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Cairo University

# **USING ARTIFICIAL NEURAL NETWORKS TO PREDICT THE RHEOLOGICAL BEHAVIOR OF DRILLING FLUIDS**

By

**Moamen Ahmed Gasser Hassan Kamel Ibrahim Kamel**

A Thesis Submitted to the  
Faculty of Engineering at Cairo University  
in Partial Fulfillment of the  
Requirements for the Degree of  
**MASTER OF SCIENCE**  
**In**  
**CHEMICAL ENGINEERING**

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**Title of Thesis:**

Using Artificial Neural Networks to Predict the Rheological Behavior of Drilling Fluids

**Key Words:**

Drilling fluids; Rheology; Additives; Nanoparticles; Artificial Neural Network

**Summary:**

Drilling fluids are essential factor in the success of the drilling operations as they perform many functions from controlling the well, lubricating and cooling the drill bit. Lately, the petroleum field has shown a grown interest in enhancing the properties of the drilling fluids using nanoparticles.

In this research, two nanoparticles (MgO and ZnO) have been used to enhance the behavior of three types of drilling fluids. The obtained experimental results in addition to data from literature have been used to build artificial neural network (ANN) models that can predict the rheological properties of the drilling fluids.

The two nanoparticles have shown improvements and promising effects on the behavior of the drilling fluids. Also, ANN models were able to predict the rheological properties of the drilling fluids based on their composition with high accuracy which paves the way to the mechanization of the drilling operations.

## **Disclaimer**

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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# Nomenclature

AARE: absolute average relative error  
ANN: artificial neural networks  
ARE: average relative error  
AV: apparent Viscosity  
DP: date pit  
ECD: equivalent circulating density  
gel 10 sec: gel strength at 10 seconds  
gel 10 min: gel strength at 10 minutes  
GNPs: graphene nanoparticles  
GS: gel strength  
HBLE: hibiscus-leaf extracts  
HLE: henna-leaf extracts  
LSNDM: low solid non-dispersed mud  
MAE: mean absolute error  
MAPE: mean absolute percentage error  
MgO: Magnesium oxide  
MSE: mean-squared error  
NPs: nanoparticles  
OBM: oil-based mud  
PEs: processing elements  
PSD: particle size distribution  
PV: plastic viscosity  
 $R^2$ : correlation coefficient  
RD: relative deviation  
RMSE: root-mean-squared error  
SBM: synthetic-based mud  
SD: standard deviation  
SSR: sum of squares error  
TEM: transmission electron microscopy  
WBM: water-based mud  
YP: yield point  
XRD: X-ray diffraction  
XRF: X-ray fluoresce  
ZnO: Zinc oxide

# Abstract

Drilling process is one of the main operations in the extraction of hydrocarbons from petroleum reservoirs. It comes right after the exploration processes. Drilling fluids are necessary for controlling the wells and performing different functions during the drilling operation. They perform many roles in lifting the cuttings from the bottom of the well to the surface and cooling/lubricating the drill string and bit. Furthermore, they provide the desired hydrostatic pressure to overbalance pore pressure in addition to produce a thin/impermeable filter cake that can prevent or reduce the possible damage to the formations. It is mandatory to keep monitoring, enhancing, and optimizing the properties of the drilling fluids.

Recently, different additives, among which nanoparticles (NPs), have been investigated to improve, and maximize the benefits of the drilling fluids accordingly to meet the new challenges. The rheological behavior of such complex fluids has shown different enhancements up on the utilization of those additives. The rheological properties of the drilling fluids are accurately measured on the surface; however, the behavior of those properties may change according to the used additives and their composition. For that, different models are introduced and used to predict and optimize the rheological characteristics of such fluids.

In this study the effect of two types of NPs (MgO and ZnO) on the rheological properties of KCl-polymer, low solid non-dispersed mud, and bentonite water-based mud have been investigated. Also, Particle size distribution (PSD), zeta potential analysis, scanning by transmission electron microscopy (TEM), and x-ray diffraction (XRD) are discussed in this section for the NPs are presented and used in explaining the behavior of the nano-modified drilling fluids. Increasing the concentration of MgO up till 0.7wt% as shown an increase in the rheological properties of the drilling fluids. While, ZnO has shown a significant improvement for at lower concentrations of 0.1wt%.

Bingham, Herschel-Bulkley, Power Law, Casson and others are commonly used as rheological models to predict the drilling fluid behavior. In the last decade, a new trend of developing new models and correlations using the artificial neural networks (ANN) have been introduced to the petroleum field. Mathematical formulas can be developed using ANN, which then can be used to predict the behavior of certain parameter(s) by knowing other ones. Using ANN have shown to be more reliable and accurate in predicting the rheological properties of the drilling fluids, such as apparent viscosity (AV), plastic viscosity (PV), yield point (YP), maximum shear stress, and change in the mud density at various conditions.

In this work five mathematical models were constructed using ANN to predict the rheological properties of the nano-modified drilling fluids based on their composition at 120 °F and atmospheric pressure. The models were evaluated by conducting statistical tests like correlation coefficient ( $R^2$ ), root mean square error (RMSE), absolute average relative error (AARE), and standard deviation. The five models are models that can predict PV, AV, YP, gel strength at 10 seconds, and 10 minutes with overall  $R^2$  of 0.9017, 0.941, 0.878, 0.961, and 0.9, respectively. The effect of NPs-type, size, concentration, and drilling fluid formulations were considered, which may pave the road for new applications and efficient utilizations.