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ABE 304

Mixing and Heat Transfer

Main types of impellers commonly used for mixing in industry

There are four common types of impellers used in industry to perform tasks related to agitation and mixing. Some of these tasks include blending two miscible liquids, dissolving solids in liquids, dispersing gas into a liquid, and increasing the heat transfer between a fluid and a jacket in the vessel wall. The first type of impeller is a three-blade propeller agitator that an axial flow pattern. This impeller is used for liquids of low viscosity and can turn at high speeds of 400 to 1750 rpm (Geankoplis, 1993, p. 154). Another type of impeller is a paddle agitator, that is used a low speeds of 20 to 200 rpm and used for viscous liquids. These impellers are not effective for mixing and sometimes need the use of a paddle in order to scrape the tank walls. Some products produced from paddle agitators are starch pastes, paints and adhesives. Turbine agitators are also used in industry that run at high speeds for liquids with a large range of different viscosities. Depending on whether there are three, four, or six blades, and if those blades are pitched or flat, this type of impeller can be used for gas dispersion or suspension of solids (Geankoplis, 1993, p. 155). The last type of impellers commonly used in industry are helical-ribbon agitators that create a flow path in a twisting motion. This impeller is used in the laminar region at a low rpm for highly viscous solutions.Viscosity is a major factor in determining which impeller to use in production. Propeller agitators are used for fluids with low viscosities (under 3 Pa.s) while a helical-ribbon agitators are used for fluids with a very high viscosity (1,000 Pa.s,) but can be used for viscosities up to 25,000 Pa.s (Geankoplis, 1993, p. 156).

Heat transfer coefficient, U

The heat transfer coefficient, *U*, is calculated by taking the reciprocal of the sum of the resistances (R_i) multiplied by the area of the contact surface (A) (Geankoplis, 1993, p. 304). This is exhibited in Equation 1.

$$U = \frac{1}{A(R_1 + R_2 + ... + R_n)} \tag{1}$$

In this equation, n represents the total number of resistances. A system of a steam-jacketed kettle has three types of resistances, convection through the steam used to heat the system (R_{steam}), conduction through the wall of the kettle (R_{wall}), and convection through the solution being heated in the kettle ($R_{solution}$). However, as the wall of the kettle is very thin, the conduction through the wall of the kettle can be ignored (Geankoplis, 1993, p. 304).

Rate of energy accumulation in system, q_{accu}

The rate of energy accumulation within the system is represented by q_{accu}. This value is calculated by finding the product of the mass of the substance being heated, its specific heat of the substance, and its temperature change (ΔT), as shown in Equation 2 (Geankoplis, 1993, p. 299).

$$q_{accu} = mc_p\Delta T \tag{2}$$

Equation for batch system with perfect insulation

The general energy balance equation for the rate of heat flow within the system can be seen in Equation 3.

$$q_{in} = q_{out} + q_{loss} + q_{accu} \tag{3}$$

For a system with perfect insulation, the rate of heat loss is negligible and can be eliminated from Equation 3 for simplicity. Thus, Equation 3 becomes the following:

$$q_{in} = q_{out} + q_{accu} \tag{4}$$

Heat transfer data analysis equation

The rate of heat entering the system can be expressed as seen in Equation 5, (Geankoplis, 1993, p. 279).

$$q_{in} = UA\Delta T \tag{5}$$

Substituting this and Equation 2 into Equation 4, the rate of heat leaving the system can be found with Equation 6.

$$q_{out} = UA\Delta T - mc_p\Delta T \tag{6}$$

References

Geankoplis, C. J. (1993). Transport Processes and Unit Operations (3rd ed.). Englewood Cliffs, NJ: Prentice-Hall.