Asteroid Gravity Test System Using a Planar Air Bearing

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Motivation

The size and makeup of near earth asteroids make spacecraft sample and return missions hazardous. Since at least one of these asteroids (101955) Bennu regularly ejects particles, nanospacecraft could be deployed to capture these objects in flight, eliminating the need for touching down on the asteroid itself.

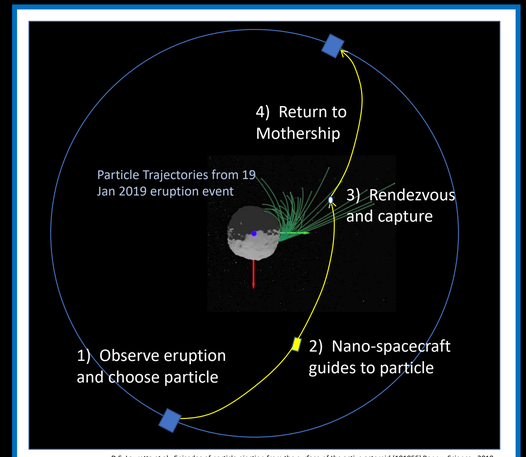
The proposed airbearing table is radially curved to mimic the low gravity of a centrally located asteroid, permitting evaluation of such a mission's navigation, guidance and docking.

Previous Approach

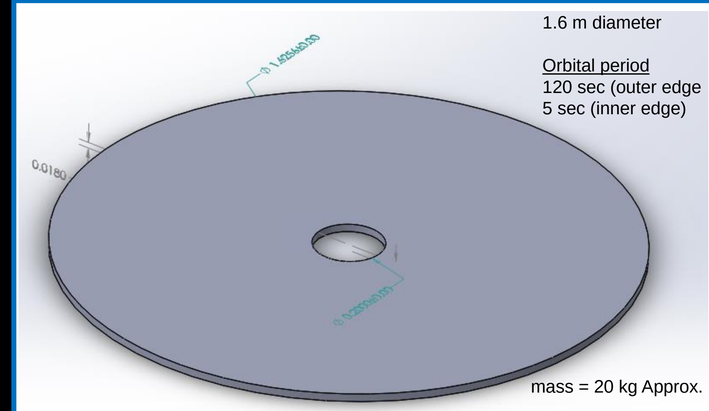
Planar Airbearing allowing 3 degree of freedom motion

Updated Approach

Radially sculpted air-bearing table to mimic a low gravity asteroid environment



D.S. Lauretta et al. Episodes of particle ejection from the surface of the active asteroid (101955) Bennu. Science, 2019



Airbearing table mimics low gravity system

Conclusion

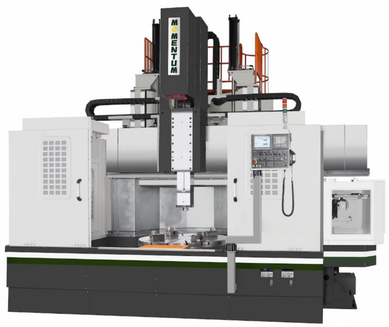
Capture of erupting particles is a plausible alternative to touchdown on the asteroid surface

Creation of a radially symmetric air bearing can reproduce aspects of the dynamic environment for system test

This air bearing table can also be used as a hands on teaching tool for Keplerian dynamics.

Manufacturing

Table requirements well within existing tooling machine capability



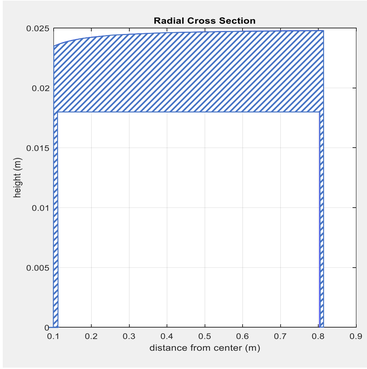
Specifications

		UNIT	MVL-12	MVL-12M	MVL-12HD
Capacity	Max. Swing Diameter	mm (inch)	Ø1,600 (62.99)		
	Max. Turning Diameter	mm (inch)	Ø1,600 (62.99)		
	Distance from Std. Turning Holder Insert to Table Surface	mm (inch)	0 ~ 1,205 (0 ~ 47.44)	0 ~ 1,155 (0 ~ 45.47)	0~1,175 (0 ~ 45.25)
	Max. Turning Height	mm (inch)	1,200 (47.24)	1,150 (45.27)	1150 (45.27)
Table	Max. Workpiece Weight	kg (lb)	8,000 (17,636)		
	Table Diameter (Manual Chuck)	mm (inch)	Ø1,250 (49.21)		
	Range of Table Speed (Low)	rpm	34 ~ 103		26 ~ 80
	Range of Table Speed (High)	rpm	104 ~ 312		81 ~ 312
	Max. of Table Torque	N·m (ft·lbs)	Std. 12,400 (9,151) / Opt. 19,000 (14,022)		19,000 (14,022)
ATC	Tool Size	mm (inch)	□ 25 / 32 / 40 (1" / 1.25" / 1.5") x 600 max. length		
	Tool Type	-	T - Puller	BT - 50 / CAT-50	T - Puller
	Number of Tool Stations	-	12 (Random)	12 (6 Turning + 5 Milling + 1 Cover)	12 (Random)
	Cross-Section Of Ram	mm (inch)	200 x 200 (7.87 x 7.87)	240 x 240 (9.44 x 9.44)	
Travel	Horizontal Travel (X-Axis)	mm (inch)	-820~1,000 (-32.28~39.37)		
	Vertical Travel (Z-Axis)	mm (inch)	900 (35.43)	1,000 (39.37)	
	Cross-Rail Travel	mm (inch)	500 (19.68), 2 steps (3 positions)		500 (19.68), 2 steps (3 positions)
Feed Rates	Rapid Rate (X & Z Axis)	m/min	1 0		
	Cutting Feed Rate	mm/min	1 ~ 2,000		
	Feed Override	%	0 ~ 150		
Motor	Main Spindle	kW (HP)	Std. 0403, 37 / 45 kW (49.6 / 60.3 HP) / Opt. 0653, 45 / 55 kW (60.3 / 73.7 HP)		0653, 45 / 55 kW (60.3 / 73.7 HP)
	Feed Servo Motor (X & Z Axis)	kW (HP)	4 0 (5.4 HP)		
	Milling Spindle Motor	kW (HP)	N/A	Ø P30i (15/18.5 kW)	N/A
	Cf Axis Servo Motor	kW (HP)	N/A	Ø 30i, 7 kW (9.4HP)	N/A
Dimensions	Floor Space (L X W)	mm (inch)	7,700 x 5,450 (303.149 x 214.566)	5,650 x 6,000 (222.441 x 236.223)	6,650 x 6,450 (261.81 x 253.937)
	Machine Max. Height (H)	mm (inch)	5,100 (200.787)	5,700 (224.409)	5,260 (207.086)
	Machine Net Weight	kg (lb)	23,500 (51,809)	26,800 (63,000)	25,400 (55,993)

CNC Vertical Turning Lathe
Accuracy usually about 0.02mm

Derivation of Surface

Table Cross Section
(Vertical Scale Exaggerated)



Diameter is chosen consistent with reasonable max handling size (r_{max} = 1.6m)

Period of max radius orbit limited with ability to level platform (t_p = 120 seconds)

Inner radius limited by ability of air bearings to plausibly maintain lift on a curved surface (r_{min} = 0.1m)

$$a(r) = -g * slope$$ Inwards acceleration at max radius

$$a(r) = -\frac{k}{r^2}$$ Gravitational model

$$k = -\frac{4\pi^2 r_{max}^3}{t_p g}$$ Value of *k* for chosen orbital period t_p

$$slope(r) = -\frac{a}{g} = -\frac{-k}{t_p g}$$ Slope required for that orbital period

$$y(r) = \int slope(r)dr = \int \frac{k}{r^2}dr = -\frac{k}{r} + y_0$$ Integration of slope to get outline

References

D.S. Lauretta et al. Episodes of particle ejection from the surface of the active asteroid (101955) Bennu. Science, 2019