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Fall Arresting System

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ABSTRACT

A major inhibition of past work in a slip / fall accident study has been due to the lack of a facility and a methodology to experimentally investigate such behavior without exposting human subjects to the natural danger of injury resulting from a fall. In order to carry out a slip / fall research, a unique facility must be created specially to investigate falling and slipping behavior. One component of this facility will be used to focus a research towards experimental investigations of the basic mechanisms involved in falls. Especially, this component must be designed, developed, and fabricated to provide passive, reactive support at the point of loss of balance. This component must allow both normal and reduced friction surfaces to be designated to investigate human falling in the experimental conditions. This study will address how a fall arresting system was designed and it would be implemented in actual case of a slip / fall study.

INTRODUCTION

Strandberg (1983) has developed an overhead support system which allowed the subjects to move along a triangular track. A somewhat similar approach has been established in the center for Safety Science at the University of New South Wales, Australia, which uses a straight track about 15 feet long. The overhead support unit appears to be the development of Perkins method (1978), which consisted of a linear track and overhead suspension trolley which was moved by a laboratory technician walking alongside of the subject.

All three systems appear to have satisfactorily removed the normal consequence of a severs slip, i. e., a fall and subsequent collision of the subject and the fixed environment. However, it is clear that, these designs produce an extremely artificial environment for the subject. A more serious effect may also result from these designs ; for example, in the linear situation, the subject must start a slip and stop in a short, pre-identified interval. The Strandberg situation is similar, for although it is a continuous track, the triangular arrangement would have required a discrete change of direction at each corner. In all cases, slipping behavior was produced by providing abnormally slippery surfaces.

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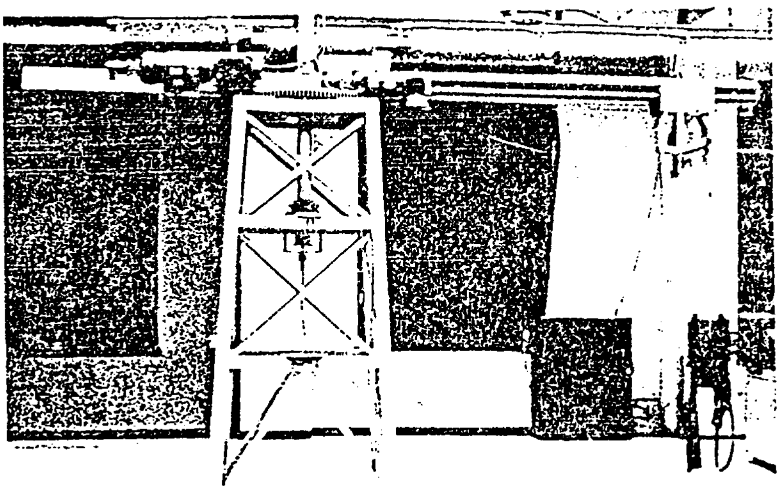

Figure 1. The fall prevention rig

It is expected that, although falls can be generated by manipulating the floor surface and producing very low static and dynamic friction conditions or by producing trips, the rate of falls will be low, especially in more normal conditions of friction. Consequently, The Texas Tech Slipping and Falling Laboratory has been developed the fall prevention rig(Figure 1) to allow the study of falls, while preventing contact between the human being and the environment in an uncontrolled manner. This particular device will allow continuous monitoring of locomotion in various conditions.

SYSTEM DESIGN

The system to utilized is an overhead active suspension and the subject is connected to this suspension via lanyards. The system must withstand static and dynamic loading conditions since a sudden impact loading is present when a fall is initiated. Decelerating forces on the subejct must be minimized through the suspension system.

The overall function of the system is to allow a subject, wearing a full-body harness, to walk in the experimental situation with little or no restriction. This lack of restriction is achieved by the fully automated overhead suspension that uses low force actuators to ensure that the suspension is largely imperceptible. Whenever an imbalance is detected, the system immediately arrests the fall and discontinues its motion.

The machine is essentially a simple robot. It has an arm that rotates about an axis at an elevation above the test subject and a sled that can traverse along the length. The sled houses the fall arresting device ; thus, the arrestor may be positioned anywhere in a plane above the test subject. The sled retracts and extends as the arm rotates ; the result of which is to create a predetermined path the test subject follows. This predetermined track is necessary in order for the fall arresting system to be virtually over the subject's head at all times in anticipation of an arbitrarily induced fall in the subject.

Initially, several specific points of the design had to be considered and compiled to create the design criteria. Among these criteria are

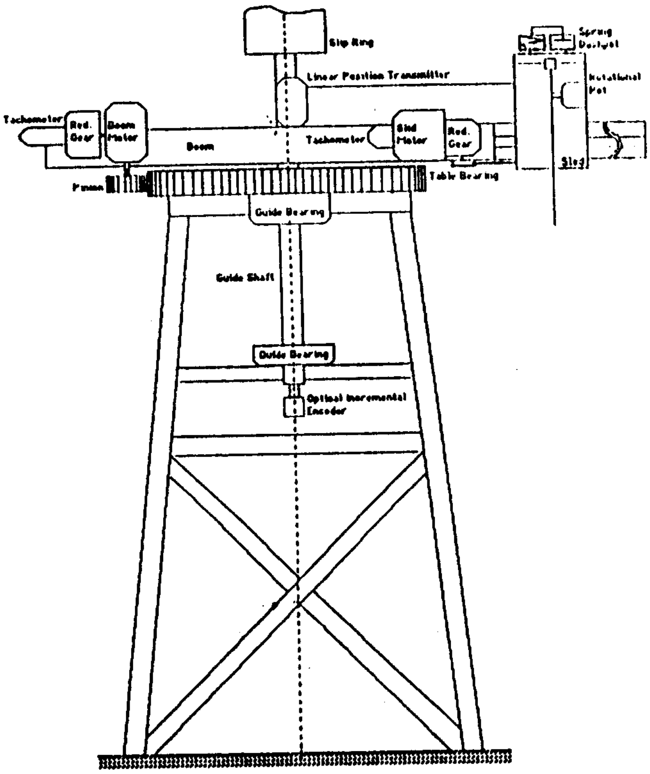

Figure 2. A schematic diagram of the system

1. Passive system
2. Minimum contact with a test subject
3. Dampening an induced fall
4. Specifically to allow data collection through video cameras
5. Adaptability to different test situations
6. Subject must follow a defined path

With these parameters in effect, it was best decided to custom tailor the system. A schematic diagram of the system is shown in Figure 2.

Mechanical Design

To initially begin sizing the components it is first necessary to determine the loading that the system must withstand. Since the experiment is dealing with human subjects, it is strongly believed that a large factor of safety be maintained, particularly in the structural integrity. The design case is general thought to be the case in which the structure maintains its form under worst loading situation. For this experiment it is necessary to support a person possibly weighing 250 lbf and allow this person to fall freely no more than 7 inches. This free fall represents an impact loading situation that must be accounted for in the design. The boom is designed as an impact loaded cantilever of square cross-section and length equal to 120 inches and support the motors, gears, sled and spring-dashpot assembly.

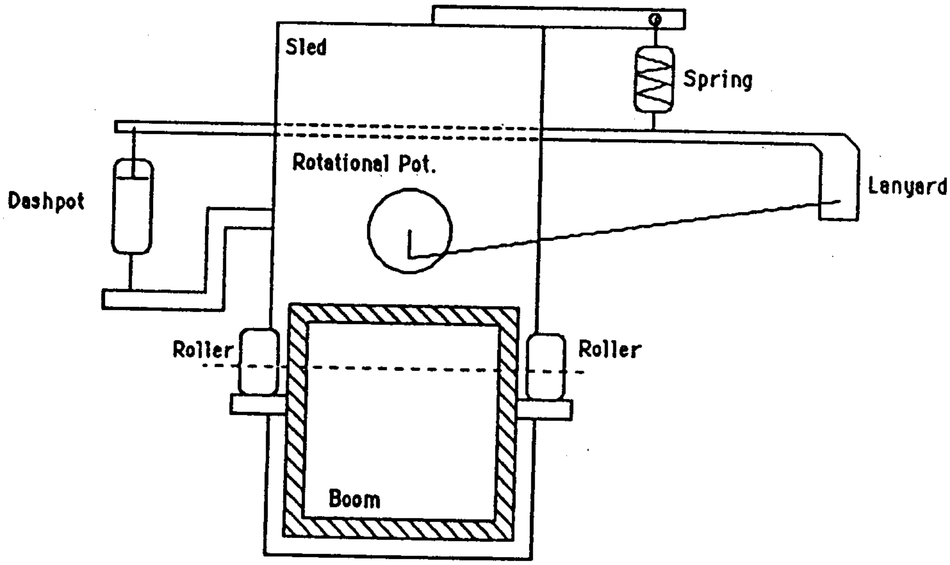

Figure 3. End view of sled.

The single most significant mechanical component of this system is the table bearing. It is of the type used in large industrial cranes. The bearing is formed by two concentric rings of different diameters. By laying the inner assembly in the outer one, and placing steel spherical balls in the grooves, a table bearing is created. The outer steel ring has teeth cut vertically into its face and is fastened rigidly to the frame, and thus the inner section is allowed to rotate.

The boom carries sled at its far end which slides along its length, thus providing a variable path as the boom rotates about the vertical axis(Figure 3). The sled carries a full body through a lanyard and a spring-dashpot mechanism. Whenever the subject has a imbalance or begins to fall, the kinetic energy of the person will be absorbed by the spring-dashpot assembly. The motion to the sled is provided by the motor via reduction gear and a wire rope pulley attachment.

Subject Harness

It is of the nature of a parachute harness with supports on both legs, both arms at the shoulders, a waist and chest strap. All of the above mentioned supports are fully adjustable to accommodate any size subject. The harness also has two attachments at the top of the shoulders. These attachments are where the lanyard will be connected to the damping system. Furthermore, from previous study, for a statistical sample of subjects, it was found that the closest approximation to a stationary node on a moving person is approximately along the spine between the shoulder blades. Thus, a provision is made on the harness for the connection to a lever-arm of the rotational potentiometer. This stationary node is desirable, since perturbations caused by the body movement will cause the boom to respond undesirably be advancing forward then stopping in a repetitive cycle causing a jerky boom motion.

Feedback Control Loops

In order to obtain an accurate data collection of the person's body mechanics during the testing period, it is imperative that the subject feels comfortable, and more importantly, unhindered both physically and mentally during the testing. Thus, the system needs to operate in a quiet manner and interact minimally with the subject. For these reasons, it is necessary to create a fully automated machine, meaning that the machine will function solely through a central controller with no subject or operator responsibilities during the testing procedure. The only external parameter to the automation processes will be a trigger governed in a passive manner by the test subject.

Electrical and Control System Design

The system is designed to be completely automatic, with five feedback devices, and two outputs. The outputs are the rotations of two motors, which position the boom and sled at correct points on a predetermined path. Two tachometers indicate the actual speed of the motors, and provide an error estimate between the actual and the desired rpm. Other feedback device are, an optical incremental encoder, a linear position transmitter, and a rotational potentiometer. These device give an indication of the fall arresting system's position at all times.

The control system consists of an Allen Bradley microprocessor. This automatic control system has two main components, a programmable controller system and a motor drive system. The controller communicates with all the other components through the backplane circuit board to which it is connected. The programmable controller has an electrically erasable program read only memory (EEPROM) module inserted that act as a permanent storage media for the program that operates the system. The programmable controller consists of a main processor, an encoder / counter module, an analog input module and analog output module.

The last component in the controller system is an industrial terminal. It communicates directly to the processor and no software is needed for this transmission. The terminal is designed specifically for the processsor, thus, it has a keyboard that is composed of relay-like commands that the processor accepts as its source language. Program flow chart is shown in Figure 4.

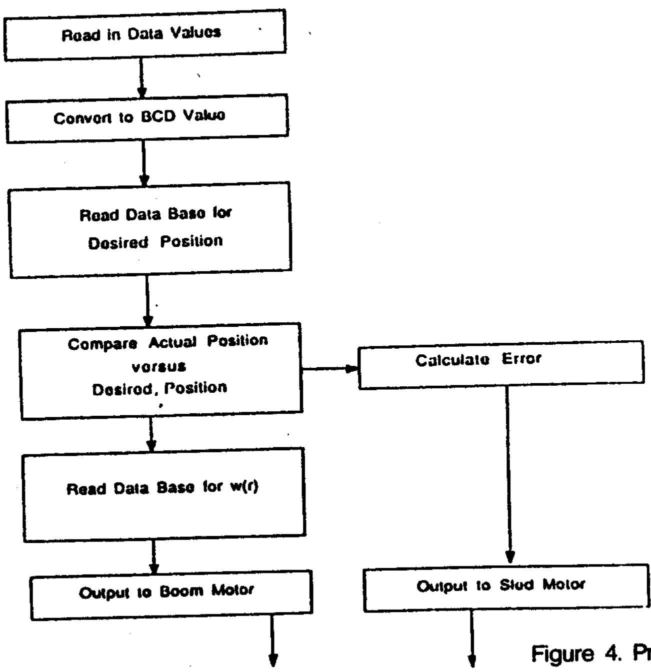

Figure 4. Program flow chart.

CONCLUSIONS

In conclusion, this system has an infinite number of applications and each application will be a specific amount of adjustments that must be made to the controlling parameters. There is an exhaustless amount of additions that can be made to the present system that will certainly improve its performance.

Additionally, since the objective of the system was to enable to begin the planned facility so that the slip / fall research may be undertaken, the project was satisfactory in that it will allow initial data of slip / fall behavior to be gathered, and modification for future test conditions shall be minimal. It should be noted that this facility is not strictly for use as slip / fall behavior data collection, but rather it shall be available jointly to mechanical engineers for tribological study, and to the bio-mechanical engineer who is interested in other human responses to such events as lifting and associated body mechanics. Furthermore, this area of study is in its youth ; thus, as other research teams become actively involved in the field, this facility may serve them in their research through open testing and foundational research.

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