2024 年 11 月 29 日

2023 年度 永守財団 研究助成 研究報告書

所 属 機 関	早稲田大学 次世代ロボット研究機構
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1. 研究題目

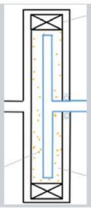
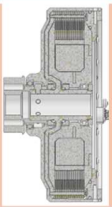
NICEBOT―安全で人にやさしいロボットの開発

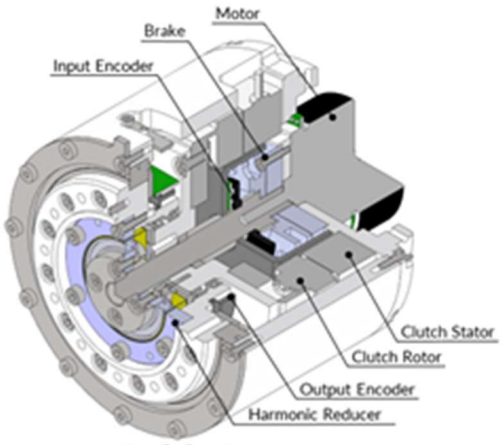
2. 研究目的

Nicebot is a robot arm equipped with special actuators: clutches are connected in series with the motors. The clutches act as adjustable torque limiters and make the robot arm extremely safe in case of impacts. The arm is also easy to move by hand, which can be used for direct teaching. Previous versions of the arm included friction clutches, which had benefits such as high torque-to-weight ratio. However, the friction clutches have a limited slip lifetime. For most applications the friction clutches are sufficient, but for certain applications the limited slip lifetime is a limitation. The next version of the robot could also use specifically designed magnetorheological fluid (MRF) clutches, which do not have these limitation. Furthermore, we will implement advanced control methods, for example for teleoperation, surgical applications and human-robot collaboration.

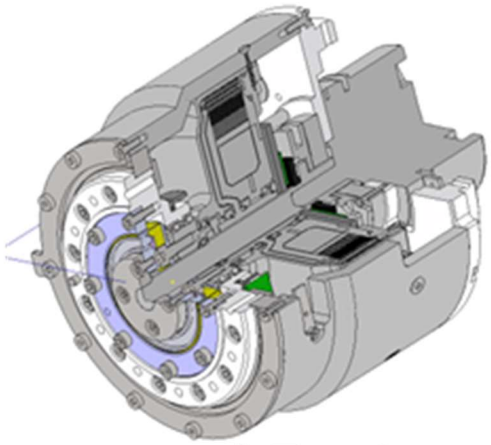
3. 研究内容及び成果

A. Design of series clutch actuators with novel MRF clutches
Together with partners we designed MRF clutches with an unprecedented torque-to-weight ratio. At the same time, they have a compact form factor. The clutch has been implemented into a prototype series clutch actuator and tested. In our tests we confirmed the torque controllability and stability.
B. Implementation of MRF clutches in robot arm
MRF clutches have a different form factor to friction clutches, which made a redesign of Nicebot necessary. However, the updated version of Nicebot has again roughly the same length, kinematic structure, payload, degrees of freedom and workspace as the previous robot.
C. Implementation of basic control functions
As with the previous iterations of Nicebot, we implemented again safety, direct teaching and force control.
D. Advanced control functions
To demonstrate the advanced features of Nicebot, we will use Nicebot for applications such as teleoperation, surgical applications and human-robot collaboration. This is ongoing.

シリーズクラッチアクチュエーター	単一円盤SCA			多重円盤SCA
				
トルク制御装置	磁性粒子クラッチ	磁気粘性流体(MRF)クラッチ	摩擦クラッチ(独自開発)	多重円盤式磁気粘性流体(Muti-Disk-MRF)クラッチ
トルク/重量 [Nm/kg]	8	15	29	42
備考欄	• 市販品 • 低トルク重量比 • 短寿命	• 市販品 • 低トルク重量比 • 長寿命	• NICEBOT-5 • NICEBOT-7	• 長寿命 • 高トルク重量比 • NICEBOT-8

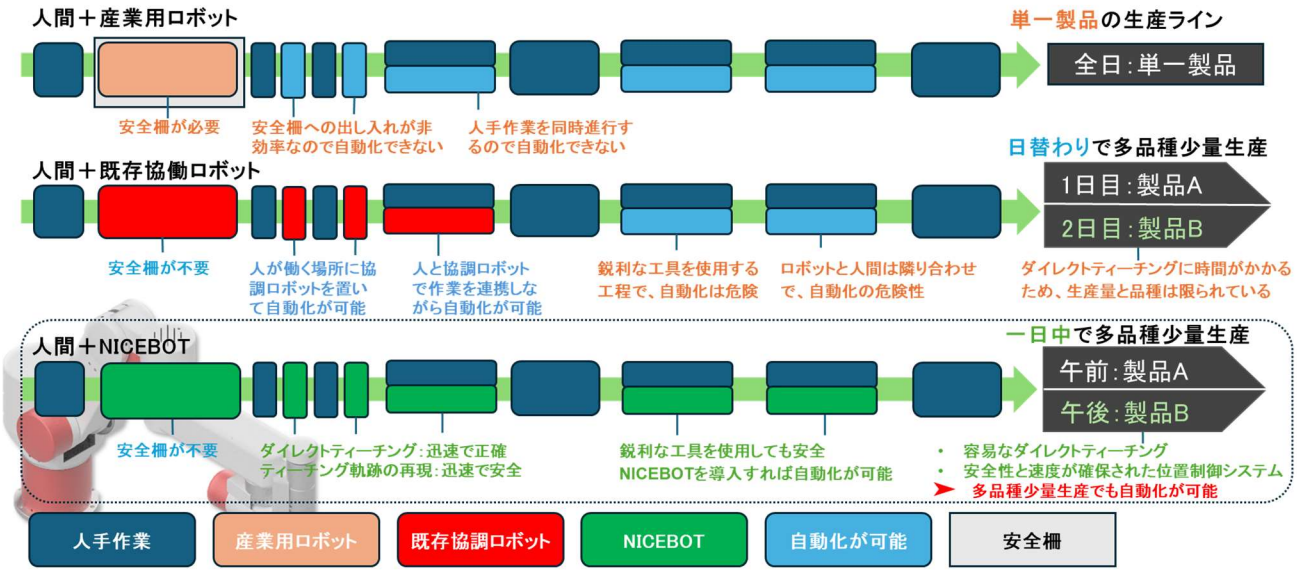


摩擦クラッチ


MRFクラッチ

4. 今後の研究の見通し

The work on advanced control functions is ongoing. For example, for teleoperation and surgical applications, we will use two Nicebots: one on the operator side will provide force feedback to the operator; the teleoperated Nicebot will use its torque-limiting function to guarantee safety.



5. 助成研究による主な発表論文，著書名

Muhammad Arifin, Yuta Kage, Yuchen Yang, Alexander Schmitz, Shigeki Sugano, “A Combination of a Controllable Clutch and an Oscillating Slider Crank Mechanism for Ease of Direct-Teaching with Various Payloads”, ICRA 2024