Concept Verification of Three Dimensional Free Motion Simulator for Space Robot

N95-23702

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KEY WORDS AND PHRASES

Motion simulator, space robot.

INTRODUCTION

In the development of automatic assembling technologies for space structures, it is an indispensable matter to investigate and simulate the movements of robot satellites concerned with mission operation. The movement investigation and simulation on the ground will be effectively realized by a free motion simulator. Various types of ground systems for simulating free motion have been proposed and utilized. Some of these methods are a neutral buoyancy system, an air or magnetic suspension system, a passive suspension balance system, and a free flying aircraft or drop tower system. In addition systems can be simulated by computers using an analytical model. Each free motion simulation method has limitations and well known problems, specifically, disturbance by water viscosity, limited number of degrees-of-freedom, complex dynamics induced by the attachment of the simulation system, short experiment time, and the lack of high speed super-computer simulation systems, respectively.

The basic idea presented here is to realize 3-dimensional free motion. This is achieved by combining a spherical air bearing, a cylindrical air bearing, and a flat air bearing. A conventional air bearing system has difficulty realizing free vertical motion suspension. The idea of free vertical suspension is that a cylindrical air bearing and counter balance weight realize vertical free motion. This paper presents a design concept, configuration, and basic performance characteristics of a innovative free motion simulator. A prototype simulator verifies the feasibility of 3-dimensional free motion simulation.

DESIGN CONCEPT

The suspension system of the simulator developed consists of three air bearings. A spherical air bearing is located at the top of the suspension system, and a flat air bearing at the bottom of it. A cylindrical air bearing is placed between the spherical air bearing and the flat air bearing.

The use of a high pressure air feed mechanism to each air bearing is a key aspect in achieving free motion simulation. The flat air bearing at the bottom and flat bearing in the middle are fed high pressure air through a rigid air pipe from a tank. A rigid air pipe can be used here because there is no relative displacement between the flat and cylindrical bearings. The spherical bearing at the top can not be fed high pressure air by a rigid or flexible air pipe from the same tank without restricting motion.

One solution to this problem might be to mount another tank at the top of suspension system. The spherical air bearing would be fed high pressure air through a rigid air pipe from another tank. Therefore, the pipe would not disturb the free vertical motion, because there is no relative displacement. Unfortunately, this mechanism make the system too complex causing troublesome operation.

An alternative solution to feeding air to the spherical air bearing without restricting motion is to use the cylindrical air bearing as a expandable air duct from the air tank to the spherical air bearing. The expandable air duct is a part of the cylindrical bearing and the duct is supported and sealed by small air bearings inside of the cylindrical bearing. This is the method implemented. Figure 1 shows a sectional view of the air duct mechanism.

CONFIGURATION

The simulator developed consists of a flat air bearing base plate which supports the cylindrical and spherical air bearings and an air-tank. The flat air bearing rides on top of a smooth granite table. The configuration of the free motion simulator is shown in Figure 2.

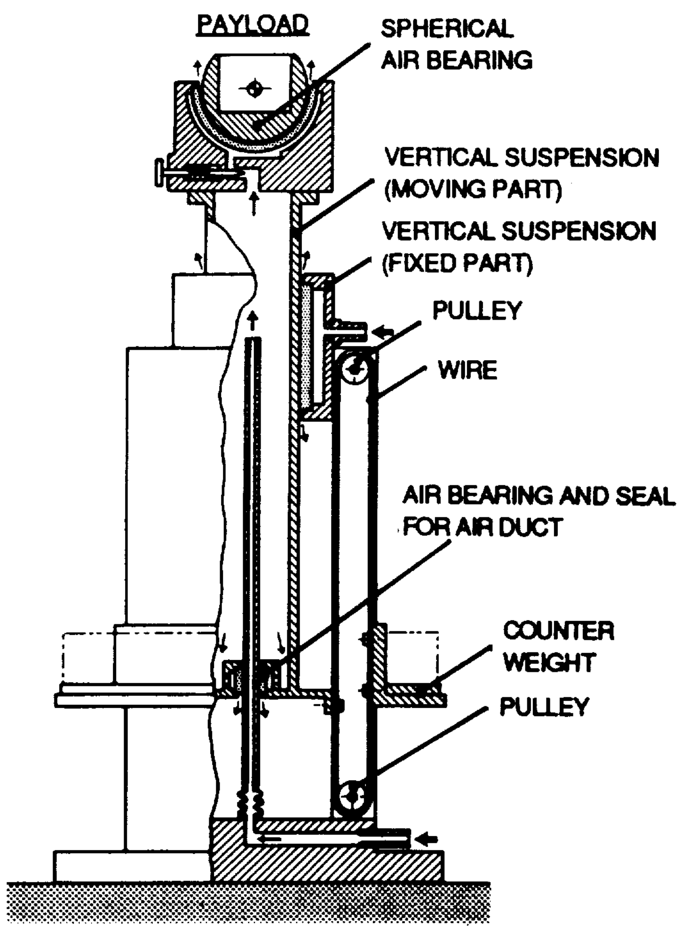

Figure 1. Illustration of sectional view of air duct mechanism.

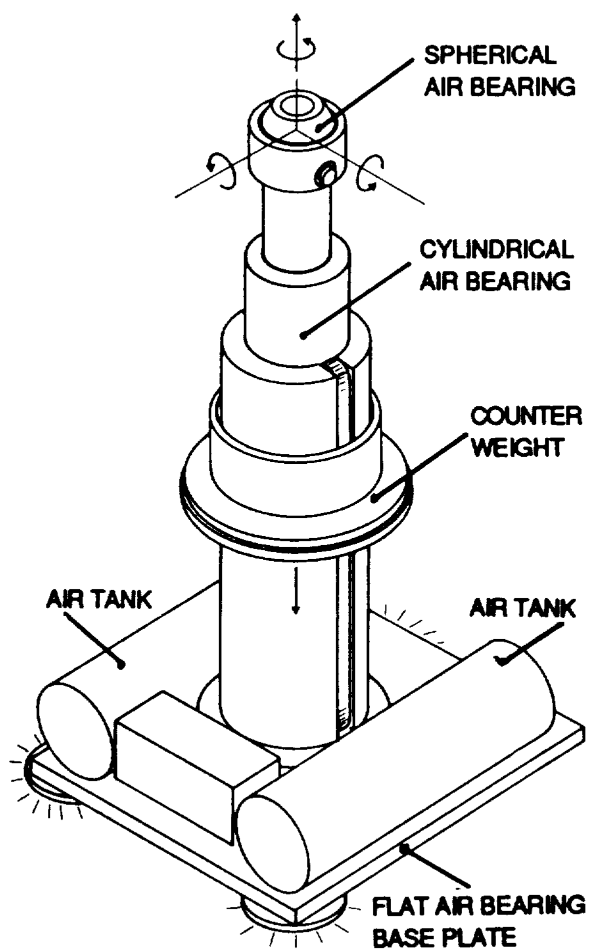

Figure 2. Configuration of free motion simulator.

The flat air bearing is made of porous sintered metal and gives smooth and stable 2-dimensional motion. The cylindrical and spherical air bearings are made of a porous graphite material and allow free vertical and rotational motion. The porous graphite material used in the air bearings prevents the seizing of the bearing.

Vertical mass is balanced by a counter weight which is suspended by a thin wire and pulley.

The payload is mounted at the top of the spherical air bearing. The center of mass of the payload is coincident with the center of the spherical bearing.

SPECIFICATION

Total mass of the free motion simulator is 80 kilograms and payload capacity is 20 kilograms. The maximum stroke of the vertical axis is 0.2 meters and +/- 45 degrees of rotational motion. Air pressure is 4 kilogram forces per square centimeter. The size of the base plate is 0.5 meter by 0.5 meters. The height of the simulator is 1.2 meters without a payload. The mass of the counter weight is 23 kilograms plus a payload weight. The capacity of the air tank is 8 litters and operational free motion time is 1 minutes. The friction of vertical suspension is less than 0.1 newtons.

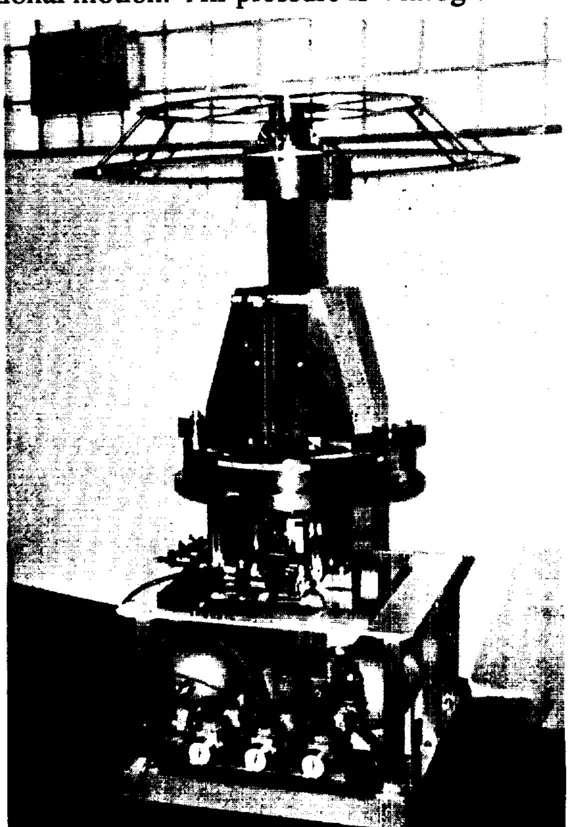

Figure 3. Photo of prototype model of simulator.

Figure 3 shows an overview of the free motion simulator and Figure 4 shows a photo of cylindrical air bearings.

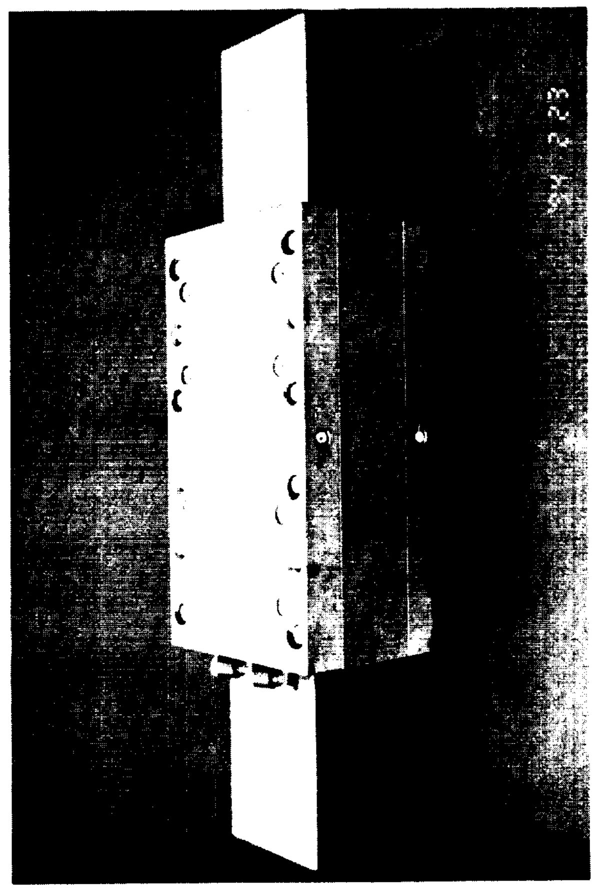

Figure 4. Photo of cylindrical air bearing.

CONCLUSION

A concept of ground free motion simulation and a prototype model for verification of concept feasibility was presented. Some future applications are illustrated in Figures 5, 6 and 7. Figure 5 illustrates the concept of a 3-dimensional manipulator test system. Figure 6 details a method of simulating docking or berthing systems. Figure 7 illustrates the application of the simulator for astronaut extra vehicular activity training.

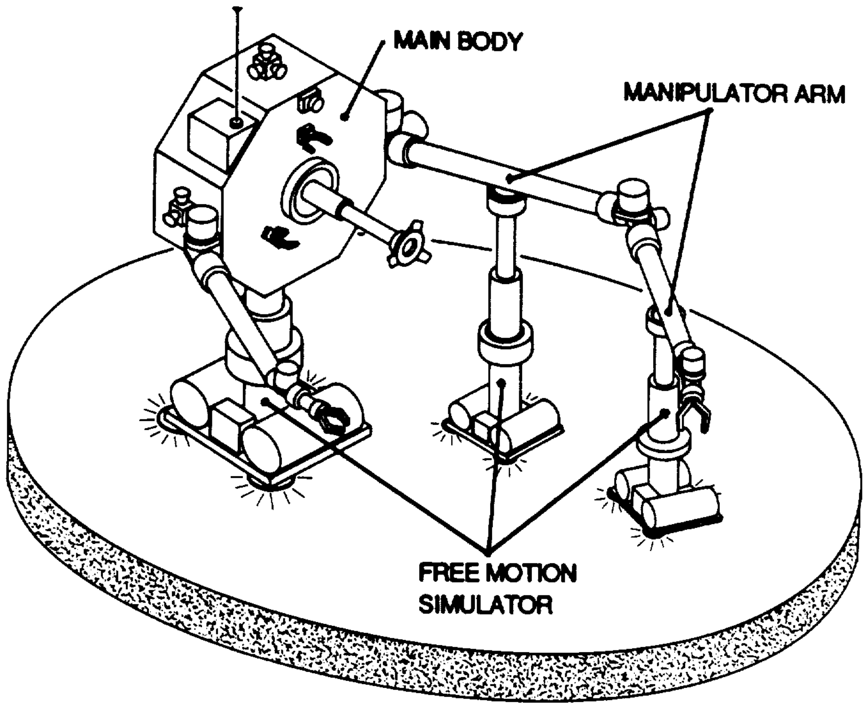

Figure 5. Concept of 3-dimensional manipulator test system.

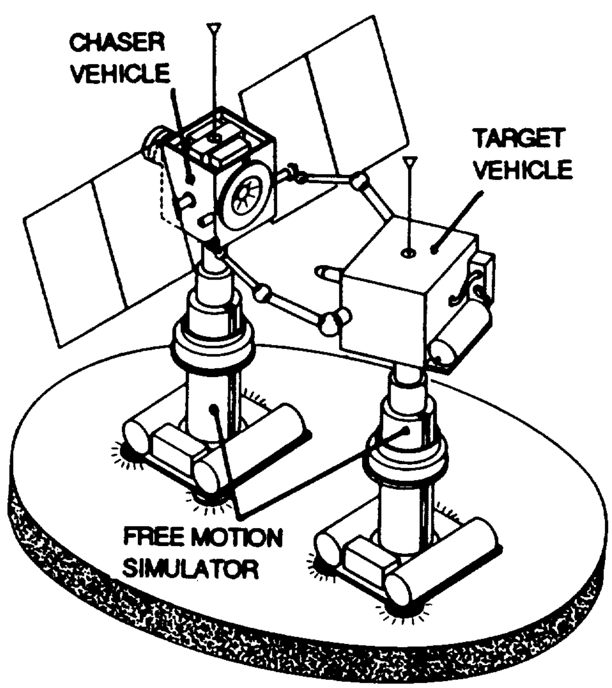

Figure 6. Method of simulating docking or berthing systems.

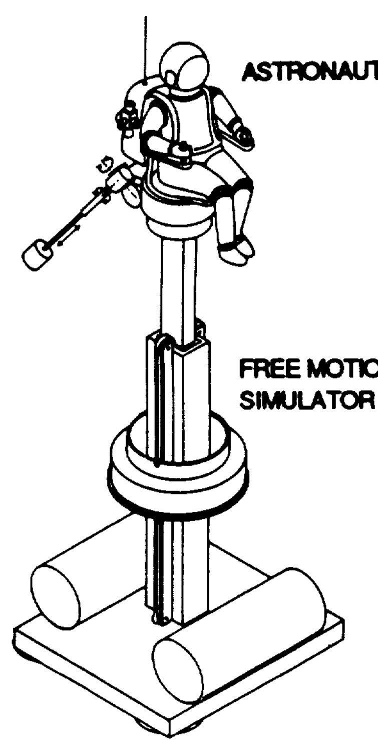

Figure 7. Application of simulator for astronaut extra vehicular activity training.