EFFECTIVE TEMPERATURE OF ACTIVE GRANULAR CHAIN ON PERIODIC POTENTIAL LANDSCAPE

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ABSTRACT

Non-equilibrium systems such as granular matter driven by vertical applied force are subject of intense study on thermodynamic physics. In this study, the researchers investigated the active granular chains (AGCs) which can exhibit persistent motion when external force is applied on an inclined periodic potential landscape. The use of the latter leads to the discovery of the transition of AGCs response modes along the spatial pattern. This would direct us to the calculation of effective temperature to the granular level in a non-equilibrium and athermal system. From the obtained probability distributions fitted with respective functions, the effective temperature is found to be varying significantly with varied particle concentration.

INTRODUCTION

BACKGROUND

An interesting model system to investigate the dynamics of particles on gradient fields is the granular particles excited by a vibrated periodic surface[1].

The use of an inclined potential landscape leads to the discovery of the transition of AGCs response modes along the spatial pattern which directs to the calculation of effective temperature to the granular level in a non-equilibrium and athermal system.

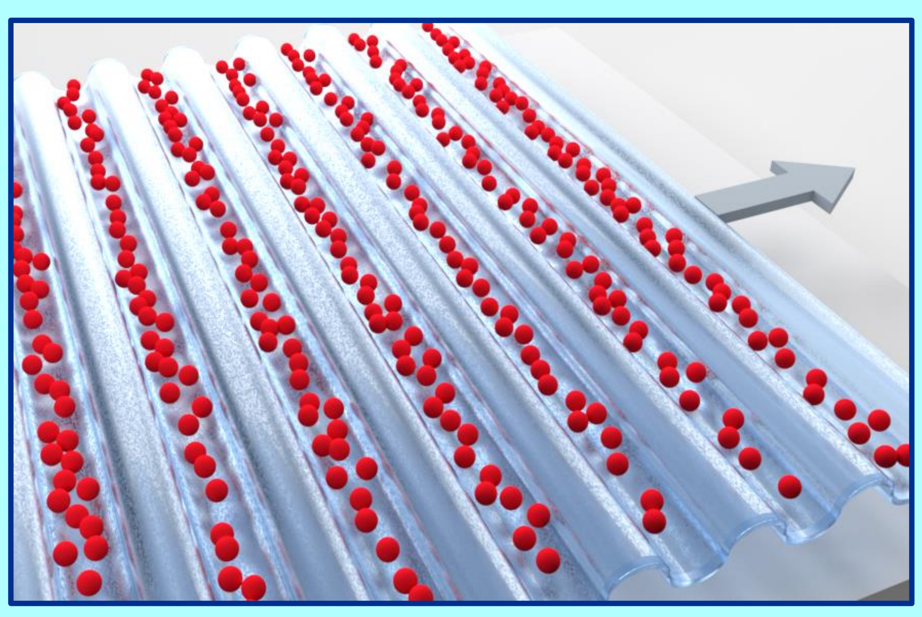

Fig. 1: Red spheres represent the active run and tumble disks in a two-dimensional system interacting with a periodic q1D traveling wave potential which is moving in the positive x-direction (arrow) [2].

MOTIVATION

The validity of the concept of temperature is not guaranteed in non-equilibrium systems which raise a challenging problem on whether it is possible to construct a coherent thermodynamic explanation for these systems. Thus, this study is intended on examining the effective temperature of the active granular chains on a periodic potential landscape via probability distribution calculation.

METHODOLOGY

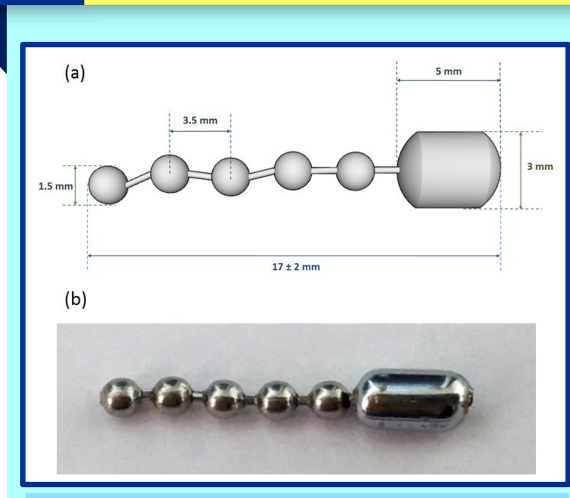

Fig.2: The AGC, (a) schematic diagram and (b) actual image.

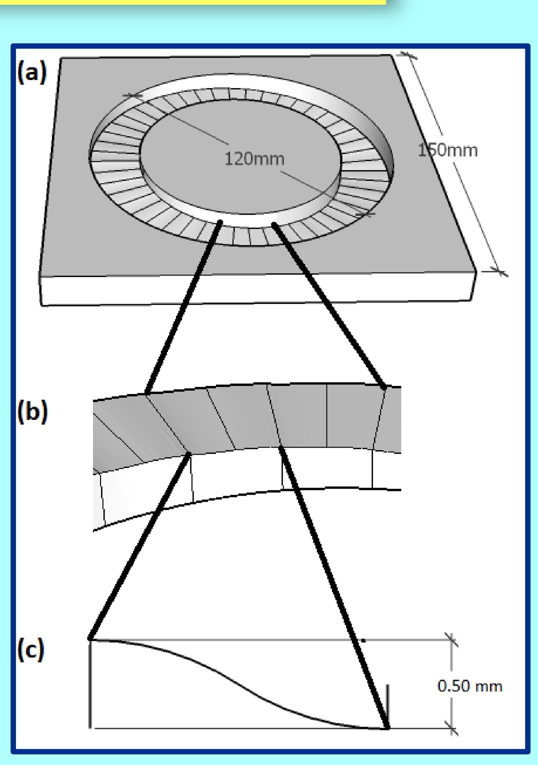

Fig.3: Inclined periodic potential landscape.

Parameters

$$\Gamma = \frac{A(2\pi f)^2}{g} \quad (1)$$

$f = 20\ Hz$ $\quad \Gamma \approx 1.5864 \pm 0.0265$

The inclined periodic potential landscapes are in a concentric form with radii 40 mm and 60 mm. It has 48 arc-divisions with a step function value of 0.50 mm.

DATA ACQUISITION

- Set the parameters in the Smart Amplifier and Function Generator, e.g. ***A, f, gain***
- Load the ***N*** amount of the particle
- Record the experiment
- Convert the video in to stacks of images (ImageJ Software)
- Data Analysis

DATA ANALYSIS

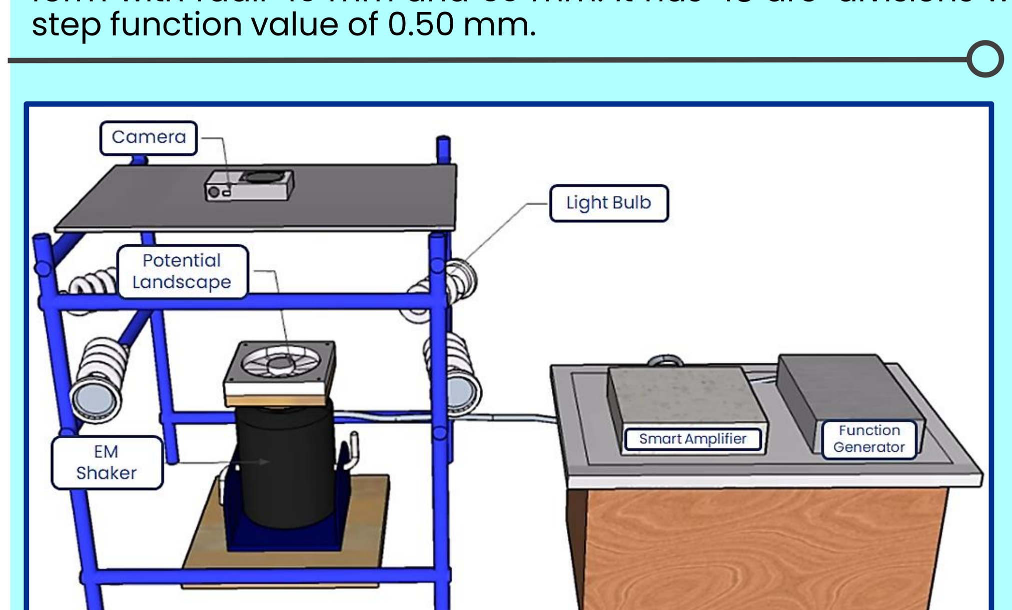

Fig. 4: Schematic Diagram of the Experimental Set-up

The calculated position probability distributions of AGC are fitted using the Boltzmann distribution function,

$$P(\theta) \approx e^{\frac{-mgh}{k_B T^{(1)}_{eff}}} \quad (2)$$

in order to determine the effective temperature $T^{(1)}_{eff}$ of the AGC.

The calculated velocity probability distributions of AGC are fitted using the Gaussian distribution defined as

$$P(v) \approx \frac{1}{\sqrt{2\pi\sigma^2 t}} e^{\frac{-mv^2}{2k_B T^{(2)}_{eff}}} \quad (3)$$

in order to determine the effective temperature $T^{(2)}_{eff}$ of the AGC.

RESULTS AND DISCUSSION

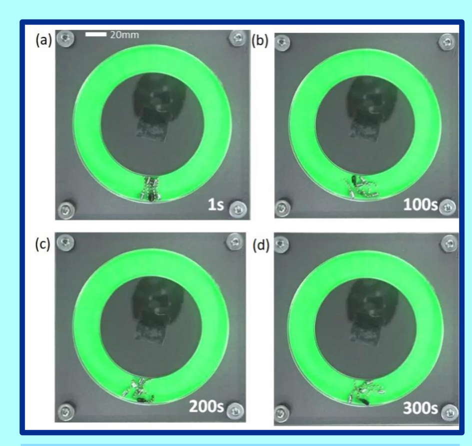

Fig.5: Time lapse images of the AGC on the inclined periodic potential landscape for t = 1 s, 100 s, 200 s, and 300 s (a-d).

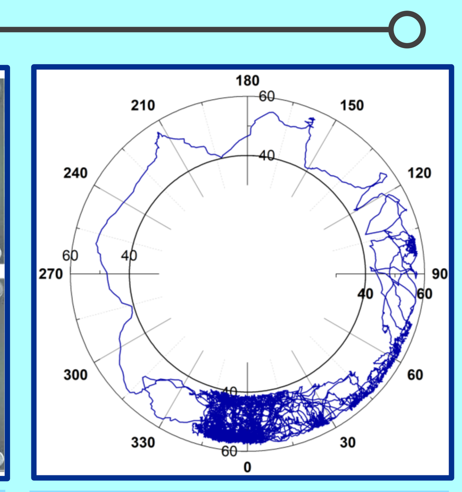

Fig.6: Trajectory plot of an AGC with particle concentration N = 5 AGCs

Generally for varied N, the random motion of the particles is influenced by the forces exerted by the EM shaker and by interaction of the neighboring particles.

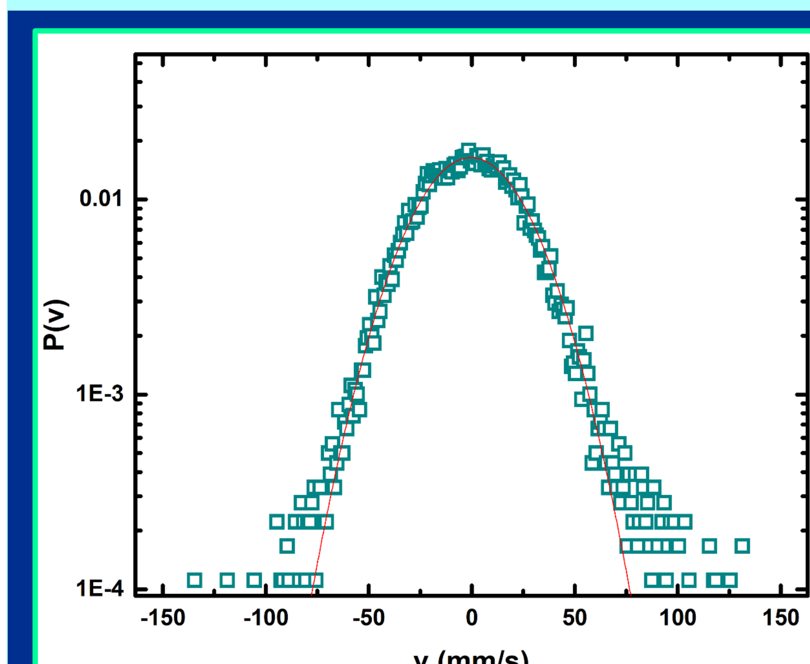

Fig.8: Velocity probability distribution of an AGC with N = 5 AGCs.

PROBABILITY DISTRIBUTION

It is found that the probability of an AGC to move up is decreasing exponentially. The solid curve corresponds to the Boltzmann distribution function in eq. (2).

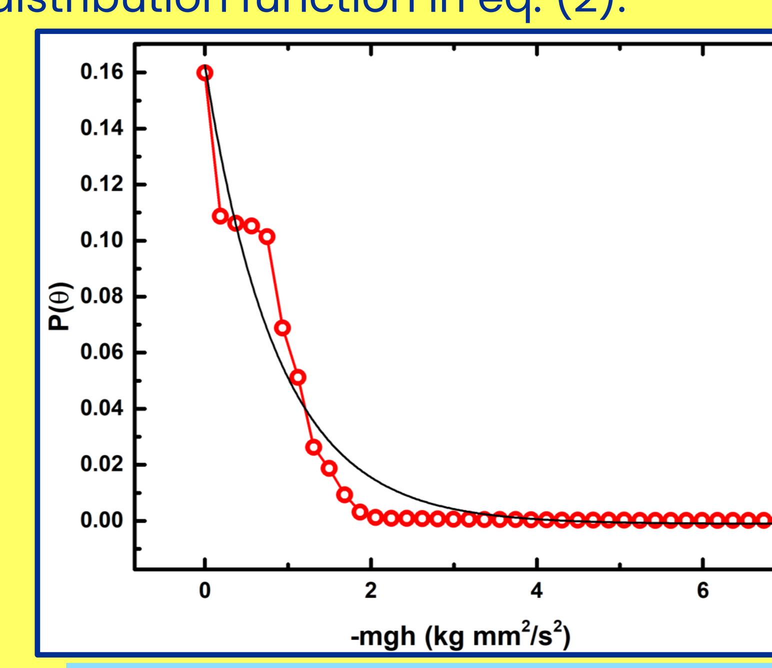

Fig. 7: Probability distribution of an AGC position with respect to θ vs U with N = 5 AGCs

Shown in Fig. 8 is the probability distribution P(v) of the velocity for a single AGC where it can be seen that at low v, the distribution can reasonably be described as Gaussian. However, P(v) deviates systematically from the fitted curve thus it is non-Gaussian. The solid curve corresponds to the Gaussian distribution in eq. (3).

EFFECTIVE TEMPERATURE

It is observed that both effective temperatures $T^{(1)}_{eff}$ and $T^{(2)}_{eff}$ differs significantly from each other on varied particle concentration N. Moreover, the large values of effective temperatures T_{eff} are expected since granular matter is an athermal system [3].

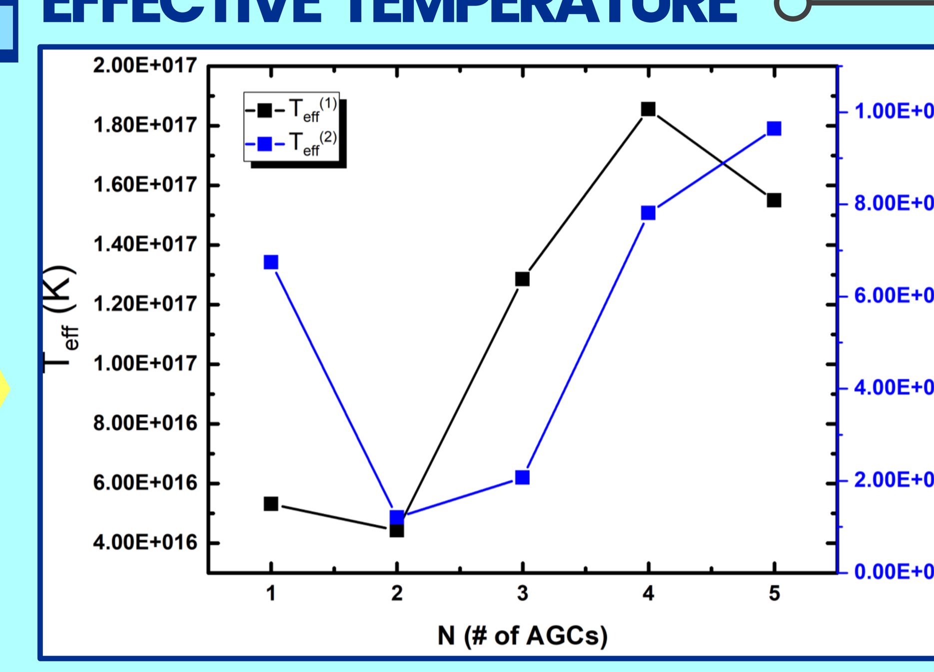

Fig. 9: Effective temperature on varied N.

CONCLUSIONS AND RECOMMENDATIONS

In this study, we are able to investigate the existence of effective temperature of an active granular chain on an inclined periodic potential landscape through tracking down the trajectory and by calculating the probability distribution of the particle's position and velocity. It is observed that both effective temperatures $T^{(1)}_{eff}$ and $T^{(2)}_{eff}$ differs significantly from each other on varied particle concentration N. Based on our results, more experimentation is needed to understand fully whether our definition of effective temperature has a physical thermodynamic meaning.

Acknowledgment: **DOST- ASTHRDP and MSU-IIT**

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[1] K. Safford, , *et. al.*, Phys. Rev. E 79, 061304 (2009)
[2] Cs. Sandor, et. al., arXiv:1611.00349v1 (2016)
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