NASA TECH BRIEF
Lewis Research Center
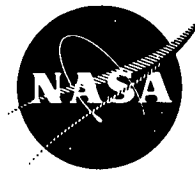
Hip-Joint Simulator Accurately Duplicates Human Walking Pattern
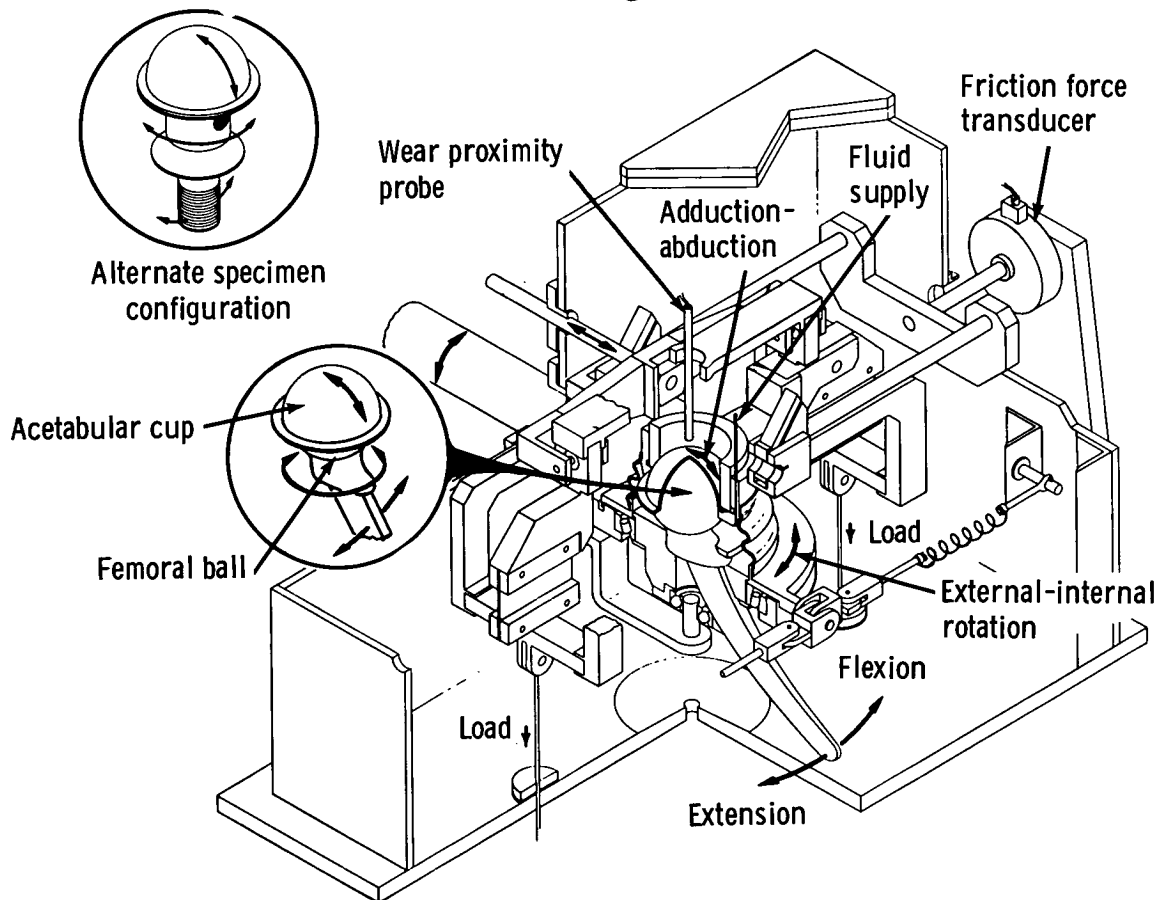
FULL PROSTHESIS HIP SIMULATOR

The Problem:

Laboratory methods are needed to establish reliable minimum wear lives and performance for orthopedic total hip prostheses.

There have been many simulators built for bioengineering laboratories of prosthesis manufacturers, universities, clinics and research institutes. There is no standard device, and virtually all of the present devices are not in operation because of difficulties in obtaining significant data with reasonable effort or because they are deficient in that the application is not adequately simulated. Most devices only provide for one type of motion and uniform loading; they are difficult to use because precise alignment of the two prosthesis parts is essential to obtain useful data.

The Solution:

A hip joint simulator that can be used to evaluate the relative friction, wear and life of orthopedic internal prostheses for human hip joints, and which can be modified for use with knee and possibly other joints. The complex motions and dynamic load patterns of human walking are accurately duplicated and can be varied while

providing unique self-alignment features that are critical to significant simulation and convenient operation.

In fatigue wear, the magnitude of maximum stresses and the direction and frequency of stress cycles determine wear rates. Thus, for fatigue wear, stem fracture, and other life limiting phenomena, an effective simulator evaluation must duplicate real load patterns as well as the motion rates, magnitude, and frequencies of real walking by humans. All of these are accomplished by this newly-developed simulator.

How It's Done:

This device simulates all three motions of walking and provides realistic variable loading during each step. The diagrammatic sketch of the apparatus in the figure shows the femoral ball component mounted in a fixture extending from the end of an oscillating shaft. The shaft oscillates $\pm20°$ simulating the extension and flexion in the sagittal plane of the primary walking motion. An arm extending radially from the fixture restrains the mounting assembly and, in turn, causes the ball to oscillate $\pm7°$ in a supporting bearing simulating the rotational mode in the transverse plane of the second walking motion as indicated by turning the feet out and in. The acetabular cup of the prosthesis is mounted in a fixture that is supported and stabilized with self-aligning tension flexures. The flexures carry the loading applied through the cup. The third motion is provided through the cup with $\pm6°$ abduction and deduction simulating the sideways extension of the leg during walking. That motion is transmitted by a push rod follower from an axial cam attached to the main drive shaft. The drive shaft crank arm is driven by a fractional horsepower electric motor through a gear box assembly at up to 60 cycles per minutee.

The flexure suspension and a force transducer provides continuous measurement of friction force in the direction of primary motion. Wear displacement is continuously measured from the center of the acetabular cup at null position.

Load is applied hydraulically to the acetabular cup through two cables and the main flexures. The hydraulic load cylinder is actuated by a servo system controlled from a commercial electronic programmer. A load program to simulate the variable loads during each step of walking (e.g., heel impact may cause loads that approach five times body weight) can be diagramed on an aluminized mylar chart attached to a rotating drum that is synchronized with the apparatus drive shaft. A capacitance probe in the instrument follows the load diagram of the chart and actuates the servo system.

An elastomeric bellows can enclose the ball and socket simulating the capsule of the joint. Fluid to simulate the synovial fluid may be pumped into the ball and socket enclosure and be retained within the bellows or circulated through an external flow system. A tubing pump is utilized for the simple supply system. The primary test components are in a chamber so the environment can be controlled.

Notes:
1. The availability of this simulator will enable more significant laboratory evaluation of all known types of total hip prostheses.
2. The wear life of present hip prostheses has been estimated at from 10 to 20 years and surgeons will not deliberately entertain the prospect for re-operation to install new appliances. Patients become sensitized to the bone cement and the surgical procedures are severe. Total hip replacement surgery is most often considered only for older persons. Extended wear life, which can be established with the simulator, may make the operation available to many younger patients now suffering pain and lack of mobility.
3. A primary advantage of this simulator is ease of set up for test. The apparatus can be modified to alter the operational parameters described. The self-aligning feature is especially important. Also, the device has adapters to fit the variety of important prosthesis types now used and they can be mounted in the adapters without the use of jigs or fixtures and bone cement mountings. A special adapter is also available so the femoral ball component can be installed without the stem, thus a reduced cost specimen can be used when test objectives permit.
4. No additional documentation is available. Specific technical questions, however, may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10148

Patent Status:
NASA has decided not to apply for a patent.

Source: R.L. Johnson and M.A. Swikert
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