



Cairo University

# **CHARACTERIZATIONS OF A NEW POLYMER- NANOCOMPOSITE PROPPANT FROM AGRO-WASTE PRODUCTS FOR HYDRAULIC FRACTURING OPERATIONS**

By

**Mohammed Mostafa Sayed Mohammed Kandil**

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  
**Petroleum Engineering**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY,  
GIZA, EGYPT  
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**Title of Thesis:**

Characterizations of A New Polymer-Nanocomposite Proppant from Agro-Waste Products for Hydraulic Fracturing Operations

**Key Words:**

Hydraulic fracturing, Polymer Nanocomposite, Agro-waste recycling, Rice Husk, Ultralight weight Proppant.

**Summary:**

This research includes an experimental study on the characteristics of a new proppant manufactured from an agro-waste, the rice husk, to act as a possible propping agent in hydraulic fracturing treatment. Polymer Nano-composite particles were added to the rice husk before using in the experiment. In this research, the physical and mechanical properties of the new proppant are studied and a fracture conductivity test is concluded to characterize the performance of the new proppant material. The results from the experiment are compared to the widely known walnut hull proppant (ULW-1.25) and Chemically Modified and Reinforced Composite Proppant (CMRCP). In addition the new polymer nanocomposite proppant characteristics are compared to the established ISO/API standards. These results may lead to a consequent enhancement towards high strength Nanocomposite proppants.

## **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 reference section.

Name: Mohammed Mostafa Sayed Mohammed Kandil      Date:

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# **DEDICATION**

To  
My Parents  
and  
My Wife

# ACKNOWLEDGMENT

In the name of Allah, the most beneficent, the most merciful.

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# Nomenclatures

<b>IOR:</b>	Improved oil recovery
<b>RCP:</b>	Resin coated proppant
<b>CP:</b>	Conventional proppant
<b>ULW:</b>	Ultra-Lightweight
<b>CMRCP:</b>	Chemically Modified and Reinforced Composite Proppant
<b>ISO:</b>	International Organization for Standardization
<b>API:</b>	American Petroleum Institute
<b>Tscf:</b>	Trillions of standard cubic feet
<b>NG:</b>	Nitroglycerine
<b>ft.:</b>	Foot
<b>Howco:</b>	Halliburton Oil Well Company
<b>USD:</b>	United States Dollar
<b>lbm:</b>	Pounds Mass
<b>HCl:</b>	Hydrochloric acid
<b>°F:</b>	Degree Fahrenheit
<b>R:</b>	Radius
<b>V:</b>	Fracture volume
<b>P<sub>net</sub>:</b>	The net pressure
<b>E:</b>	Young's modulus
<b>ν:</b>	Poisson's ratio
<b>γ<sub>F</sub>:</b>	Specific surface energy of the fracture
<b>q<sub>i</sub>:</b>	Injection rate
<b>t:</b>	Time
<b>h<sub>r</sub>:</b>	Height of the fracture
<b>̄w:</b>	Average fracture width
<b>μ<sub>slurry</sub>:</b>	Proppant-laden slurry viscosity

<b><math>\mu_{base}</math>:</b>	Base carrying fluid viscosity
<b><math>\mu_r</math>:</b>	Viscosity ratio
<b><math>f_v</math>:</b>	Fraction of the proppant volume
<b><math>f_{vM}</math>:</b>	Maximum fraction of mobile slurry.
<b>TSO:</b>	Tip-screen out
<b><math>\rho_{sol}</math>:</b>	Density of the solid particles
<b><math>\rho_f</math>:</b>	Density of the fluid
<b><math>d_{sol}</math>:</b>	Diameter of the solid particles.
<b><math>u_{sol}</math>:</b>	Particle velocity
<b>PI:</b>	Productivity index
<b>TEA:</b>	Tri-Ethanol Amine
<b>WRA:</b>	Water recovery agent
<b>bpm:</b>	Pound per Minute
<b>HEC:</b>	Hydroxyethyl cellulose
<b>HPG:</b>	Hydroxypropyl guar
<b>CO<sub>2</sub>:</b>	Carbon dioxide
<b>N<sub>2</sub>:</b>	Nitrogen
<b>Psi:</b>	Pound per square inch
<b>USA:</b>	United States of America
<b>Mt:</b>	Metric tons
<b>USGS:</b>	United States Geological Survey
<b>T<sub>g</sub>:</b>	Glass transmission temperature
<b>HDC:</b>	High density ceramics
<b>IDC:</b>	Intermediate density ceramics
<b>LWC:</b>	Lightweight ceramics
<b>UHSP:</b>	Ultra-High-Strength proppant
<b>SG:</b>	Specific gravity
<b>MD-ft:</b>	Millidarcy- foot
<b>nm:</b>	nanometer

<b>VES:</b>	Viscoelastic surfactant
<b>CMC:</b>	Critical micelle concentration
<b>ZnO:</b>	Zinc oxide
<b>SiO<sub>2</sub>:</b>	Silicon dioxide
<b>Fe<sub>2</sub>O<sub>3</sub>:</b>	Iron (III) oxide (Hematite)
<b>AOS:</b>	Alfa olefin sulfonate
<b>MgAl<sub>2</sub>O<sub>4</sub>:</b>	Magnesium aluminate (spinel)
<b>m<sup>2</sup>/g:</b>	Square meter per gram
<b>RP:</b>	Recommended Practices
<b>ml:</b>	Milliliter
<b>g/cm<sup>3</sup>:</b>	gram per cubic centimeter
<b>NTU:</b>	Nephelometric Turbidity Units
<b>HF:</b>	Hydrofluoric acid
<b>KCl:</b>	Potassium chloride
<b>K:</b>	Fracture permeability
<b>W<sub>f</sub>:</b>	Fracture width
<b>KW<sub>f</sub>:</b>	Proppant pack conductivity
<b>Q:</b>	Flow rate
<b>L:</b>	Length between pressure ports
<b>W:</b>	Cell width
<b>ΔP:</b>	Pressure drop
<b>ml/min:</b>	Milliliter per minute
<b>cm:</b>	Centimeter

# ABSTRACT

Well Stimulation is considered the most effective technique of improved oil recovery (IOR). Stimulation technique comprises several operations to enhance and maintain the productivity of oil and gas wells. Hydraulic fracturing is the main operation to stimulate wells and starts with pumping the fracturing fluids into the well to raise the pressure above fracturing pressure of the formation. Proppant is an essential component of the injected slurry; and comprises any non-liquid phase utilized to provide support for the induced fracture to keep it open. Once the fracture is induced, slurry with proppant is injected to keep flow path open for reservoir fluids towards the wellbore at a higher rate. Proppants can be ceramics, sand, or resin coated proppant (RCP), which are known as conventional proppant (CP).

Due to the high expense of the conventional proppant types that may reach up to 40% of the stimulation job, the need for new proppants has become a very important topic of research. Agro-waste such as rice husk is renewable resources and can be used as propping agent in hydraulic fracturing treatment; however it is not yet widely studied. This research includes an experimental study on the characteristics of a proppant prepared from the rice husk as an agro-waste, to act as a possible propping agent in hydraulic fracturing. Polymer Nano-composite materials were added to the rice husk before conducting the experiment. In this study, the physical and mechanical properties are investigated and a fracture conductivity test is implemented to characterize the efficiency of the new proppant material. The characteristics envisaged are grain shape and size, bulk density, specific gravity, turbidity and acid solubility. The results from the experiments are compared to the commonly known walnut hull proppant (ULW-1.25) and Chemically Modified and Reinforced Composite Proppant (CMRCP). The new polymer nanocomposite proppant showed promising results according to the established ISO/API standards. This research provides technical information on the new agro-waste renewable resource to confirm its strength when subjected to high closure stresses; which has not been mentioned in the literature. These results may lead to a consequent improvement towards high strength Nanocomposite proppants for applications in hydraulic fracturing operations and other petroleum engineering applications.