# Chapter 5

# Conclusion

This study shows that a higher Cu-Zn loading on the impregnated catalysts leads to a higher activity of the catalysts which results in a higher hydrogen yield for the 20 wt% Cu-Zn loading catalysts than for the 10 wt% Cu-Zn loading catalysts. The use of urea in catalyst preparation can improve the activity of the impregnated catalysts for methanol steam reforming reactions which are indicated by the impregnated Cu-Zn catalysts treated with urea (CZU) exhibits a higher activity than those of the catalysts without urea treated (CZ). The impregnated catalysts treated with urea, using lower Cu-Zn loading, can exhibit comparable hydrogen yield to that of higher Cu-Zn loading commercial catalyst. The hydrogen yield of the commercial catalyst is only about 1.02 times higher while the Cu-Zn loading is about 4 times higher than that of the impregnated catalyst treated with urea (20CZU2) at 523 K. The catalysts were investigated in order to study the role of urea. The SEM-EDS images show that the Cu and Zn are deposited as a cluster over $Al_2O_3$. The images also show that the use of urea in catalyst preparation can reduce the size of Cu-Zn compounds clusters and provide better dispersion of Cu-Zn compounds clusters throughout $Al_2O_3$ surface. This phenomenon can be explained from the presence of ammonium nitrate produced by the reaction of urea and metal salt solution which is evidenced in the XRD pattern of the impregnated catalyst treated with urea before calcination. Ammonium nitrate can reduce the size of Cu-Zn compounds clusters over $Al_2O_3$ and also the crystallize size of CuO determined via XRD. Good dispersion of small Cu-Zn compounds clusters over $Al_2O_3$ results in a higher activity of hydrogen production. The study show that the improvement of catalytic activity of the catalysts treated with urea does not result from the basicity of the metal salt solution in the preparation process. This study also shows that the methanol reforming reaction can be carried out at as low a temperature as 453 K, which can save a lot of energy expenditure.

The production cost of the catalysts can be lower due to the ease of the preparation process and lower Cu-Zn loading compared to the commercial catalyst. Proper Cu-Zn loading with urea impregnated on the high surface area support can enhance the reaction activity and lower the operation temperature. The results of this study lead us further to the development of a novel catalyst for hydrogen production from the methanol reforming process.

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