Scale growth study in a concentric reducer: Measurement of instantaneous velocity using Particle Image Velocimetry

By

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To my parents with respect

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Abstract

Gibbsite scale growth in pipe fittings is a major problem for an alumina refinery. A recent investigation into the scale growth mechanism at an alumina refinery found almost 60 % more scale growth in a reducer when compared with the connecting straight pipe sections for similar flow conditions.

Scale growth occurs where liquor (supersaturated solutions) come in contact with solid surfaces and it is affected by the liquor flow velocity besides other physical and chemical parameters. The present work is dedicated to study the hydro-dynamical aspects of the mechanism of scale growth. In particular, the role of the phenomenon of turbulent bursting, stream wise and cross stream fluctuating velocity components (U_x and U_y) was investigated as the flow moves through the reducer. Particle Image Velocimetry (PIV) technique was used to get a full view of the reducer and the readings close-to-the-wall of the reducer at Reynolds number of 27,000 and 44,000 upstream which corresponds to Reynolds number of 41,500 and 66,000 downstream of the reducer respectively.

The results showed an increase in cross stream and a decrease in magnitude of stream wise fluctuating velocity components, whereby we presume that the increased cross stream fluctuating velocity component increases the frequency of impacts of the scaling particles on the wall thus initiating excessive scale growth in the reducer when compared with the connecting straight pipe sections, for similar flow conditions.

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List of acronyms

2D	Two dimensional
3D	Three dimensional
A/C ratio	Alumina to Caustic ratio
AIA	Analogue interface adapter
°C	Degrees Centigrade
CCD	Charge-Coupled Device
CCI	Charge Contrast Imaging
CFD	Computational Fluid Dynamics
CQU	Central Queensland University
DC	Direct Current
ρ_p	Density of Particle
ρ_f	Density of fluid
DNS	Direct Numerical Simulation
d_p	Diameter of particle
dt	Time separation between 2 pulses
e_r	Percentage error
FFT	Fast Fourier Transformation
g	Acceleration due to gravity
g/dm^3	Grams per decimetres
gpl	Grams per litre

HFA	Hot Film Anemometry
HWA	Hot Wire Anemometry
Hz	Hertz
kPa	Kilopascal
kW	Kilowatt
LDA	Laser Doppler Anemometry
LIF	Laser Induced Fluorescence
m/sec	Metre per second
mJ	Millijoule
mm	Millimetre
mm/sec	Millimetre per second
MQD	Mean Quadratic Difference
msec	Millisecond
NaI	Sodium Iodide
Nd:YAG	Neodymium: Yttrium Aluminium Garnet
nm	Nanometre
PELM	Process Engineering and Light Metals Centre
PIP	Pattern Image Matching
PIV	Particle Image Velocimetry
PLIF	Planner Laser Induced Fluorescence
POD	Proper Orthogonal Decomposition
ps	Pico second
QAL	Queensland Alumina Limited.

r	Radius at a certain distance “x” from the centre in a section
R	Full radius of the section
Re	Reynolds number
RPM	Revolution per minute
SEM	Scanning Electron Microscope
TB	Turbulent Bursting
TKE	Total Kinetic Energy
TPD	Transfer Pulse Delay
u	Velocity of fluid at a certain distance “y” from centre of section
U	Centre-line velocity
μm	Micrometer
μsec	Microsecond
U_0^2	Average velocity
$U_x^{'}$	Fluctuating velocity component in x – direction (stream-wise)
$U_y^{'}$	Fluctuating velocity component in y – direction (cross-stream)
v	Kinematic viscosity of fluid
VFD	Variable frequency drive
V_s	Sedimentation velocity
δ	Boundary layer thickness

List of Publication

Following conference papers were published as a result of this Masters in Mechanical Engineering,

1) ***Energy saving potentials in an Alumina refinery : A review***
   Central Region Engineering Conference" 5-6 Sept. 2003, Rockhampton.

2) ***Viability of steam injection in gas turbines (co-authored)***
   BSME-ASME,
   International conference on Thermal Engineering, 2-4th January 2004, Dhaka, Bangladesh.

3) ***Scale growth study in a concentric reducer: Measurements of instantaneous velocity using Particle image velocimetry***
   VSJ – SPIE
   International conference on advanced optical diagnostics in fluids, solids and combustion, 4-6 December 2004, University of Tokyo, Tokyo, Japan.

A journal publication is in progress to be published in a major fluid mechanics journal such as Journal of Fluid Mechanics, or Experiments in Fluids or Journal of Turbulence etc.

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