**Influence of impeller geometry on hydromechanical stress in agitated bioreactors**

Chrysoula Bliatsiou1, Robert Panckow1, Philipp Waldherr1, Lutz Böhm1, Matthias Kraume1

*1 Chair of Chemical and Process Engineering, Technische Universität Berlin, Fraunhoferstr. 33-36  
10587 Berlin, Germany*

*\*Corresponding author: c.bliatsiou@tu-berlin.de*

**Highlights**

* Hydromechanical stress crucial for shear-sensitive filamentous microorganisms.
* Impeller geometry determining factor for particle breakage in bioreactors.
* Quantification of particle breakage by means of in situ endoscopic technique.
* Investigation of novel impellers.

**1. Introduction**

As part of the DFG priority program SPP 1934 DiSPBiotech, this study focuses on the characterization of local mechanical stresses occurring in stirred tank bioreactors and their effect on biological agglomerates. This work intends to identify and develop low-shear stirrers for cultivations of filamentous microorganisms. As case study, the cultivation of the filamentous fungi *Aspergillus niger* is used. Direct measurements of mechanical stresses in real cultivation broths are barely possible. Thus, the investigations are carried out by using model systems [1], which simulate the most significant properties of the biological system (broth rheology, bio-agglomerates morphology). Conventional and newly developed stirrer types are characterized in terms of particle stress, which is quantified by measuring particle breakage in the agitated reactor by means of an in situ particle size measuring technique. The interpretation of the breakage mechanisms in the stirred vessel succeeds through quantification of shear and elongation stresses by using Particle Image Velocimetry (PIV).

**2. Methods**

Experiments were conducted in a 3-L lab scale baffled agitated tank, geometrically similar to a fermenter. 15 impellers were used for the investigations. Among the conventional agitators (Rushton, pitched blade turbines etc.), five novel agitators were developed in cooperation with EvoLogics GmbH (Fig. 1).

Development of model systems: As particulate systems fluid/fluid and solid/fluid systems were used. Particularly, droplets of silicon oil and clay/polymer flocs were chosen as dispersed phase to approximate a wide range of *Aspergillus* morphology (spherical pellets and mycelial forms). The cultivation broth appears to be low viscous up to a specific level of biomass concentration and then it develops a shear thinning behavior. Water and a Xanthan gum solution were used as model fluids for the continuous phase to approximate the broth rheology at initial and later cultivation phases.

In situ particle size measurement: An in situ analysis method was used to monitor the particle breakage kinetics in the stirred tank. The photo-optical SOPAT measurement technique for particle sizing (SOPAT GmbH) uses endoscopic probes, capable to obtain two-dimensional images of a disperse phase during a process and measure the sizes and shapes by an automated image analysis [2].

Fluid dynamic investigations: Mechanical stress is quantified by recording the velocity vector field by means of Particle Image Velocimetry (PIV) and calculating shear/elongation gradients in the tank.

**3. Results and discussion**

The particle breakage caused by the investigated stirrers was measured in the stirred tank for the developed particulate model systems. The particle stress caused by each stirrer is quantified as a function of a steady state characteristic particle diameter with the average energy dissipation rate. Fig. 2 indicates that an axial propeller causes stronger breakage, producing smaller droplets in comparison to a radial Rushton turbine, which in the biotechnological field has been wrongly considered as high shear impeller. Through PIV measurements, the particle breakage caused by 15 stirrer types is further analyzed. Fig. 3 shows that mixing with a propeller produces significantly high shear gradients, inducing consequently stronger particle breakage as depicted in Fig. 2.

|  |  |
| --- | --- |
| EVO1MBS_GW_edit | |
| **Figure 1.** Patent pending novel impeller geometries; Bionic Loop (left) and Wave-Ribbon impeller (right) (EvoLogics GmbH) | |
| C:\Users\c.bliatsiou\tubCloud\Shared\Lutz-Sissy\Konferenzen\9-ECCE12-ECAB5 2019\Präsentation.tif | |
| **Figure 2.** Steady state particle diameter as a function of the av. energy dissipation rate for two impellers; drops dispersion (left) and flocs suspension (right) | **Figure 3.** Cum. distribution of the shear rates produced by two impellers for |

**4. Conclusions**

The results of the abovementioned experimental work contribute significantly in the design of low-shear impellers to be used for the cultivation of shear sensitive filamentous microorganisms.

**References [Calibri 10]**

1. Henzler, H-J.,2000 Particle Stress in Bioreactors. In: Schügerl K. et al. (eds) Influence of Stress on Cell Growth and Product Formation. *Adv. Biochem. Engin./Biotechnol*. 67, Springer.
2. Panckow, RP., Reinecke, L., Cuellar, MC., Maaß, S., 2017. Photo-Optical *In-Situ* Measurement of Drop Size Distributions: Applications in Research and Industry. *Oil Gas Sci. Technol.* 72, 3, 14.