Aggregating Alginate for Drag Reduction

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Polymeric drag reduction (DR) is the effect of reducing the flow resistance in turbulent flow of liquids achieved by polymers with high molecular weight dissolved in the flowing liquid [1]. Polymer degradation in turbulent flow limits the application, as interaction with turbulent vortices decreases the molecular weight and diminishes drag reduction [2]. Covalent bonds are broken irreversibly and DR is lost. We explored the potential of noncovalent bonds to provide structures of high molecular weight for DR which can reform after degradation and prevent covalent bond scission in turbulent flow DR [3]. Strong noncovalent bonds are needed in order not to be destroyed already at low shear rates [3]. The polysaccharide alginate forms strong aggregates in the precence of Ca^{2+} ions. In unaggregated state alginate is known as a DR agent albeit limited by its molecular weight and chain rigidity [4]. We varied alginate and Ca^{2+} concentration in flow experiments to achieve high molecular weight aggregates, resulting in increased DR. If the aggregates are exposed to turbulent flow, DR decreased rapidly, indicating the breakup of the supermolecular structures. When we applied some resting time at ambient conditions (1 to 7 days) after degradation and repeated the flow experiments high DR was recovered as visible in Figure 1, indicating a re-formation of the aggregates. Again turbulent flow lead to a decrease in DR. The cycle of degradation in flow and re-aggregation at ambient conditions was repeated multiple times, proofing the reversibility of the process in contrast to the irreversible loss of DR in polymer structures based solely on covalent bonds. Multi angle light scattering provided additional insight into polymer and aggregate size.

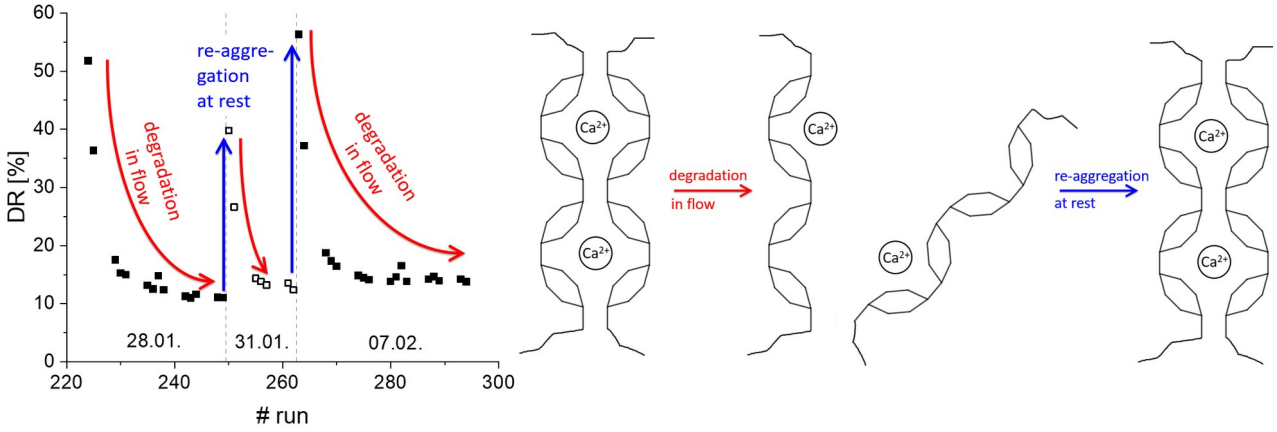

Figure 1: DR of an alginate solution in the presence of calcium ions. Turbulent flow led to a rapid decrease of DR within a few runs of the flow facility. DR was recovered if the solution rested for a few days. Repetability of decrease and recovery of DR for the alginate solutions indicated a reversible aggregation mechanism.

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References

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