C16

ADR 用銛機構の性能向上に向けた日本刀技術導入の検討

A Study on Improving Performance of Harpoon Mechanisms in ADR Using Japanese Sword Technologies

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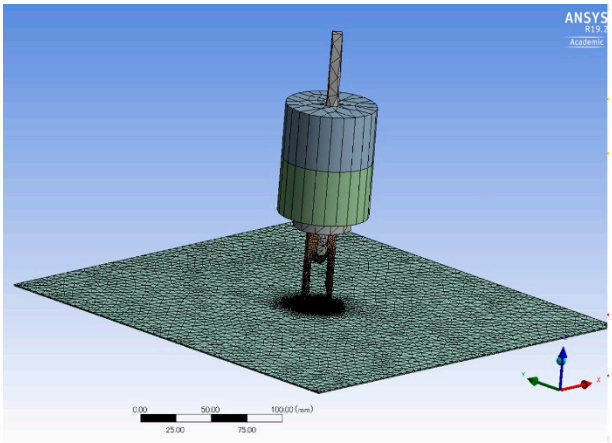
著者らの研究グループは、これまで、始原天体の表層サンプリング装置の貫入性能を高めるために日本刀技術を応用することを試み、実験的検討を中心に様々な研究を実施してきた。それらの知見を活かし、近年は日本刀技術を能動的デブリ処理(ADR)における銛機構の性能向上に役立てるための検討を始めている。この研究は、特に、シンプルな構造を保ちつつ、ターゲットとなる衛星表面の薄板構造をより小さな力学的条件で貫通させることができる銛機構の開発を目指すものである。
日本刀技術は、日本古来より対象物を効率よく切断または貫通するために高められてきた伝統技術で、1000 年以上の歴史を持つ非常に枯れた技術とみなすことができる。日本刀技術は主に「作刀技術」と「操刀技術」からなり、それぞれ多くの技術要素から構成される。本発表では、日本刀技術の特長やこれまでの取り組み状況などを紹介する。

Traditional Japanese sword smithing has become a mature technology in Japan, one that has been refined since antiquity to cut or pierce an object as efficiently as possible.
Japanese sword smithing has a history of more than 1000 years, including a rich, progressive improvement of refining techniques, and their effectiveness has been furthered by centuries of enhancing the finesse of the operating of a sword.
Against that background, the authors have been conducting research on applicability of traditional Japanese sword technologies to enhance penetration power of sampling device for the surface layer of minor planets. Also, based on these researches, improving performance of the harpoon mechanisms in active debris removal (ADR) was investigated of experiments and finite element method (FEM). The objective of this research is to develop a harpoon that can penetrate the thin-gauge structure of a target satellite's surface. Another objective is maintaining reliability of the harpoon mechanism while seeking a simple and effective design.
In this presentation, some features of Japanese sword technologies and the status of their research activities are shown.



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ADR用銛機構の性能向上に向けた日本刀技術導入の検討

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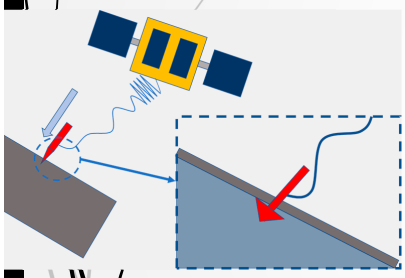
Application of Japanese Sword Technology
日本刀技術の応用

2



Debris Capture Technology by Harpoon Mechanism
(Penetration and Coupling into Aluminum Plate)
銛機構によるデブリ捕獲技術(アルミ板に対する貫入と結合)

⇩

Simple structure and mechanism
シンプルな構造、機構
Controllability of secondary debris
二次デブリの抑制
Reduction of mechanical conditions required for penetration
貫入に要する力学的条件の低減

⇩

Application of Japanese Sword Technology
日本刀技術の応用

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Background

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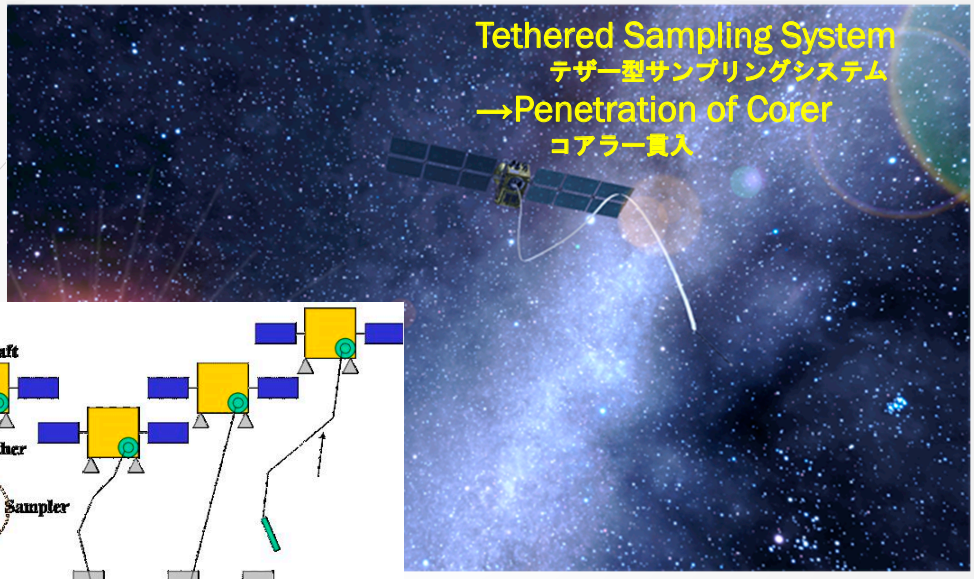

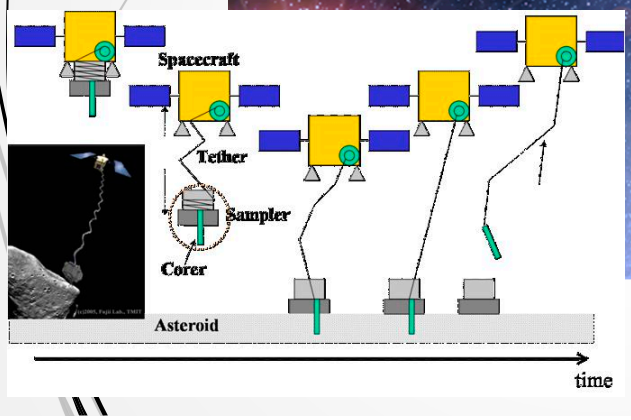

Background

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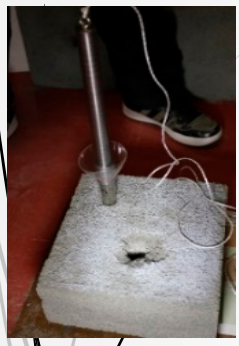
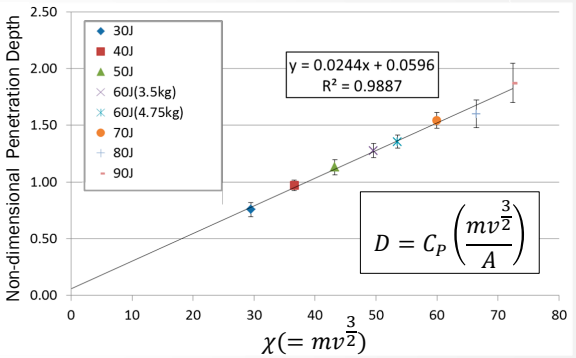
Penetration of Corer
コアラー貫入性能





- Penetration Test for Light weight concrete
  軽量コンクリートに対する貫入実験
- Sharpening the tip to enhance penetration performance
  >> Japanese Sword Technology
  貫入性能向上のために、先端を鋭く加工→日本刀技術の応用

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Background

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Japanese Sword Technology
日本刀技術

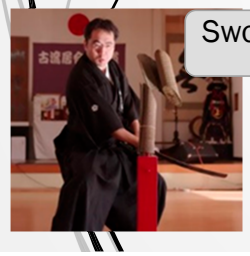
Japanese Sword Technology
日本刀技術

Sword Smithing
作刀技術

- Materials 素材
- Shaping 形状
- Heat Treatments 熱処理
- Sharpening 研ぎ

Sword Operating
操刀技術

- Power Transmission 手の内
- Control 刃筋
- Safety 鞘引き



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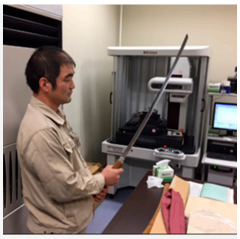

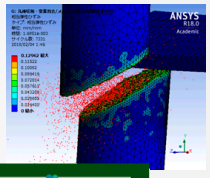

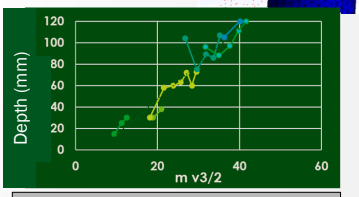

$$D = C_P \frac{mv^{\frac{3}{2}}}{A}, \quad C_P = C_{P0} - a\alpha$$

Background

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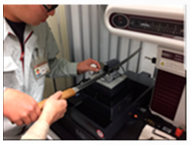
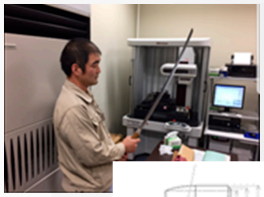
Sword Smithing 作刀技術

- The four elements: material, shape, heat treatment, sharpening
  素材、形状、熱処理、研ぎ

Material: “TAMA-HAGANE”,
素材：玉鋼





Shape: taking measurements from a Japanese sword and design
形状：真剣からの採寸・設計

Heat treatment
熱処理：焼き入れ

Sharpening
研ぎ

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Background

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Measurement and analysis equipment, Examples of measurement

測定・分析装置、測定例

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AUTOMATED MULTIPURPOSE X-RAY DIFFRACTOMETER
全自動多目的X線回折装置
SmartLab

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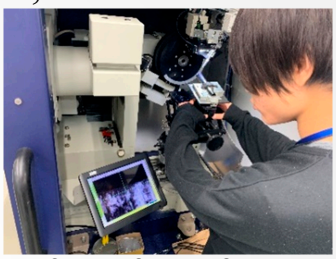
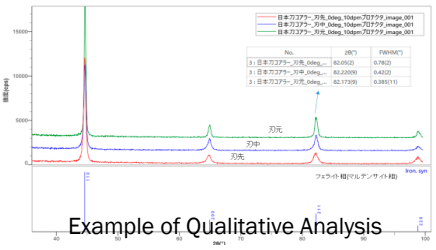
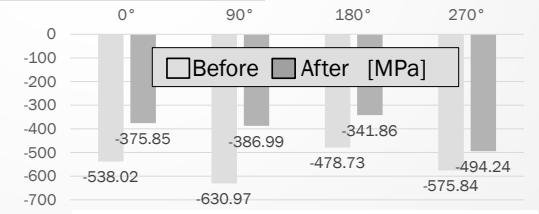
MICRO-AREA X-RAY RESIDUAL STRESS MEASUREMENT SYSTEM
微小部X線応力測定装置
AutoMATE Ⅱ



Device Quality Control Considerations through Scientific Analysis
Supported by Rigaku Corporation
各種科学的分析によるデバイスの品質管理を検討
協力：株式会社リガク



Example of Qualitative Analysis



Example of Residual Stress Measurements

Background

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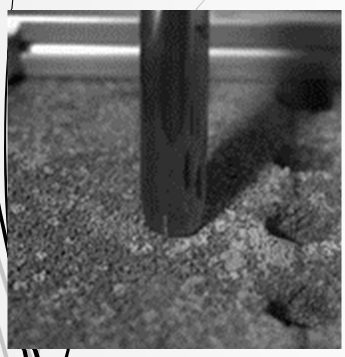
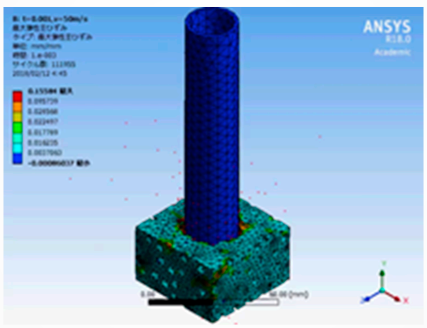
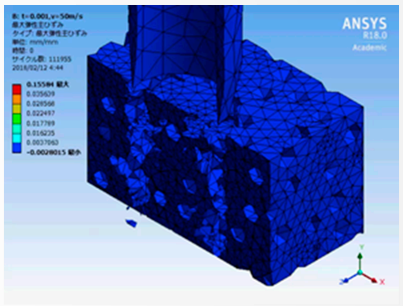
Penetration of Corer (Experiment / FEM)

コアラー貫入解析（実験／有限要素法解析）







Examples of Drop Weight Experiment and FEM Analysis
落錘実験とFEM解析

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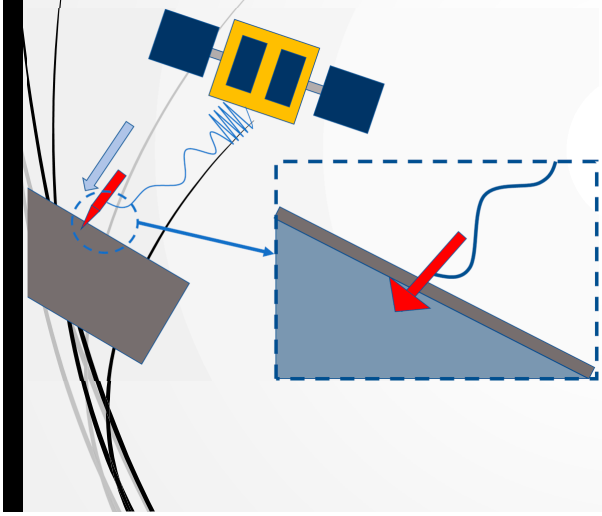
Application to Harpoon Mechanisms
銛への応用



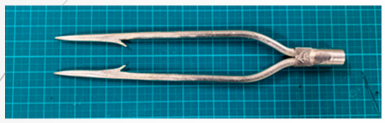
Key elements of harpoon technology:
Penetration performance and combining
銛技術の主要要素：貫入性能＋結合性能

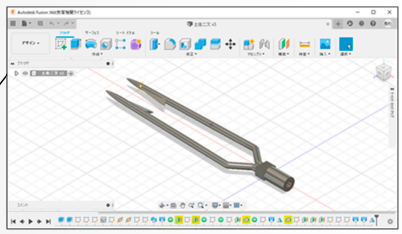
>>Control of Penetration and Fracture in Thin Plate Structures
>>薄板構造への貫入と破壊のコントロール

>>Combining by barb mechanism
>>カエシによる結合

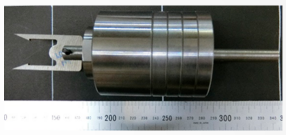
10

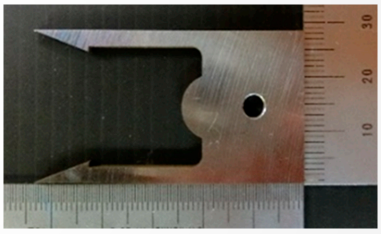
TOSA-Futamata
土佐二又銛





Traditional Japanese harpoon tips
(TOSA-Futamata: biforked harpoon)
伝統的な二又銛（土佐二又銛）





An experimental model adapted to a metal plate
金属板からの切り出し加工

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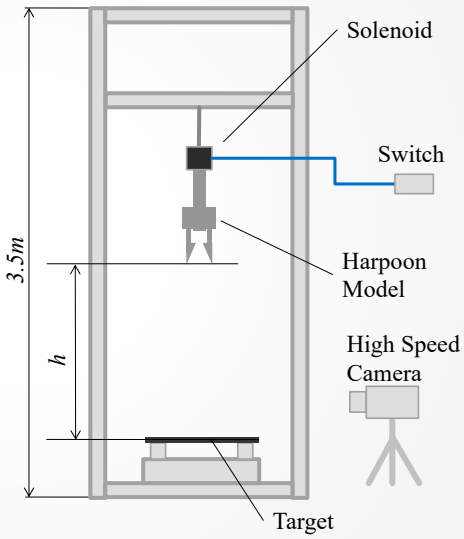
Drop Test System
3.5m級落錘式試験機



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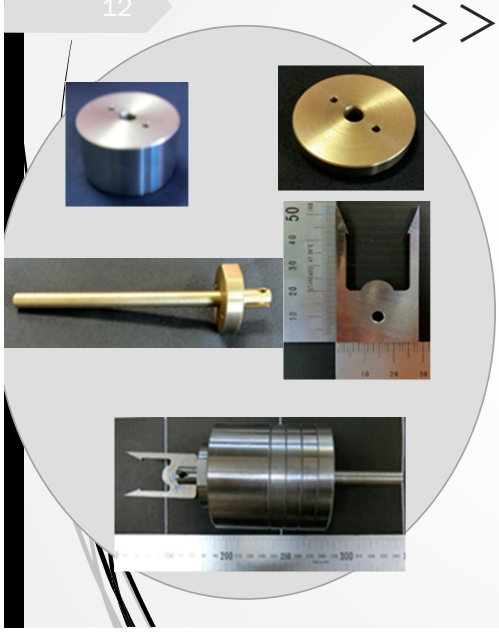
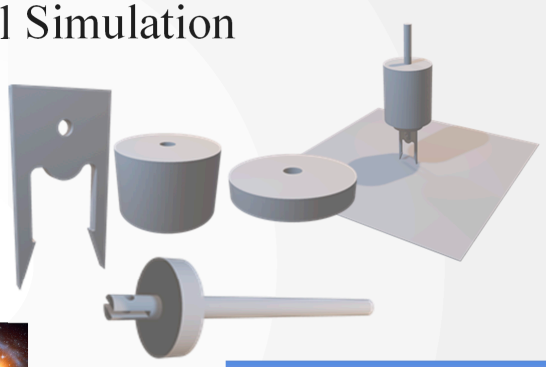
Experimental Equipment / 3D Models
＞＞Numerical Simulation

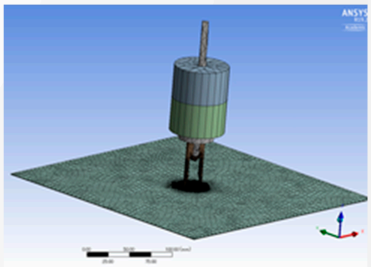




CATIA

AUTODESK® FUSION 360™

ANSYS



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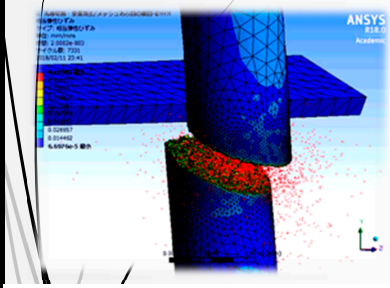
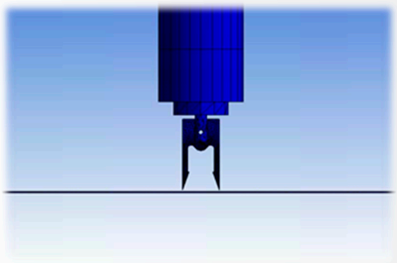
Simulation of Harpoon Penetration



Simulation of Cutting with the Japanese Sword
日本刀で藁を切断時の数値解析

Biforked Harpoon models
二又銛モデル



Simulation of Harpoon Penetration
銛貫入のシミュレーション

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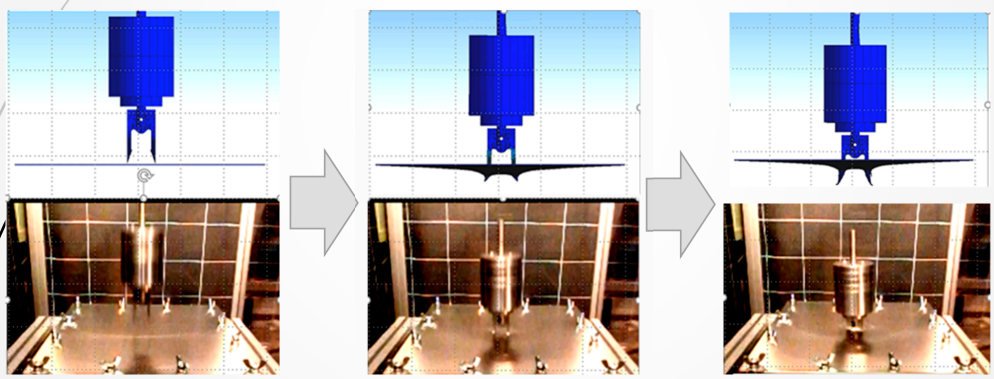
Biforked Harpoon Test Results and Simulations

m：2.2[kg]　　h：1.56[m]（34.3[J]）



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Conclusions and Future Works

- Activities to apply Japanese sword technology to improve the penetration performance of debris catching harpoons are presented

  デブリ捕獲用銛の貫入性能を高めるために、日本刀技術の導入を検討

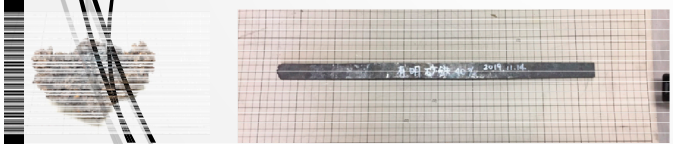
- Introduction to sword smithing and sword operating techniques

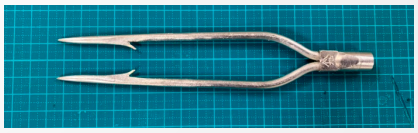
  作刀技術と操刀技術について紹介

- Exemplify the results of experiments and numerical simulations with basic models

  基礎的なモデルを用いた実験と数値シミュレーションの結果を例示

- Prototyping of the experimental model using Sword smithing technology
- **作刀技術による実験モデルの試作と実験の準備**





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Kenshiro Okui（**奥井謙志郎**）, Ayana Ohyama（**大山綾菜**）,

and Keita Itagaki（**板垣慶太**）

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