無飛翔型MEID機構の提案と月惑星探査機着陸脚への応用

Proposal of Non-Flying-Type MEID Mechanism and Its Application to Lunar/Planetary Exploration Spacecraft Landing Gear

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This study discusses a lunar/planetary exploration spacecraft landing mechanism using NFMEID. NFMEID can exchange the vertical shock into the spacecraft to the rotary momentum of the landing gear and damper masses. Further, NFMEID can be applied to shock response control of the general mechanical structures because of its compact structure. This report shows the effectiveness of NFMEID in vertical landing case.

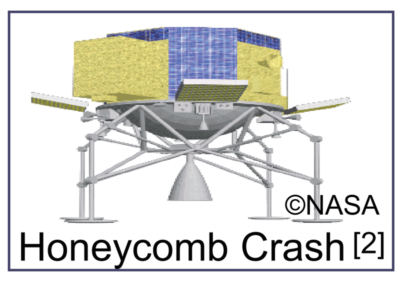
Background

◆ Necessity for detailed Lunar/Planetary explorations by spacecraft

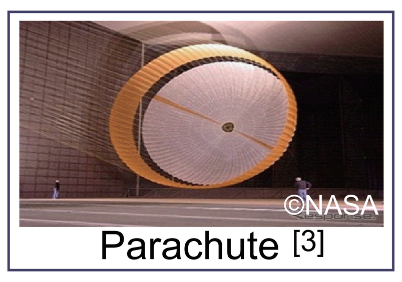
Requirement: Development of soft landing mechanism for shock response control

◆ Previous methods and their problems

Airbag[1]



Honeycomb Crash [2]

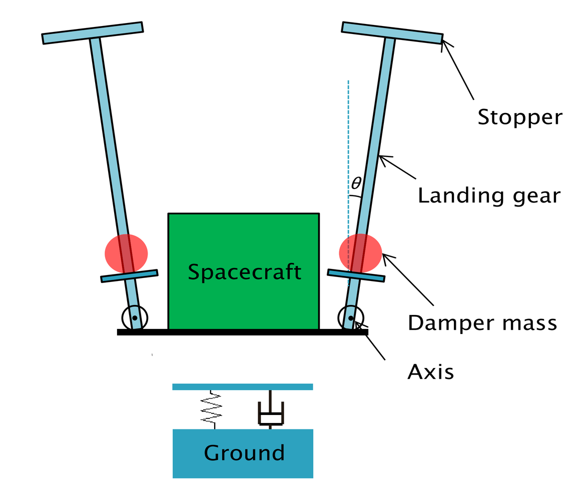


Parachute [3]

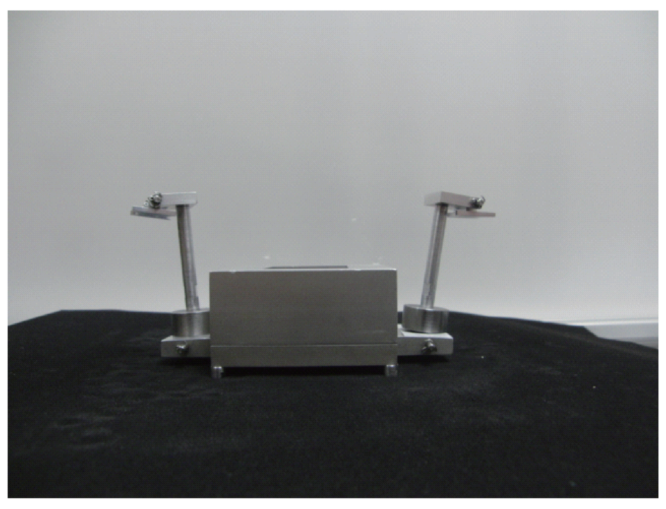
Problems
- High rebound
- Impossibility to reuse
- Necessity of air

NFMEID

Non-Flying-Type Momentum Exchange Impact Damper



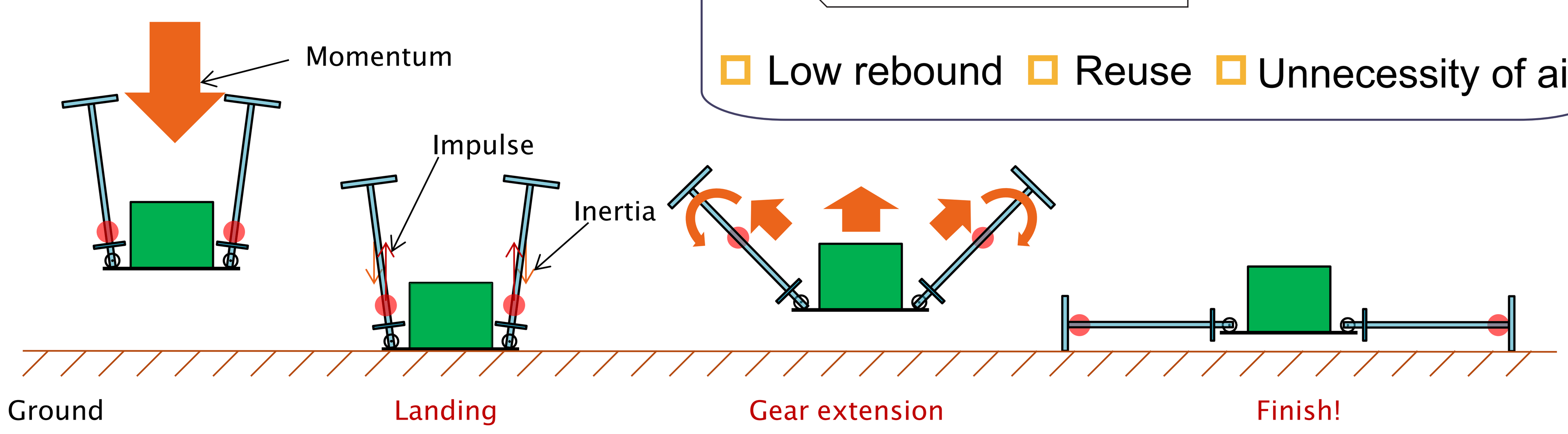
Components of NFMEID



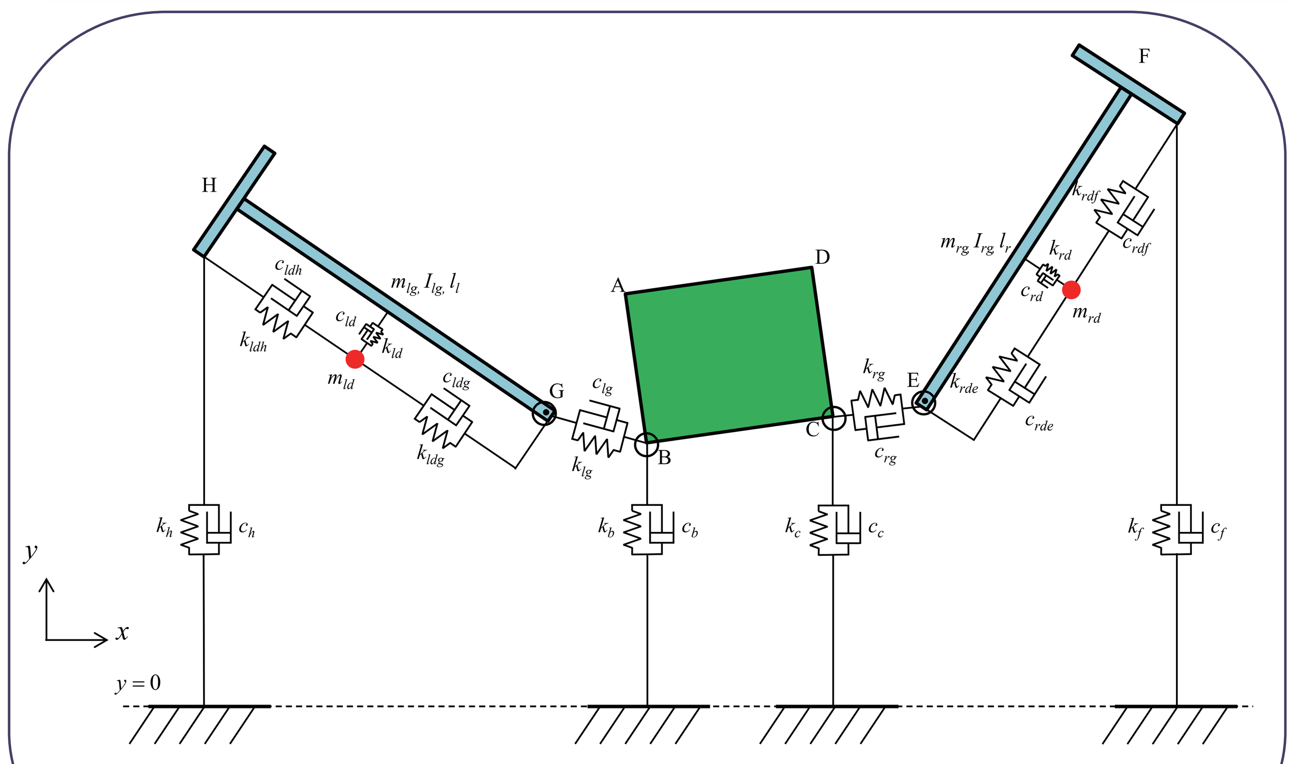
Prototype of NFMEID

NFMEID can realize…

□ Low rebound □ Reuse □ Unnecessity of air



Model for simulation



A simulation model of NFMEID

□ Initial height : 0.5 m

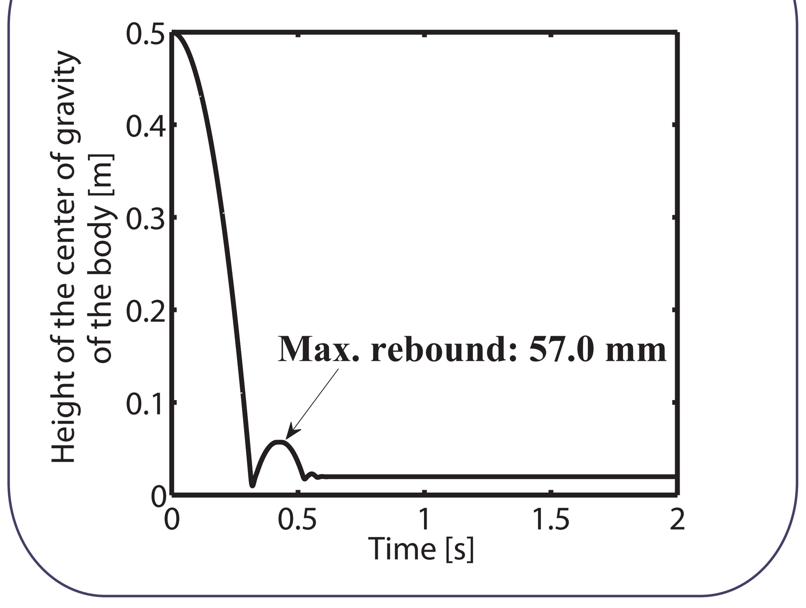
m_b	Body mass [kg]	0.45
m_{rg}	Right gear mass [kg]	0.0034
m_{rd}	Right damper mass [kg]	0.044
m_{lg}	Left gear mass [kg]	0.0034
m_{ld}	Left damper mass [kg]	0.044
I_b	Moment of inertia of the body [kg·m^2]	4.0×10^{-4}
I_{rg}	Moment of inertia of right gear [kg·m^2]	1.0×10^{-6}

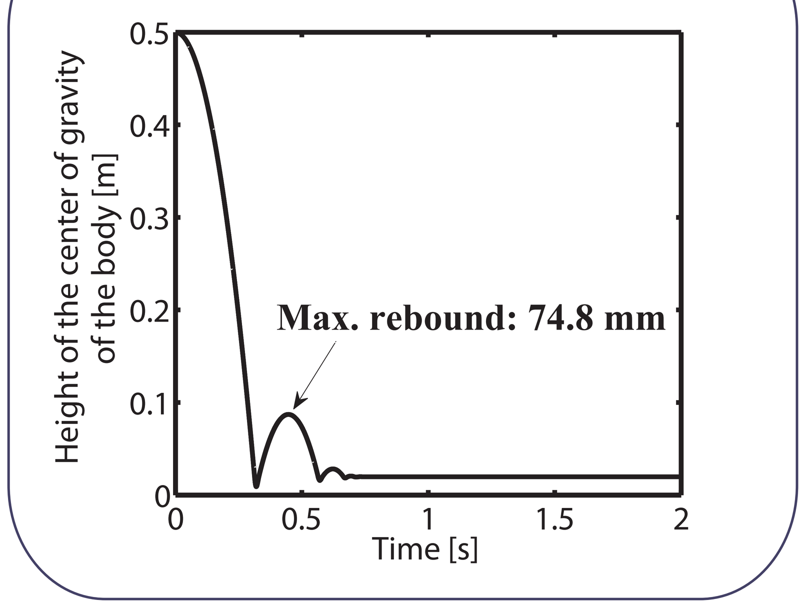
I_{lg}	Moment of inertia of left gear [kg·m^2]	1.0×10^{-6}
l	Width of the body [m]	0.10
l_{rg}	Length of right gear [m]	0.060
l_{lg}	Length of left gear [m]	0.060
h	Thickness of the body [m]	0.050
k_b	Vertical stiffness between B and ground [N/m]	1.0×10^{4}
c_b	Vertical damping between B and ground [N·s/m]	30

k_c	Vertical stiffness between C and ground [N/m]	1.0×10^{4}
c_c	Vertical damping between C and ground [N·s/m]	30
k_f	Vertical stiffness between F and ground [N/m]	1.0×10^{4}
c_f	Vertical damping between F and ground [N·s/m]	30
k_h	Vertical stiffness between H and ground [N/m]	1.0×10^{4}
c_h	Vertical damping between H and ground [N·s/m]	30
k_{rg}	Stiffness of the restriction between the body and right gear [N/m]	1.0×10^{4}
c_{rg}	Damping of the restriction between the body and right gear [N·s/m]	100
k_{lg}	Stiffness of the restriction between the body and left gear [N/m]	1.0×10^{4}
c_{lg}	Damping of the restriction between the body and left gear [N·s/m]	100
k_{rd}	Stiffness of the restriction between right gear and damper mass [N/m]	1000
c_{rd}	Damping of the restriction between right gear and damper mass [N·s/m]	10
k_{ld}	Stiffness of the restriction between left gear and damper mass [N/m]	1000
c_{ld}	Damping of the restriction between left gear and damper mass [N·s/m]	10
k_{rde}	Stiffness of the restriction between E and right damper mass [N/m]	1000
c_{rde}	Damping of the restriction between E and right damper mass [N·s/m]	5.0
k_{rdf}	Stiffness of the restriction between F and right damper mass [N/m]	1000
c_{rdf}	Damping of the restriction between F and right damper mass [N·s/m]	5.0
k_{ldg}	Stiffness of the restriction between G and left damper mass [N/m]	1000
c_{ldg}	Damping of the restriction between G and left damper mass [N·s/m]	5.0
k_{ldh}	Stiffness of the restriction between H and left damper mass [N/m]	1000
c_{ldh}	Damping of the restriction between H and left damper mass [N·s/m]	5.0

Simulation results

◆ Vertical displacement of the body

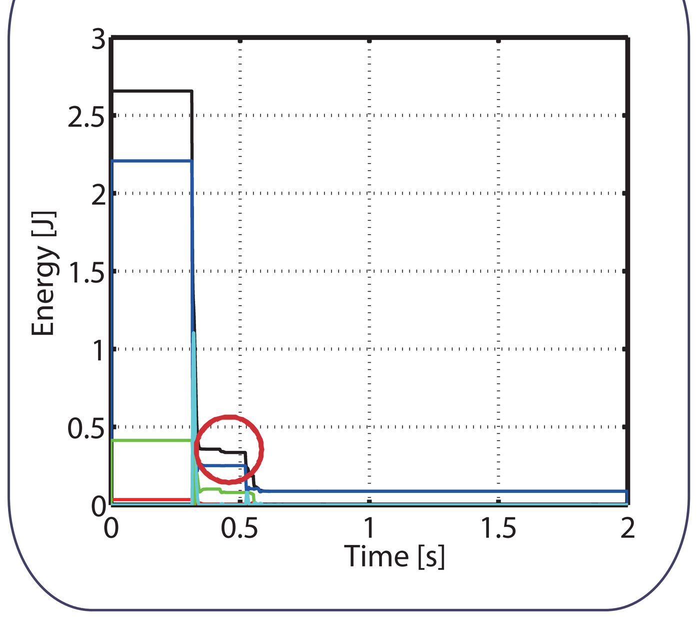


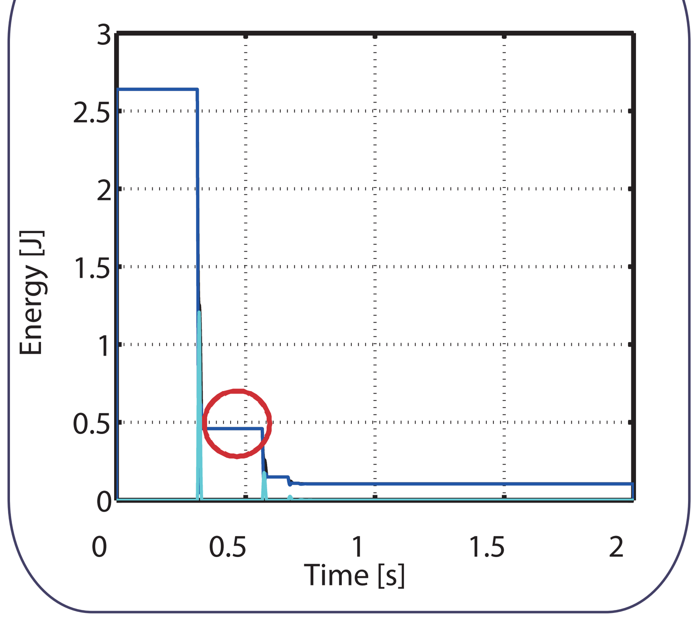


● 暫定的なパラメータを用いて，リバウンドを約25%抑制できた.

□ NFMEID can reduce the rebound to around 25%.

◆ Mechanical energy of the system



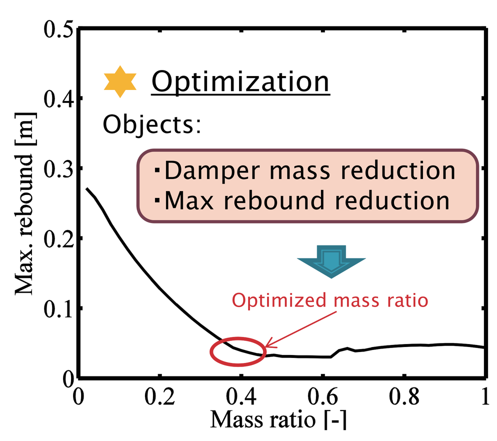


Black: entire system Blue: the body Red: landing gears
Light blue: springs Green: damper masses

●本体の力学的エネルギーを散逸させることができた.

□ NFMEID can distribute the body's energy to other parts.

◆ The ratio of damper masses



$$\text{Mass Ratio} = \frac{\text{Right + Left damper masses}}{\text{Body}}$$

● ダンパ質量の割合が増えるにつれ，リバウンド量が抑制されているため，NFMEIDの有効性が確認できる.

□ This figure shows NFMEID's effectiveness.

□ Considering the damper mass reduction, and maximum rebound reduction, the optimized mass ratio is 30～40%.

Conclusion

□ NFMEID can convert the vertical momentum of the body to the rotary momentum of landing gears and damper masses.

□ To improve the NFMEID's performance, parameter optimization should be investigated.

□ For detailed investigation, the falling simulation onto slope and step should be practiced in the future.

References

[1] ESA.ESA - "ExoMars - Vented airbag". ESA - Home(online), available from <http://www.esa.int/SPECIALS/ExoMars/SEM2QQ3MDAF 0.html>, (accessed 2014-6-4).

[2] Rogers, W. F., Apollo Experience Report – Lunar Module Landing Gear Subsystem, Technical Report TND-6850, NASA (1972).

[3] Blamont, J. and Jones, A. J., A New Method for Landing on Mars, *Acta Astronautica*, Vol. 51, Issue 10 (2002), pp. 723-726.

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