دانشگاه سیستان و بلوچستان
تحصیلات تکمیلی

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این پایان نامه از حمایت مالی معاونت پژوهشی دانشگاه سیستان و بلوچستان بهره مند شده است

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این پایان نامه ...... واحد درسی شناخته می شود و در تاریخ .... توسط هیئت داوران بررسـی و درجـه .... به آن تعلق گرفت.

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تعهدنامه اصالت اثر

اینجانب محمد شاهچراغی تعهد می کنم که مطالب مندرج در این پایان نامه حاصل کـار پژوهشـی اینجانب است و به دستاوردهای پژوهشی دیگران که در این نوشته از آن استفاده شده است مطـابق مقررات ارجاع گردیده است. این پایان نامه پیش از این برای احراز هیچ مدرک هم سـطح یـا بـالاتر ارائه نشده است.

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Modeling and Simulation for Riser Reactor of a Fluidized Bed Catalytic Cracking

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These theses counts as 6 credit units and Granted grade ……. on the date ….……by evaluation committee.

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The information and procedures contained in this theses are based upon the research and the personal experiences, except otherwise has been mentioned. Every effort has been made to ensure that all researchers granted by addressing to their work accordingly. This thesis has not been offered for obtaining an equivalence degree or higher degree by any mean.

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Dedicated to My dear mother

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ABSTRACT:

A one dimensional dynamic model for a riser reactor in a fluidized bed catalytic cracking unit (FCCU) for gasoil feed has been developed in two distinct conditions, one for industrial FCCU and another for FCCU using various frequencies of microwave energy spaced at the height of the riser reactor (FCCU-MW). In addition, in order to increase the accuracy of component and bulk diffusion, instantaneous and overall fractional yield is used in a heuristic manner. Furthermore, the effect of various catalysts to oil ratio on gasoline yield with FCCU-MW has been studied. The results of the convectional FCCU simulation show great compatibility with the plant data in hand. Comparison of the two models shows that microwave energy gives better results in terms of gasoline yield. Also it has been shown that the increase of catalyst to oil ratio leads to the increase of gas oil conversion and especially gasoline yield.

Keywords: Modeling – Simulation **-** Fluidized bed catalytic cracking – Microwave energy – riser reactor

The work done in this study is organized into six chapters. **The first chapter** represents introduction of the fluid catalytic cracking unit (FCCU). A literature review on the modeling and simulation of FCCU follows in the **second chapter** which consists of kinetic development, modeling and simulation review and FCC evolution. **Chapter 3** deals with the riser model development. In this section energy balance, partial and overall mass balance equations have been derived. Also, energy balance for a model of a FCCU riser reactor exposed to microwave energy (FCCU-MW) is given. Experimental relationship is used to model the pressure behavior in the riser section of FCCU. Instantaneous and overall fractional yield is used to increase the accuracy of component and bulk diffusion in a heuristic manner. **Chapter 4** represents simulation steps of riser reactor of a FCC and FCC-MW models. Results of the riser simulation in both FCCU and FCCU-MW are presented and discussed in **Chapter 5**. Simulation results are compared with industrial data and other simulations that have been reported in the literatures. After that results of the models that simulated in the present work are compared. **Chapter 6** summarizes the conclusions drawn from the study. Also a new FCCU using microwave energy is recommended which has been registered as a patent in the Iranian Patent Organization.

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NOMENCLATURE

a, b	Dimensions of the waveguide (m)
C_o	Velocity of light in vacuum ($m.s^{-1}$)
C_d	Drag coefficient
Cp_{cat}	Heat capacity of catalyst ($kj.kg^{-1}.k^{-1}$)
Cp_{ds}	Heat capacity of dispersion steam ($kj.kg^{-1}.k^{-1}$)
Cp_i	Heat capacity of ith component ($kj.kg^{-1}.k^{-1}$)
Cp_{go}^{l}, Cp_{go}^{v}	Heat capacity of gas oil in liquid and vapor phase, respectively ($kj.kg^{-1}.k^{-1}$)
Cp_{mix}	Heat capacity of gas.solid mixture ($kj.kg^{-1}.k^{-1}$)
CTO	Catalyst to oil ratio ($kg_{cat}.kg_{oil}^{-1}$)
d_i	Specific gravity of hydrocarbon
$D_{i,m}$	Diffusivity of ith component into mixture ($m.s^{-2}$)
$D_{i,j}$	Diffusivity of ith component into jth component ($m.s^{-2}$)
D_{mix}	Diffusivity of mixture ($m.s^{-2}$)
d_p	Depth of adsorption (m)
E	Activation energy
f	Frequency of electromagnetic radiation (Hz)
F_0	Microwave power flux at the surface ($W.\ m^{-2}$)
F_{cat}	Catalyst mass flow ($kg.s^{-1}$)
F_{ds}	Dispersed steam mass flow ($kg.s^{-1}$)
F_{go}^{l}, F_{go}^{v}	Gas oil mass flow in liquid and vapor phase, respectively ($kg.s^{-1}$)
Fr	Froude number
Fr_t	Froude number on terminal velocity
$f(KT/\varepsilon_{ij})$	Collision function
g	Gravity ($m.s^{-2}$)
G_s	Solid mass flux ($kg.m^{-2}.s^{-1}$)
ΔH_i	Heat of reaction for ith component ($kj.kg^{-1}$)

ΔH_{go}^{vap}	Heat of vaporization for gas oil component ($kj.kg^{-1}$)
K_i	Thermal conductivity of ith component ($w.m^{-1}.k^{-1}$)
K_{mix}	Thermal conductivity of mixture ($w.m^{-1}.k^{-1}$)
k_1, k_2, k_3, k_4, k_5	Reaction rate constants ($m^6 kmol^{-1} kg_{cat}^{-1} s^{-1}$)
l	Length of gas in eqn. 10 (m)
M	Molecular weight of mixture ($mol.kg^{-1}$)
M_i	Molecular weight of ith component ($mol.kg^{-1}$)
N_i	ith Component mass flux ($kg.m^{-2}.s^{-1}$)
P	Total pressure (Pa)
Q	Volumetric heat generation term in eqn. 8 ($W.m^{-3}$)
Q'''	Volumetric heat received to gas.solid mixture in eqn. 1 ($W.m^{-3}$)
R	Universal gas constant ($j.mol^{-1}.k^{-1}$)
r_i	Rate of reaction for ith component ($m^6 kmol^{-1} kg_{cat}^{-1} s^{-1}$)
$r_{i,j}$	Molecular separation at collision (nm)
T	Temperature (k)
T_{cat}	Catalyst temperature at riser entrance (k)
t	Time (s)
tc	Residence time of catalyst (s)
T_{ds}	Dispersed steam temperature at riser entrance (k)
T_{vap}	Vapor phase temperature at riser entrance (k)
T_{go}	Gas oil temperature at riser entrance (k)
u	Velocity ($m.s^{-1}$)
u_p	Particle velocity ($m.s^{-1}$)
u_o	Riser superficial velocity ($m.s^{-1}$)
y_i	ith Component mole fraction
z	axial coordinate (m)

Greek Letters

α	Decay coefficient of catalyst
ε'	Dielectric constant
ε''	Dielectric loss factor
ε_{bed}	Bed porosity
$\zeta(i/j)$	Overall fractional yield
$\xi(i/j)$	Instantaneous fractional yield
μ_g	Gas viscosity (Pa.s^{-1})
ρ_{cat}	Catalyst density (kg.m^{-3})
ρ_s	Dispersed steam density (kg.m^{-3})
ρ_{mix}	Mixture density (kg.m^{-3})
υ	Slip factor
β	Momentum transfer coefficient
γ	Volume fractions

Subscripts

bed	Bed
cat	Catalyst
ck	Coke
ds	Dispersed steam
gl	Gasoline
go	Gas oil
mix	Mixture
lg	Light gas
p	Particle
s	Solid

Superscripts

l	Liquid phase
v	Vapor phase
vap	Vaporization