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,
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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:

Signature:

DEDICATION

To

My Parents

and

My Wife

ACKNOWLEDGMENT

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

I would like to express my great appreciation and deep gratitude to Dr. Abdulaziz Mohamed Abdulaziz, for the infinite assistance, endless support, sincere advises and honest guidance he gave for the achievement of this work in spite of his numerous duties.

I am grateful to Dr. Rehab El-Maghraby, Suez Canal University and Prof. Dr. Ahmed Youssef, The National Research Center at Dokki for their effective role in the accomplishment of the work. Also I would like to express my great appreciation to Dr. Mohamed El-Karmoty, Rock Mechanics Lab, Cairo University and Dr. Adel Mady, University of Banha for their great role in collecting and cutting the core sample used in this study experiment. I also would like to extend my sincere thanks and respect to all the professors in the Petroleum Engineering Department at Suze University who taught me in all sincerity and love to get my Bachelor of Sciences in Petroleum Engineering. Also I would like to extend my sincere thanks and respect to the professors in the Petroleum Engineering Department at Cairo University who kept on giving me everything new in the oil industry and helped me to get the master's degree. Finally, I would like to express my thanks and appreciation to my family especially, my mother and my wife for the great help and support.

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Nomenclatures

IOR: Improved oil recovery

RCP: Resin coated proppant

CP: Conventional proppant

ULW: Ultra-Lightweight

CMRCP: Chemically Modified and Reinforced Composite Proppant

ISO: International Organization for Standardization

API: American Petroleum Institute

Tscf: Trillions of standard cubic feet

NG: Nitroglycerine

ft.: Foot

Howco: Halliburton Oil Well Company

USD: United States Dollar

lbm: Pounds Mass

HCl: Hydrochloric acid

°F: Degree Fahrenheit

R: Radius

V: Fracture volume

P_{net}: The net pressure

E: Young's modulus

***v*:** Poisson's ratio

γ_F: Specific surface energy of the fracture

q_i: Injection rate

t: Time

h_f: Height of the fracture

$\bar{w}$: Average fracture width

μ_{slurry}: Proppant-laden slurry viscosity

μ_{base}: Base carrying fluid viscosity

μ_r: Viscosity ratio

f_v: Fraction of the proppant volume

f_{vM}: Maximum fraction of mobile slurry.

TSO: Tip-screen out

ρ_{sol}: Density of the solid particles

ρ_f: Density of the fluid

d_{sol}: Diameter of the solid particles.

u_{sol}: Particle velocity

PI: Productivity index

TEA: Tri-Ethanol Amine

WRA: Water recovery agent

bpm: Pound per Minute

HEC: Hydroxyethyl cellulose

HPG: Hydroxypropyl guar

CO_2: Carbon dioxide

N_2: Nitrogen

Psi: Pound per square inch

USA: United States of America

Mt: Metric tons

USGS: United States Geological Survey

T_g: Glass transmission temperature

HDC: High density ceramics

IDC: Intermediate density ceramics

LWC: Lightweight ceramics

UHSP: Ultra-High-Strength proppant

SG: Specific gravity

MD-ft: Millidarcy- foot

nm: nanometer

VES: Viscoelastic surfactant

CMC: Critical micelle concentration

ZnO: Zinc oxide

SiO_2: Silicon dioxide

Fe_2O_3: Iron (III) oxide (Hematite)

AOS: Alfa olefin sulfonate

$MgAl_2O_4$: Magnesium aluminate (spinel)

m^2 /g: Square meter per gram

RP: Recommended Practices

ml: Milliliter

g/cm^3: gram per cubic centimeter

NTU: Nephelometric Turbidity Units

HF: Hydrofluoric acid

KCl: Potassium chloride

K: Fracture permeability

W_f: Fracture width

KW_f: Proppant pack conductivity

Q: Flow rate

L: Length between pressure ports

W: Cell width

ΔP: Pressure drop

ml/min: Milliliter per minute

cm: 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.