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Flow and Power Characteristics of Three Types of In-Line Rotor-Stators

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Power numbers estimated from numerical modeling were in agreement with experimental values when average torque rather than local energy dissipation rate was used.
In the case of GPDH and Emulsor geometries, the zone of high turbulence energy dissipation rate, where breakage would occur, was located in the head and jets leaving the outer holes. In the Ytron Z unit, energy dissipation rate was more uniformly distributed in the chamber. In addition, at a given average power input, local energy dissipation rates that particles would experience in a solid-liquid system were higher, which is an advantage of this design.

Whilst the specific geometry of an in-line rotor-stator varies from one design to another, certain features such as the narrow gap in the mixer head and/or blades on the rotor, holes on the stator, combined with high operating speeds of thousands of rpm, result in high levels of local energy dissipation rate and liquid velocities in the mixer head. Therefore, they are used in a wide range of energy intensive applications in the chemicals, food, personal and health care industries for foam generation, chemical reactions, break up of liquid droplets or de-agglomeration.

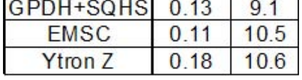
In this study, three rotor-stator heads were investigated in terms of their flow and power characteristics:

- inner General Purpose Disintegrating Head (GPDH) and an outer Square Hole Screen (SQHS) and
- dual Emulsor screen (EMSC) from Silverson and
- Z unit from Ytron.

The set up included a stirred tank with a total dispersion volume of about 100 l. Power consumption was determined using the calorimetry technique and flow through the rotor-stators was studied through 3-D CFD simulations (Fluent 6.3).
Both the rotor speed (up to ~ 8000-9000 rpm) and flow rate range (0.3-1.5 l/s for the Silverson; 0.16-0.5 l/s Ytron) were varied, covering a rotor Reynolds number range of 2 7.4 x 105 (gap Reynolds numbers will also be given during the presentation). Different approaches used to calculate the power number will be discussed along with that used by DOMINO:

$$Po = \frac{P}{\rho N^3 D^5} = Po_1 + \frac{Po_2 Q_2}{ND^3} = Po_1 + Po_2 Fl$$

Characteristic power numbers obtained for the different geometries are summarised in the Table.



	Po_1	Po_2
GPDH+SQHS	0.13	9.1
EMSC	0.11	10.5
Ytron Z	0.18	10.6

Re-circulating flow rates were found to be higher for Ytron Z geometry over the whole range of conditions covered. The fluid circulated mainly within gaps of the stator and there was little exchange with the fluid in the chamber. With the GPDH and Emulsor designs, the fluid in the chamber appeared to be re-circulated back into the mixer head. The mean velocities in the mixer head of the Emulsor were lower than those for the GPDH. This would mean that particles would stay longer in the zone of high energy dissipation rate, which proved to be an advantage of this design over GPDH. Findings from the study have been used to complement the results obtained on the break up of nanoparticle clusters using these rotor-stators.

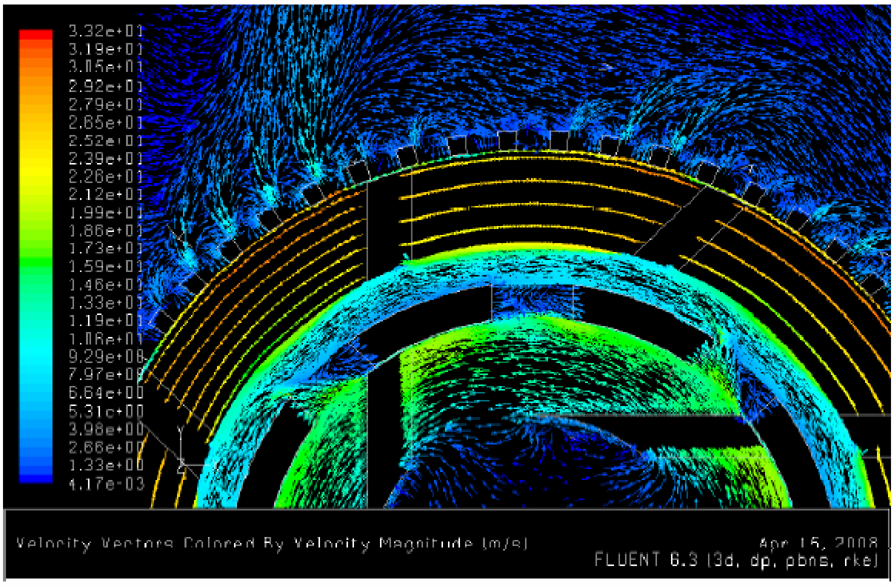


Figure 1. Velocity vectors for GPDH-SQHS (N=9000 rpm, P= 9.6 W kg^{-1}, Q= 0.6 l s^{-1})

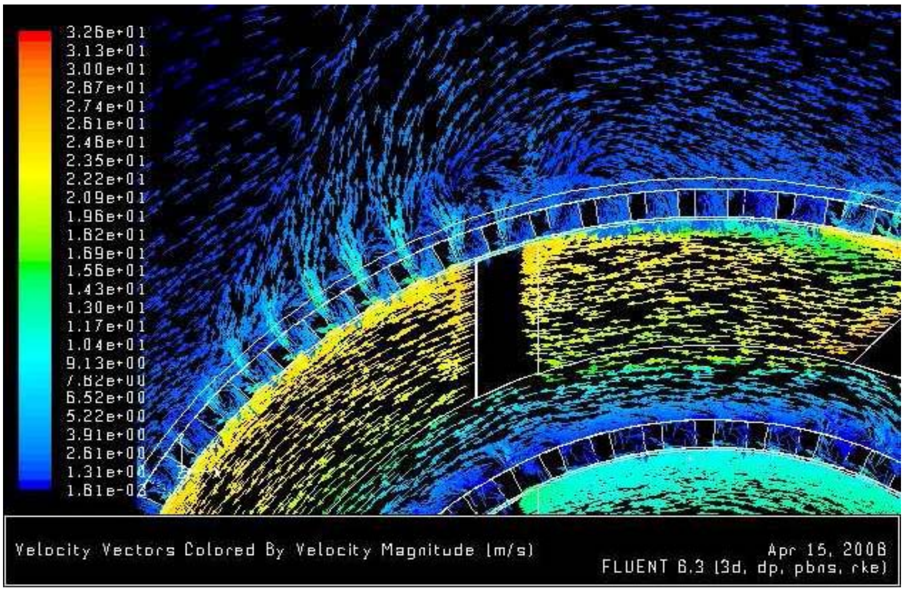


Figure 2. Velocity vectors for Emulsor (N=7950 rpm, P= 7.1 W kg^{-1}, Q= 0.6 l s^{-1})

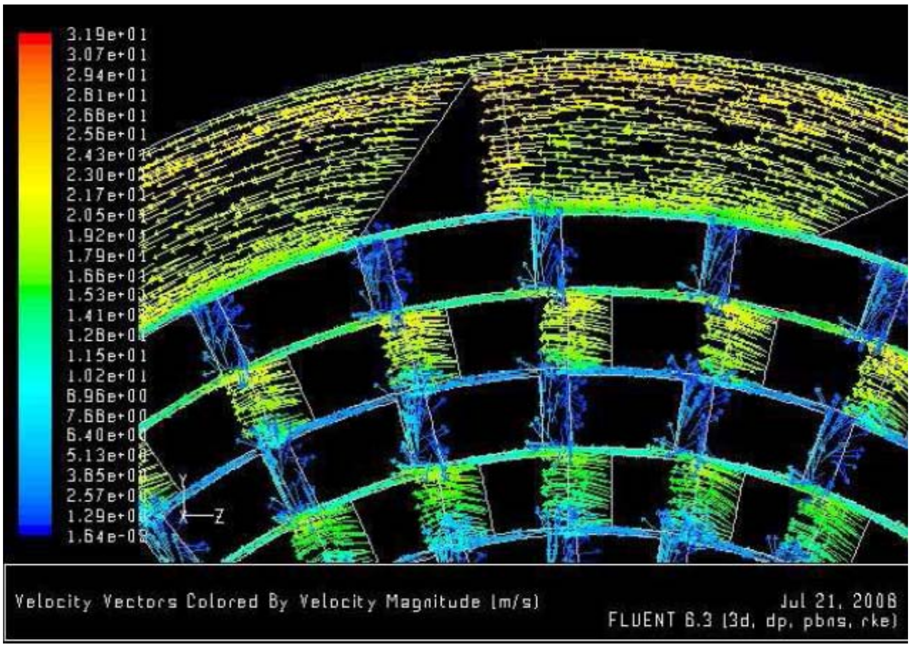


Figure 3. Velocity vectors for Ytron Z unit (N=6610 rpm, P= 7.4 W kg^{-1}, Q=0.5 l/s)