

**THE FIRST UK NATIONAL STANDARD
STATIC TORQUE CALIBRATION MACHINE
NOW COMMISSIONED AT MOREHOUSE**
www.mhforce.com

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United Kingdom

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- In 1996 NPL was commissioned to design and manufacture the UK's first National standard torque calibration machine
- The specifications of the machine were determined after a period of industrial consultation and visits to other NMIs

Aims

- To create a torque calibration machine of the highest accuracy
- To disseminate the unit of torque in industry through the calibration of transfer devices

- Torque machine specification

Torque range	1 N·m – 2 kN·m
Deadweight loading	✓
Target uncertainty	1×10^{-5}
Clockwise and anti-clockwise	✓
Incremental and decremental	✓
Working envelope	1 m ³

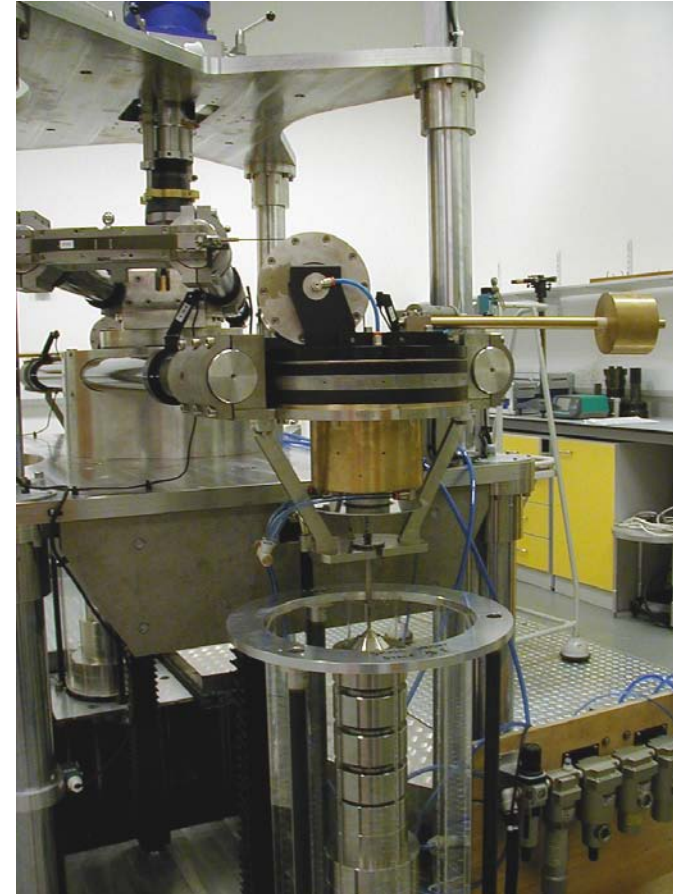
Conceptual design

- 2 kN·m lever deadweight machine (1475.12 LB FT)
- Realised uncertainty 0.002 %
- Novel vertical design – pure torque generated via identical weightstacks located at either end of the lever beam
- Twin beam carbon fibre lever arm mounted on a central air bearing



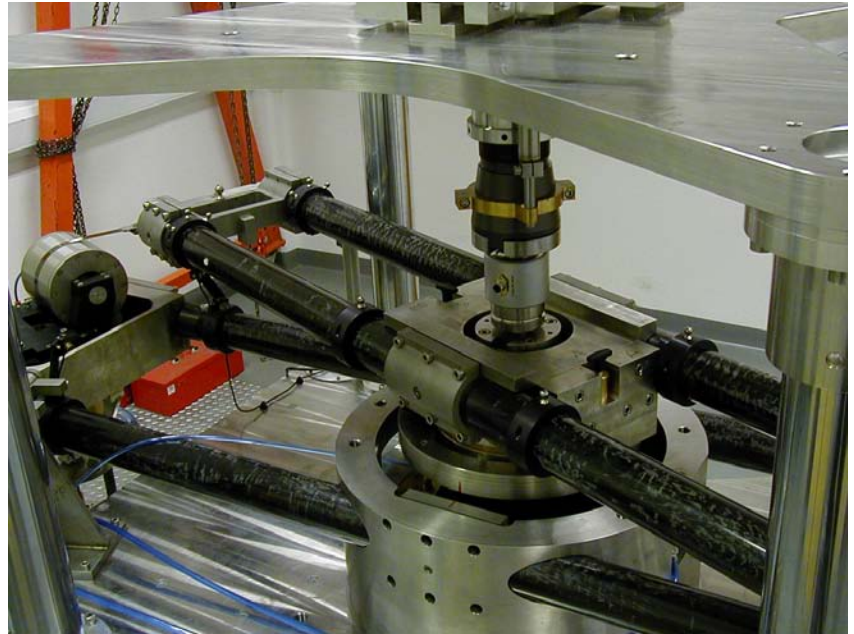
Conceptual design

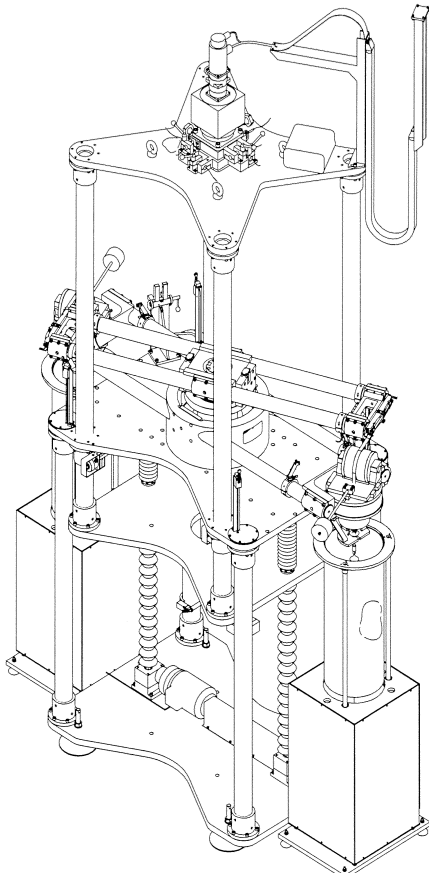
- Vertical torque axis necessitates a change in force direction
- Vertical force generated by the weightstacks is converted to a horizontal force connecting to the lever arm
- Achieved using boron fibre tapes and a pulley air bearing



Conceptual design

- Lever beam can be rotated independently of the torque transducer
- Pulley system is castored to allow rotation about its vertical axis
- The same beam and weightstacks used for clockwise and anticlockwise measurements





Ranges

- Primary: 20 N·m to 2 kN·m in approximately 28 steps
- Secondary: 1 N·m to 100 N·m in approximately 25 steps

Other features

- Continuous torque calibration
- Ability to introduce and measure misalignments
- Asymmetric torque mode

Criteria

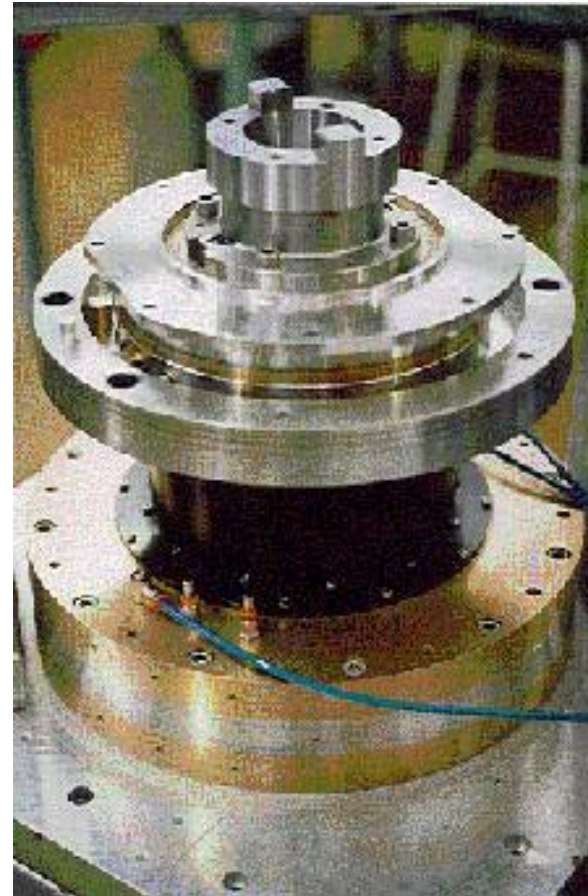
Requirement to provide both radial and axial stiffness to support the predicted forces.

Minimal friction target (0.1 to 0.5) $\mu\text{N}\cdot\text{m}$
(Friction is a combination of boundary and viscous shear of air film plus turbine torque)

Air bearings

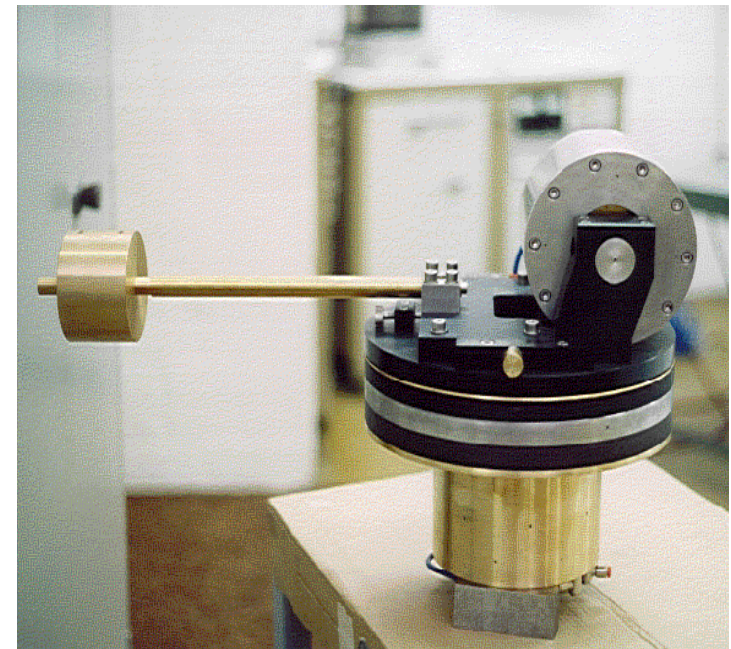
Central pivot air bearing

- Double thrust and air bearing system
- Upper bearing enables rotation of the lever beam
- Lower bearing supports the transducer
- Incorporates a drag cup damper to compensate for the natural frequency of the system



Air bearings

- Boundary and viscous shear influences are time dependant and so can be ignored
- Turbine torque measured with calibrated “micro air jet”
- $220 \mu\text{N}\cdot\text{m}$
- This is constant and so is tared so that target uncertainty is not exceeded
- Castor pulley bearing system provides horizontal and vertical rotation
- Designed to carry a load of 1 kN transmitted by suspension tape at supply pressure of 345 kPa



The lever and reaction beam

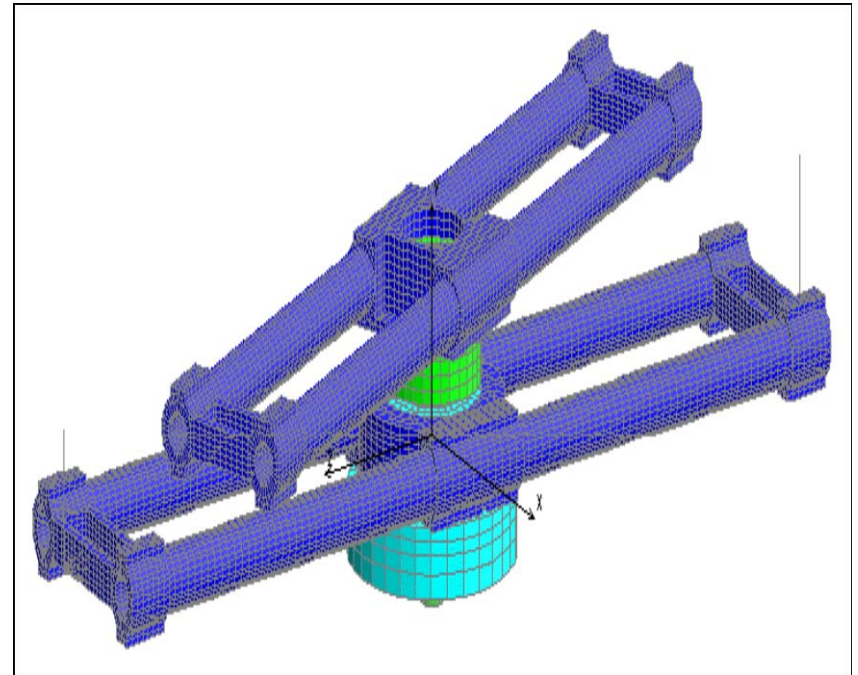
- Designed by NPL materials team

Criteria

Lightweight construction to reduce inertia

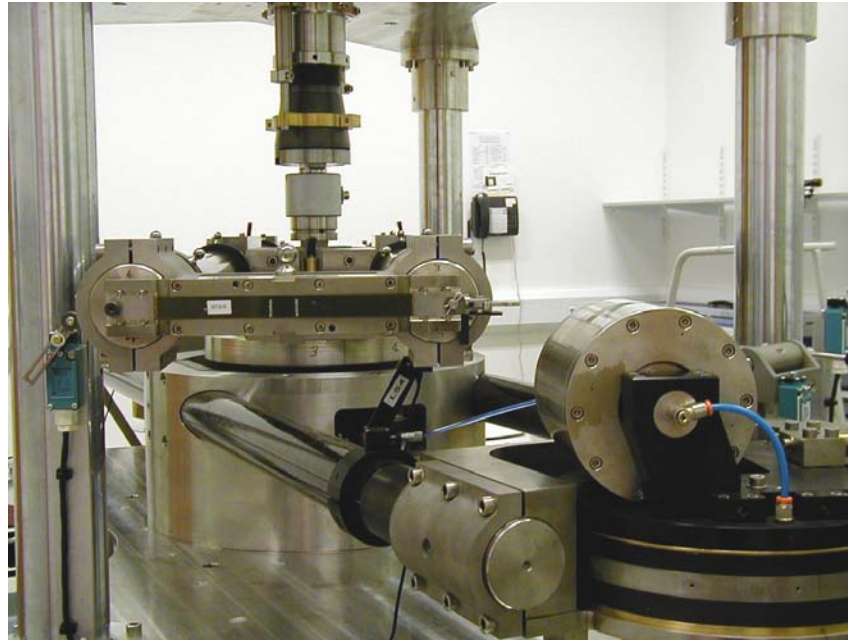
Very low deflection under load

Thermal expansion of beam considered critical



The lever and reaction beam

- Two parallel 2 m long high-modulus carbon fibre tubes
- Stainless steel end fittings and central boss
- Calculated coefficient of thermal expansion = $0.3 \times 10^{-6} \text{ K}^{-1}$
- Finite element analysis used to provide confidence in design



The lever and reaction beam

- Beam has nominal 1.000 000 m length measured to a relative uncertainty of 3.3×10^{-6}
- Length is monitored using a comparator
- With an uncertainty of 2.0×10^{-6} data show that length has changed by less than $3 \mu\text{m}$ over a 1 m length
- Overall length uncertainty contribution - 5.3×10^{-6}



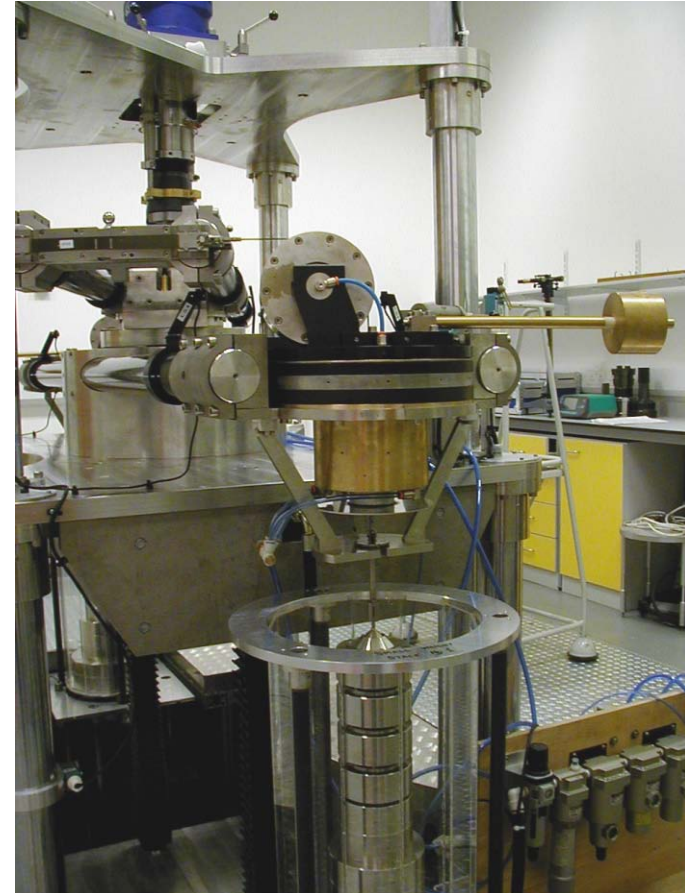
Boron fibre tapes

Criteria

No deformation under load

Lightweight

Flexible



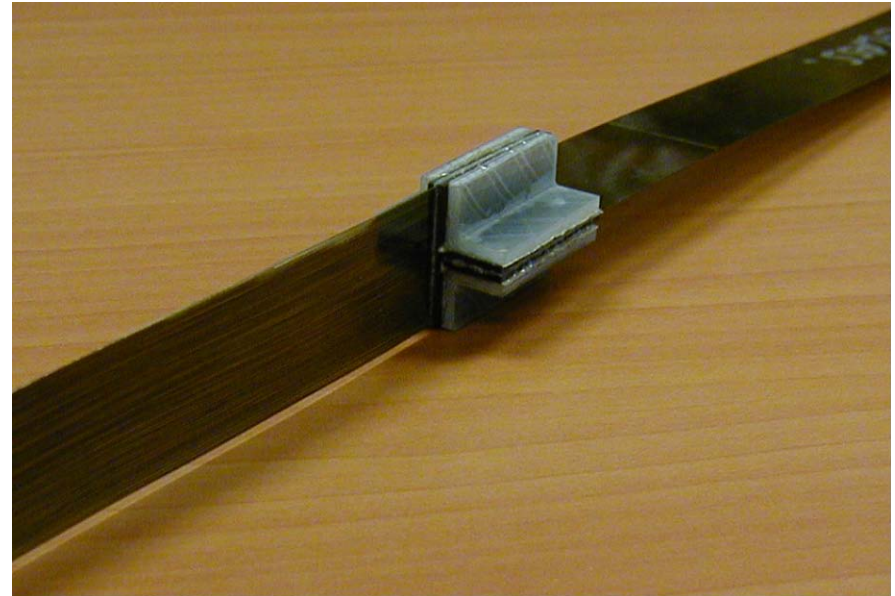
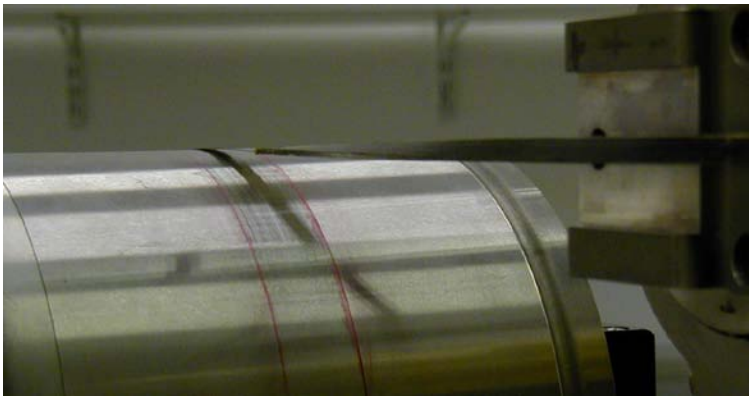
Boron fibre tapes

- Epoxy pre-impregnated tape of 150 μm boron fibre tapes
- Chemical vapour deposition of a boron fibre gas on to fine tungsten wire
- Sandwiched and bonded between a titanium end connector
- 5 mm tape used for torques up to 100 N·m
- 20 mm tape used for torques up to 2 kN·m

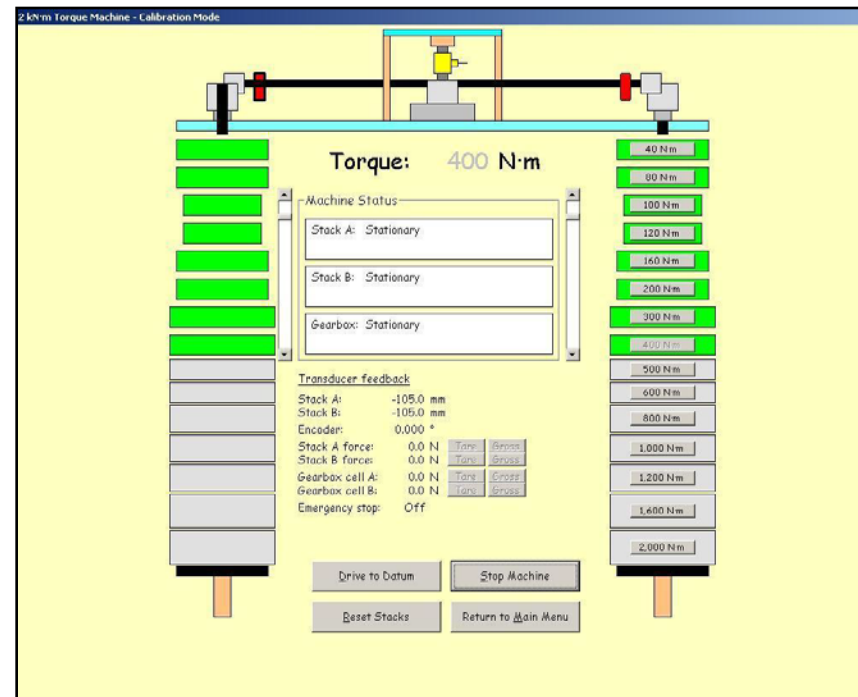


Boron fibre tapes

- Tape is required to change orientation
- 20 mm tape has 90° joint made from carbon and glass fibre
- 5 mm tape has a pre-formed twist

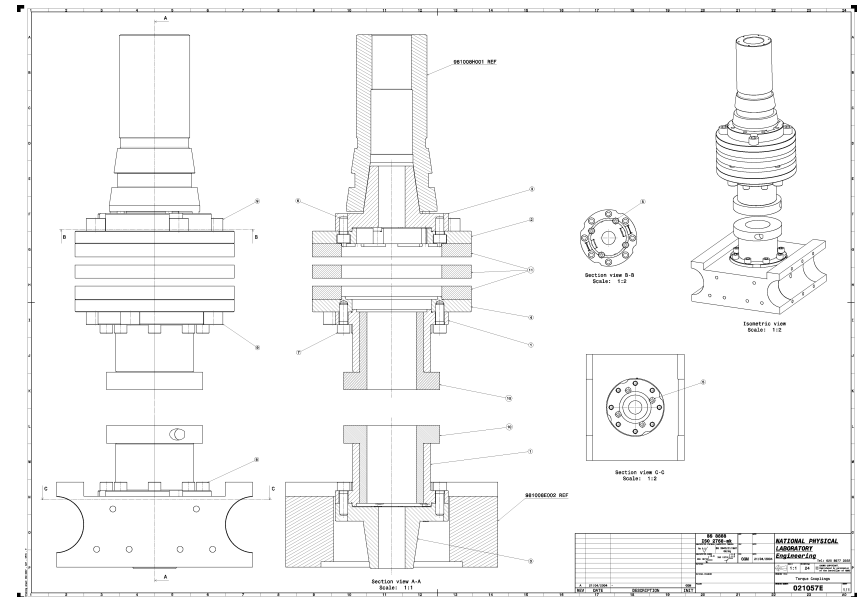


- Graphic user interface – Visual Basic 6.0
- Several working modes
- Displays real-time machine outputs
- Complex motion profiles – weightstack platforms slow as each weight is added or removed
- The lever beam is re-datumed after each weight increment



Couplings

- Adaptability - capable of incorporating most shaft, flange, and square drive transducers
- Based around a hydraulic friction joint
- Incorporates Rexnord flexible couplings – eliminating radial, axial, and angular misalignments



- Relative expanded uncertainty 1.5×10^{-5}
- Traceable to base SI units of mass, length, and time
- Major contributors
 - Force & alignment of force
 - Length
 - Alignment of boron tapes

Validated through intercomparison work with other labs and re verified after being commissioned at Morehouse

Conclusion

- Commissioning completed in December 2005 , May 2010 (MIC)
- Achieved target of realising uncertainties at world leading levels via an novel and innovative design
- Dissemination of the unit of torque expected to have a significant impact in North American industry
- Flexibility of the machine will provide a powerful research tool

