Drying of Supported Catalysts -
A Comparison of Model Predictions and Experimental Metal Profiles

Xue Liu, Johannes Khinast and Benjamin J. Glasser
Department of Chemical and Biochemical Engineering,
Rutgers University, Piscataway, NJ, 08854

Introduction

Supported catalysts are essential components in a variety of industrial processes, ranging from catalytic converters to production of new drugs. They are generally required because of their high surface area and high mechanical and thermal stabilities. The performance of a catalytic process is intimately related to the catalyst design - uniform, egg-yolk, egg-shell and egg-white metal profiles. Although catalyst preparation and catalytic processing have been investigated for many years, many aspects of catalyst manufacturing are still not fully understood and the design of catalysts is often based on trial and error.

It is generally believed that the metal profile is controlled by the conditions that are applied during impregnation where the metal contacts the solid support for the first time. However, experiments have shown that drying may also significantly impact the metal distribution within the support. Therefore, to achieve a desired metal profile we need to understand impregnation, but we also need to have a fundamental understanding of the drying stage. Controlling the drying conditions can enhance catalyst performance, and minimize the production of useless batches that have to be disposed, or recycled.

Materials and Methods

In this work we have developed a theoretical model for drying. In this model, we have taken into account heat transfer from the hot air to the wet support, solvent evaporation in the support, convective flow towards the support external surface due to capillary forces, and metal diffusion and metal deposition due to adsorption and crystallization. In general, convective flow is the main driving force to transport the metal component and the solvent towards the support external surface, while back-diffusion causes metal to transport towards the support center. An increase in the evaporation rate may greatly enhance the convective flow.

It is of particular interest to compare simulation results and experimental measurements to determine the key parameters used to predict the impregnation and drying processing. Experimental work has been carried out based on Nickel/Alumina systems

Results and Discussion

To compare simulations and experiments under low metal concentration conditions, four parameters in the theoretical model are required, which can be obtained from separate experiments: 1) the metal effective diffusion coefficient into the pores of the support, 2) the equilibrium adsorption constant and 3) the kinetic adsorption constant of the adsorption and desorption processes, and 4) the permeability of the support. We have established separate experiments to measure / calculate the above parameters. Film-breakage is also an important phenomenon during drying. To consider the effect of film-breakage in our model, we added a factor on the water flux term, and varied its value with the water volume fraction during drying. For low metal load conditions, we have obtained good agreement between the simulations and experiments if the effect of film-breakage is considered (see Figure 1). For high metal load conditions, our experiments have shown that crystallization and pore-blockage become important during drying.

Significance

The goal of this research is to develop a fundamental understanding of the impact of impregnation and drying on the metal distribution. By validating our theoretical models, we can quantify the impact of impregnation and drying, and provide efficient tools to monitor and control the final quality of supported catalysts.

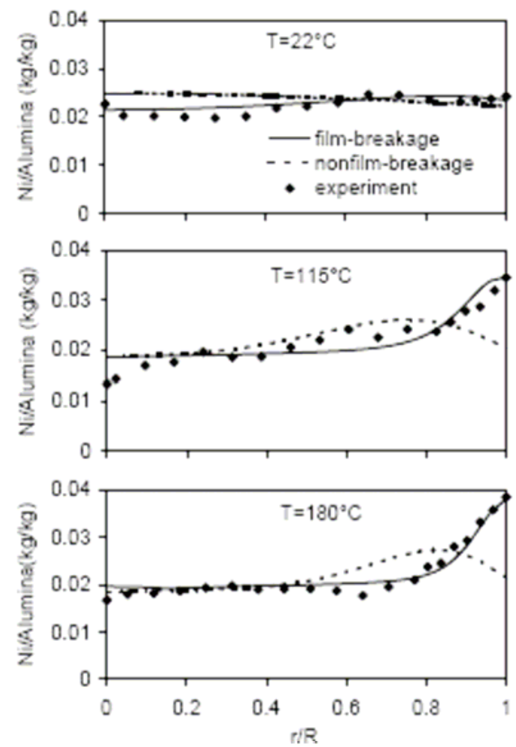

Figure 1. Final metal profiles for different drying temperatures.