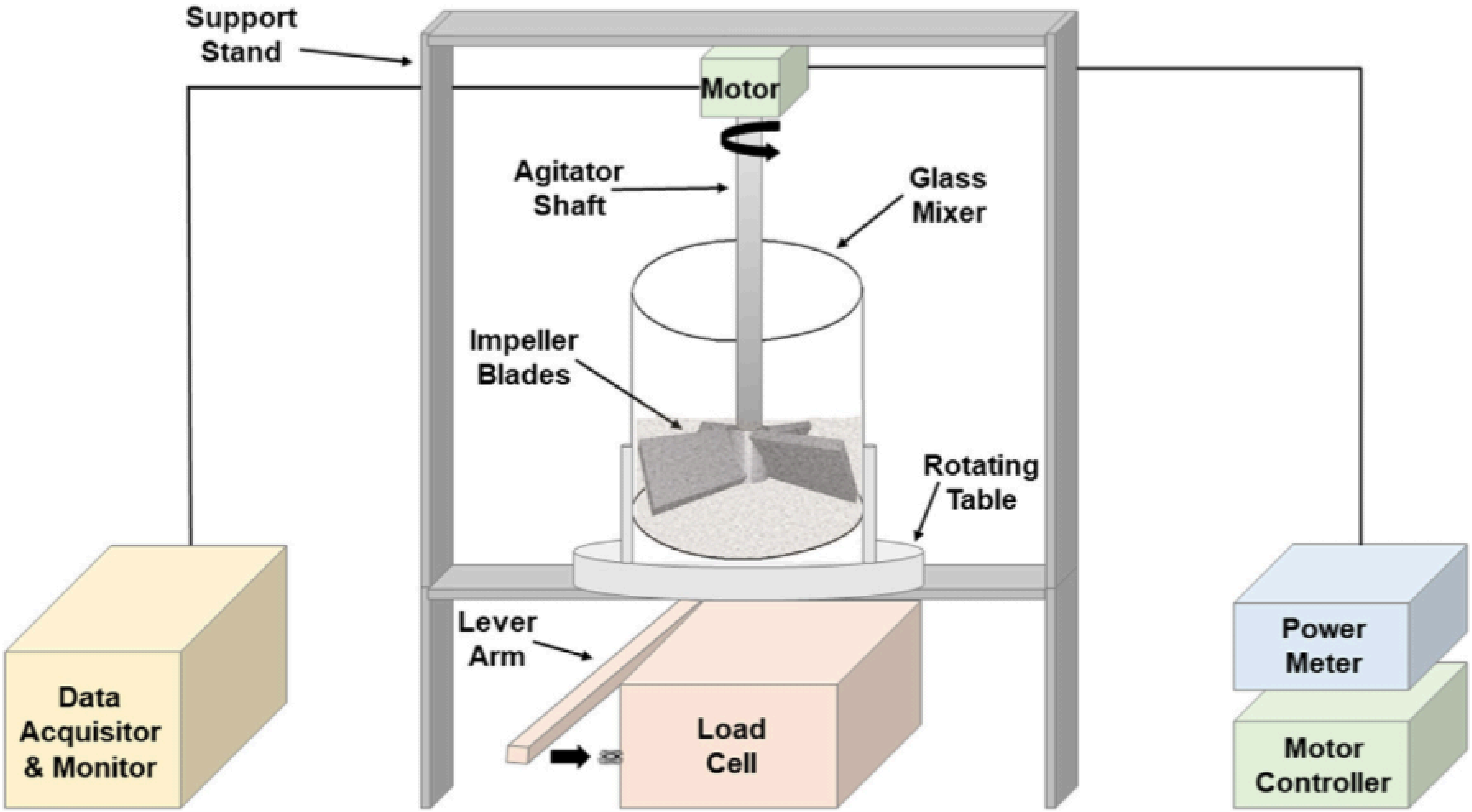
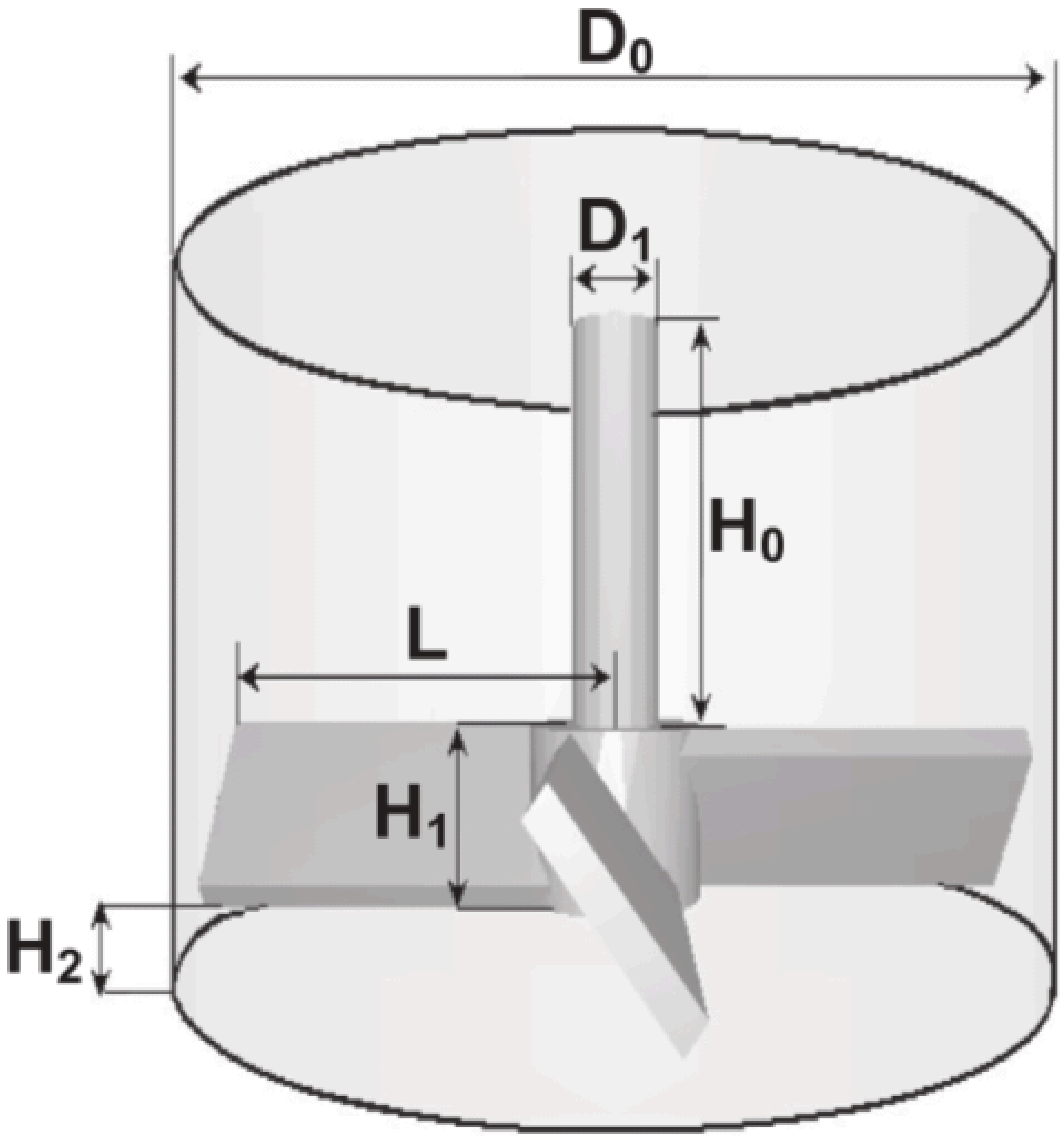
Flow of
GRANULAR MATERIAL IN BLADED MIXTURE

BY - KANISHQ SAHU

LIST OF CONTENTS

SCHEMATICS


Support
Stand
Motor
Agitator
Shaft
Glass
Mixer
Impeller
Blades
Rotating
Table
Lever
Arm
Load
Cell
Data
Acquisitor
& Monitor
Power
Meter
Motor
Controller

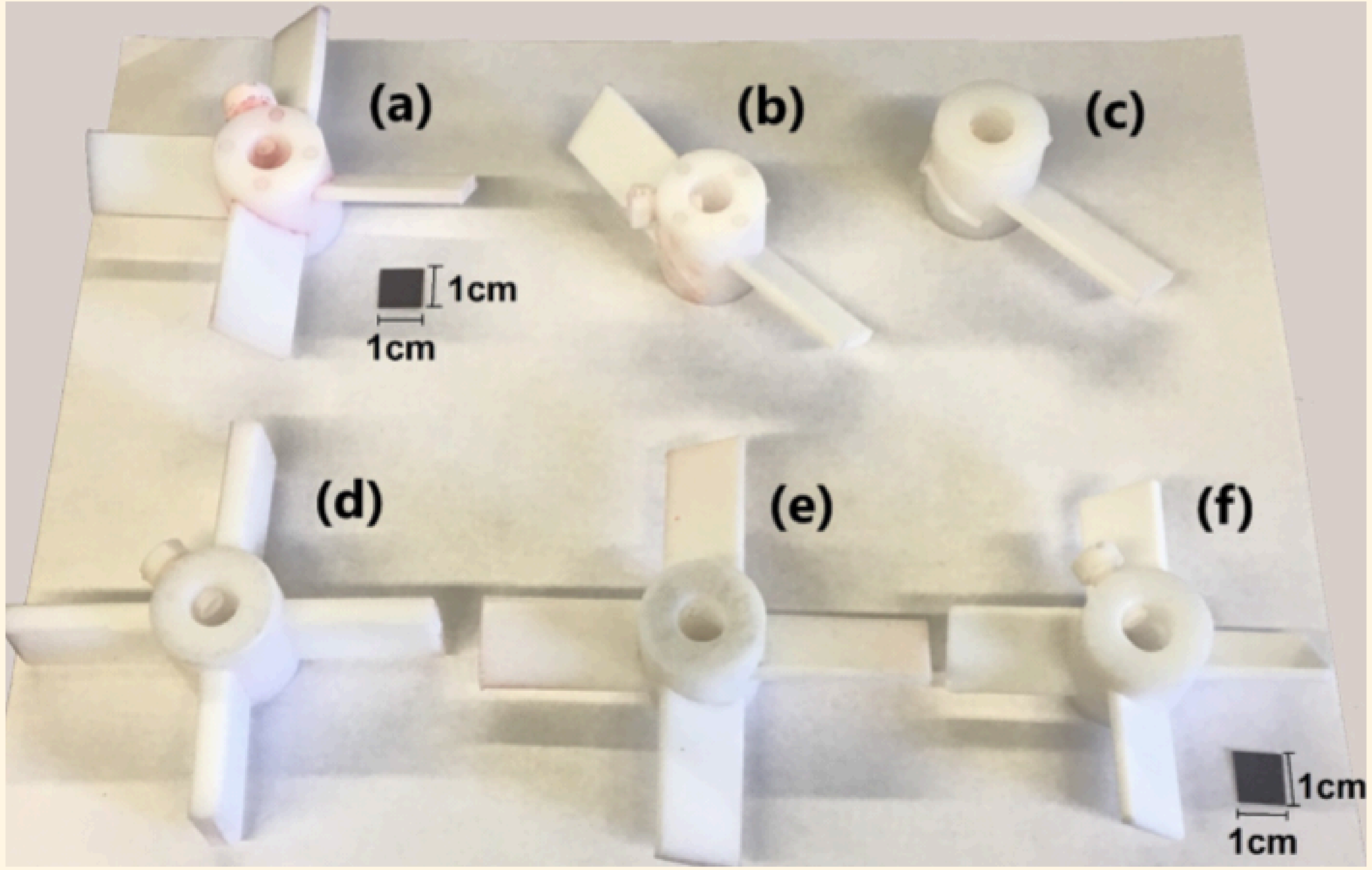


DIMENSIONS

Dimension	Value(mm)
D0	100
D1	10
L	45
H0	128
H1	25
H2	2

MATERIALS

Variable	Value
Particle diameter	1 , 2, and 5 mm
Partticle density	2.50 - 2.55g/ml
Friction coefficient	0.32
Mass of granular bed	300 - 900 g



THE BASE CASE

1. 2-mm monodisperse, cohesionless, spherical, uncoated red glass beads

2. 300 g of granular material loaded in the mixer

3. (H/D) = 0.30.

4. Shallow bed configuration

5. Impeller: 4 blades pitched at 135° angle

6. Blade length of 45 mm

IMPELLER TORQUE AND POWER MEASUREMENT

BLADE MOVEMENT INITIATED IN COUNTER-CLOCKWISE DIRECTION

SHEAR RATES CATEGORIZED INTO

- Quasi-static. (y*<0.1)
- Intermediate regimes (y*>0.1).

y* = Dimensionless Shear rate

TORQUE **CALCULATED FROM** FORCE **MEASURED BY LOAD CELL MULTIPLIED BY** LEVER ARM LENGTH.

$$\vec{T} = \ell \times \vec{F}$$

AVERAGE SHEAR STRESS:

$$\langle \tau_{\theta r} \rangle = \frac{T}{2\pi R_{\text{cyl}}^2 H}$$

POWER COMPOSED OF TWO COMPONENTS:

- Motor power (P emp)
- Power to move particle bed (P*)

P* = P - P emp

P = Power measured by Power meter

TORQUE AND POWER MEASUREMENTS

Dimensionless Shear rate:

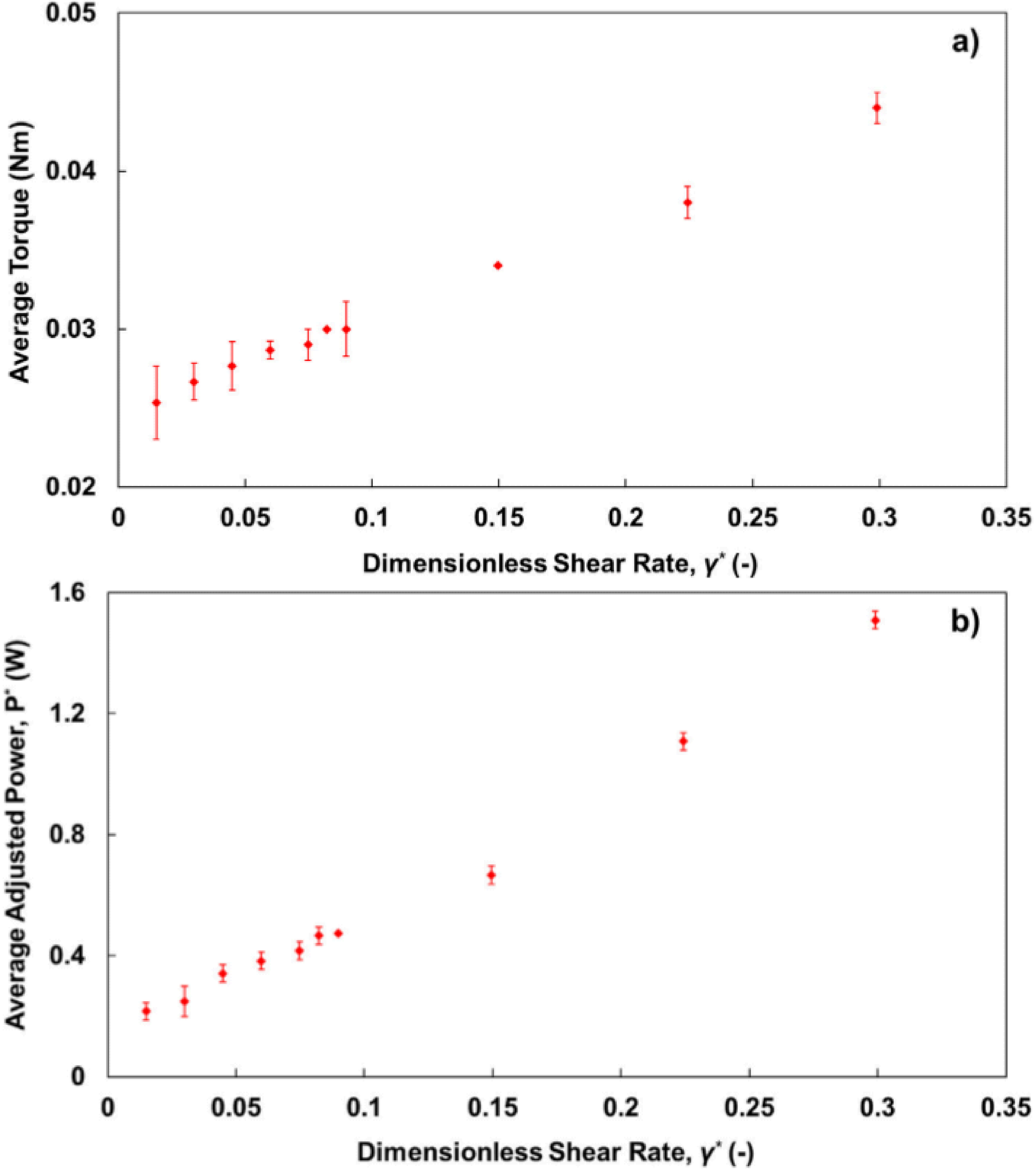
$$\gamma^* = \gamma^\circ \sqrt{\frac{d}{g}}$$

Shear rate (s-1):

$$\gamma^\circ = \frac{2\pi \times \text{Rotational Speed}}{60}$$

Assumption made that power needed to run the motor under load can be separated from power needed to move the impeller.

Quasi-Static regime seen in Deep bed case, not in shallow Bed case.



FLUCTUATION ANALYSIS OF TORQUE DATA

Instantaneous torque values normalized by time-averaged torque at each blade rotational speed.

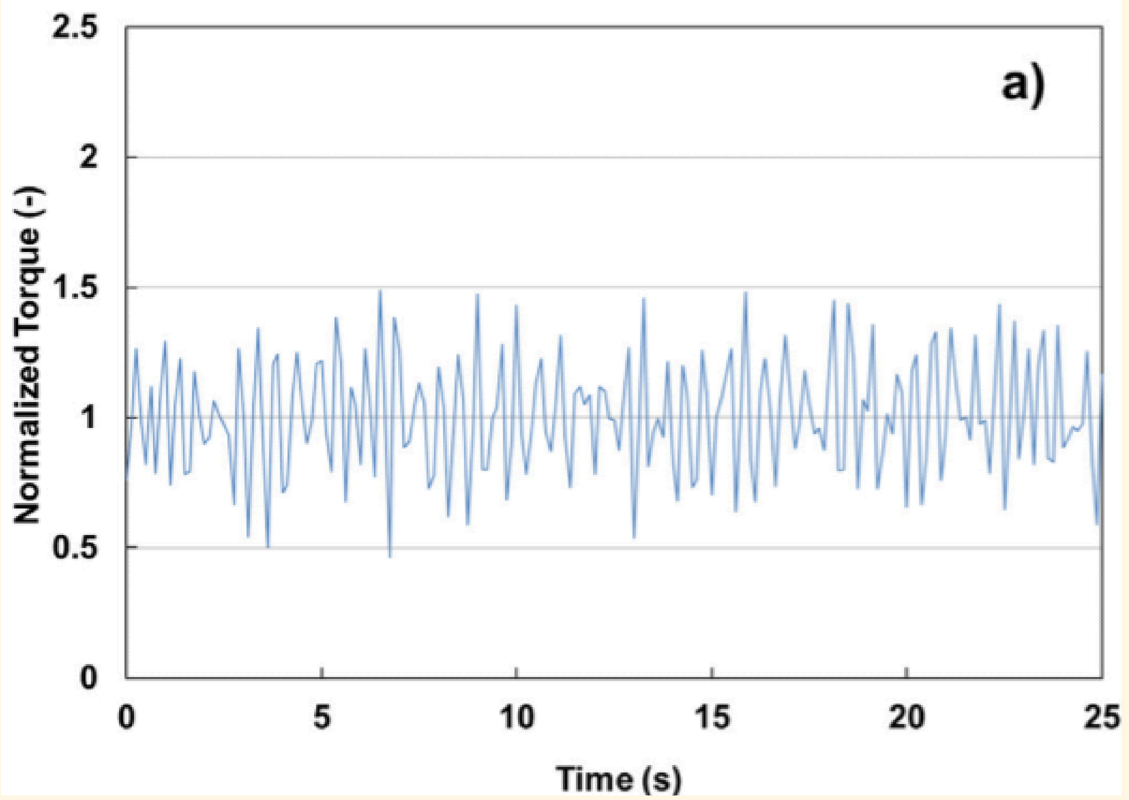
Torque Signal recorded every 0.125s

$$\vec{T}^{*} = \frac{T}{\langle \vec{T} \rangle}$$

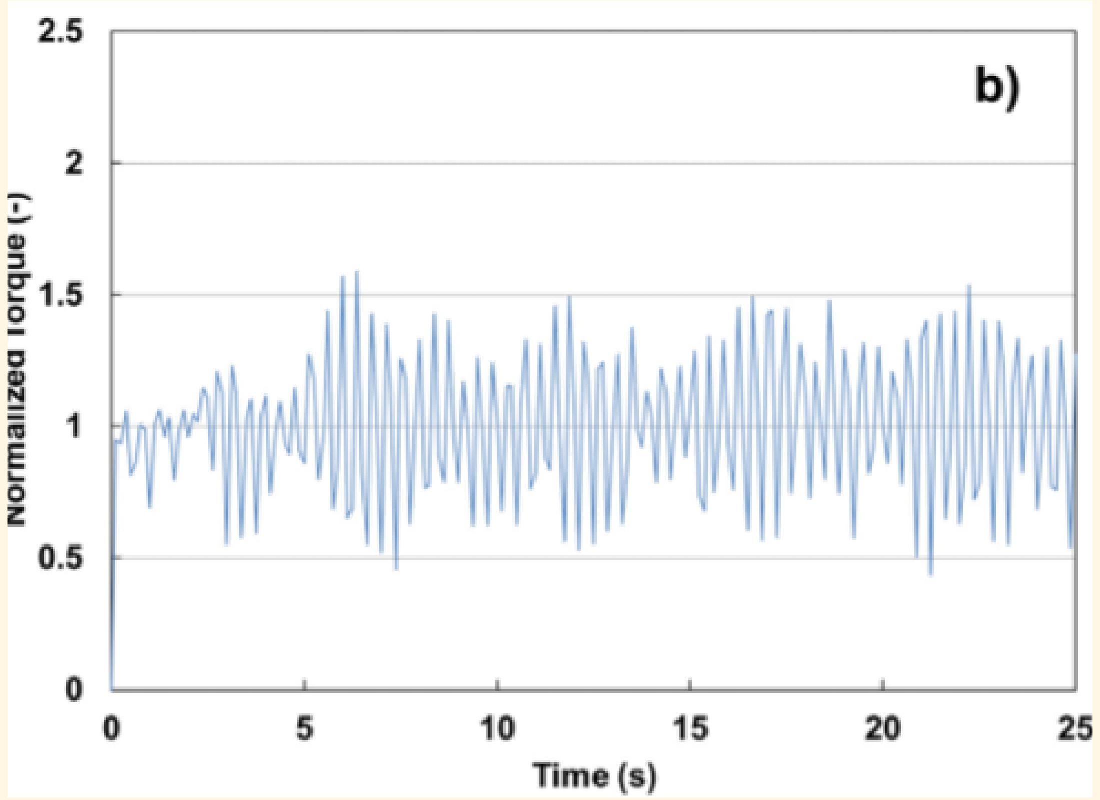
T* =Dimensionless Normalized Torque
T = Instantaneous torque
<T> = Time averaged Torque

At 200 RPM, periodic burst behavior of torque fluctuations observed.

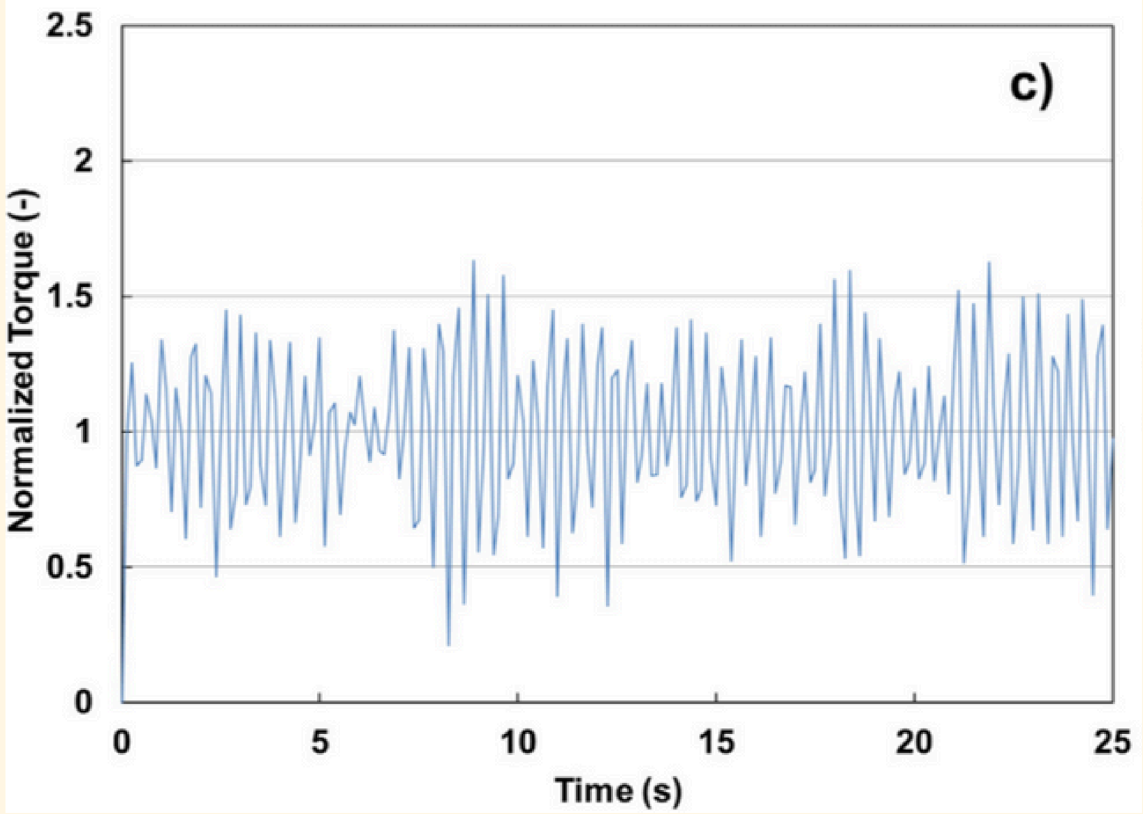
Attributed to expansion and compression states of granular bed in highest shear rate conditions.



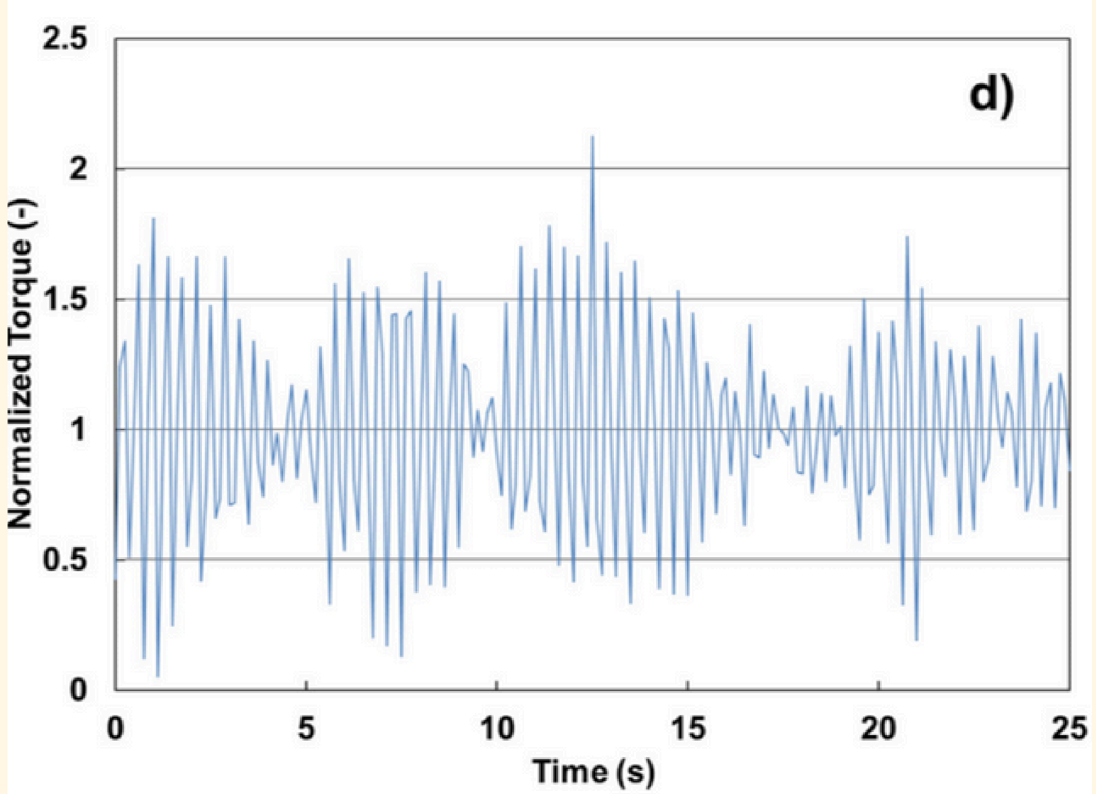
10**RPM**



20**RPM**



60**RPM**



200**RPM**

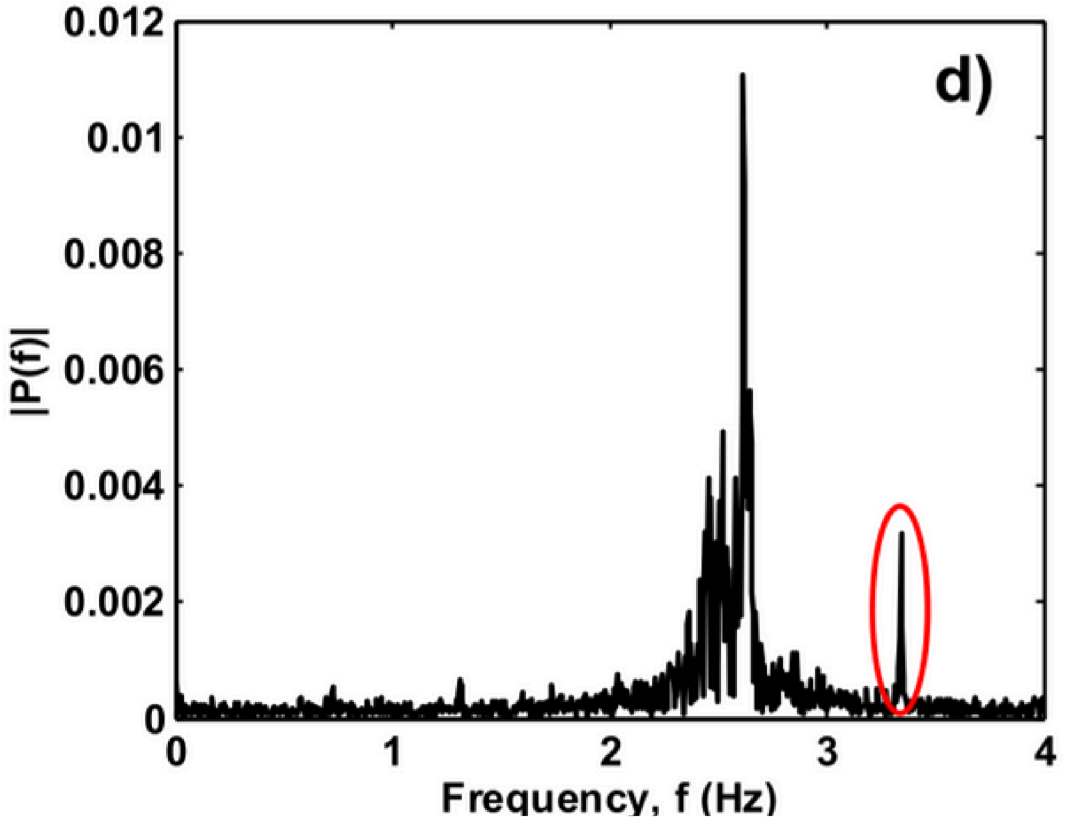
FFT OF TORQUE DATA

$$f = \frac{\text{Rotational Speed}}{60}$$

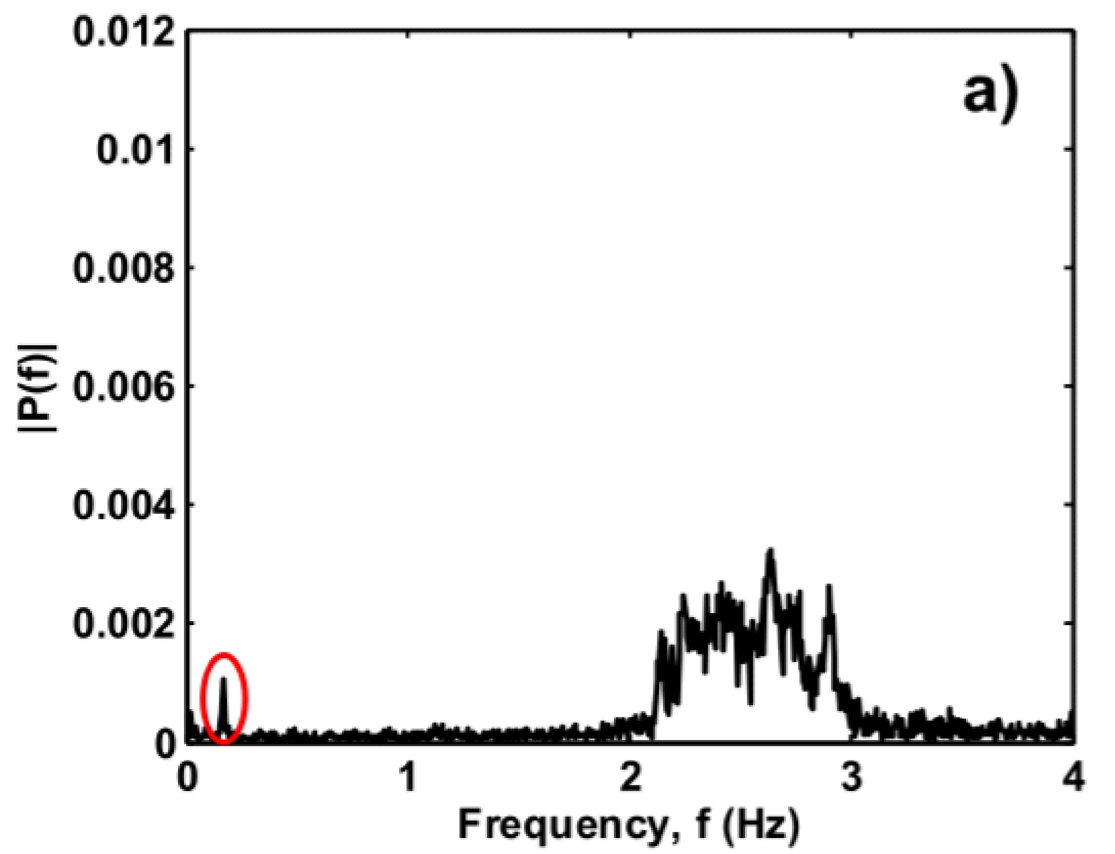
Peaks corresponding to Rotational rate can be observed

Height of blade frequency peaks increases with rotational speed

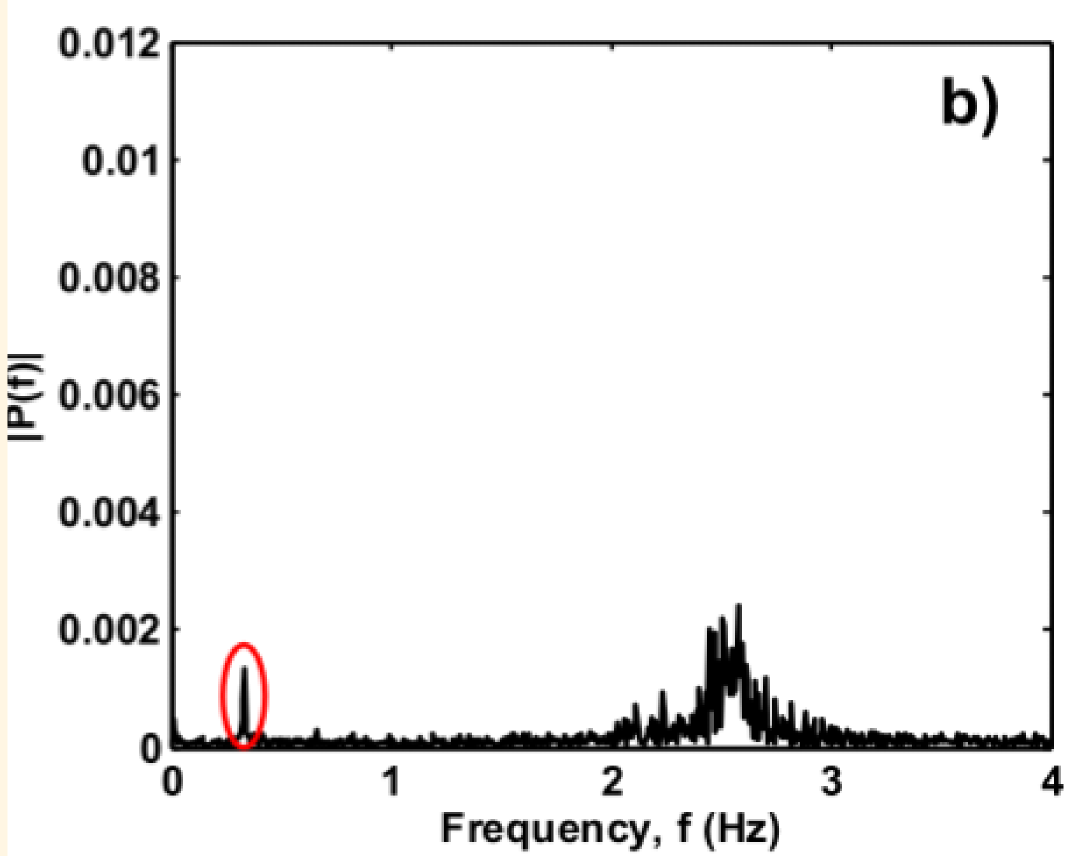
Between 2-3 Hz natural frequency of particles are observed



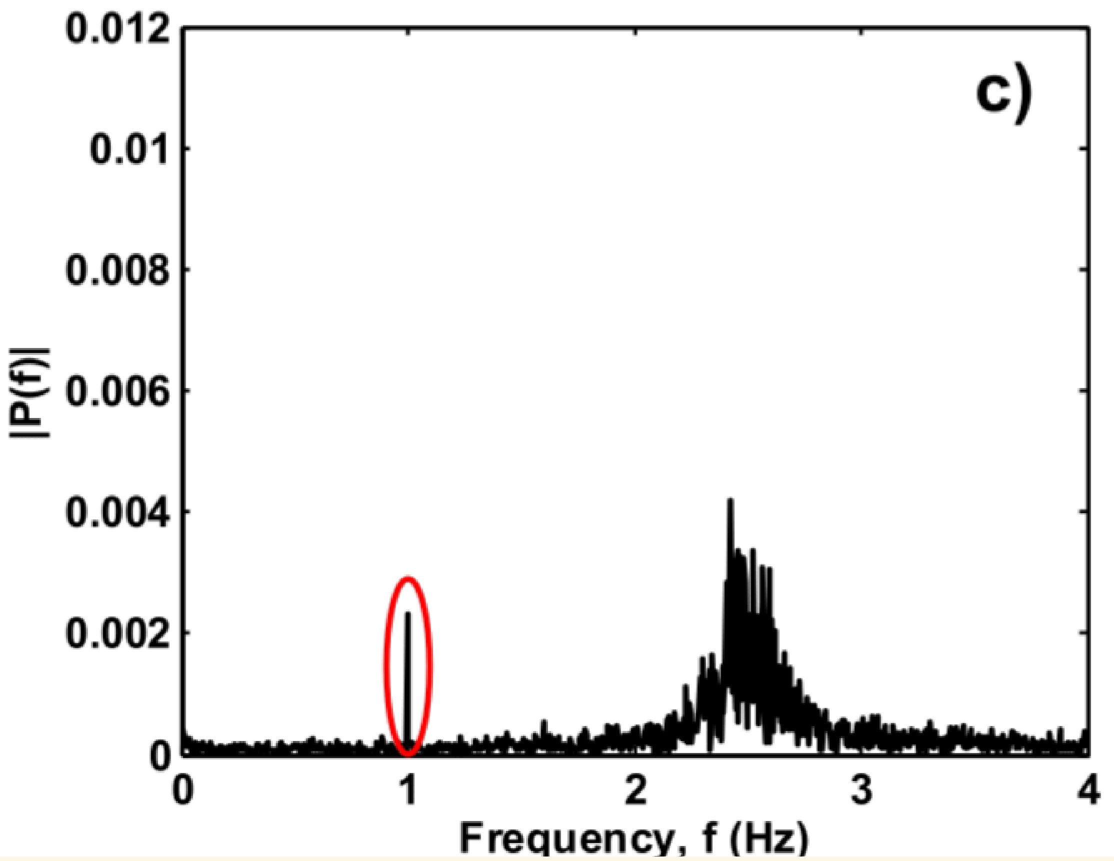
200RPM



10RPM



20RPM



60RPM

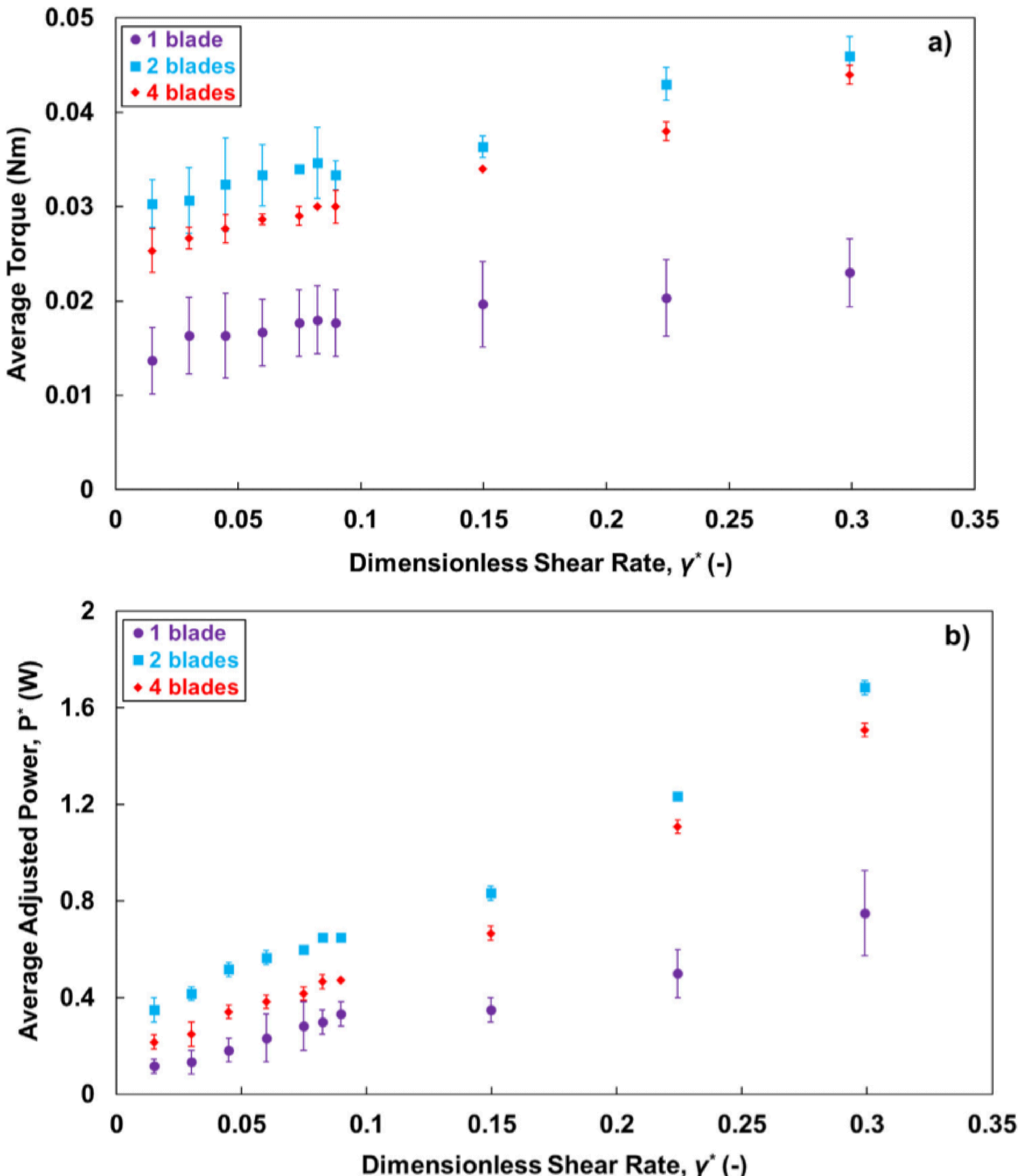
Effect of
NO. OF IMPELLER BLADES

Higher radial velocity component of particle - 1 and 2 bladed mixers
(better 3-D rrecirculation patterns)

Higher tangential velocity components of particle - 3 and 4 bladed mixers.

In 1 bladed mixer avg tangential contact force impeller blade exertss on particle is less.

Torque and power value fluctuations in 1 bladed mixer is higher because of asymmetry.



Effect of

IMPELLER BLADE ANGLE

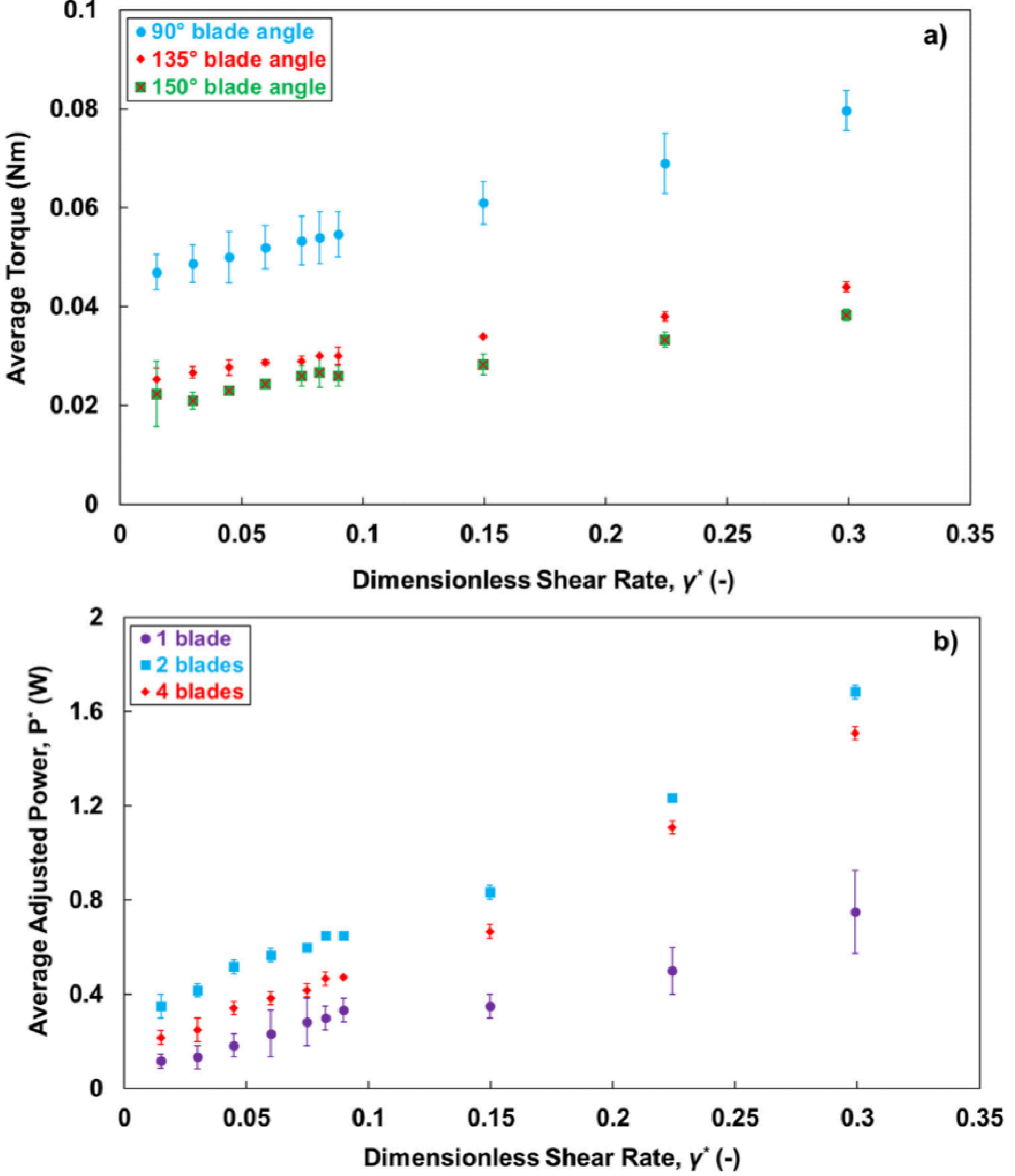
Decrease in average torque observed with increase in impeller blade angle.

Less variation in adjusted power readings.

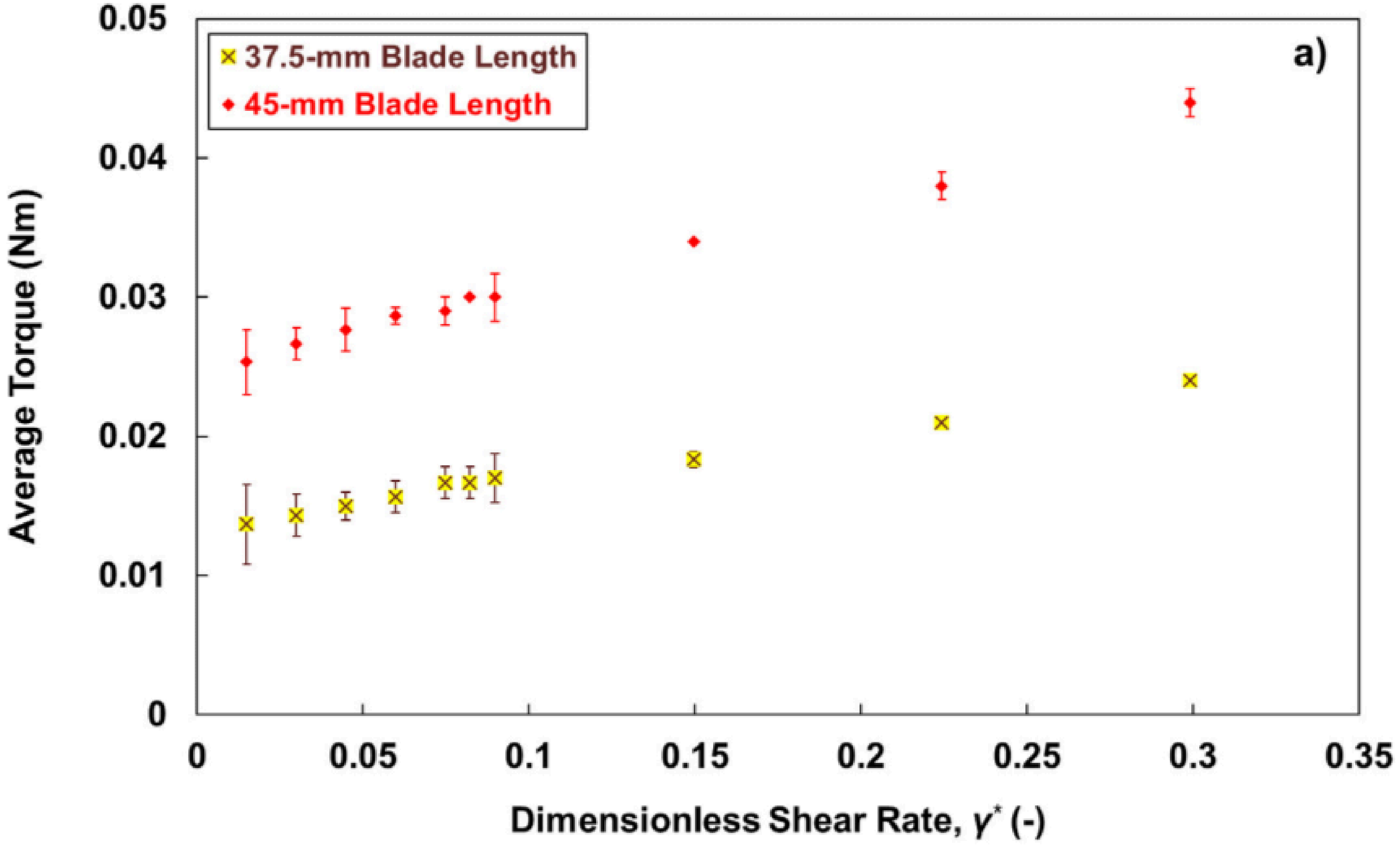
↓

Reason: Complexity in measuring power consumption due to two components

Assumption made that power needed to run motor with charged particles is equal to empty mixer

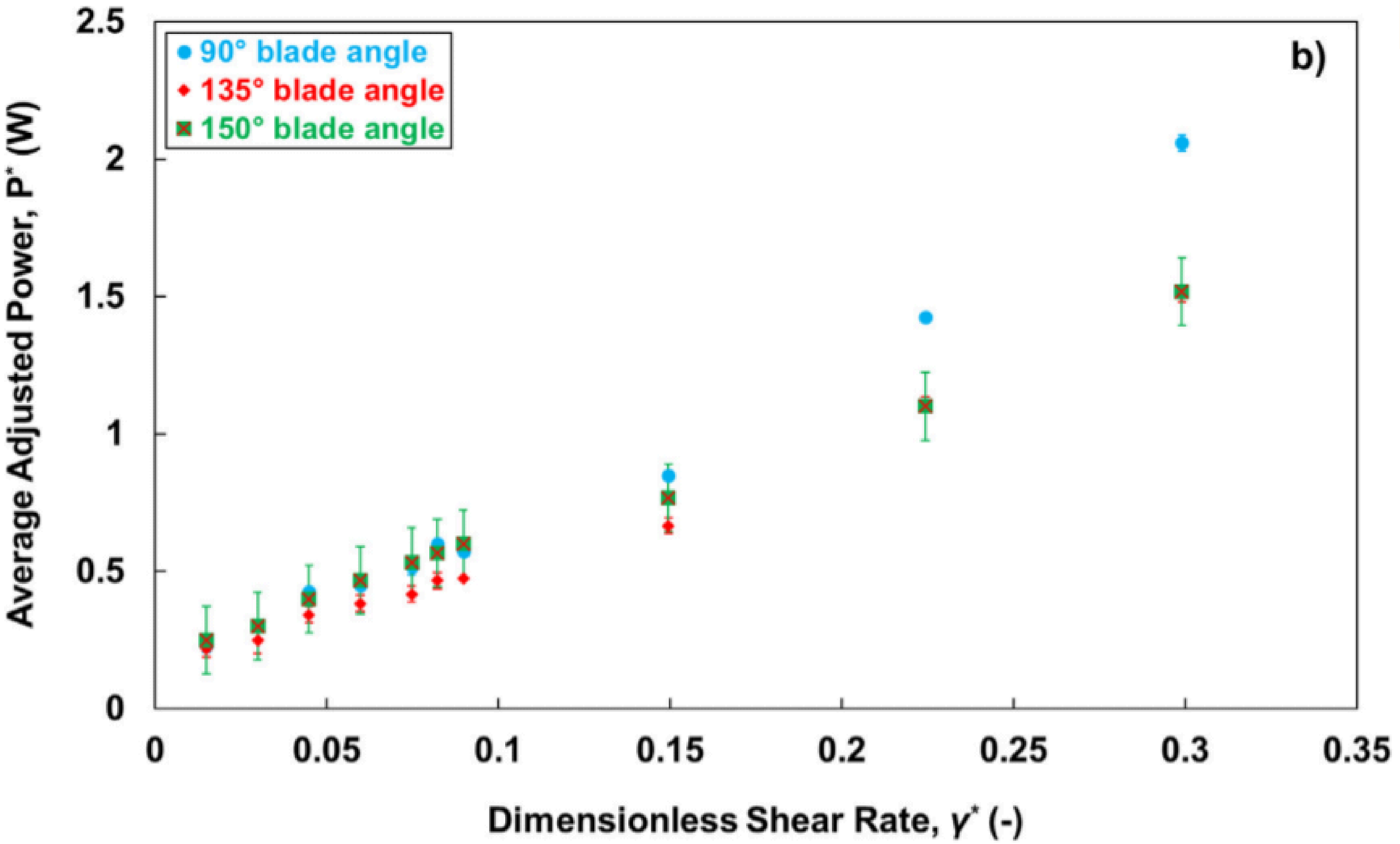


Effect of IMPELLER BLADE LENGTH

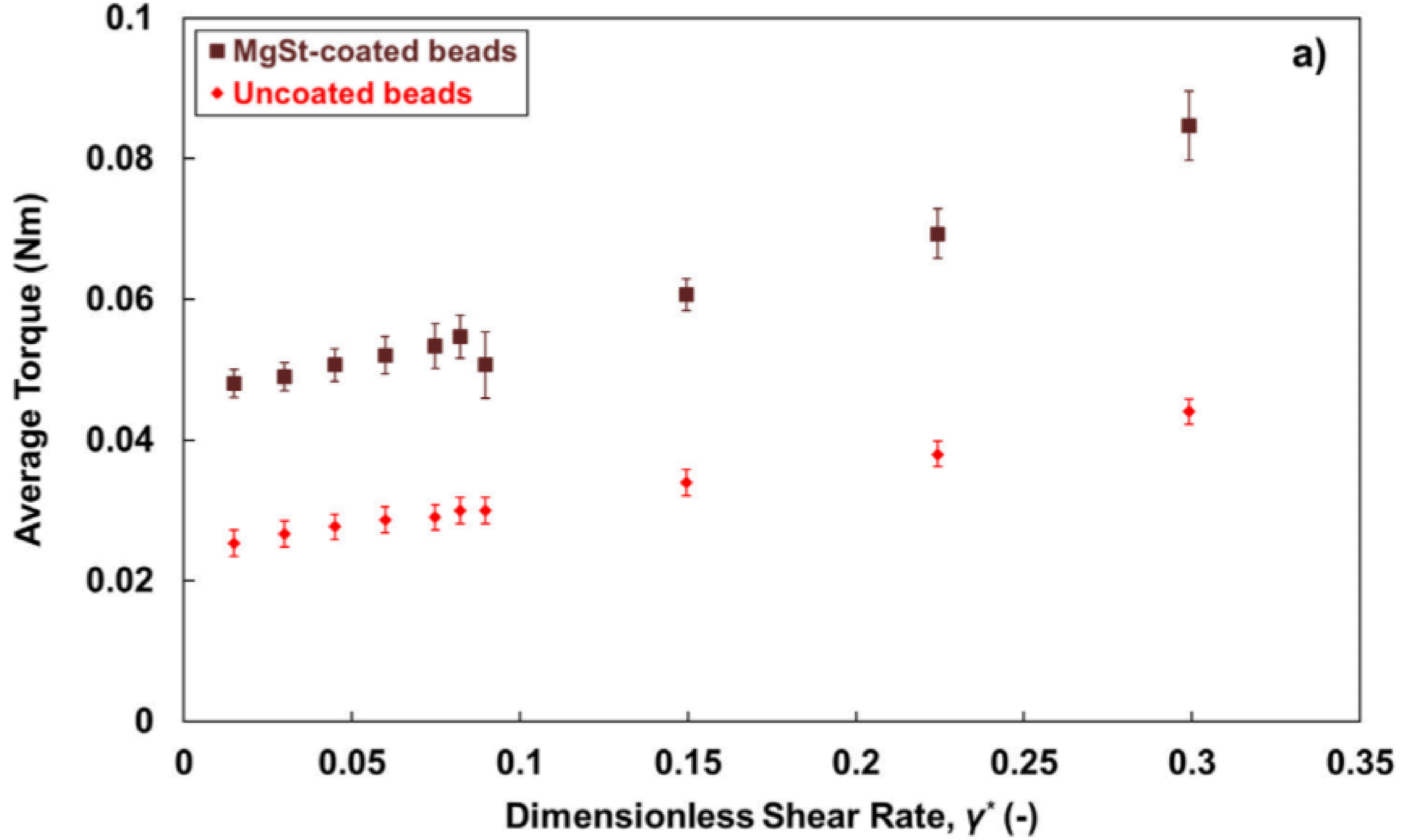


Average adjusted powers at low shear rates show no obvious difference between the two blade lengths.

At higher shear rates, average adjusted power higher for 45-mm standard blades compared to 37.5-mm blades.

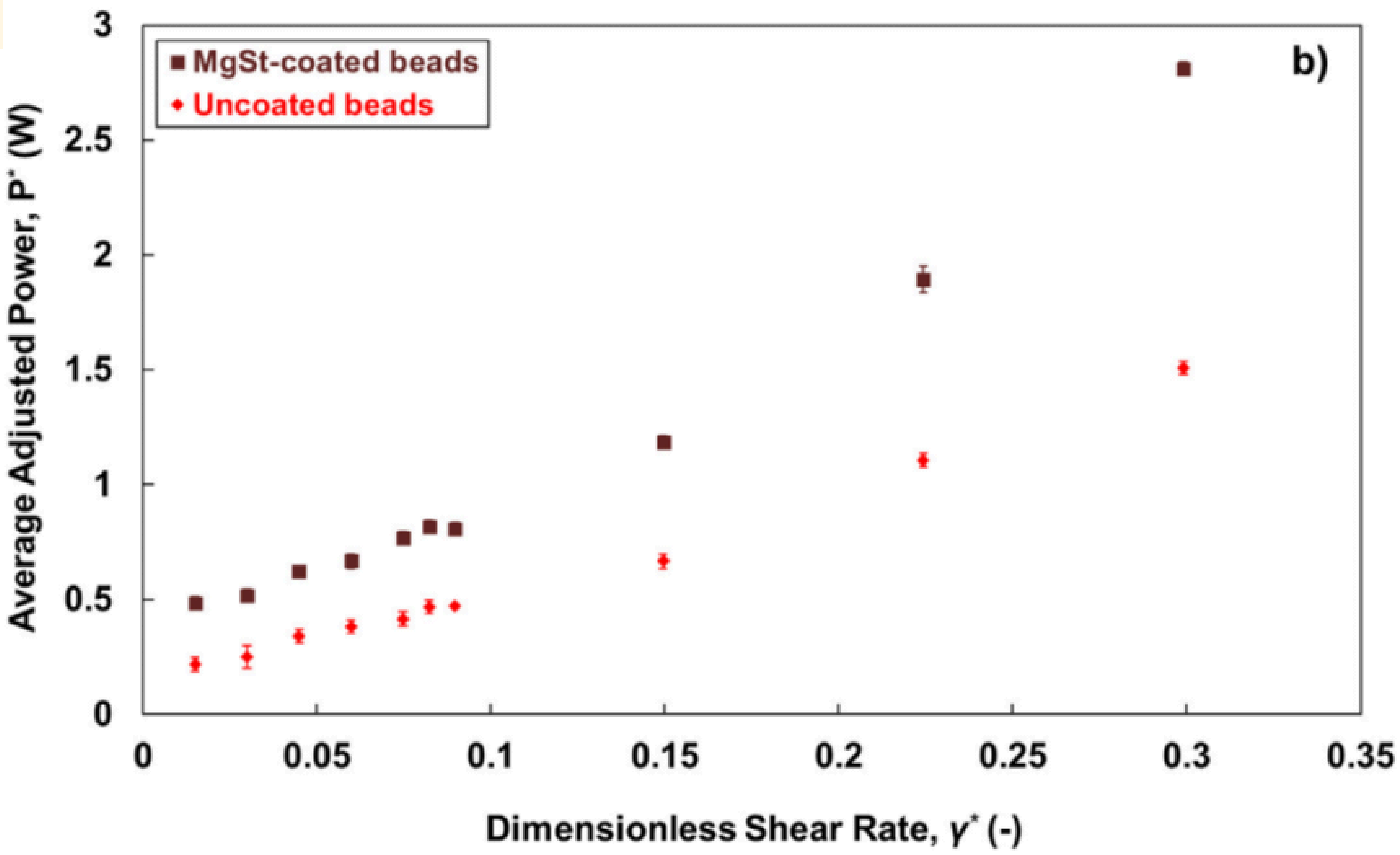


Effect of PARTICLE FRICTION COEFFICIENT



MgSt-coated beads exhibit distinctly higher average torque compared to uncoated beads.

Standard deviations of torque values higher for MgSt-coated beads, indicating greater variability

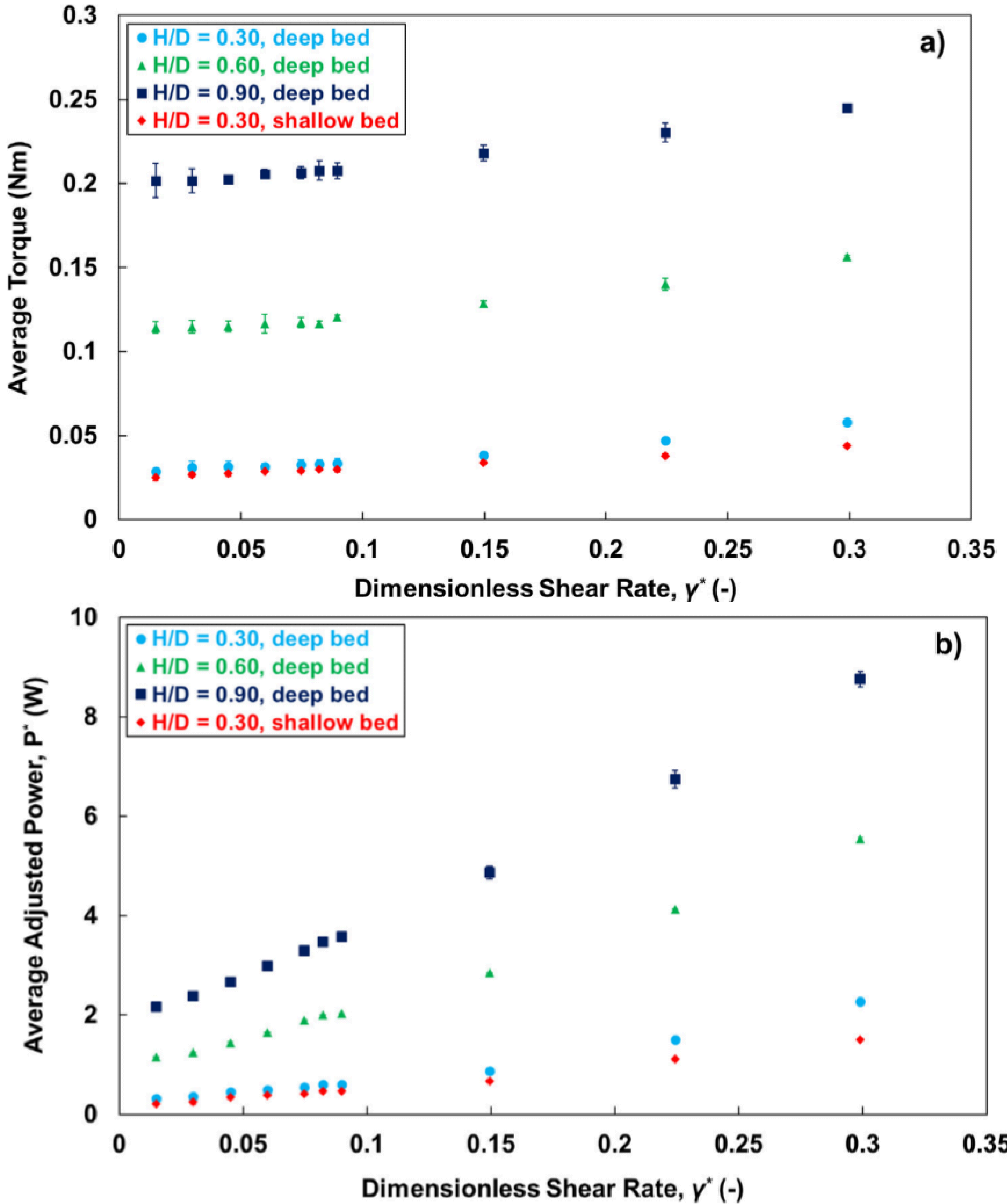


Effect of IMPELLER POSITION IN DEEP GRANULAR BED

Quasi-static region observed at low shear rates in deep bed cases

Materials underneath impeller blades have limited influence on flow of grains in mixing system.

Minor differences observed between shallow and deep bed cases attributed to downward movement of particles caused by rotating impeller.

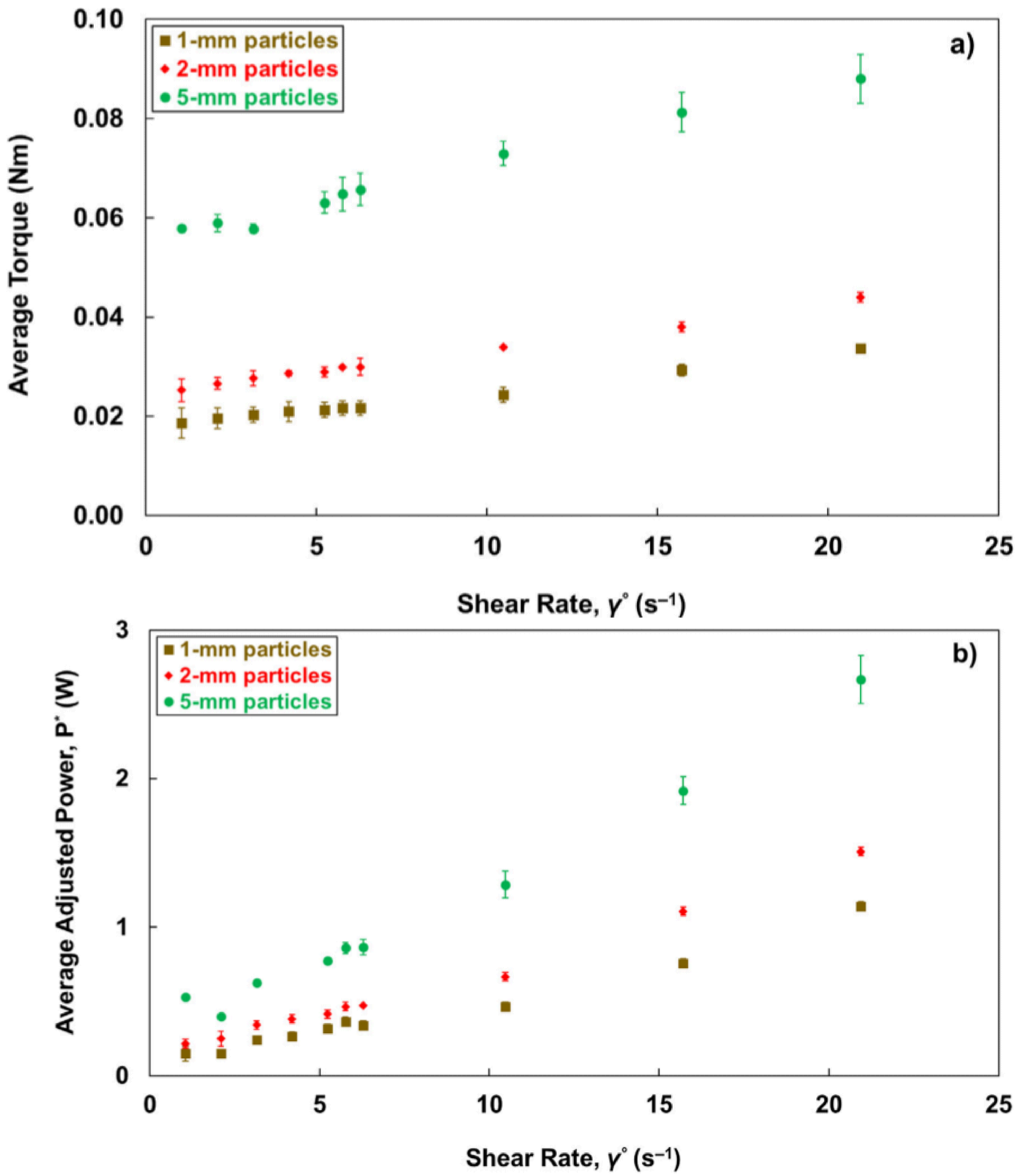


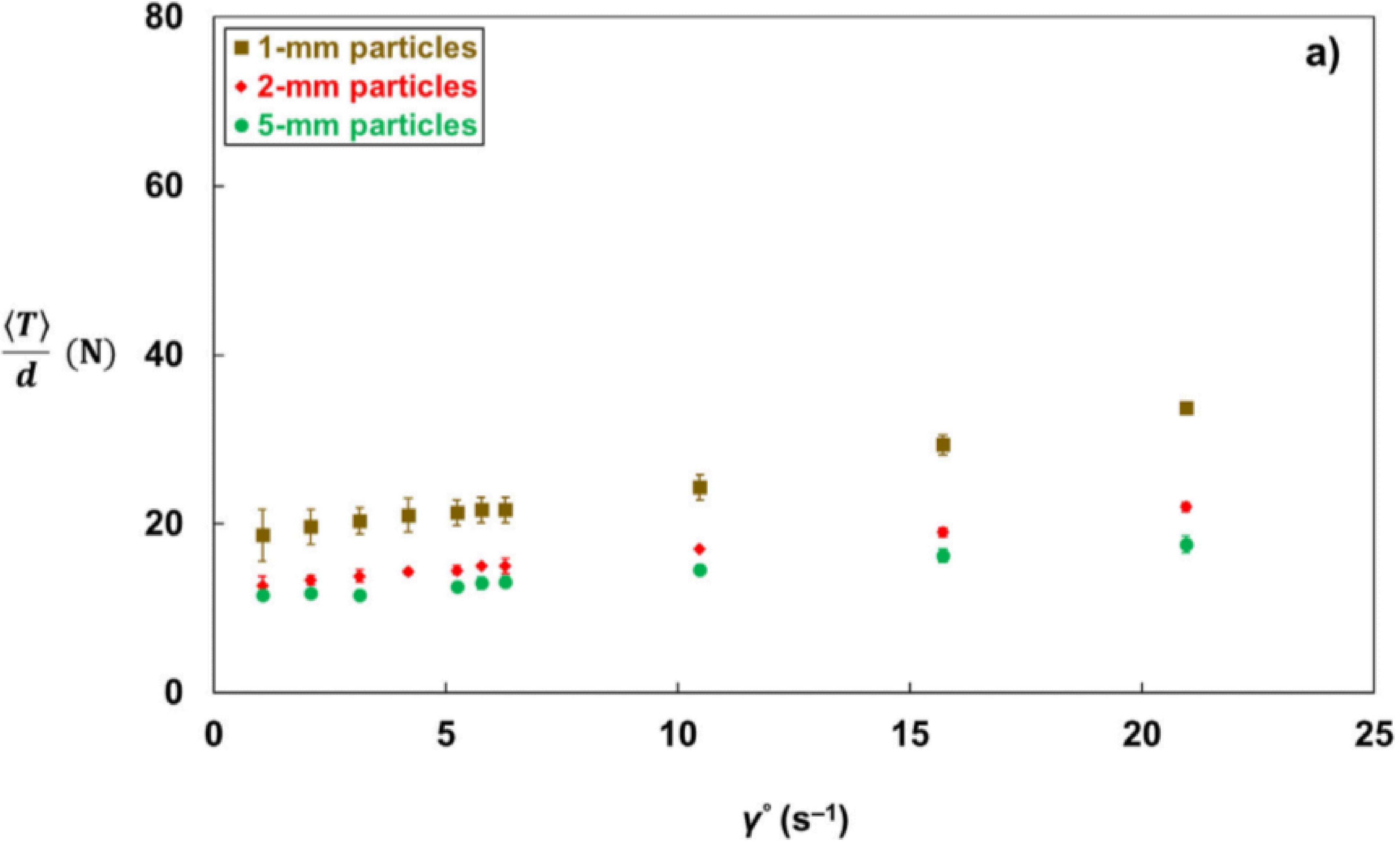
Effect of PARTICLE SIZE

When Plotting wrt dimensionless shear rate, the datapoints for different bed sizes will not lie on same x axis

Highest average torque measured for 5-mm diameter particles, followed by 2-mm and 1-mm beads.

Quasi-static regime observed for 5-mm beads at low shear rates.





NORMALIZATION BY PARTICLE DIAMETER

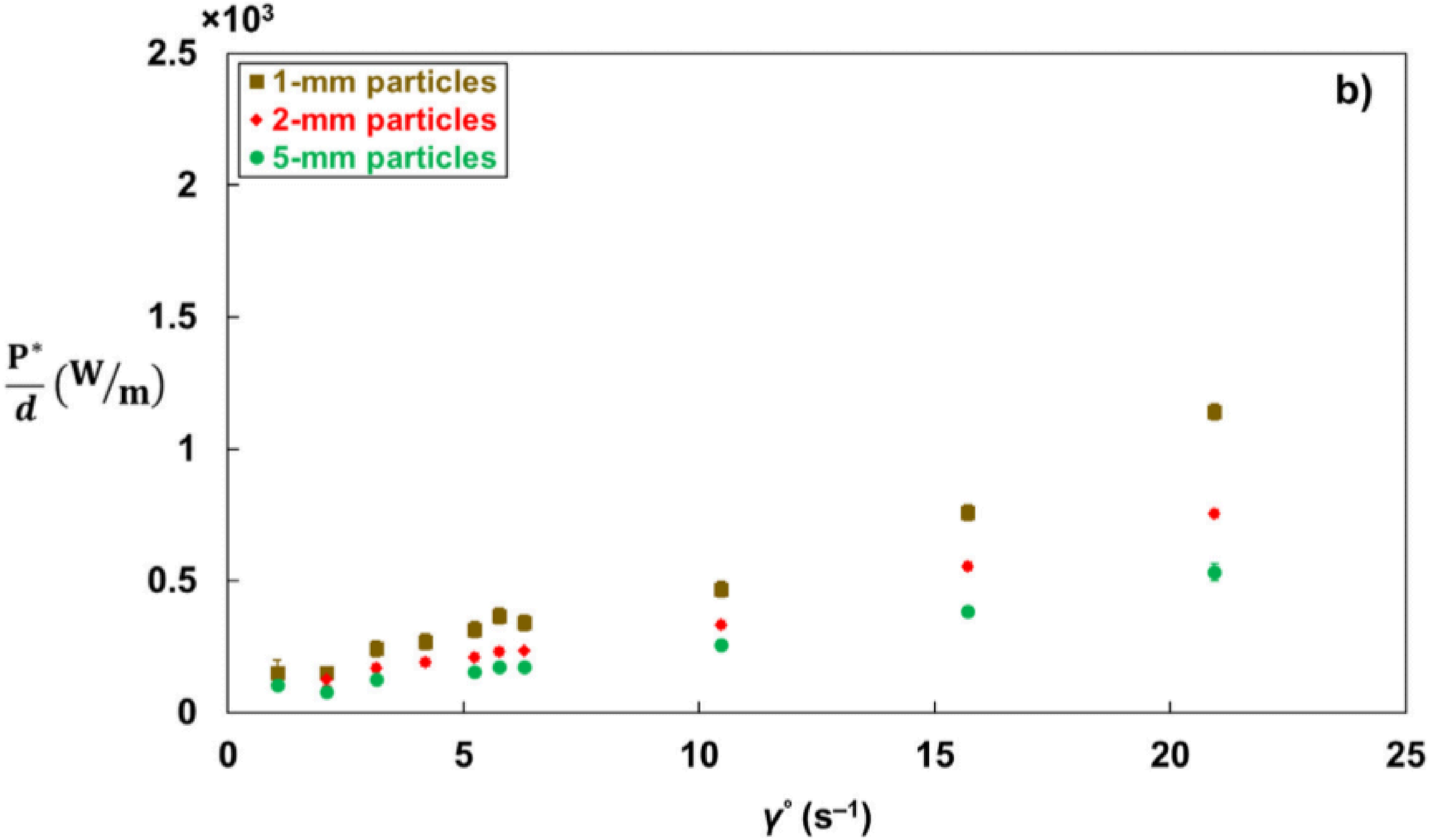
Granular flow = DImensionless inertial no. ∝ d

Time-averaged torque and average adjusted power normalized by particle diameter.

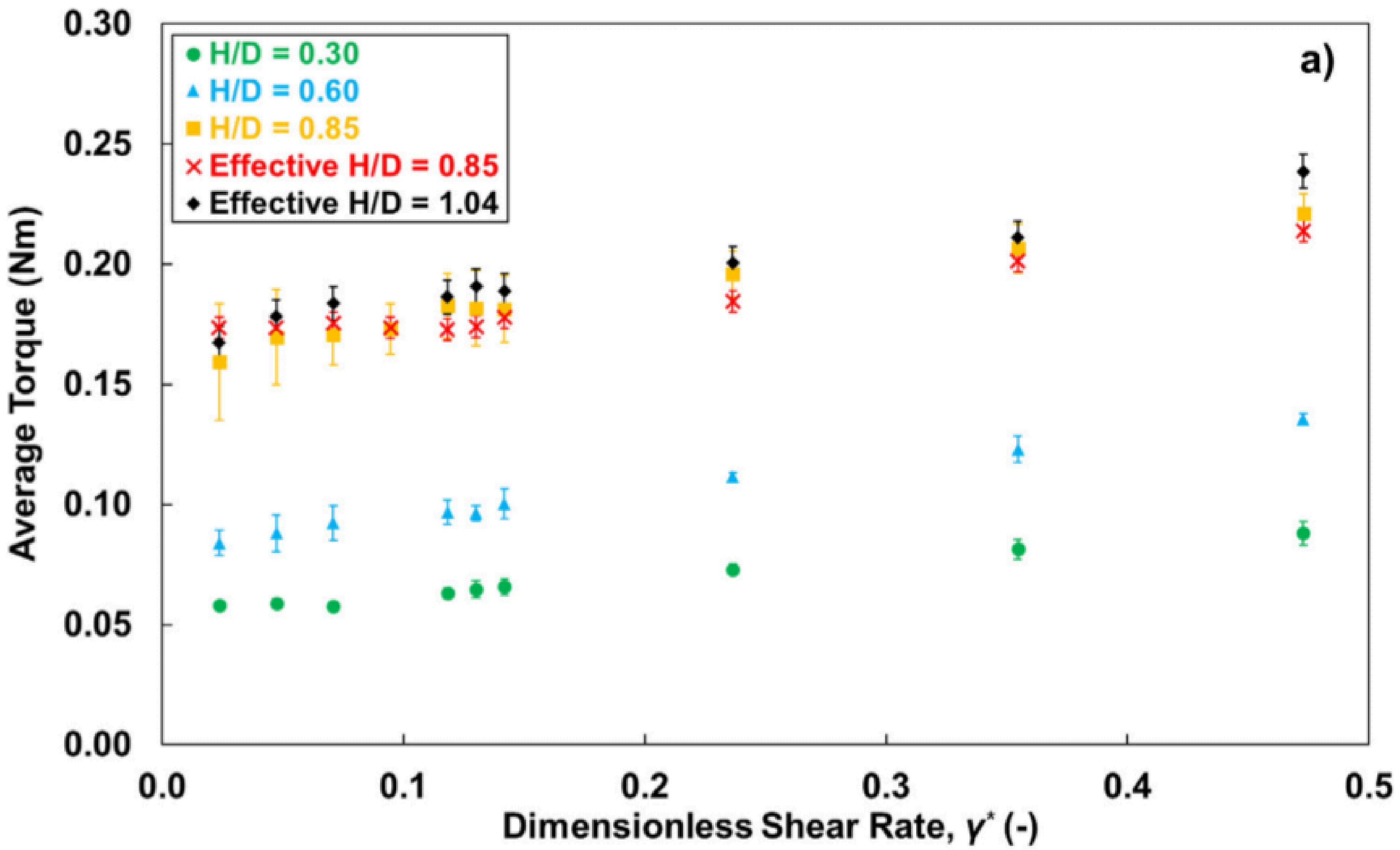
Normalized torque (<T>/d) :

Normalized power (P*/d):

Highest for 1-mm particles, lower but similar for 2-mm and 5-mm particles.

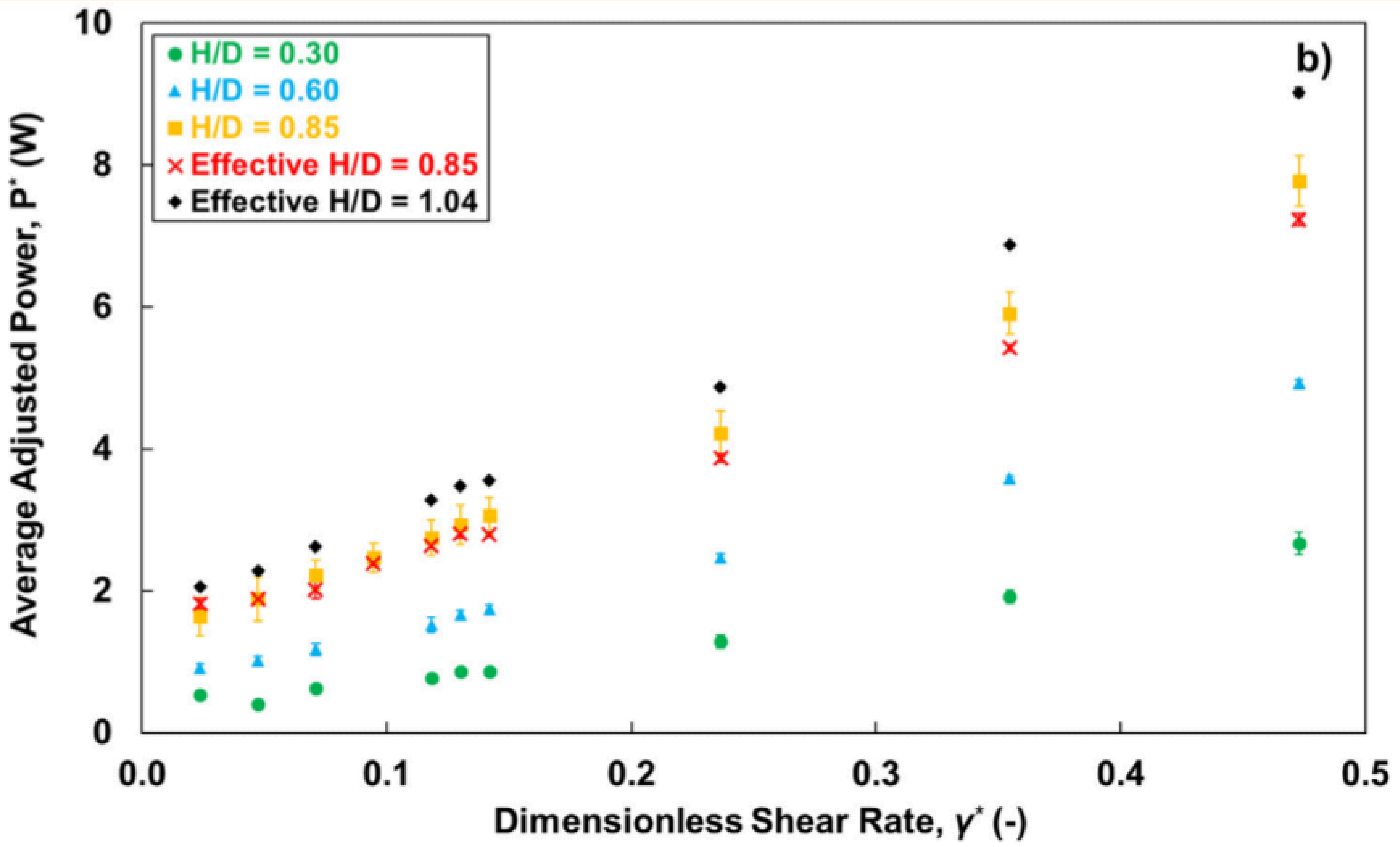


Effect of MATERIAL FILL HEIGHT



Circular lead weight placed on cardboard on top of glass beads to distribute normal load.

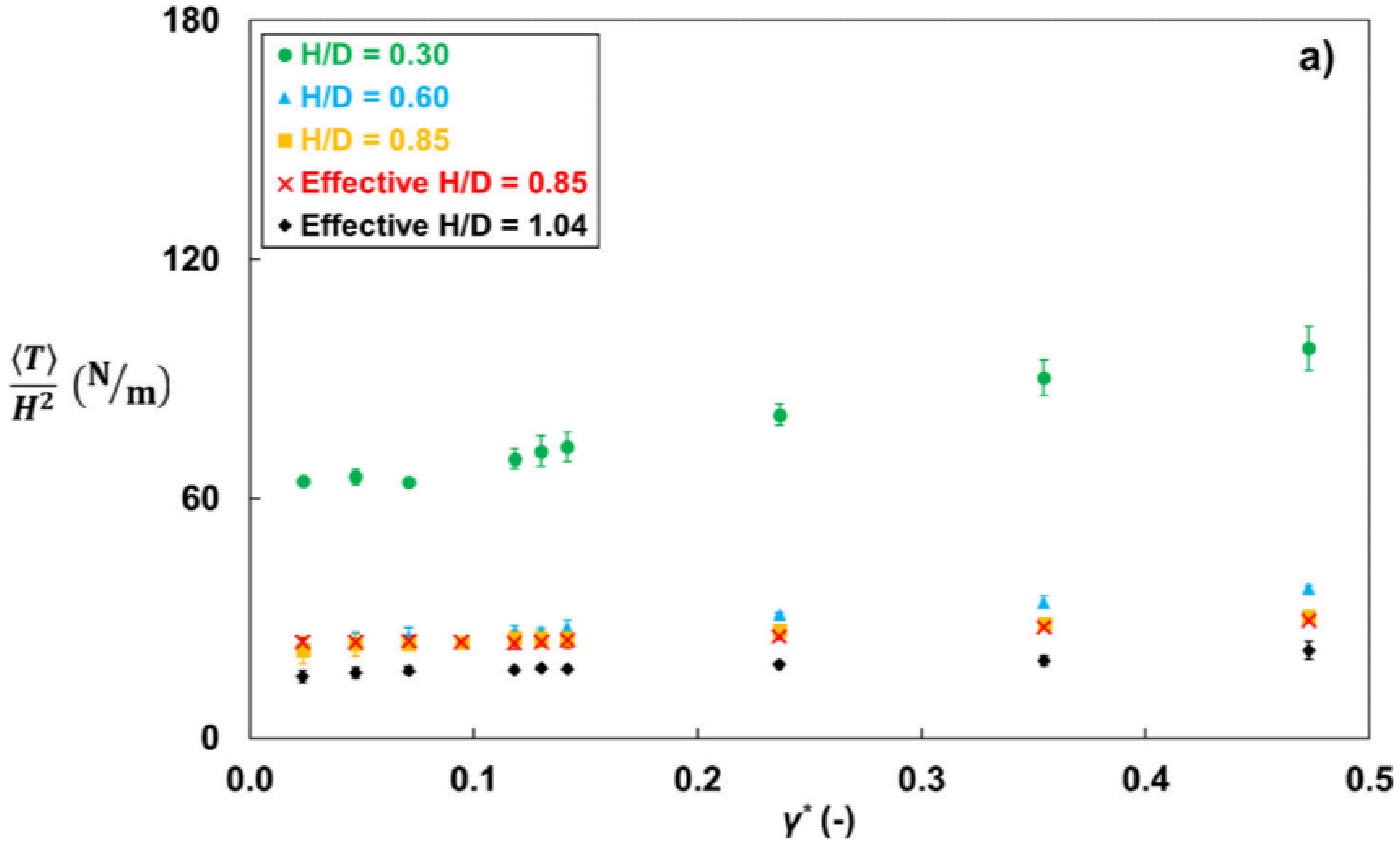
Lead weight equivalent to mass of 44 mm fill height used to simulate deeper beds.



SCALE UP RELATIONSHIP

$$\vec{T} = 2\pi R_{\text{cyl}}^2 H \langle \tau_{\theta r} \rangle$$

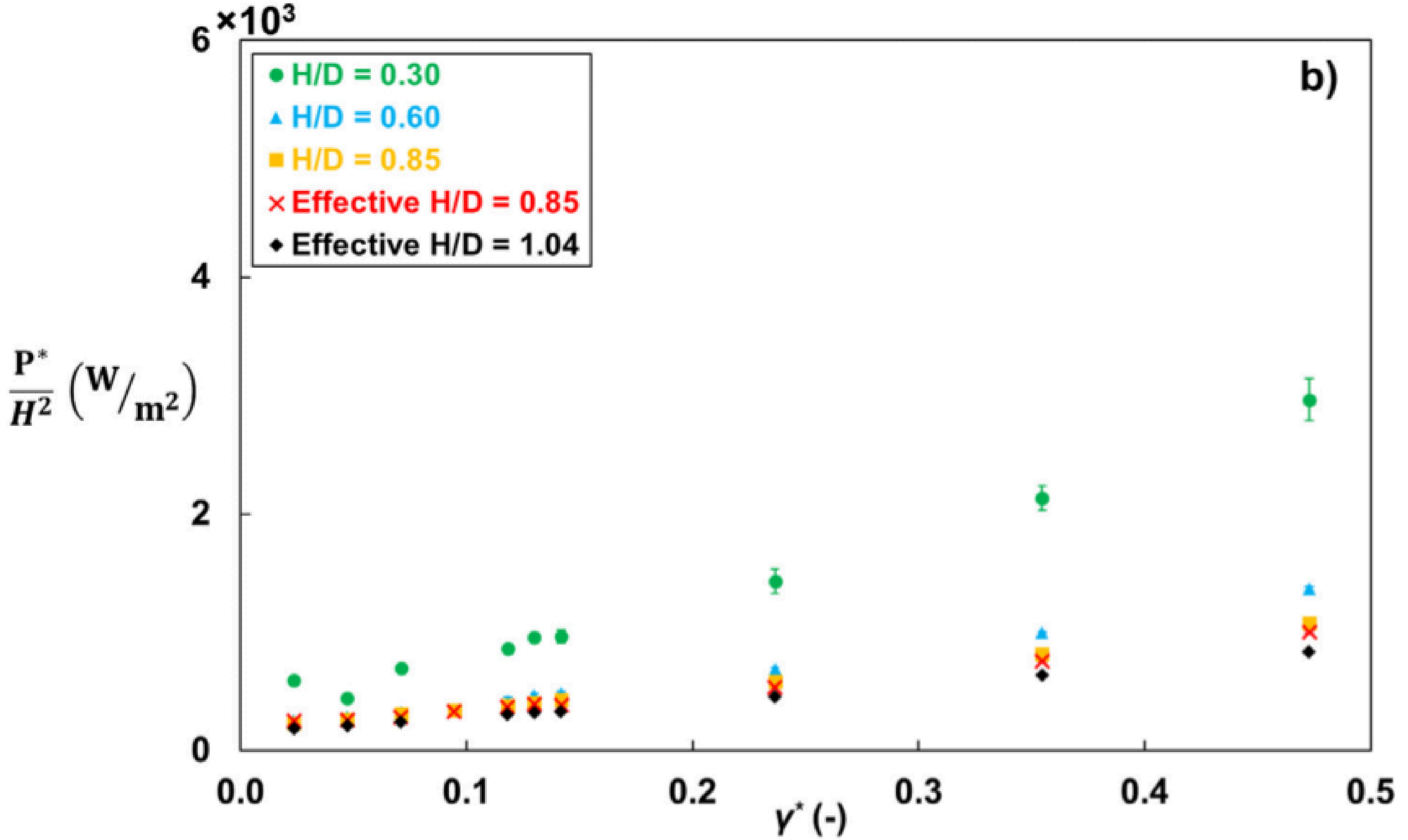
$$\langle \tau_{\theta r} \rangle = \mu \rho_{\text{bulk}} g H$$

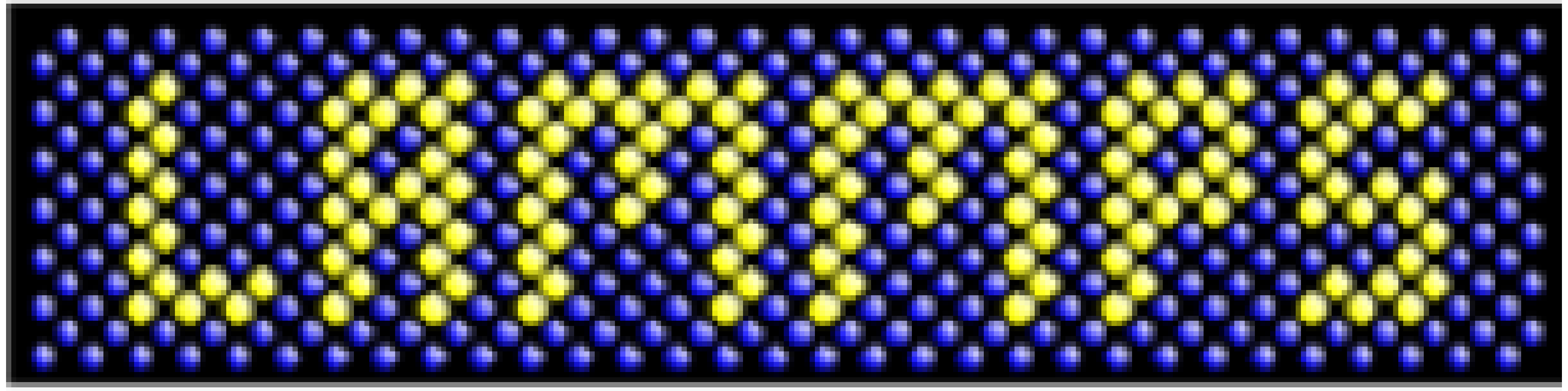


$$\vec{T} = 2\pi \mu \rho_{\text{bulk}} g R_{\text{cyl}}^2 H^2$$

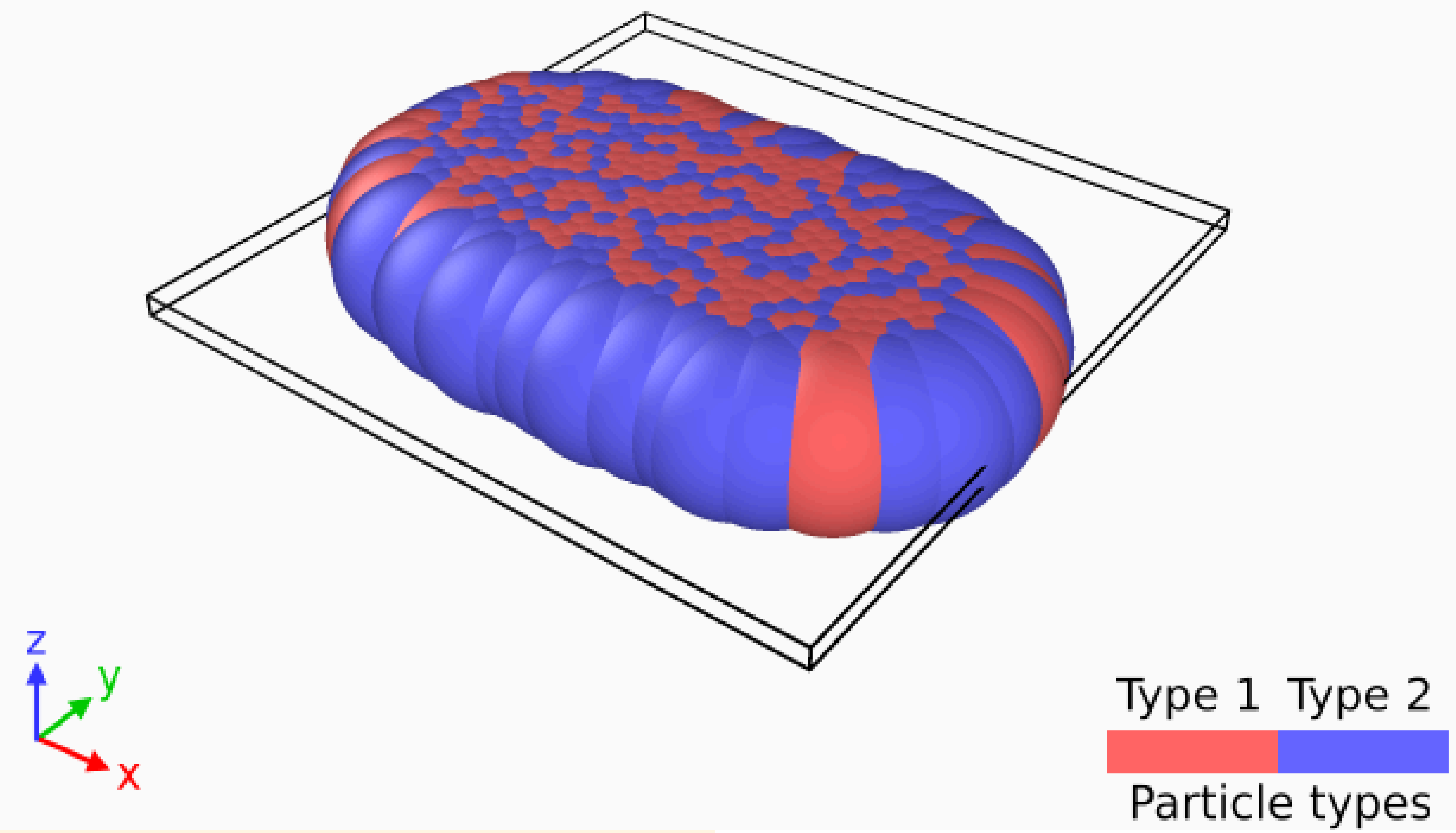
T ∝ H^2

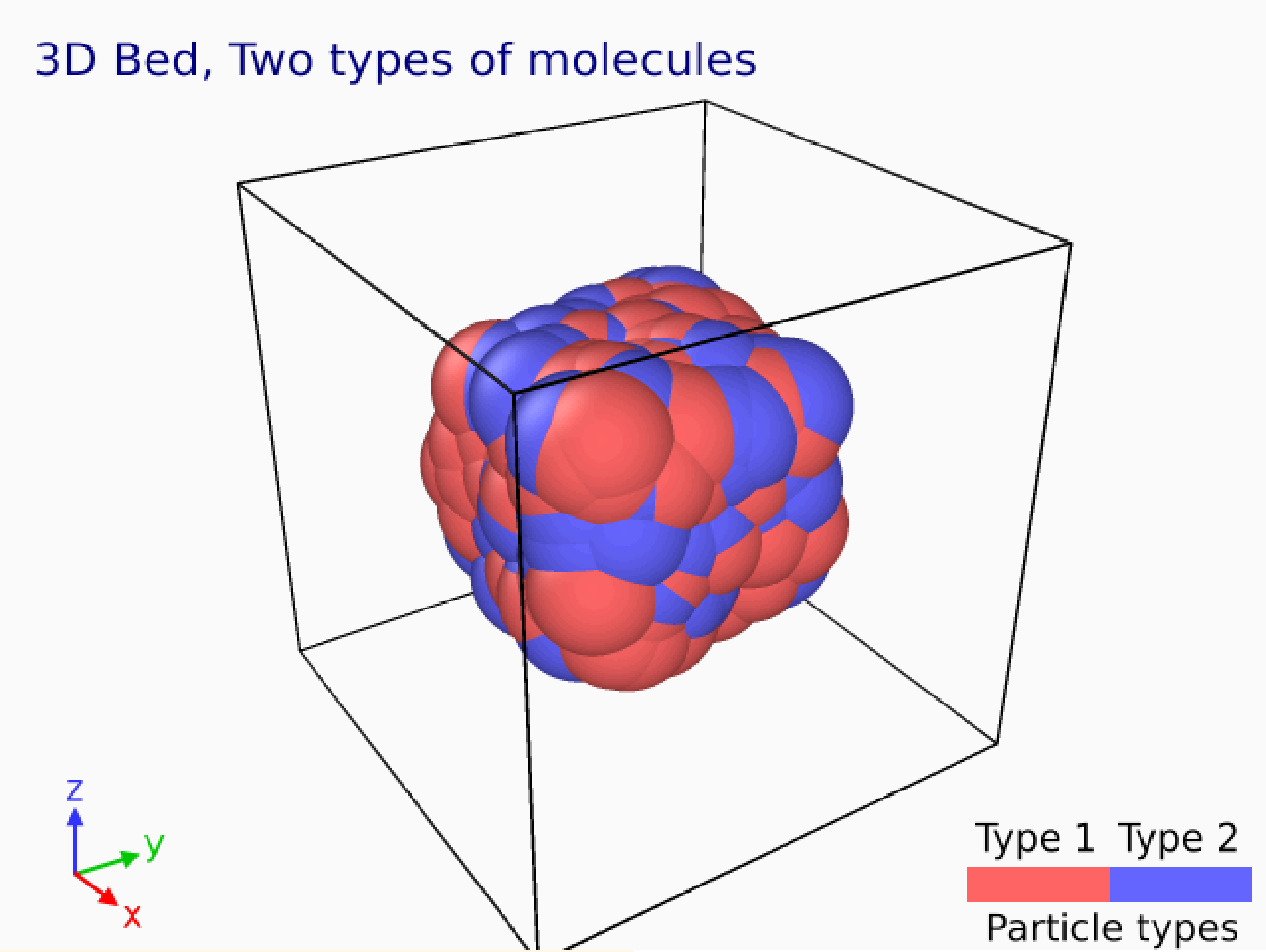
Shallow bed exhibits different torque behavior due to surface particles forming heaps and valleys during rotation, affecting torque scaling relationship.




LAMMPS

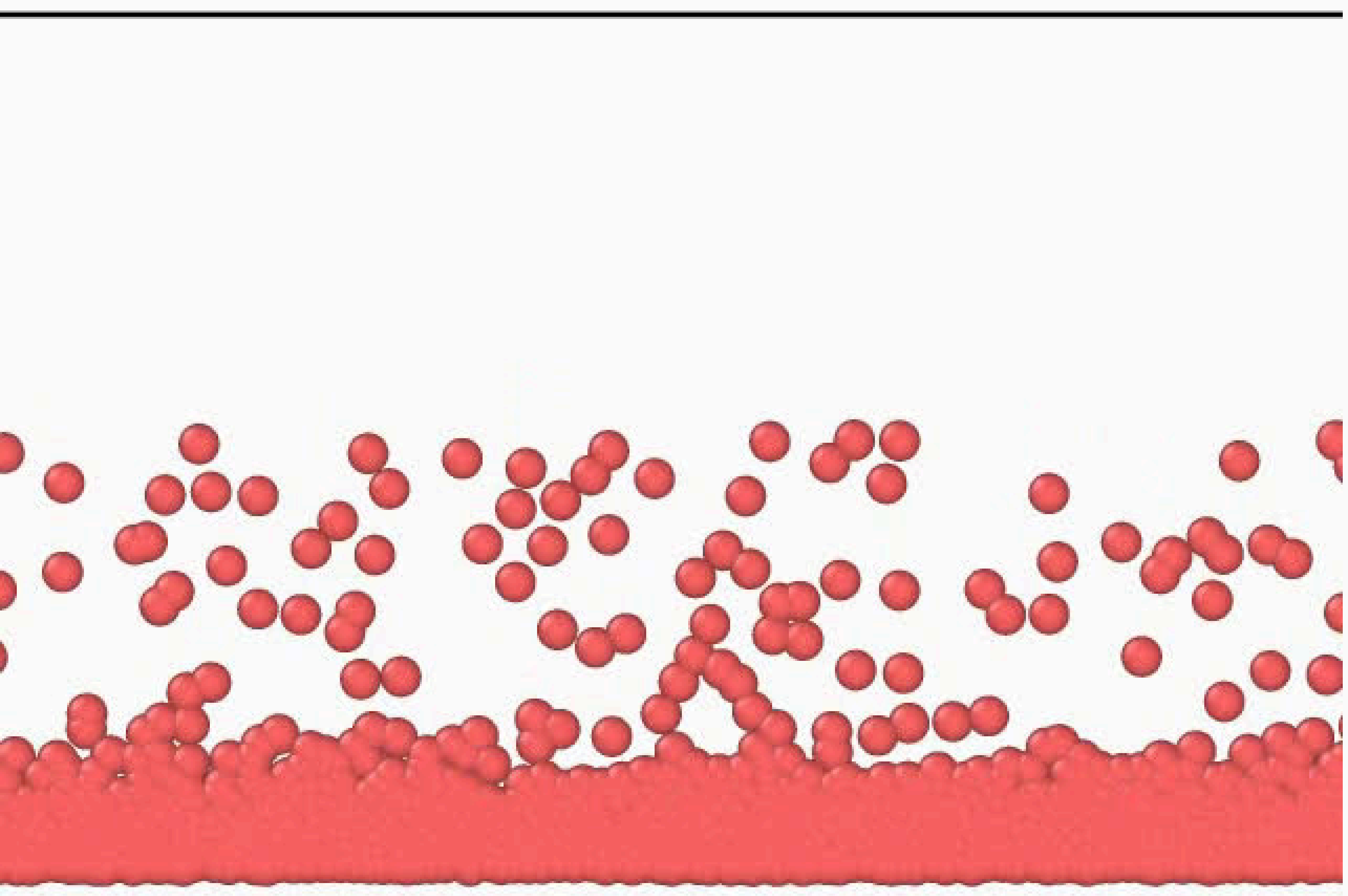
2D Bed

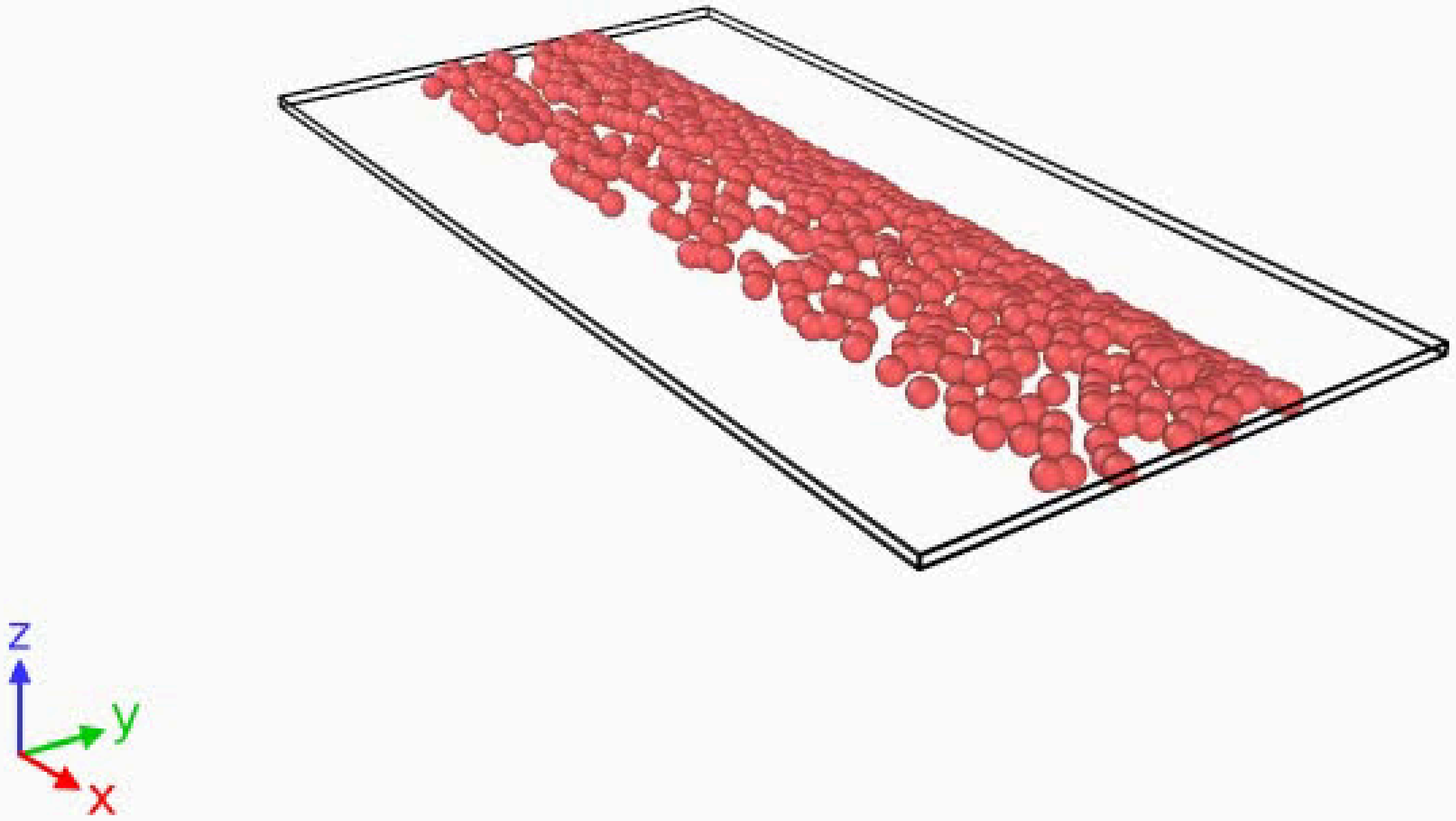


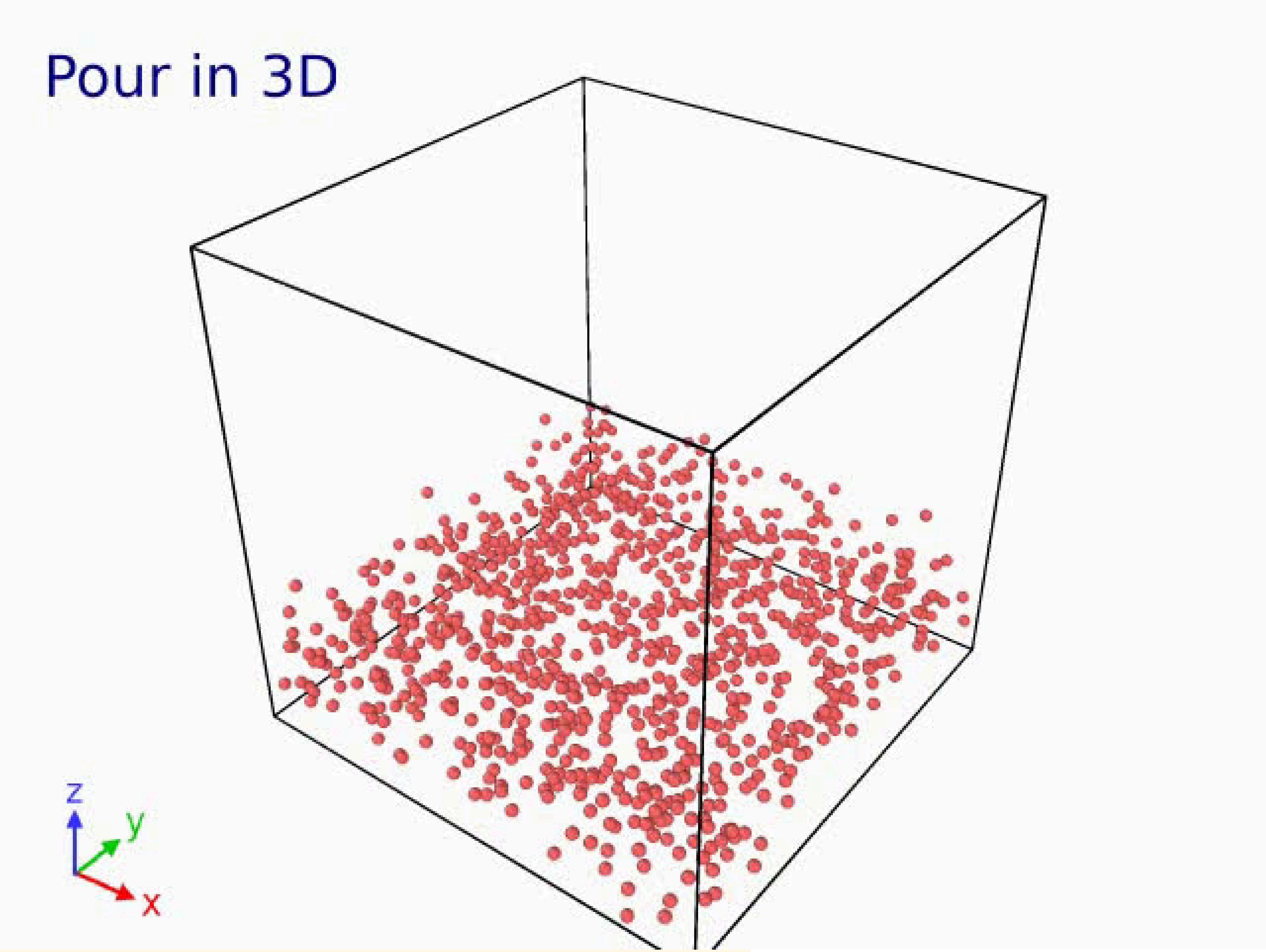


Removing overlapping of particles in 3D Bed

Pour in 2D






Pour in 3D
z
y
x

THANK YOU!

KANISHQ SAHU

2022chb1049@iitrpr.ac.in

+91 9009730530