Optimisation of $Cu/ZnO/Al_2O_3$ Catalyst Slurry for Dip-Coating Applications

Haroon Al Kasim Panangadantakath (B.Tech), Fabian Klein (M.Sc.), Abdolkarim Raeisi (M.Sc.)

INTRODUCTION

Copper-based catalysts play a pivotal role in CO_2 hydrogenation to methanol, offering **high activity and selectivity** for sustainable fuel production. Structured catalysts, particularly dip-coated metallic monoliths, enhance **mass and heat transfer,** improving efficiency. However, achieving a **uniform and adherent coating** depends on slurry stability **during dip-coating** [1].

Slurry stability is influenced **by rheology, milling conditions, and material composition,** affecting particle dispersion, wettability, and film uniformity [1] [2]. Poor formulation can cause aggregation, uneven deposition, and weak adhesion, compromising durability. Optimising these factors ensures a well-suspended, stable slurry for repeatable and controlled dip-coating.

OBJECTIVE

To systematically establish a stable and well-suspended $Cu/ZnO/Al_2O_3$ catalyst slurry for dip-coating by:

I. Determining the **optimal catalyst concentration** for slurry formulation
II. Identifying the **best combination of organic and inorganic binders**

The goal is to achieve zeta potential (≥±15 mV) to obtain a sufficient repulsive force between particles to avoid agglomeration and sedimentation and **optimal viscosity (5 cP ≤ x ≤ 30 cP)** to ensure proper wettability and uniform coating [2][3].

METHODOLOGY

Slurries are milled for 24 hours in a ball mill to ensure uniform dispersion.
Viscosity is measured first after milling to assess initial flow properties and again after zeta potential analysis once the slurry is adjusted to the optimal pH to ensure **suitability for dip-coating.**
Zeta potential is measured using pH titration to determine the pH at which particle repulsion is maximum to ensure a well-suspended slurry.

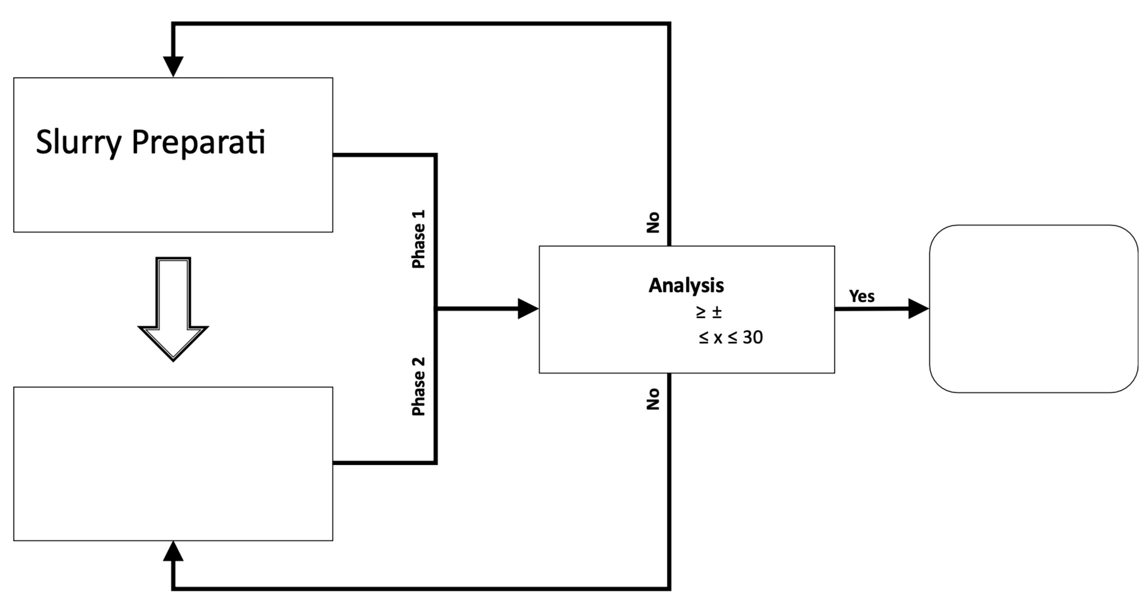


Fig. 1: Experimental matrix for the preparation of stable slurry

Phase 1: Catalyst Concentration Variation

Different catalyst concentrations, 1**0, 15, 20, 25 and 30 wt.%,** are tested while keeping binder composition constant (2 wt.% polyvinyl alcohol & 7 wt.% colloidal alumina), and slurries are named from SL01 to SL05, respectively. The best concentration is selected based on achieving the target zeta potential and viscosity range.

Phase 2: Binder Optimisation

Two organic binders (PVA, PVB) and three inorganic binders (colloidal alumina, silica, and zinc oxide) are evaluated. The effect of binder combinations on rheology was analysed.

ANALYSIS RESULTS

Slurry ID	Concentration (wt.%)		
	Catalyst ($Cu/ZnO/Al_2O_3$)	Organic binder (Polyvinyl alcohol)	Inorganic binder (Colloidal alumina)
SL01	10	2	7
SL02	15		
SL03	20		
SL04	25		
SL05	30		

Slurry ID	Material		
	Catalyst (15wt.%)	Organic binder (2 wt.%)	Inorganic binder (7 wt.%)
SL06	$Cu/ZnO/Al_2O_3$	Polyvinyl alcohol (PVA)	Colloidal silica
SL07			Colloidal zinc
SL08		Polyvinyl butyral (PVB)	Colloidal alumina
SL09			Colloidal silica
SL10			Colloidal zinc

Phase 1: Slurries with Different Catalyst Concentration

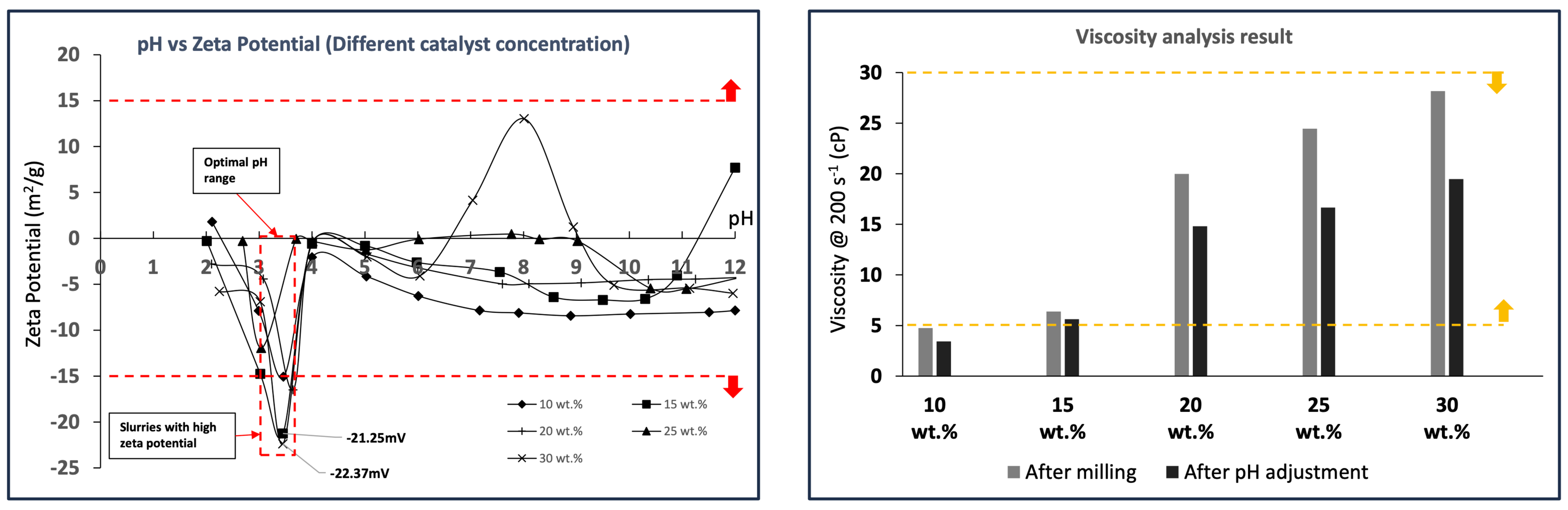
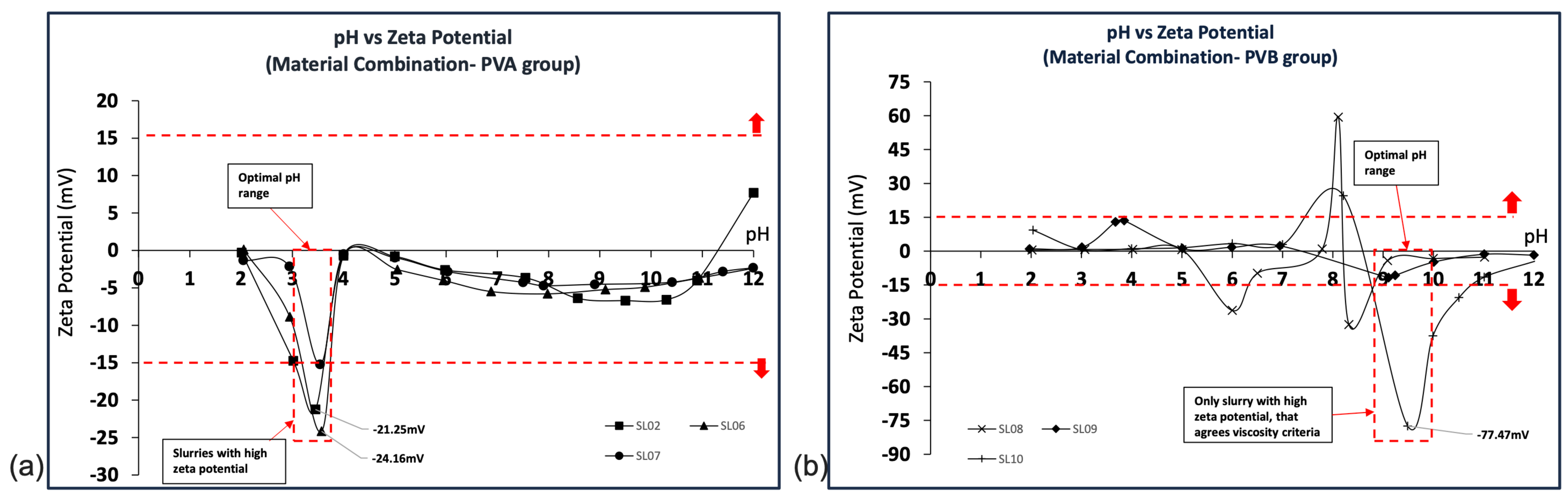


Fig. 2: Zeta potential (left) and viscosity (right) measurements of slurries with different catalyst concentrations

Phase 2: Slurries with Different Combinations of Binders



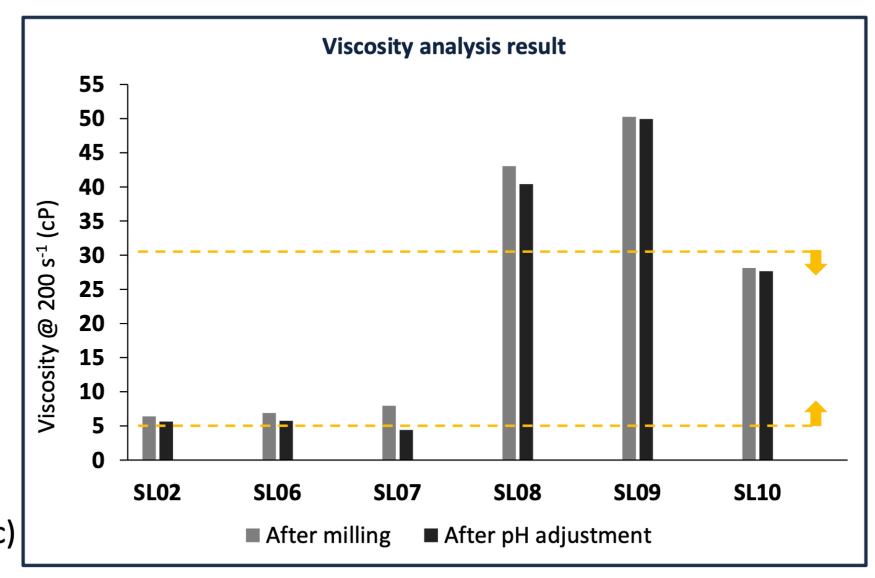


Fig. 2: Zeta potential analysis of (a) PVA-based and (b) PVB-based slurries, and (c) viscosity measurements of slurries with different combinations of binders

KEY FINDINGS

15 wt.% slurry achieved **optimal stability,** while **30 wt.%** led to excessive thickness and poor adhesion. **SL06** performed better than **SL02,** while **SL07** failed to meet the zeta potential target (±15 mV). **PVB-based slurries** were **highly viscous,** with excessively high zeta potential in the basic region and only **SL10** met the stability and viscosity criteria. In dip-coating performance, **SL02 and SL06** exhibited good coating quality and adhesion.

RESEARCH OUTLOOK

Dip-coating optimisation, followed by investigation on **post-treatment parameters.** Further refinement of slurry stability through **binder and dispersant optimisation.** Evaluating long-term performance of coated catalysts under reaction

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CONTACT:
SynFuels @ ttz Bremerhaven | Am Lunedeich 12 | 27572 Bremerhaven
Phone: 0471/ 80934-200
Email: info@ttz-bremerhaven.de

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