Analele Universităţii de Vest din Timişoara
Vol. LI, 2007
Seria Fizică

STEWART PLATFORMS EQUIPPED WITH MAGNETORHEOLOGICAL FLUID DAMPERS

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Abstract
In the paper, the main types of Stewart platforms are presented and some of their specific applications in the field of vibration insulation, at precision measurement devices, used in the space technology, especially for the communication antennas and solar cell panels [1], [2]. In the specialty literature the component parts (dampers and actuators with magnetorheological fluid) are well studied, but the Stewart platform realized with this components are not enough approached in the researches until now. Using magnetorheological fluid components in the construction of Stewart platforms leads to significant decreasing of costs and also to more simple and precision control.
Keywords: Stewart platform, vibration, magnetorheological fluid.

1. Introduction

Parallel platform mechanisms with 6 degrees-of-freedom (DOF) are ideal candidates for precision positioning applications. Compared to serial kinematic mechanisms, their 6 kinematic chains give them greater load carrying capacity, higher stiffness, the ability to remain stable in the unpowered configuration, and redundancy in motion. Many of the precision positioning applications are located in environments where certain degrees of disturbances exist. These disturbances in the form of vibrations degrade the performance of the sensitive instruments needed for precision positioning. Therefore, it is important to create a vibration-free environment to enable precision positioning. From a design perspective, it would be logical to have a parallel platform mechanism which is inherently an ideal mechanism for precise positioning to provide vibration isolation at the same time.

The robustness and the simple mechanical design of magnetorheological (MR) dampers make them a natural candidate for a semi-active control device. They require minimal power while delivering high forces suitable for full scale applications. They are fail-safe since they behave as passive devices in case of a power loss [3]. MR fluids are suspensions of small iron particles in a base fluid. They are able to reversibly change from free-flowing, linear viscous liquids to semi-solids having controllable yield strength under a magnetic field. When the fluid is exposed to a magnetic field, the particles form linear chains parallel to the applied field. These chains impede the flow and solidify the fluid in a matter of milliseconds. This phenomenon develops a yield stress which increases as the magnitude of the applied magnetic field increases [4].

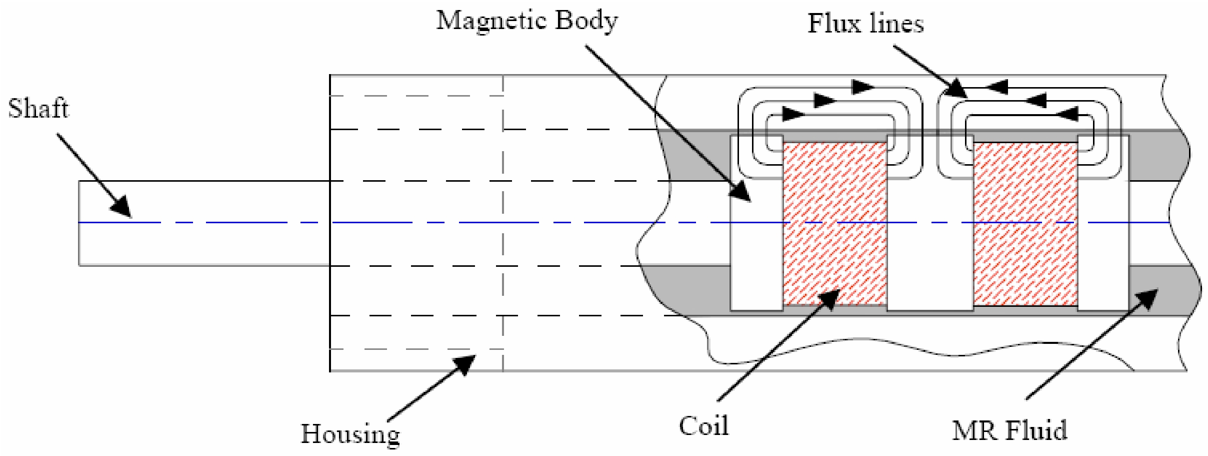

Fig. 1. Schematic of the double-shafted MR damper

In literature, the most known model to characterize the behavior of MR dampers is the Bingham plastic model. This model is an extension of the Newtonian flow and it is obtained by also taking into account the yield stress of the fluid. It assumes that flow will occur when the dynamic yield stress is reached. The total stress is given by $\tau = \tau_y \, sgn(\dot{\gamma}) + \eta\dot{\gamma}$, where τ_y is the yield stress induced by the magnetic field, $\dot{\gamma}$ is the shear rate and η is the viscosity of the fluid. In this model, the relationship between the damper force and the shear velocity may also be given as $F = \begin{cases} F_y \, sgn(\dot{x}) + C_0\dot{x}, \dot{x} \neq 0 \\ -F_y \prec F \prec F_y, \dot{x} = 0 \end{cases}$, where C_0 is the post-yield damping coefficient and F_y is the yield force. In the post-yield part, the slope of the force-velocity curve is equal to the damping coefficient which is essentially the viscosity of the fluid, η. Both C_0 and F_y are functions of the control current input, i, and can be modeled as second order polynomial functions: $F_y(i) = F_{yc}i^2 + F_{yb}i + F_{ya}$, $C_0(i) = C_c i^2 + C_b i + C_a$.

The model coefficients may be found by minimizing the mean square error between the experimental and the model-predicted damper force. The values used in this work were experimentally calculated by Ni et al. and are as follows [5]: $F_y(i) = -39.8i^2 + 95.1i + 21$, $C_0(i) = 25.6i^2 + 376i + 220$.

Other MR damper fluid models in the literature include the Herschel-Bulkley model which takes into account the post-yield shear thinning and thickening behavior and the Bouc-

Wen model where the parameters of the model can be adjusted to control the linearity in the unloading and the smoothness of the transition from the pre-yield to the post-yield region [6].

2. Stewart Platform

While passive vibration control and active vibration control have been extensively used in parallel platforms, a 6 DOF parallel platform which uses semi-active vibration control has not received as much attention. Advantages of semi-active control include reduced cost (by using a simpler actuator intended for only positioning), reduced power requirements, and improved stability.

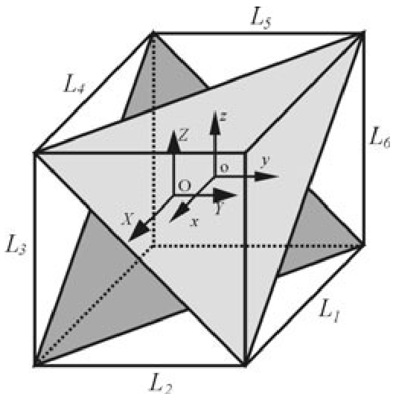

Fig. 2 Cubic configuration of a Stewart platform

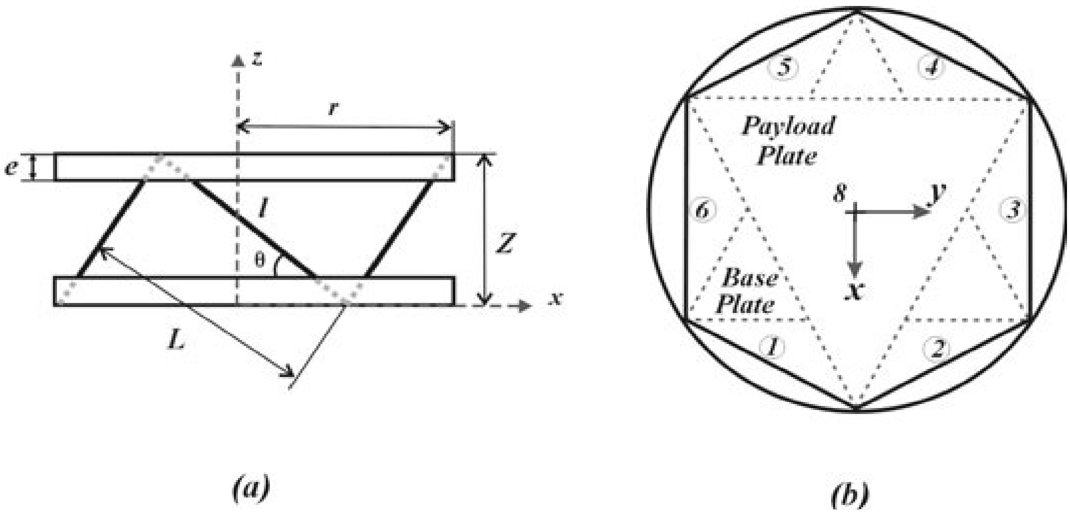

Fig. 3. Schematic drawing of Stewart platform; (a) side section, (b) top view [9]

The ”cubic configuration” was invented by Gough [7] and has been used by Intelligent Automation Inc. (IAI) [8] to fulfill most of the above properties. The nominal configuration is obtained by cutting a cube by two planes as illustrated in Fig. 2; these planes constitute the base plates of the Stewart platform. The edges of the cube connecting the base plates constitute the six legs of the platform. The cubic configuration has other interesting features.

The adjacent legs are orthogonal to each other resulting in a decoupled control action in the three translational directions *X, Y,Z*, (Fig. 2); actuators *L*1 and *L*4 control the translation in the *X* direction, etc.. This feature also leads to a maximum uniformity of control authority in all direction. The Stewart platform is symmetrical in its nominal configuration and all legs are identical.

3. Conclusions

The major conclusion is that the vibration isolation, using Stewart platforms, equipped with MRF dampers, becomes a simple and reliable solution, of high precision and low cost.

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