C08

金属製銛のデブリ模擬構造への撃込みにおける先端形状の影響評価

Study on effect of metal anchor shapes on harpooning to space debris structure

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金属製銛によるデブリ捕獲技術の確立を目指し, デブリ模擬構造への金属製銛撃込みにおけるその先端形状の影響を評価した. 先端形状として, 円錐形銛, および, 二山形状の2種類を有する金属製銛を製作し, 撃ち込み試験を実施, 試験結果を比較した. 試験の結果, 以下の知見が得られた. 貫入に必要な撃込み速度は, 先端二山形状銛の方が小さく, 射出システムが与えるべきエネルギーの観点からは, 先端二山形状銛が優れている. しかし, 先端二山形状銛では貫入孔がきれいな円形となり, 金属製銛との引っ掛りが生じないため, 銛単体での貫入後保持力については, 先端円錐形状銛の方が優れている. 速度によっては, 先端二山形状銛ではターゲットに貫入後, 弾性変形の復元力により金属製銛が跳ね返る現象も確認された. 以上より, 先端二山形状銛を用いる場合, 展開型の引き抜け防止機構など, 引き抜き強度を上げるための何からの工夫が必要となる.

The effects of metal anchor shapes on harpooning to space debris structure were investigated. Two types of head shapes, a v-groove head and a cone shape head were employed. The experiments on capturing using metal anchors have been carried out and their results were compared. It was observed from the experimental results that minimum penetration velocity of the v-groove head was lower than that of the cone shape head and it indicates that the required kinematic energy for capturing can decrease by using the v-groove head. Sufficient pulling strength was achieved by using the cone shape head. However, the pulling strength using the metal anchor with v-groove head was very small and it is difficult to achieve an appropriate capturing state. Therefore, some mechanisms will be required to anchors with v-groove head for capturing space debris.

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Missions scenario for space debris removal

Approach and Rendezvous

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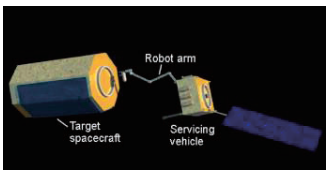
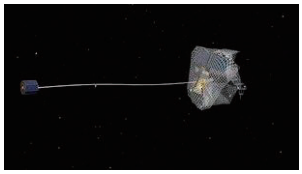
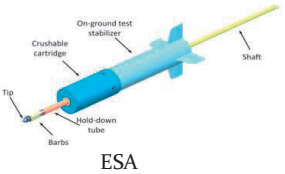
Docking / Capturing



Robot system
© JAXA



Netting system © ESA



ESA

NDA

Harpoon / metal anchor with a tether

This study focuses on the docking using a metal anchor.

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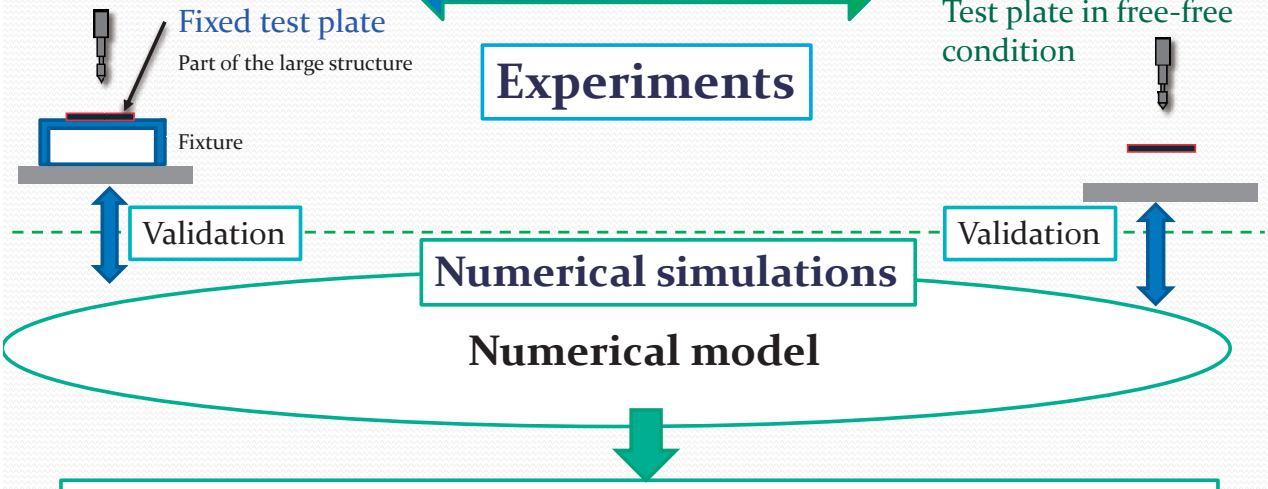
Deorbit

Steps of our study

Large debris

Space debris

Small debris



Performance evaluation of the metal anchor method for various space debris

Requirements for a metal anchor and aims of this study

- **Requirements for metal anchor**
  - **Penetrate to the debris structure and achieve appropriate docking state.**
  - **Small minimum penetration velocities are suitable for docking.**

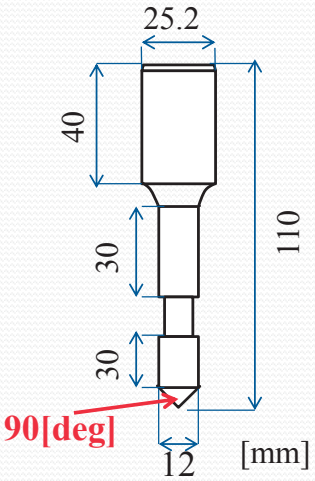
Aims of this study

Investigate the effects of head shape on penetration states through the comparison of experimental results.

- **Manufacture the metal anchors whit cone heads and v-grooves.**
- **Perform the experiments.**
- **Investigate the relationships between head shapes and penetration states.**

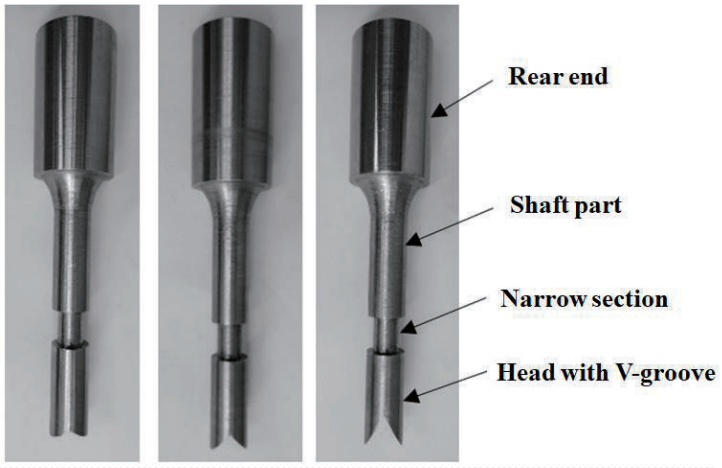
Metal anchors with cone shape head

Material: SS400
Mass: 204 [g]

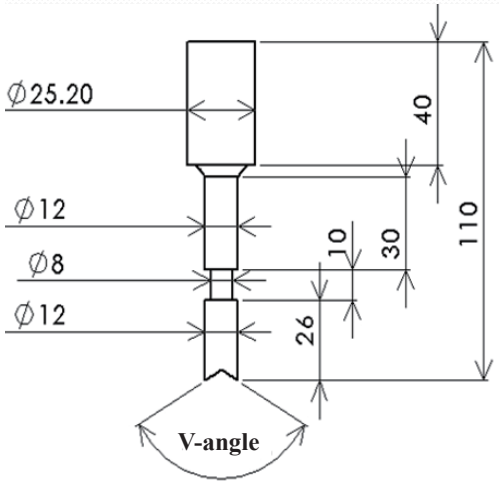


In order to avoid passing through the rear end was made thicker.
In order to increase the pull-out strength, the shaft part of the tip has a narrow section.

Metal anchors with V-groove

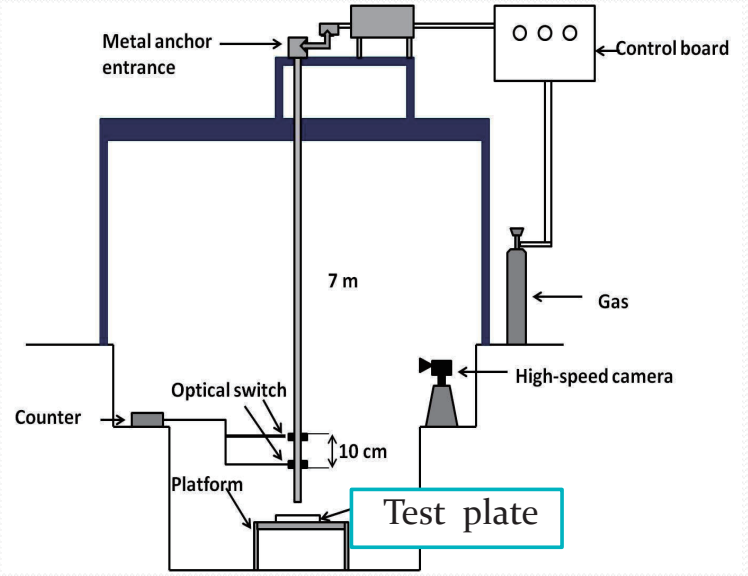


Photographs of metal anchors with V-goove
(Angel of V-groove 120, 90, 60 [deg])
Material: SS400, Mass: 215-218 g



Shape of metal anchor

Experimental equipment for fixed test plate



Overview

Appearance

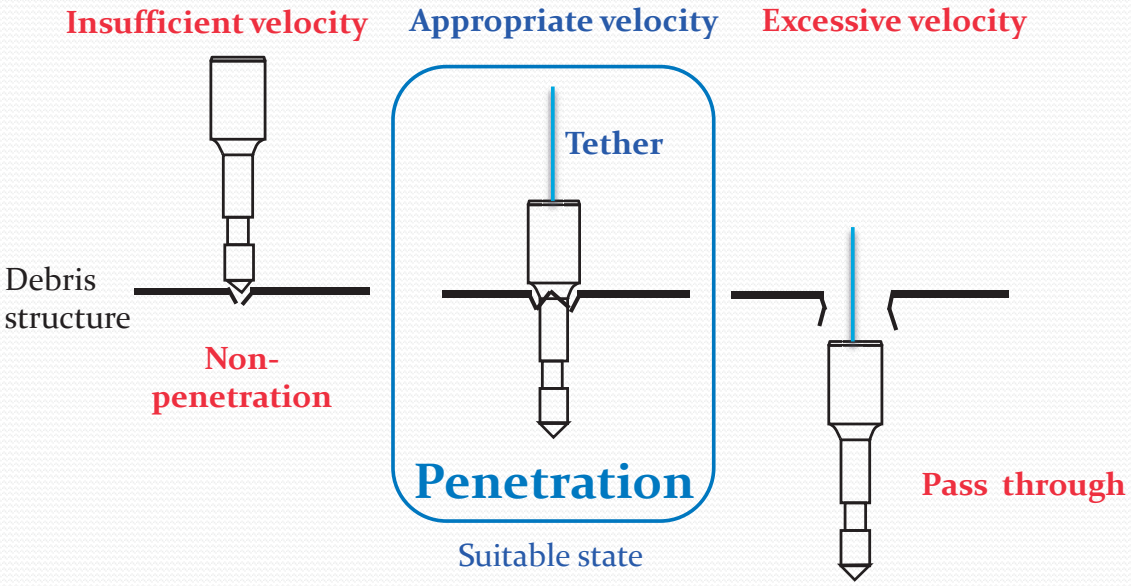
Specimen

- **Material: Aluminum alloy 2024-T3**
- **Size: 250×250×1mm**

Specimen

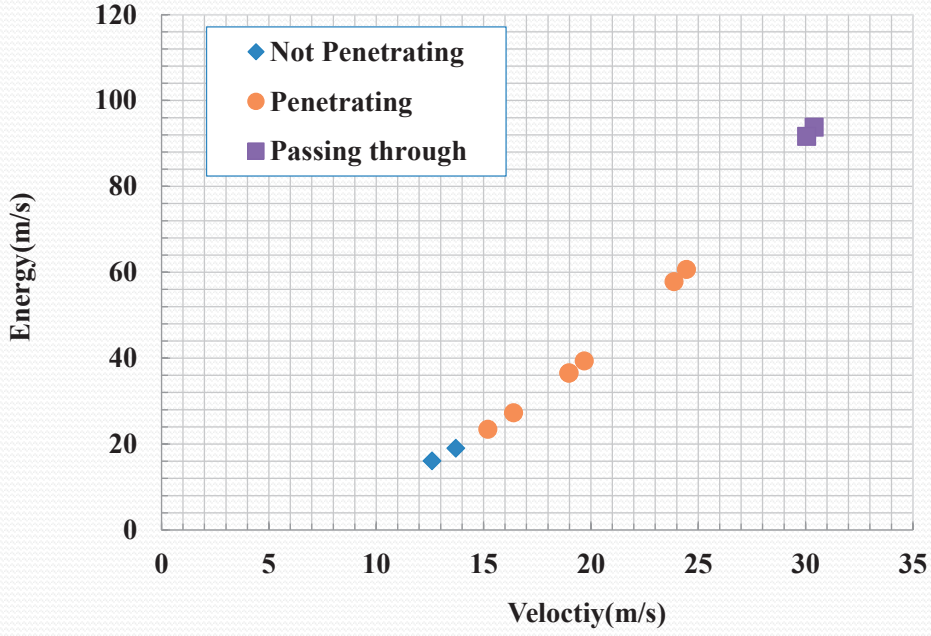
Fixture jigs

Docking states of metal anchor with cone shape head

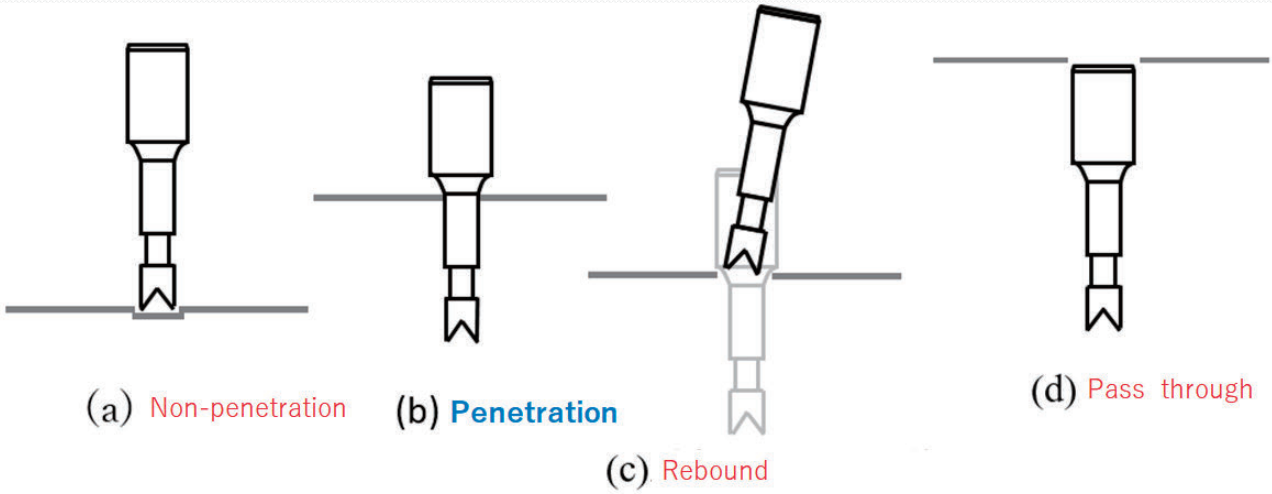


Projectile velocity and docking state

- metal anchor with cone shape head

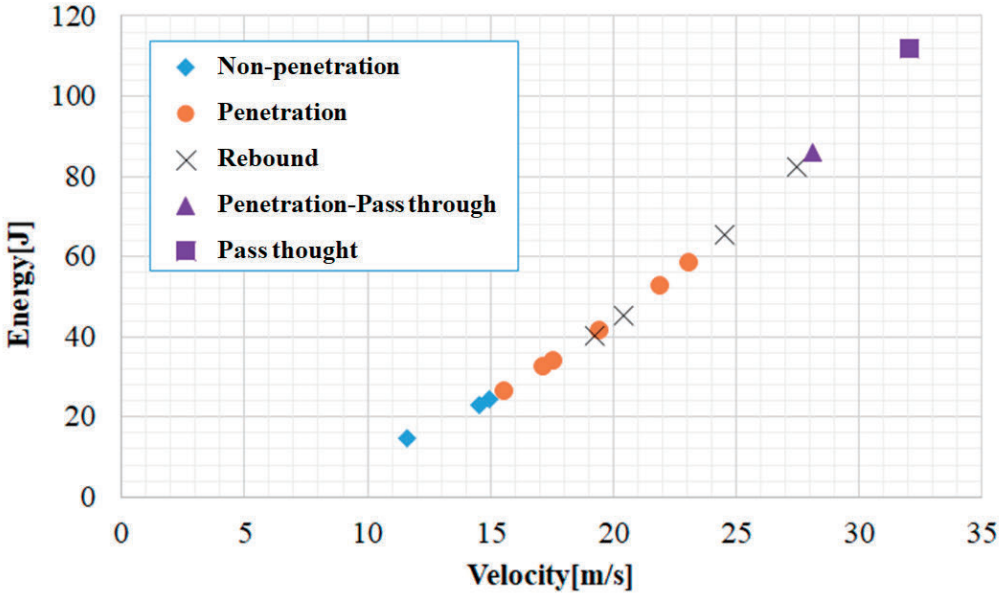


Docking states of metal anchor with V-groove



Projectile velocity and docking state

- metal anchor with V-groove



Comparison of the penetration hole

Metal anchor with V-groove

Velocity: 21.1m/s

The sufficient tensile strength for a tether system to remove space debris is not obtained.

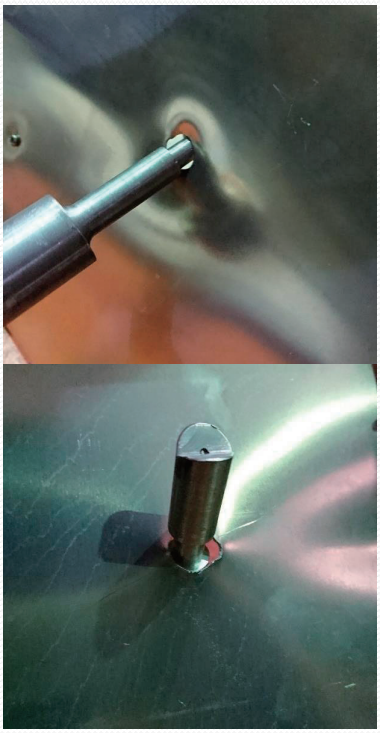
Metal anchor with cone head

Velocity : 22.5m/s

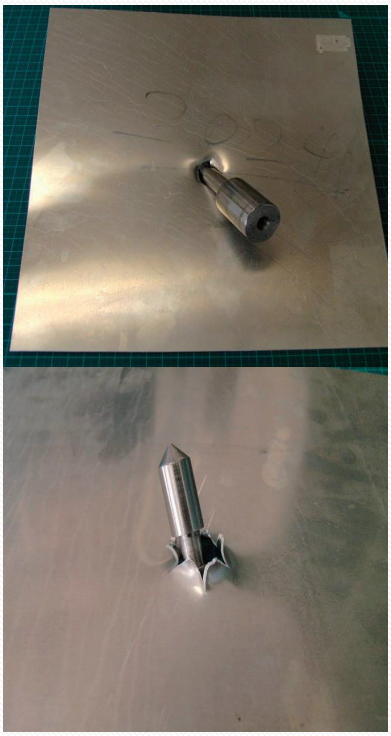
The metal anchor penetrates into the structure in the form of tearing with petal shapes

Comparison of the penetration state

Metal anchor with V-groove

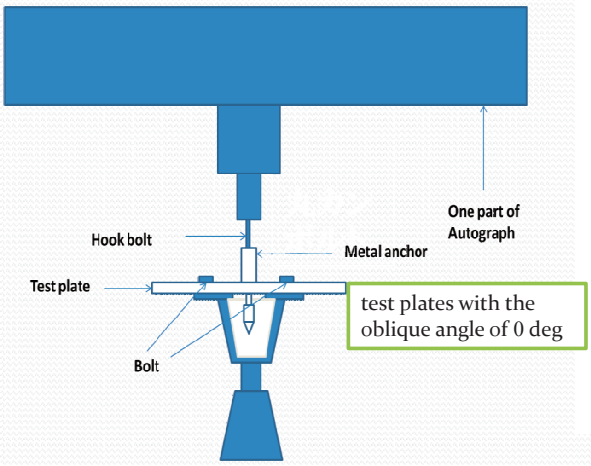


Metal anchor with cone head

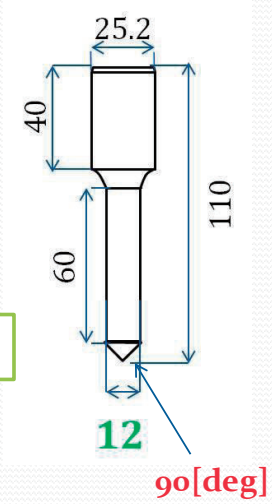


Pull-out experiment equipment

Appearance of Equipment (ShimazuAG-250kN)



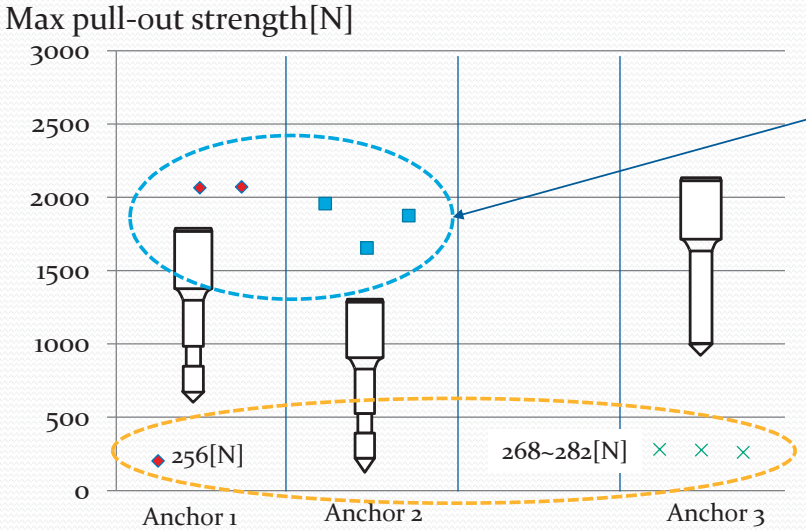
Overview of pull-out experiment

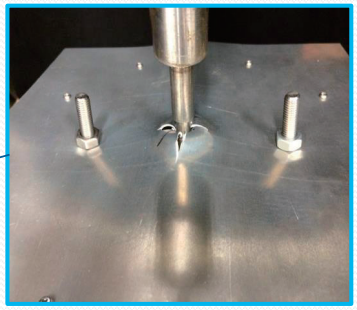


Overview of anchor 3

Confirm the effect of the narrow section of the metal anchor's shaft part on the pull-out strength

Pull-out experiment result





Comparison of the minimum penetration velocities

Metal anchor with V-groove

Angle[deg]	velocity [m/s]	Kinematic energy [J]
60	19.6	41.3
90	16.0	27.7
120	15.6	26.4

Metal anchor with cone shape head

Angle[deg]	velocity [m/s]	Kinematic energy [J]
60	18.5	35.0
90	19.0	36.5

Penetration states are obtained by smaller velocities by using the metal anchors with v-groove than those with cone shape heads.

Conclusion

- Experiments on capturing using metal anchors with cone shape heads and V-groove have been carried out and the results were compared.
- It was observed from the experimental results that minimum penetration velocity of the metal anchor with V-groove was lower than that of the cone shape head and it indicates that the required kinematic energy for capturing can decrease.
- The pulling strength using the metal anchor with V-groove head was very small and it is difficult to achieve an appropriate capturing state.
  - Some mechanisms will be required of these anchors for capturing space debris.