be designed to achieve a desired flow rate and velocity profile. This presentation discusses a second generation *super-pitch* propeller design that is optimized for the mixing condition where the prop diameter is small compared to the diameter of the mixing vessel such that the fluid velocity at the prop leading edge equals that associated with fluid drawn from a stationary sump. Design goals - Maximize pumping & outlet fluid velocity for a given prop diameter, minimize power consumption, minimize production cost, and minimize overall prop diameter for insertion into standard manholes. Prop design employs the novel, patent pending, concept of circular rake, along with the established concepts of helical profile, 2'nd order camber, and skew. The effective pitch-to-diameter ratio at a given point on the leading edge varies with respect to the radius and has been tailored to match the slope of the incoming fluid vector which accounts for both the apparent fluid velocity due to impeller rotation as well as the velocity profile of the incoming fluid. Effective trailing edge pitch-to-diameter ratio was set to a magnitude commonly known as super-pitch. A series of (3) Ø8 inch prop CAD models were created using PTC Pro/Engineer software to explore the relationship between three, four and five evenly spaced propeller blades. All other geometry was held constant. CAD Models were rendered in glass filled nylon using the selective laser sintering (SLS) rapid prototype process. Performance of CAD models was simulated using power consumption formulas derived from an energy perspective and implemented in Mathcad. Structural integrity was determined using Pro/Mechanica (FEA). Fluent computational fluid dynamics (CFD) analysis was used to verify inlet flow field hypothetical shape. The performance (power number Np and pumping number Nq) was evaluated using a digital torque arm & tachometer and a Dantec laser based particle image velocimetry (PIV).