# The Effect of Process Variables on Blend Time in a Continuous Stirred Tank

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## Abstract

It is well known that the performance of a CSTR is highly dependent on the operating conditions, the agitator and vessel geometry, as well as the positions of the inlet and outlet streams. These process variables determine the hydrodynamics and the turbulence levels generated in the tank, which are important for blending at the macro scale and chemical reaction at the micro scale. A typical rule of thumb employed in the design of continuous stirred tank processes is the ratio $\tau/t_m \geq 10$, which means that the residence time ($\tau = V/Q$) should be at least ten times the batch blend time, $t_m$. This time ratio involves the feed flow rate and information concerning the impeller rotational speed and geometry, but does not include any data on the positions of the inlets and outlets or the number of inlets.

Several authors have studied the effect of different variables, including flow rate, feed and outlet positions, feed diameter and impeller pumping direction, on the hydrodynamics in CSTRs [1-5] and residence time distribution models [5, 6]. Roussinova and Kresta [7] took another approach and compared the continuous mixing time to the ideally mixed continuous stirred tank theory. Amongst this literature there are apparent discrepancies in the way to scale CSTR data. Some studies have shown that the data can be correlated by the timescale ratio $\tau/t_m$ [7], others show the opposite trend [5, 6]; Jones et al. [6] have shown better correlation of their data with the momentum ratio (impeller momentum/jet momentum). The momentum ratio is indeed attractive since it takes into account the impeller speed and characteristics, as well as the feed flow rate and velocity, the latter which takes into account the size and number feed tubes.

In this work, we have studied the effect of process variables, including the position of the feed and outlet streams, the number of feed streams, the feed flow rate, as well as the impeller pumping direction and rotational speed, on the blend time in a continuous stirred tank. The objective was to investigate how continuous mixing time correlates with $\tau/t_m$ and the momentum ratio.

The blend time is determined experimentally by following the decay in the variance of tracer concentration in the vessel. It is defined as the time when the concentration variance reaches 95% of its final value. Tracer concentration is measured

simultaneously at three strategic points in the vessel using a spectrophotometer equipped with three *in-situ* probes.

The results in Figure 1 show that the mixing time is independent of the impeller pumping direction and the position and number of feed inlets. There also seems to be no effect of impeller rotational speed for the conditions studied. In fact, the data are clearly dominated by the mean residence time. Figure 1 also shows that the measured continuous mixing times are always longer (10-30%) than the theoretical value for a 95% mixed ideal CSTR. Further analysis shows that the data correlate well with the timescale ratio $\tau/t_m$, whereas for certain conditions, the same blend time is measured for different values of the momentum ratio. However, the momentum ratio appears to be more help in the analysis of the deviation of the experimental results from the ideal CSTR values. This deviation is smallest at very high momentum ratios ($Mo_{imp}/Mo_{jet} > 20$) and also very low ratios $Mo_{imp}/Mo_{jet} < 5$. This decrease in deviation from ideality at very low momentum ratios suggests that in such cases, the jet plays a role in mixing.

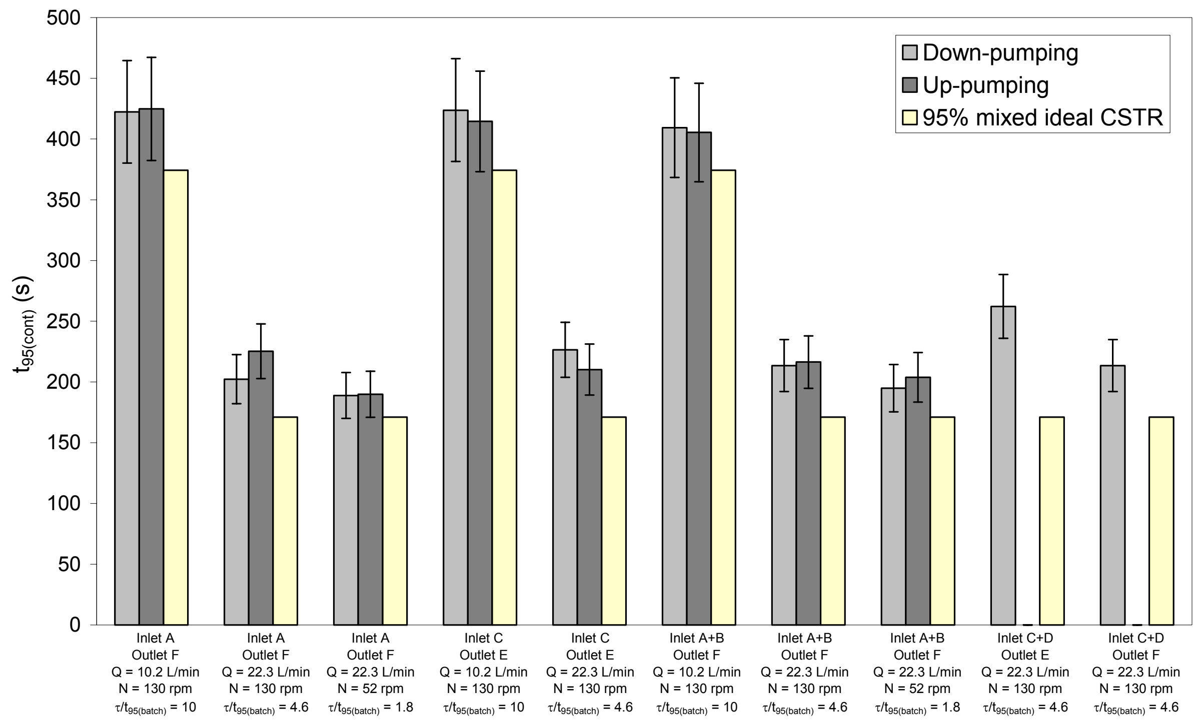


Figure 1: Experimental mixing times obtained for various process conditions are compared with the theoretical values of a 95% mixed ideal CSTR.

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**keywords:** stirred tank, mixing, blend time, CSTR

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