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# Design and Dynamic Analysis of a Parallel Compliant Vibration Mechanism for High Precision Production Line

***Thanh-Phong Dao and Shyh-Chour Huang***

Department of Mechanical Engineering, National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan, R.O.C



**ABSTRACT:** This study proposes a new design concerning a parallel compliant vibrating mechanism for high precision production lines and enforces dynamic simulating analysis. The conventional mechanism for separating fine particles has based on advantages of spring to make vibrating motion to separate out various particles with radius ranges from 7 mm to 20 mm. But it also has a few defects such as additional weights of the springs, the wear between the kinematic joints. To overcome these limitations, this paper applies the conception of compliant mechanism to design novel model. First, using the principle of compliant mechanism, a parallel compliant vibrating mechanism is developed. The use of ANSYS, finite element analysis (FEA) is performed to explore the results of dynamic analysis concerning both angular velocity of mechanism and both angular acceleration and both equivalent stress and total deformation of compliant segments. The results show that a proposed mechanism can be used in high precision manipulators, actuators, and production line chain. Future work will conclude an investigation into the vibration frequency.

**KEYWORDS:** Compliant mechanism, Parallel vibrating mechanism, FEA, Dynamic behavior, High precision Production line.

## BACKGROUND

A traditional straight vibration mechanism have widely used in many industries such as manufacturing and processing plastics, abrasives, chemicals, pharmaceuticals, foodstuffs, construction materials, fertilizer, coal mining, processing, etc. It is used to separate the materials with corresponding size of particles but it also exists many disadvantages such as expensive cost of maintenance, assembly, high cost manufacturing, a lot of components in a kinematic chain, need for lubricant, etc. In the last decades, Flexure based mechanisms, compliant mechanisms, are mechanisms that reply on elastic deform of components to transfer force, moment, translation, rotation, etc. They have been commonly used in high precision actuators, manipulators, robotics, and chemical environment to other industrial areas because they are a monolithic mechanism, lowest cost for manufacturing. From these view of points, a novel vibrating mechanism is designed to separate the various particles with radius ranges from 7 mm to 20 mm. Compared with the traditional vibrating mechanism, this novel mechanism is monolithic mechanism and offers a lot of advantages such as no joint, high accuracy, no friction, no clearance, backlash, no lubricant, and no maintenance.

## 1 INTRODUCTION

The vibrating mechanism can separate particles of immovable dimensions by vibrator motion. The linear vibration sieves are widely used in the separation and classification of materials in powder and granular materials. In addition, it is also widely used in many industries such as manufacturing and processing plastics, etc. Conventional vibrating mechanism has some problems concerning the heavy weight, the wear and the lubrication due friction. Therefore, an intermixing the vibrating mechanism and compliant conception was studied to design a novel vibrating model. Compliant mechanisms gain their mobility due to relative flexibility of their flexible hinges. There are many advantages the compliant joints as a mechanism can be built in one piece, the weight, wear, and noise can be reduced, no clearance, no friction, and need for lubrication can be eliminated. In the literature review, many previous scientists and engineers, and academic researchers studied on traditional vibrating mechanisms in different fields.

A rotational vibrated disk for separating various particles developed in [1]. And then another study focused on separation of differently shaped fine particles by a new wet shape separator [2]. Next, experimental study on shape separation of particles by using radial settling characteristics through stationary liquid in rotating vessel investigated in [3]. In other study, a settler for continuous particle shape separation presented in [4]. Almost these studies researched on various vibrating mechanisms for separating different particles.

In recent years, there has been great interest of flexible based mechanisms that also called compliant mechanisms using flexure hinges. Several design methodology for compliant mechanisms was presented in [5], while ultra-high precision mechanisms presented in [6]. Elastic elements were also considered in [7]. A flexible micro-gripper was designed and fabricated in [8]. A large variety of high precision mechanisms based on flexible bearings was presented in [9].

The vibration of flexible mechanism versus time effects on the fatigue life, the strength as well as motion specifications; therefore, this research concentrates on the dynamic behaviors.

In this study, this paper uses ANSYS software to perform dynamic analysis. The process of motion in the simulation as follow: the platform 2 of parallel compliant vibrating mechanism moves along the ray with a stable velocity, and then the platform 1 vibrates by four flexible segments. This motion can separate particles whose size smaller than that of the sieves. Finally, this paper explores the result of dynamic analysis concerning both of the angular velocity and the angular acceleration as well as the equivalent stress and the total deformation of compliant segments.

## 2 SIGNIFICANT AND CONTRIBUTION OF PROPOSED APPROACH

A vibrating compliant mechanism was developed because of monolithic, high accurate, no joint, no friction, no clearance on backlash, no lubricant, and no maintenance. The most special is that it can store elastic energy. This study provides a concept about compliant mechanism used in industrial high precision production line chain.

## 3 PRINCIPLE OF THE PARALLEL COMPLIANT VIBRATING MECHANISM

### 3.1 TRADITIONAL STRAIGHT VIBRATING MECHANISM

First, straight vibrating sieve fitted with vibrator motor, the materials are put into it. Next, through a vibration motion of this sieve, the materials ready to move along the prepared tray and separated by the hollows gradually. Thus, for the linear vibration sieves can provide large amount of materials at the inlet and continuous data. Due to the multi-layer structure can be ready to separate the materials with corresponding size, enhanced the capacity and the effectiveness of its removal. The linear vibration sieves are widely used in the separation and classification of materials in powder and granular materials. In addition, it is also widely used in many industries such as manufacturing and processing plastics, abrasives, chemicals, pharmaceuticals, foodstuffs, construction materials, fertilizer, coal mining, and processing, etc. The characteristics of the conventional mechanism include: (1) Vibrating straight low energy consumption, high energy kind of separation, (2) simple structure, operation, and easy maintenance, (3) vibrating screen is designed with straight-closed structure completely, (4) no diffuse dust, (5) continuous operation with high performance, great durability, straight vibrating screen used in the proper connect with other industrial chain. A traditional vibrating mechanism for separating particles is illustrated as in Fig. 1.

*Fig. 1. A system diagram of a traditional vibrating mechanism*

### 3.2 PARALLEL COMPLIANT VIBRATING MECHANISM

Based on these characteristics of the conventional vibrating mechanism, a novel compliant vibrating mechanism was designed using flexible hinges and the concept of compliant mechanism in order to separate the various particles with radius ranges from 7 mm to 20 mm. The principle of this mechanism describes as follows: The platform 2 moves along the ray of z-direction with 100mm/s. platform 1 vibrates along x-direction due to flexible segment, which are the elastic elements. The platform 1 has many holes of 15 mm. The range of particle with radius ranges from7mm to 25mm, based on this vibrating mechanism, the particles size is smaller than 15 mm, and they can be separated. Compared with the traditional vibrating mechanism, this novel mechanism is monolithic mechanism and offers a lot of advantages such as no joint, high accuracy, no friction, no clearance, backlash, no lubricant, and no maintenance. Fig. 2 shows a novel compliant vibrating mechanism for separating particles in high precision production line chain.

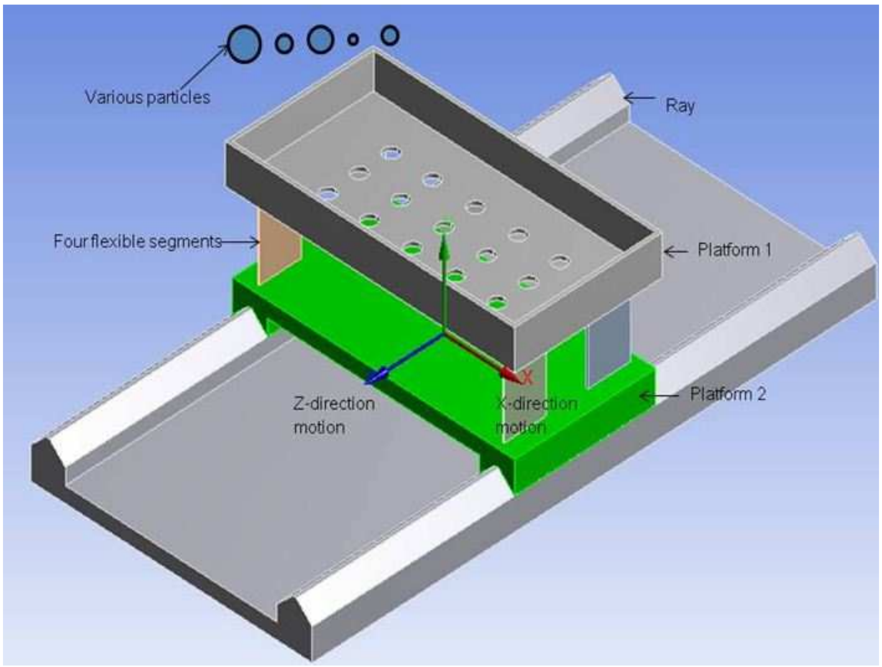


*Fig. 2. A system diagram of a novel compliant vibrating mechanism*

## 4 RESULTS AND DISCUSSIONS

In this paper, using ANSYS software, the finite element analysis (FEA) was conducted to explore the equivalent stress and the total displacement of a proposed vibrating mechanism; the position of platform 1 along the X-axis direction, the angular velocity of platform 1 along the Z-axis direction, and the angular acceleration of platform 1 along the Z-axis direction. As the previous analysis settings, this research only focuses on four flexible segments for vibrating. So the total displacement and equivalent stress refers to these ones.

The equivalent stress was shown as in Fig. 3, it shows that the maximum value does not exceed the yield strength (25 MPa), as a result, the structure is safety. Fig. 4 draws the total displacement of the flexible segments. The angular velocity of platform 1 was illustrated as in Fig. 5. And the angular acceleration of platform 1 was explored in Fig. 6. In Figs. 5 and 6 show that before 0.2 seconds, the disturbance is quite large; the possible reason is that it has friction force generation between platform 2 and its rail.

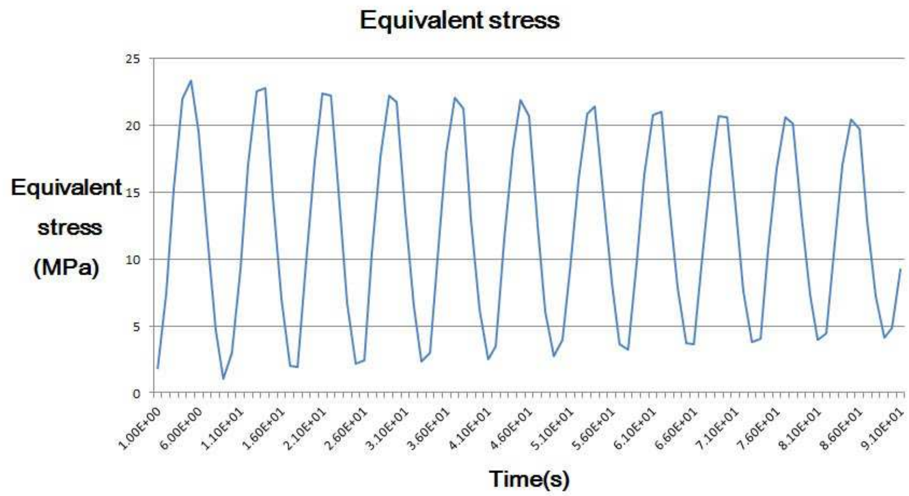


*Fig. 3. Diagram of equivalent stress distribution*

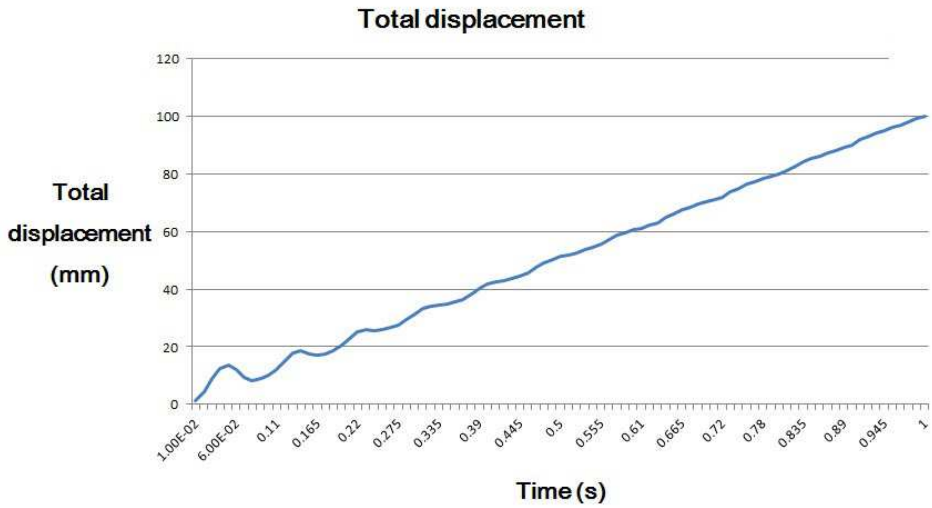


*Fig. 4. Schematic diagram of total displacement*

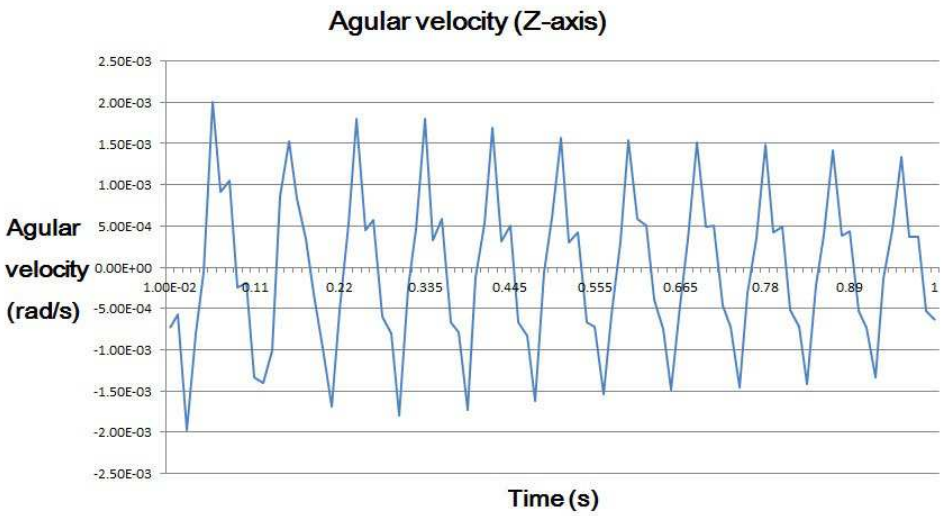


*Fig. 5. Schematic diagram of the angular velocity along the Z-axis*

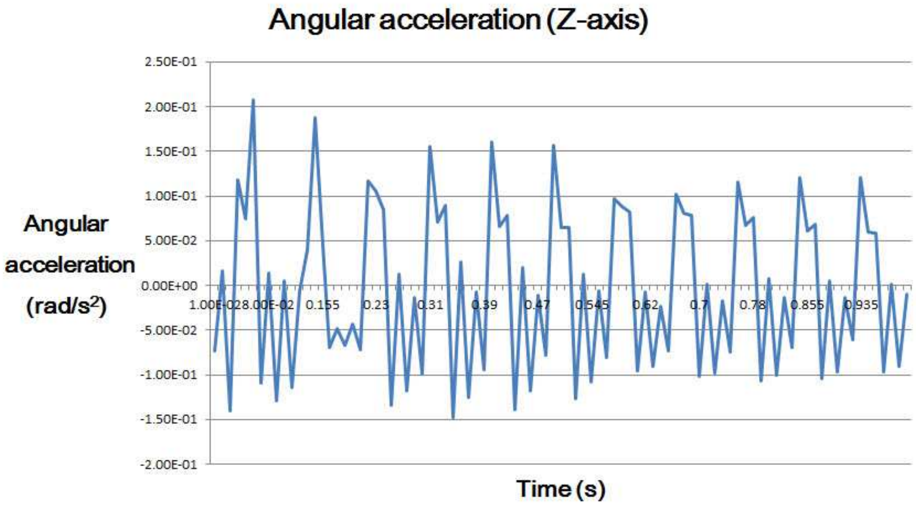


*Fig. 6. Schematic diagram of the angular acceleration along the Z-axis*

## 5 CONCLUSION

This paper has focused on a parallel vibrating mechanism based on the flexible segments for industrial production lines. Platform 1 of vibrating mechanism moves along X-axis direction, which contains the hollow with radius of 15 mm, in order to separate the various particles in the radius range from 7 mm to 20 mm. To consider on harmonic vibration, the dynamic behaviors was performed using FEA in ANSYS software. Future work will conclude an investigation into the vibration frequency. It is expected to be used in high precision manipulators, actuators, and production line.

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