VIVO™

VIVO™

Bringing New Life to Joint Motion Simulation

AMTI
FORCE AND MOTION
www.AMTI.biz

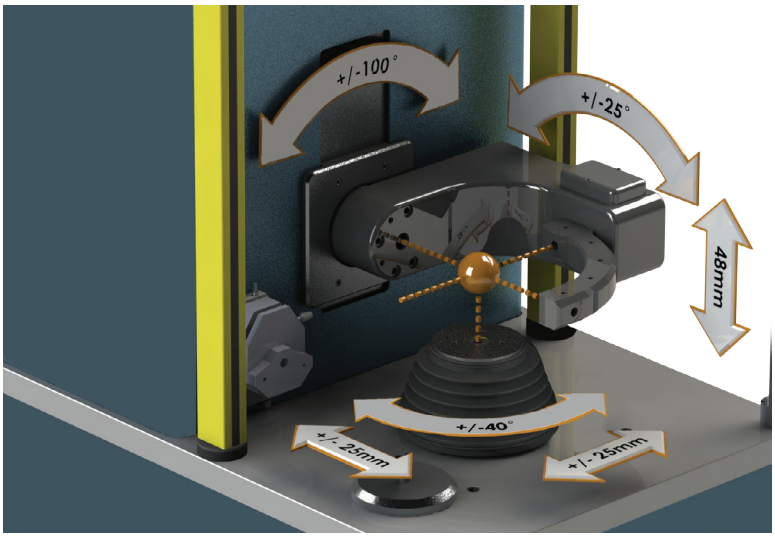
Versatile Design Tests All Joints of the Body

The VIVO™ Joint Motion Simulator

AMTI'S VIVO brings new life to joint motion simulation, dramatically increasing simulation realism. It provides realistic simulation of knee, hip, shoulder, temporomandibular, elbow, ankle and spinal joint motions. Its advanced control capabilities and extended range of motion enable simulating activities of daily living.

VIVO's patented design provides a fully servo controlled six degree-of-freedom environment in which to test total joint replacements as well as biological joint specimens. In addition to implant wear and lifetime durability testing, VIVO enables testing of real world implant failure modes that occur due to in-vivo multi-axis loading conditions. VIVO's virtual soft tissue constraint system and other control features further increase simulation realism and research flexibility.

Six-Axis Orthopaedic Testing System



DEGREE OF FREEDOM	RANGE
1. Axial load	4500 N Compression 3500 N Distraction
2. Flexion	110° G-S, 200° Max
3. IE rotation	±40°
4. Y-Axis (AP) Translation	±25 mm
5. X-Axis (ML) Translation	±25 mm
6. Abduction/Adduction or Valgus/Varus	±25°

SIX DEGREES OF FREEDOM

Each test station is equipped with six precision displacement sensors to monitor translations and rotations of the joint components, and a six-axis force sensor to monitor the contact forces and moments.

Each of VIVO's six degrees of freedom may be independently under force control or displacement control. For example, a knee test can have the flexion axis in displacement control; joint compression, anterior-posterior, and medial-lateral motions in force control; and varus-valgus along with internal-external rotation in torque control.

MODULAR DESIGN & LARGE SAMPLE AREA

Capable of performing short-term kinematic and long-term durability evaluations, the configurable VIVO can have from one to three test stations. Each station is equipped with six servo-hydraulic actuators. The stations are programmed independently. Setups may be copied so that stations can perform the same test procedure.

VIVO's substantial sample workspace accommodates large test specimens such as shoulders and total joint replacement systems.

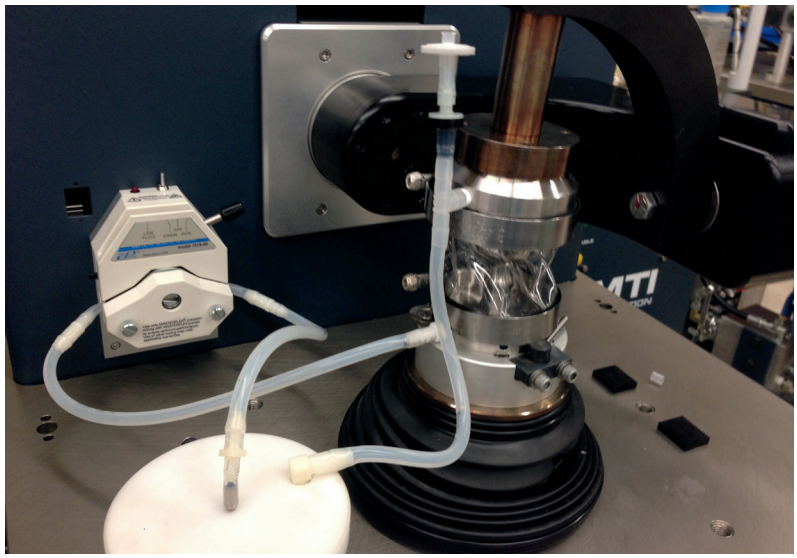
Advanced Features for Unsurpassed Simulation Accuracy

CONTROL FEATURES ENHANCE REALISM

The unique lower actuator design provides a floating instant center of rotation on the lower platen. This more accurately simulates in-vivo joint conditions and eliminates joint alignment issues found in legacy test machine designs. VIVO™ also saves test sample preparation time and enables more reliable life testing through its flexible, programmable software implementation of soft tissue constraints - no need to mount constraining hardware to each test specimen.

TEMPERATURE-CONTROLLED ENVIRONMENTAL FLUID SYSTEM

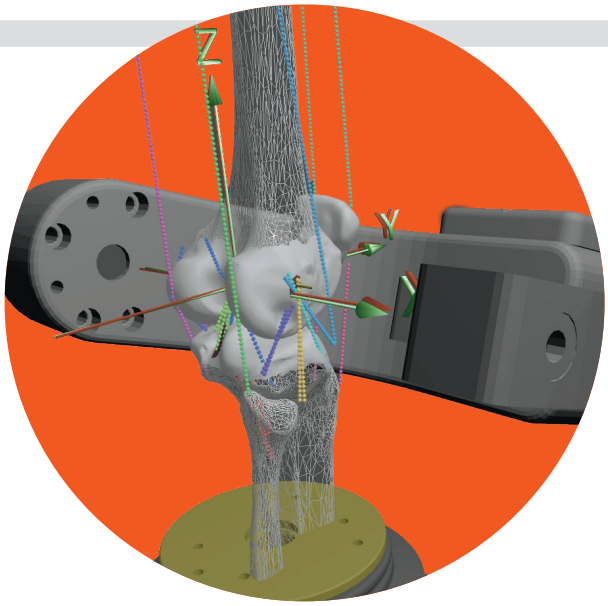
Simulation of an implant's in-vivo environment is accomplished using VIVO's temperature-controlled recirculating fluid system. The fluid provides continuous lubrication of the specimen's contact surfaces, at a controlled temperature, programmable from 10° to 45°C. Fluid level and temperature are continuously monitored during testing and appropriate actions may be taken in the event of a fault.



PROGRAMMABLE TEST SPECIMEN PROTECTION

VIVO sets a new standard of protection for your valuable test investment. Every physical quantity is continuously monitored and corrective or emergency actions may be enabled in the event of a fault. This rapid response prevents inadvertent specimen damage during setup as well as during operation of the machine. Safety is also enhanced with system control interlock circuits and a light curtain interlock which encloses the working volume of the machine.

Advanced Soft Tissue Models



VIVO SOFT TISSUE MODELS

The implanted joint is a composite of biological structure and artificially engineered components. Understanding kinematics, kinetics and durability of the implanted joint structure requires simulation in a realistic environment. To facilitate such studies, VIVO's Virtual Soft Tissue control system provides two simulation scenarios:

• The heuristic soft tissue constraint model (Patent number 7823460) permits testing to today's ISO and ASTM standards as well as to proposed ASTM standards of the future.

• The multi-fiber ligament constraint model enables more life-like testing, simulating the complex inter-axis coupling exhibited by the natural knee. For example, it is possible to simulate ligament balance and post-surgical ligament condition with this more advanced model.

The heuristic soft tissue model simulates the constraint characteristics of the joint using a two-dimensional interpolation for each of the controlled axes. Every axis in force-controlled mode can have its own model. One of the input axes is the axis under control; the second may be chosen from any of the other five axes of the machine.

The multi-fiber ligament model uses a database of up to 100 ligament fibers, representing the insertion sites on the proximal and distal joint halves, the stiffness and the zero-force length of each fiber. Multiple fibers can be used to model the spatial extent of a real ligament. During operation, ligament forces and moment-of-force values are calculated and applied to the joint to model the 6-DOF cross coupling of the actual soft tissue structures. The ligament fiber calculations are performed in real time at every control tick so they are always exactly synchronized with the joint's pose.

"VIVO's multi-fiber ligament model uses a database of ligament fiber elements..."

VIVOSIM SOFTWARE

VivoSim is a new software product from AMTI. While the VIVO and its control software are a completely functional stand-alone system, VivoSim is an optional add-on that is designed to assist in visualizing and evaluating the performance of the multi-fiber ligament model.

VivoSim offers a virtual model of the VIVO machine. Researchers can use a wireframe model of the joint under test, and the same multi-fiber ligament database used in the VIVO control software, to build a virtual model of the test.

VivoSim has a stand-alone solver that uses a simple contact model to provide approximate solutions for the kinematics and kinetics of the joint.

When paired with a VIVO machine, VivoSim can operate in linked mode. In this mode, VivoSim uses the mechanical position of the VIVO's actuators to drive the virtual machine. Motions can be recorded and played back frame by frame, and detailed per-fiber output of the multi-fiber ligament model is available.

More information about VivoSim is available on the AMTI website or by contacting AMTI's sales department.

Sophisticated Robotic Control System

THE CONTROL SYSTEM

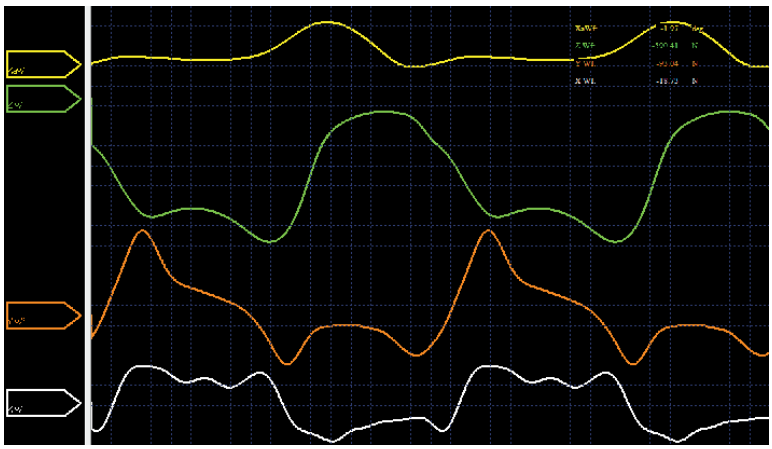
The VIVO™ Joint Simulator control system is the most sophisticated robotic control system available for joint motion simulation. AMTI's extensive biomechanical simulation experience, coupled with the most recent advances in control technology, has culminated in the new VIVO control system. The control system provides two modes of operation:

Joint Coordinate System mode - implements the Grood and Suntay Joint Coordinate System (JCS). In JCS mode, control inputs and data outputs are resolved to represent forces and displacements relative to the joint itself. The JCS has been adopted by the International Society for Biomechanics and ISO for describing joint motions.

Cartesian Coordinate System mode - similar to traditional machines, this mode provides control of kinematics and kinetics relative to an orthogonal world coordinate system.

POWERFUL SIMULATION CONTROL SOFTWARE

VIVO's simulation control software, running on a PC, provides the user interface, supervisory functions and powerful motion programming tools. The control system accepts six reference waveforms, which are temporal signals representing either the kinematics or kinetics of a particular physiologic activity.



DESIGNED FOR LONG SERVICE LIFE

For compactness and maximum service life, VIVO utilizes an all-hydraulic actuator design. The main bearing of the system uses a hydrostatic design to, provide low friction, more accurate control, and long life. AMTI's unique seal-less actuators reduce maintenance downtime and provide maximum service life. A separate hydraulic power unit is required for operation. Customers can provide this facility; AMTI also offers a line of hydraulic power units matched to the VIVO.

Technical Data

HARDWARE REQUIREMENTS & DIMENSIONS VIVO requires an external 5.5 MPa (800 psi) hydraulic power supply. Overall VIVO system dimensions shown below do not include the computer or hydraulic power unit.

VIVO OVERALL DIMENSIONS	PER TEST STATION
Height	1900 mm
Width	635 mm
Depth	965 mm
SPECIMEN WORKING AREA	**WITH ABDUCTION / ADDUCTION GIMBAL**
Vertical	
Below gimbal centerline	Adjustable, 130 mm - 310 mm
Above gimbal centerline	To Safety Shield
Width	
Right of gimbal centerline	120 mm
Left of gimbal centerline	To Safety Shield
Depth	135 mm

ISO & ASTM TESTING STANDARDS

VIVO performs a wide range of testing standards—capable of performing tests to

ISO 14242-1
ISO 14243-1
ISO/CD 14243-3
ISO 14879-1
ISO 16402
ISO18192-1
ISO/TR 22676
ISO 7206-4
ASTM F1223-08
ASTM F2790-10
ASTM F2694-07
ASTM F2777-10
ASTM F2028-08
ASTM F1829-98

SPECIFICATIONS

TEST STATIONS	SPECIFICATION	
Modular, 1 to 3 test stations	All stations' motions are independent.	
DEGREE OF FREEDOM/AXIS	**FORCE/TORQUE**	**DISPLACEMENT/ROTATION**
Axial Load	4500 N Compression, 3500 N Distraction	48 mm
Flexion	±80 N-m	110° G-S, 200° Cartesian
IE Rotation	±40 N-m	±40°
Y-Axis (AP) Translation	±1000 N	±25 mm
X-Axis (ML) Translation	±1000 N	±25 mm
Abduction/Adduction or Valgus/Varus	±40 N-m	±25°

CONTROL AND DATA ACQUISITION ELECTRONICS

VIVO includes a complete data acquisition system, supervisory PC and internal real-time controller.

CONTINUED

SPECIFICATIONS CONTINUED

ACTUATOR TYPE	SPECIFICATION
All Degrees of Freedom	Servo-hydraulic

D.O.F. / AXIS	SENSORS	AVAILABLE CONTROL MODES
Vertical Actuator	Fz force & position	Force or displacement control
Flexion	Mx torque & position	Torque or displacement control
IE Rotation	Mz torque & position	Torque or displacement control
Y (AP) Translation	Fy force & position	Force or displacement control
X (ML) Translation	Fx force & position	Force or displacement control
Abduction/Varus	My torque & position	Torque or displacement control

LOAD CELL	SPECIFICATION	COMMENT
Six Component	Fx, Fy, Fz, Mx, My, Mz native axes. Automatically mapped to G-S axes.	Replaceable

PHYSICAL SPECIFICATIONS	SPECIFICATION
Height	1900 mm
Width	635 mm
Depth	965 mm
Weight	272 kg (800 lbs)

HYDRAULIC SYSTEM [1]	SPECIFICATION	COMMENT
External hydraulic power supply		Required, quoted separately
Pressure	5.5 MPa (800 psi)	Required
Required Flow	30 LPM (8 GPM) Max	Required
Oil Temperature	38°C	Recommended at inlet

POWER [2]	SPECIFICATION	COMMENT
Electric	115/230 VAC, 50/60 Hz	1 phase, 1000w max
CE Compliant		

DYNAMIC PERFORMANCE

D.O.F	MAXIMUM REPETITION RATE (REPETITIONS/SECOND) [3]	MAXIMUM SPECTRAL CONTENT (HZ) [4]	RMS ERROR (% FS) [5]
Axial Load	2.0 Hz	10 Hz	< 1 %
Flexion Extension	2.0 Hz	10 Hz	< 1 %
IE Rotation	2.0 Hz	10 Hz	< 1 %
Y (AP) Translation	2.0 Hz	10 Hz	< 1 %
X (ML) Translation	2.0 Hz	10 Hz	< 1 %
Abduction/Varus	2.0 Hz	10 Hz	< 1 %

ENVIRONMENTAL CONDITIONING FOR SPECIMENS

SPECIMEN FLUID RECIRCULATION	SPECIFICATION	COMMENT
Pump	100 ml/min	60 RPM peristaltic with #25 silicone tubing
Reservoir	500 ml	Stainless steel tank
Fluid Level	High/Low	Magnetic sensor/float

SPECIMEN FLUID TEMPERATURE	SPECIFICATION	COMMENT
Temperature Controller	50 watts heating/cooling	Thermoelectric

SPECIMEN FLUID	SPECIFICATION
Suitable fluids	Bovine serum, saline solution, water

MEASUREMENT INSTRUMENTATION

DATA ACQUISITION	CHANNEL	RANGE	COMMENT
Data Rate	All channels	2000 samples/sec	
ADC Resolution	All channels	14 bit	
Digital Filters	All channels	none, 10-300 Hz	User selectable
Anti-Aliasing Filters	All channels	600 Hz	

MULTI-AXIS LOAD CELL	CHANNEL	RANGE
Axial Load	Fz	±4500 N
AP Force	Fy	±2200 N
ML Force	Fx	±2200 N
Flexion Moment	Mx	±200 N-m
Valgus Moment	My	±200 N-m
Axial Moment	Mz	±100 N-m

ANGLE AND POSITION	RANGE	NOMINAL RESOLUTION
Axial Position	48 mm	0.1 mm
Flexion	±100°	0.1°
IE Rotation	±40°	0.1°
X, Y (ML, AP)	50 mm diameter work space	0.1 mm
Abduction/Varus	±25°	0.1°

OTHER SENSORS	COMMENT
Serum Temperature	
Oil Temperature	Table top temperature
Serum Fluid Level	High/low safety shutoff
Hydraulic Pressure	Dual gauges and supply sensor

CONTROL SYSTEM

NETCONTROL INTERFACE	SPECIFICATION	COMMENTS
Included Computer Hardware		Windows based PC and accessories

REAL-TIME CONTROLLER	CHANNELS	RANGE	COMMENTS
Pentium Controller		Intel Core 2, 3.4 GHz	Double precision floating point math
Update Rate		2000 Hz	
Output Channels	8	±10 Volt	Per Station
Analog Inputs	30	±1.25 Volt	High-level analog
Digital Inputs	8		Digital I/O
RDI Link	500 Mbps		

CONTROL MODES	SPECIFICATION	COMMENTS
State Space Control	6 axes per station	Force or Position
Iterative	Every axis	Feed-Forward
Virtual Soft Tissue	Every axis	2-input
Multi-Fiber Ligament Model	100 fibers	6 DOF

WAVEFORM GENERATOR	CHANNELS	RANGE	COMMENTS
Channels	6		
Repetition Rate	All channels	0.01 to 30 Hz	
Programmable		1023 points	Automatic Interpolation

EVENT MONITOR	CHANNELS	SPECIFICATION	COMMENTS
Threshold Trigger	5 per station		inside/outside limits, signed value or magnitude of selected signal
Response Time	All channels	0.0005 seconds	
Programmable Response	All channels		Soft stop, hold, shut down

LOGGING OUTPUTS AVAILABLE	OUTPUT RATE
Reference Waveforms	User selectable 1-2000 data sets/sec
Servo Drive Signals	User selectable 1-2000 data sets/sec
Soft Tissue Constraint	User selectable 1-2000 data sets/sec
Sum Signals	User selectable 1-2000 data sets/sec
Environmental Error	User selectable 1-2000 data sets/sec

[1] The external hydraulic system requires cooling water for operation, usually available from your laboratory's infrastructure. If not available, contact AMTI for information about chillers. [2] Contact AMTI for other power configurations. [3] The repetition rate corresponds to the maximum rate at which satisfactory performance can be achieved running the ISO standard gait cycle waveforms for knee testing. This is a somewhat subjective indication of dynamic performance. Typically overall tracking performance is reduced with higher frequency of operation. [4] The ISO waveforms contain spectral content in considerable excess of the fundamental repetition rate. Analysis of these waveforms indicates that tracking performance at a 1 Hz repetition rate is excellent up to the indicated frequency. [5] The RMS error provides a measure of the simulator's tracking performance (the extent that the machine's outputs differ from the target inputs). These values are typical for testing at a 1 Hz repetition rate while running the ISO waveforms and represent standard results while evaluating conventional prosthetics using AMTI's Adaptive Control Technology (iterative learning control algorithm). Different prosthetic devices or conditions may result in an increased or decreased tracking error.

Service & Support

BACKED BY GLOBAL SUPPORT

AMTI offers state-of-the-art technical support and field service through its ASAP service plan. The ASAP plan provides remote support from AMTI engineers and substantial discounts for on-site preventative maintenance and other post-warranty service needs.

The ASAP plan is highly customizable and can be constructed to meet the specific requirements of your lab. The AMTI sales team will be happy to assist you in determining the options that provide the greatest benefit to you.

ABOUT AMTI

As an ISO 9001-certified company, AMTI is committed to the constant evaluation and refinement of our products in order to best meet the needs of the clinical and research communities we serve. This collaborative relationship with our clients is the guiding force behind our company's evolution.

We currently design and manufacture the industry standards in force measurement devices, orthopaedic implant testing machines, and other specialty instruments. Our joint motion simulators, like our knee simulator and our hip simulator, are relied on by most major implant manufacturers. Our force measurement devices, such as our force plates and force sensors, are similarly well-used among clinical researchers in areas such as biomechanics, gait analysis and ergonomics.

AMTI also regularly partners with research institutions, such as NASA and the National Science Foundation, which have awarded AMTI numerous grants to conduct novel research in various areas of medical and industrial technology.

VIVO™

AMTI Worldwide Installations

AMTI simulators are the most advanced, reliable and accurate method for evaluating the design and materials of orthopaedic implants. Their unique combination of capabilities, performance and consistent operation has made them the most relied upon simulators of their kind in the world.

ISO 9001:2008 certified

CE

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FORCE AND MOTION

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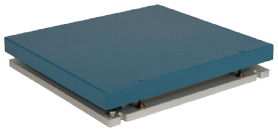
AMTI MULTI-AXIS FORCE MEASUREMENT AND TESTING



Biomechanics Force Platforms

Force Sensors

Instrumented Equipment

Multi-Axis Testing Machines

Amplifiers and Software