Your Evaporation Guide
Operation – Rotation speed

Achieve higher distillation efficiency when using a rotary evaporator – Impact of rotation speed

Summary

The evaporation rate of a rotary evaporator is greater than that of static distillation apparatus. Moreover, the evaporation rate increases with higher rotation speed. This is, among other factors, due to the greater surface area inside the evaporating flask at one given time. Especially significant is the dissipation at lower rotation speeds. For instance an increase in speed above 200 rpm has a relatively low influence on the evaporation output. A rotation speed above 300 rpm can result in mechanical problems, vibrations and spillage from the heating bath. Thus, considering the advantages and disadvantages of different rotation speeds, the optimum rotation speed is around 250 to 280 rpm.

Introduction

Even 50 years after the launch of the first rotary evaporator, there is much ambiguity concerning evaporation in the rotating evaporating flasks.

Figure 1: *First generation rotary evaporator (BUCHI Rotavapor, Model 1957).*

Even nowadays, evaporation and distillation are still one of the most frequently used separation methods. In fact, the evaporation output of a rotary evaporator during single-stage distillation is around four times greater than that of conventional, static distillation apparatus [1]. There are several reasons why the rotation influences the evaporation output:

- Through the rotation, the liquid inside the heating bath is agitated, causing additional turbulence, which leads to a massive improvement of the heat transfer coefficient and, therefore, to an increase of heat transfer from the heating bath to the evaporating flask as well as from the flask to the solvent.
- Rotation greatly enlarges the active surface area inside the evaporating flask, thus accelerating the evaporation. As the solvent is heated via the heating bath, it is distributed as a thin film over the warm, inner surface of the rotating evaporating flask. This film partially vaporizes, resulting in a higher evaporation rate. With the liquid remaining at any one point of the flask wall for a short time only, rotation homogenous mixture of the sample is ensured and overheating, thus incrustation inside the flask is reduced.
- The frictional force and the centrifugal force between the wall of the rotating evaporating flask and the liquid inside the flask, result in the formation of a thin film of warm solvent spread over a larger surface.

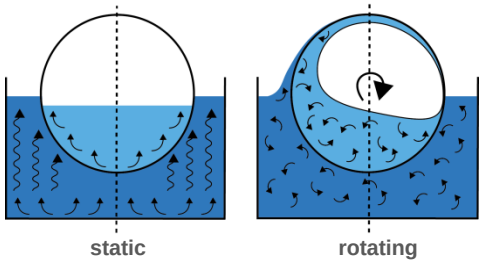

Figure 2: *Representation of heat transfer of a static and rotating evaporating flask. Convection → free convection, slow equalization of temperature (left); Turbulence → forced convection, improves heat transfer, thus a faster evaporation by keeping the liquid in motion (right).*

Additional advantages are that the forces created by the rotation suppress bumping, foaming and boiling delays.

However, the higher the rotation speed, the greater is the chance that mechanical problems with the rotary evaporator occur and the resulting vibration is more likely to cause deterioration of the instrument.

Experiment

Rotation certainly speeds up the evaporation. It is of great importance to scrutinize to what extent the speed of the rotation influences the evaporation output. For this reason, the dependence of the rotation speed on the evaporation rate should be determined.

The aim of the following experiment was to analyze the impact of the rotation speed on the evaporation rate of a single-stage solvent distillation. The experiment was executed with a modified BUCHI Rotavapor® where the rotation speed was adjustable to 500 rpm.

The experiment was executed in two steps. Firstly, in order to get a broad overview, the evaporation output of acetone was measured at nine different rotation speeds (from 50 up to 500 rpm). Secondly, the evaporation output of water was measured at stillstand and six different rotation speeds, within the actual operating range of up to 280 rpm.

Parameter

Solvent	acetone water
Heating bath temperature	60 °C
Cooling temperature	10 °C
Pressure	556 mbar (acetone) 72 mbar (water)
Flask size	1 L
Content	500 mL
Immersion depth	fill level

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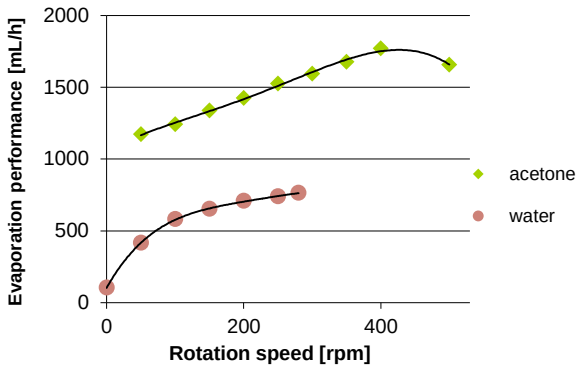
Results



Graphic 1: *Illustration of influence of the rotation speed on the evaporation output.*

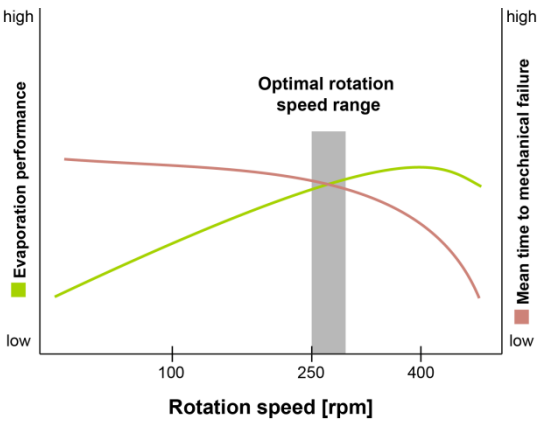
The graphic above shows that an increase of the rotation speed up to 400 rpm raised the evaporation output. Though, the evaporation rate decreased again at speeds above 400 rpm (acetone). The test series with water clearly showed that the dissipation was especially significant at lower rotation speeds and relatively less above 200 rpm.

Interpretation

The experiment shows that the maximum evaporation output is achieved at a rotation speed around 400 rpm. This is because the rotation speed can be raised to a point where the content will be pressed against the wall by centrifugal force and corotate with the flask. In this case the turbulence will decrease again, which consequently results in a lower evaporation rate. The optimal turbulence depends on the flask size, the consistency and texture of the solvent/substance and the filling quantity.

Recommendation

The rotation speed should be selected to produce maximum turbulence inside the flask as well as in the heating bath, in order to reach maximum evaporation output and still guarantee a long lasting life of the rotary evaporator.



Graphic 2: *Representation of the optimal rotation speed by the intersection of the two curves.*

The graphic illustrates the ideal rotation speed range, where the problems, such as spillage, vibration, mechanical problems, are still low.

Considering the factors of maximum output and long lifetime of the instruments, the optimum rotation speed of a BUCHI Rotavapor® is from 250 to 280 rpm. For this reason the Rotavapors are limited to a rotation speed of 280 rpm.

References

[1] BUCHI Training Paper, “Distillation with a Rotary Evaporator”