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Development of a switchable system for longitudinal and longitudinal-torsional vibration extraction

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The Martian subsurface – a habitat for life?

Near Hephaestus Fossae, Utopia

University of Glasgow

Planetary drill tools

Why is drilling into the regolith so difficult?

Power – limited to a few tens of W

Preload – limited to the weight of a lightweight rover in low g

Torque – limited traction is available in the loose soil

Can ultrasonic techniques overcome these problems?

Victoria Crater, Meridiani

Traditional ultrasonic cutting

We could attempt to use ultrasonic cutting tools to penetrate the regolith directly, like in food cutting...

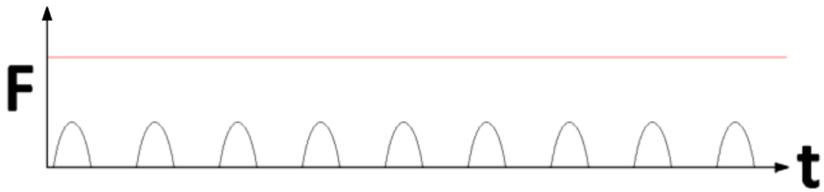
...but on Mars we encounter rock. Each ultrasonic cycle does not deliver enough impulse above the compressive limit and so does not cause shattering.

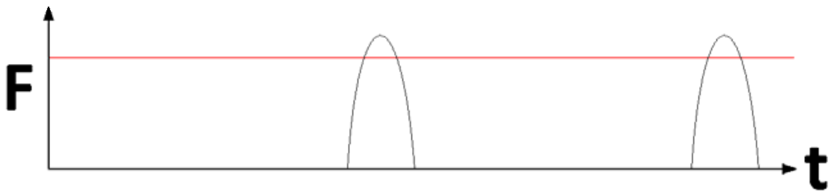
We need to consolidate the impulse high-frequency impacts into fewer, more substantial blows.

High-frequency/low-frequency drilling...

High-frequency/low-frequency drilling

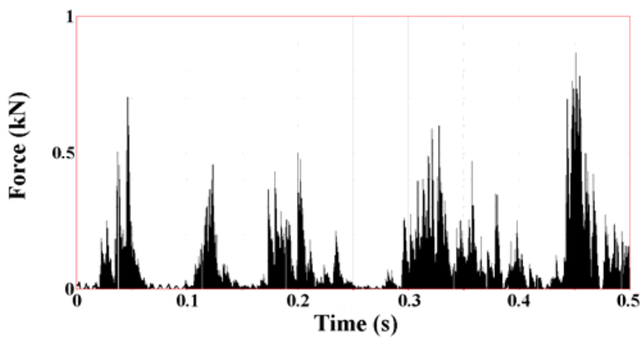
JPL have pioneered the use of free-masses shuttling between the horn and drillbit to consolidate the blows...

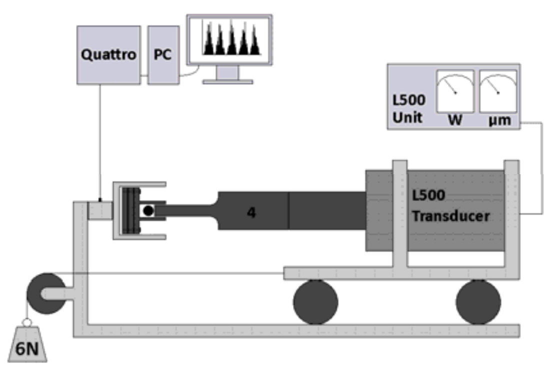


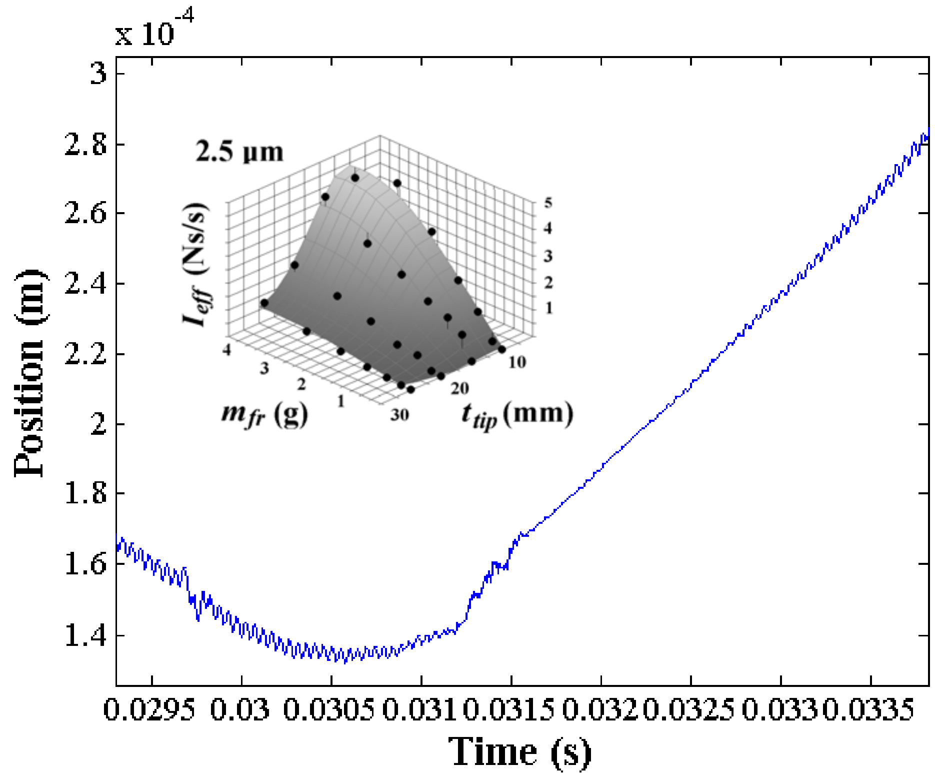


High-frequency/low-frequency drilling

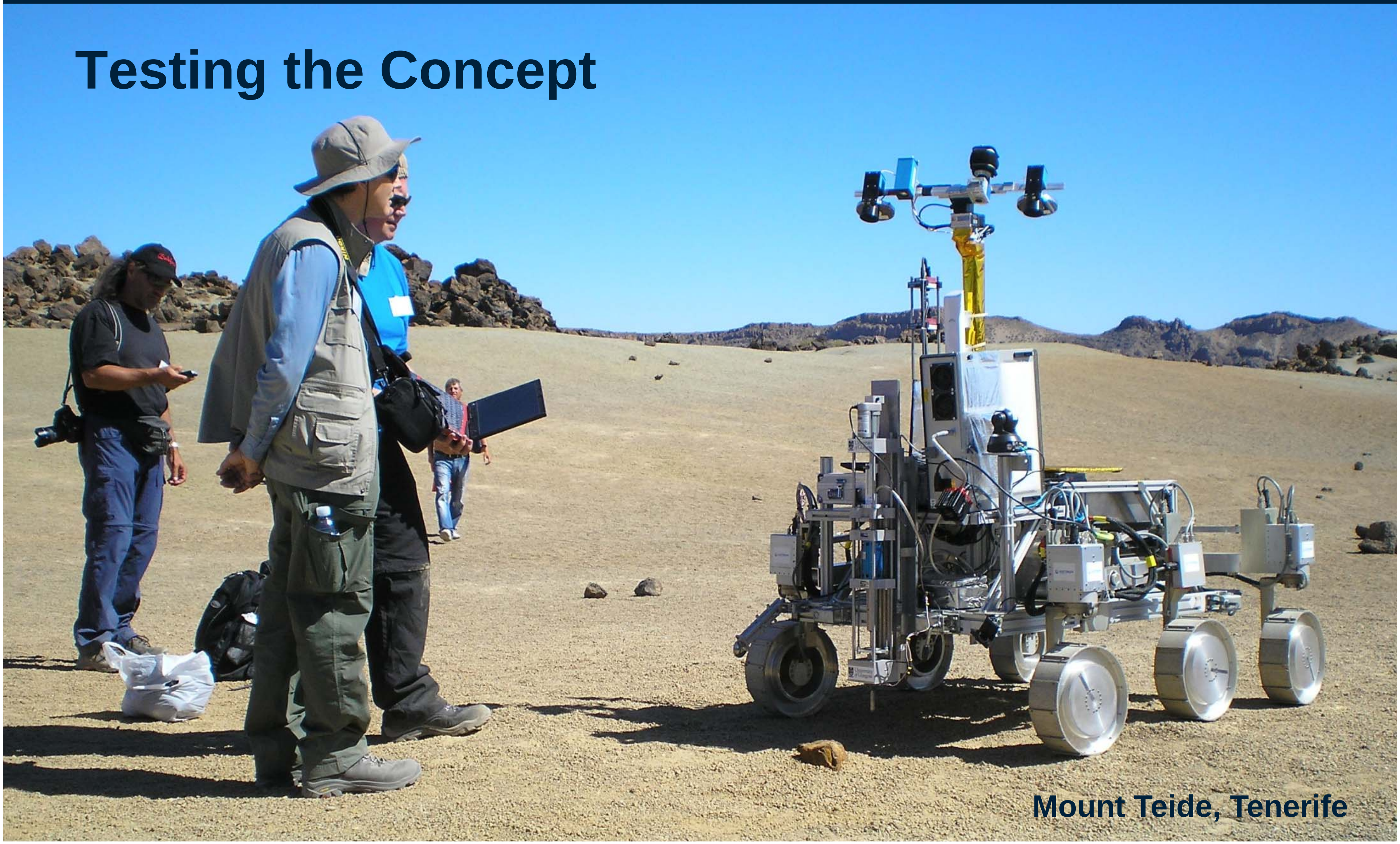
...and the University of Glasgow have optimised the system parameters to maximise I_{eff}.





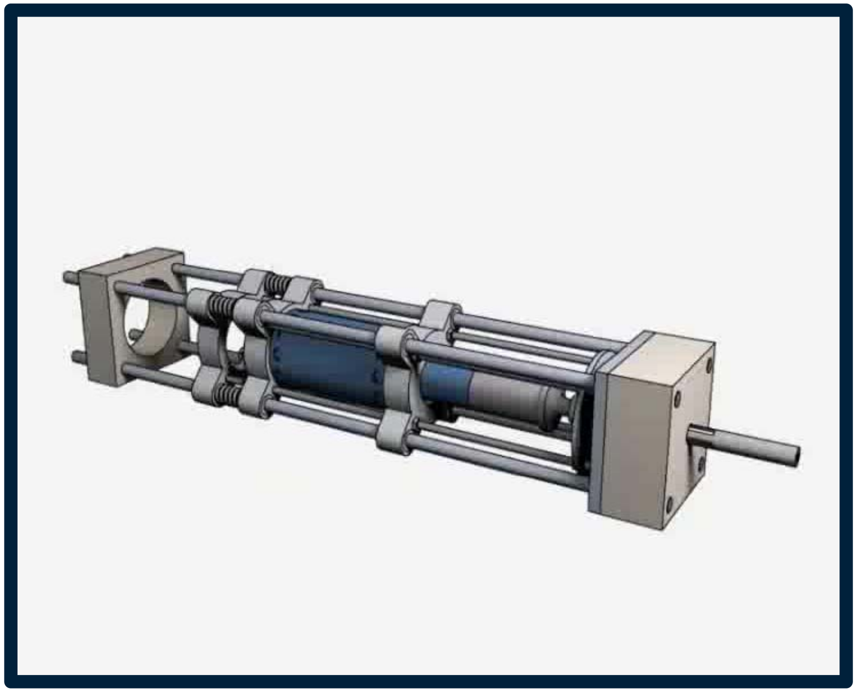


Testing the Concept



Mount Teide, Tenerife

Operation of the Ultrasonic Drill



Additional Drill Systems – electrical bit rotation

Some difficulties we might encounter…

Tribology

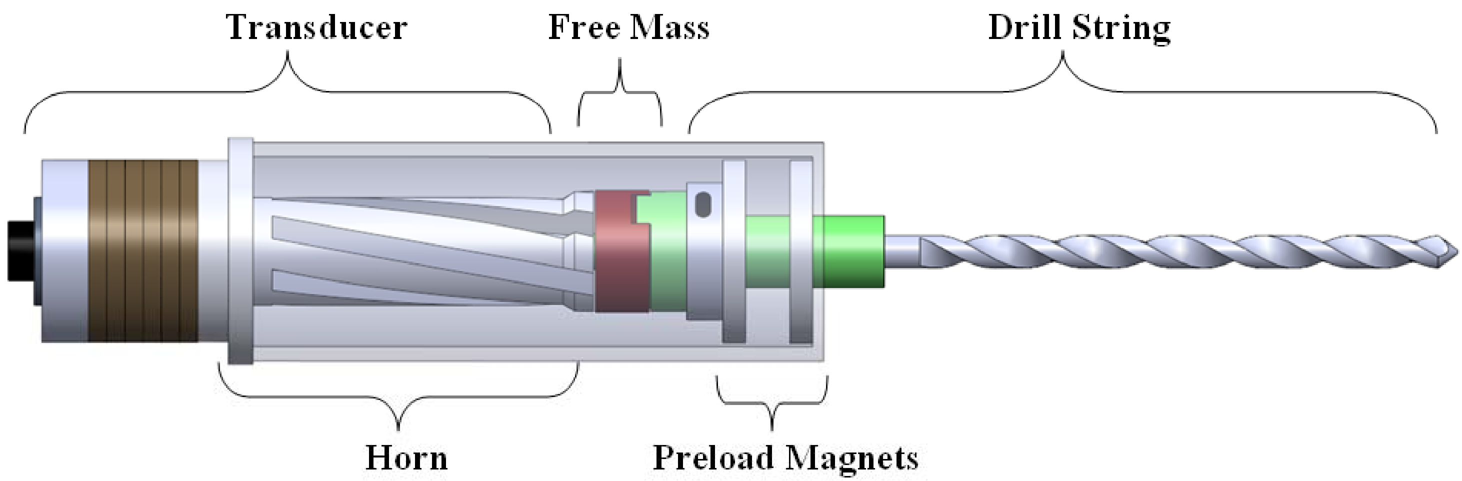
Complexity

Weight

Could we replace this with ultrasonic bit rotation?

Technique #1

JPL propose using longitudinal-torsional horns, similar to those developed by Al-Budairi, to spin the free-mass.



Technique #2

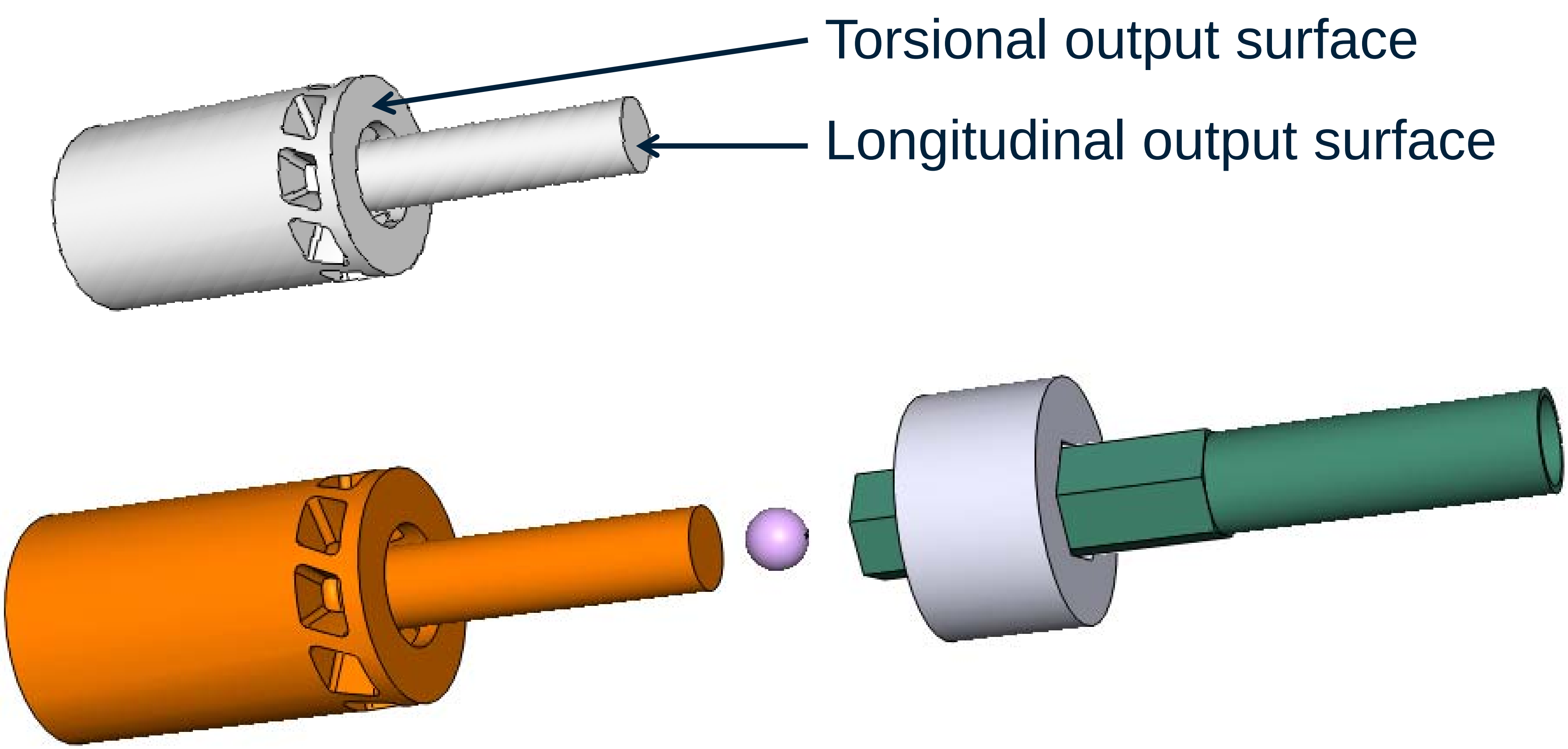
However, bit-walk can be troublesome when coring...

...so if we can decouple rotation and percussion perhaps the operator could select between them?

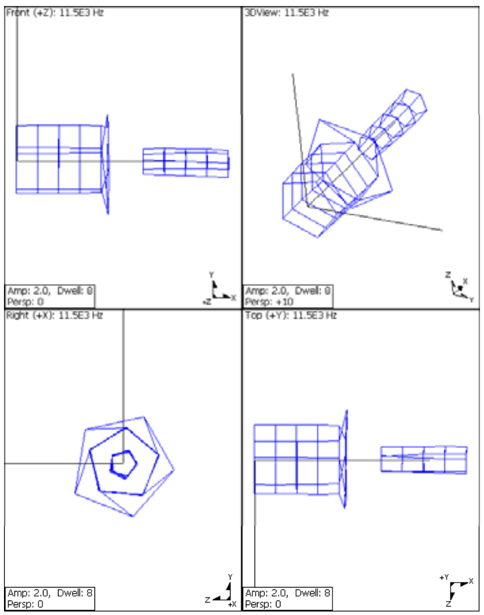
We need a horn with:

1. A longitudinal output surface for percussion
2. A torsional output surface for rotation
3. Selectability between the outputs (different frequencies)

The Selectable Drill Horn Concept

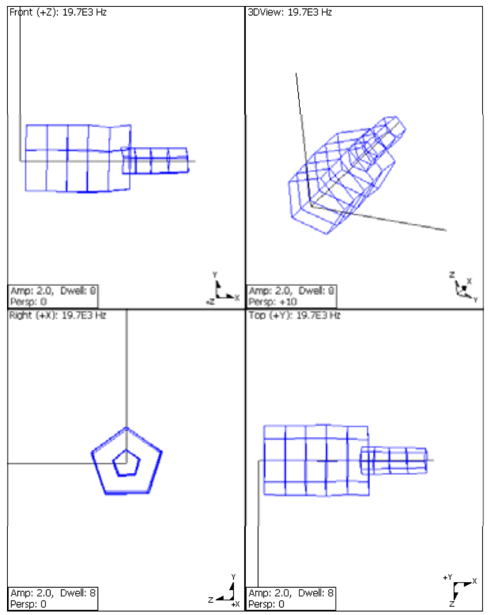


Modal Analysis of the Selectable Drill Horn



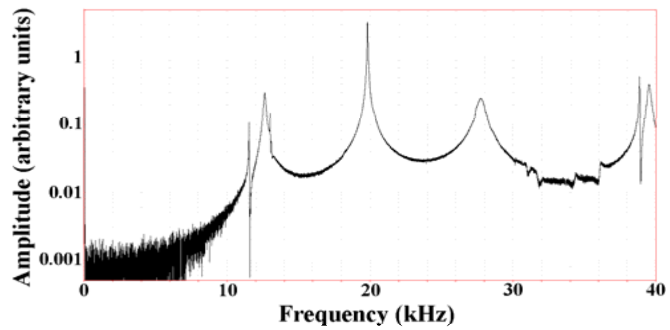
11.5 kHz
Ring Torsional Mode

Rotating Action

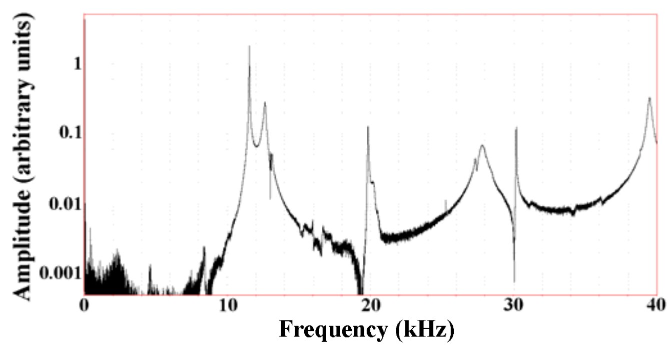


19.7 kHz
Stem Longitudinal Mode

Percussive Action



Longitudinal output at the tip

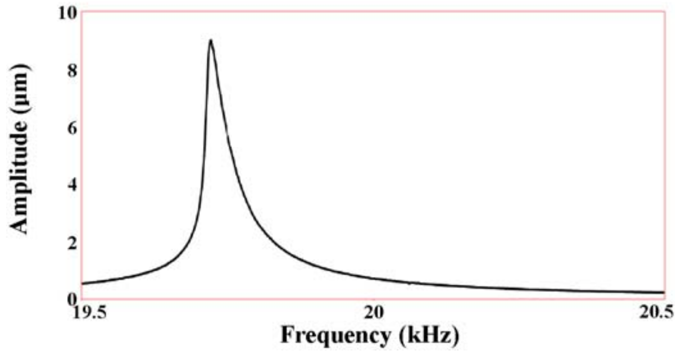


Tangential output at the disc

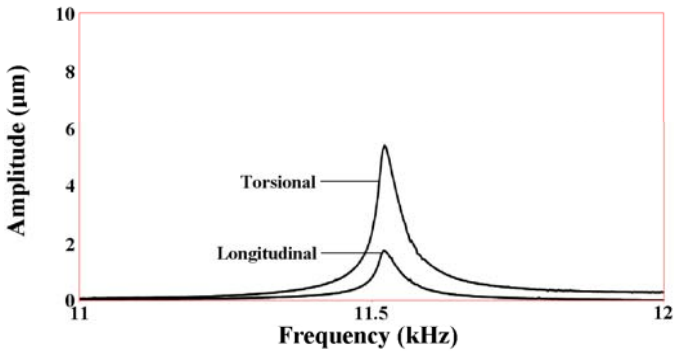
Harmonic Analysis of the Selectable Drill Horn

The shape of the harmonic responses suggest some nonlinearities.

The horn is manufactured in two parts with a thermal fit. Internal friction is an unavoidable consequence of our manufacturing technique.



Output at the tip

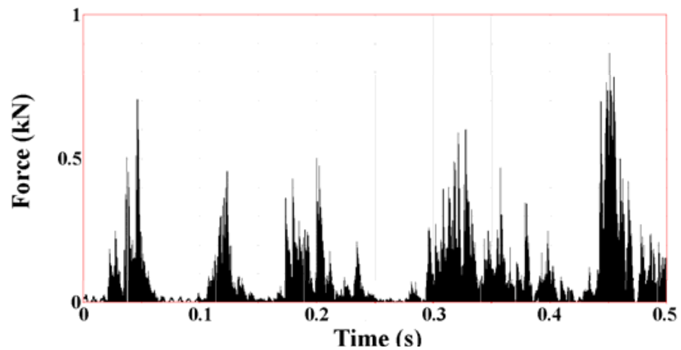


Output at the disc

Rotating Action of the Selectable Drill Horn

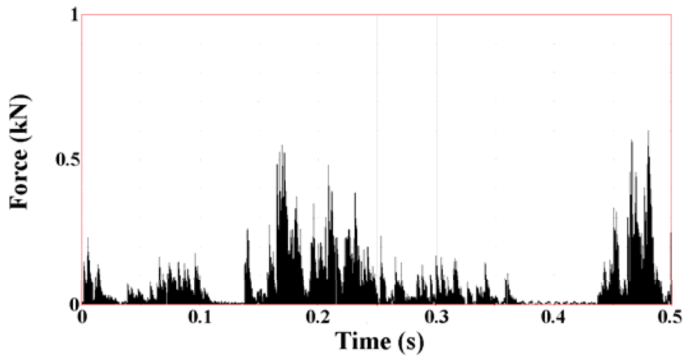
Volts	Cap revolutions per minute at 11.5 kHz				
	2.1 N	3.1 N	4.1 N	5.1 N	6.1 N
300 V	erratic	erratic	erratic	erratic	12.8
400 V	9.2	11.7	14.6	16.7	18.2
500 V	12.2	15.0	23.0	28.6	31.6

Percussive Action of the Selectable Drill Horn



Control horn

I_{ff} above 100 N = 0.080 Ns/s



Selectable horn

I_{ff} above 100 N = 0.048 Ns/s

Conclusions

Reasonably high I_{ff} can be maintained in a switchable horn

Rotation is achievable using a different mode of the same horn

Manufacturing techniques may be responsible for some losses

The Future

We have an application for further work live under the FP7 programme... and will report back next time!

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