Fluid Power Transmission & Intelligent Control Technical Seminar 2019 Keynote, Taiwan

Current Status of Pneumatic Industry and New Technology in Japan

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Okayama

Today's Topics

1. Introduction of Okayama and OUS
2. Current Status of Pneumatic Industry
3. Some New Technologies in Japan
4. Our Research Projects

Attention:
In the presentation, there are some slides which don't appear in this handout.
部分投影片不會出現在資料中

Okayama Castle and Korakuen Garden

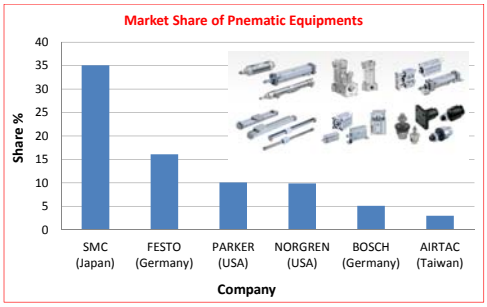
Okayama University of Science

Established in 1964
Private university
6,586 students
(207 graduate students)
392 faculties
(196 full professors)
2019.5.1

Faculty of
Science (7 departments)
Engineering (7 departments and 1 course)
Informatics (1 department)
Biosphere-Geosphere Science (1 department)
Education (2 departments)
Management (1 department)
Veterinary Medicine (2 departments)

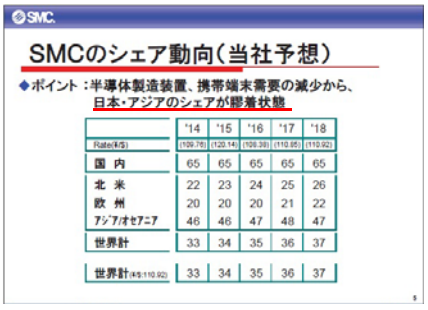
Current Status of Pneumatic Industry

- Market Share of Pneumatic Equipments in the world -



Current Status of Pneumatic Industry

- Case of SMC Corporation -


SMC

SMCのシェア動向(当社予想)

◆ポイント:半導体製造装置、携帯端末需要の減少から、日本・アジアのシェアが膠着状態

	'14	'15	'16	'17	'18
Rate(¥/$)	(109.76)	(120.14)	(108.38)	(110.85)	(110.92)
国内	65	65	65	65	65
北米	22	23	24	25	26
欧州	20	20	20	21	22
アジア/オセアニア	46	46	47	48	47
世界計	33	34	35	36	37
世界計(¥/$:110.92)	33	34	35	36	37

2019年5月17日開催「2019年3月期決算説明会」資料より

Current Status of Pneumatic Industry

- Case of SMC Corporation -

SMC

空気圧需要の環境

☆ 貿易摩擦、
技術覇権も絡んで激化！

【留意点】

【1】グローバルベースでの競争多元化
新たな生産拠点立地、新市場、流通業態

【2】IoT化、スマートファクトリー化、クラウド化への流れ
サーバーのFlash化、通信5G革命

【3】環境対応の要請
自動車EV化への流れ、省エネ・省資源・省スペース

2019年5月17日開催「2019年3月期決算説明会」資料より

Current Status of Pneumatic Industry

- Case of SMC Corporation -

SMC

'19年度重点施策

☆ 先進国の少子化・労働力不足を背景に
今後とも空気圧機器の成長を見込む！

【1】安定地域での生産拠点立地とグローバル供給網強化を加速

【2】アジア巨大市場を中心に営業活動を強化

【3】製 - 販 - 技 グループ間グローバル連携、
その為の情報ネットの強化

【4】環境対応の適正な品質・価格商品を市場へ提案

2019年5月17日開催「2019年3月期決算説明会」資料より

Current Status of Pneumatic Industry

- Case of SMC Corporation -

SMC

サマリー

【1】空気圧機器は製造業のキーデバイスとして今後とも安定した成長が見込まれます。

【2】激化するグローバル競争に対し、更なる体質強化を進めます。
・製 - 販 - 技の機動力発揮、合理化、コストダウンを徹底
・将来に向けた新製品、設備、研究、人への投資

【3】安定かつ適正な『株主様還元』に注力してまいります。
コーポレートガバナンス体制に留意し、業績拡大を通して企業価値を高め、社会へ貢献することが投資家の皆様にお応えすることと考えております。

2019年5月17日開催「2019年3月期決算説明会」資料より

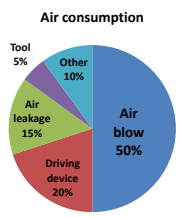
Example of Current Technical Report

ピーク圧を利用したエアブローとインパクトブローガンの紹介

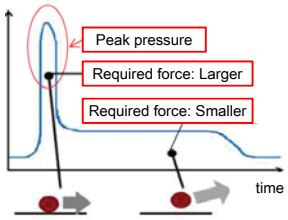
○大島雅之*, 佐々木博章*

Air blow utilizing peak pressure and Introduction of Impact blow gun

Masayuki OSHIMA*, Hiroaki SASAKI*

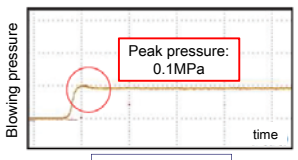


Air consumption in a factory

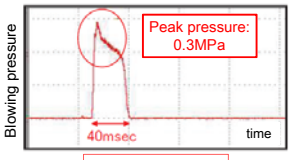


Required force to move an object

Example of Current Technical Report



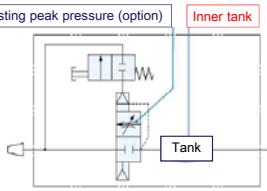
Conventional blow



Improved blow gun

Adjusting peak pressure (option)

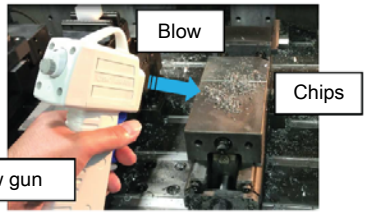
Inner tank



By using an inner tank, the blowing pressure is not influenced by the pressure loss in a primary-side pipe.

Pneumatic circuit of blow gun

Example of Current Technical Report



Experiment by improved blow gun

	Air consumption	Working time
Conventional	17 litter	5 seconds
Improved (%)	2.5 (-85%)	0.5 (-90%)

Supply pressure: 0.5MPa

Some New Technologies in Japan

1. Pneumatic Surgical System

being developed by
Prof. Kenji Kawashima(Tokyo Medical and Dental University) et al.

2. Science of Soft Robot

being studied by
Prof. Koichi Suzumori (Tokyo Institute of Technology) and 35 researchers

Pneumatic Surgical System

Popular 'da Vinci surgical system' (Master-slave control system)

Problems:
At present, an operator performs a surgery based on only sight information from the endoscope image. → Operation becomes more difficult.

Solutions:
Next step, we need a 'Force feedback system (Bilateral control system)'.

Pneumatic Surgical System

How to realize a 'Bilateral control system'?

If we adopt an Electric System, we need a motor with high reduction gear, which has no back-drivability.

We need a contact force sensor at the forceps tip. However, this is not suitable from the view points of miniaturization, sterilization (滅菌), calibration, cost and noise from electric knife.

On the other hand, when we use a Direct Drive motor (DD motor) which the contact force can be estimated by using back-drivability. However, we need a large-sized motor to get sufficient torque. This is also not suitable.

Pneumatic System

What is Back-drivability ?

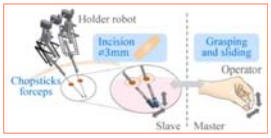

Forceps


DD motor

Pneumatic Surgical System

Comparison between Electric System and Pneumatic System

	Electric System	Pneumatic System
Actuator	Electric motor	Pneumatic cylinder
	With high reduction gear → No back-drivability	No reduction gear → Back-drivability
Force sensor at the forceps tip	Necessary	Not necessary (estimated by cylinder pressure)
Size and weight	Large and heavy	Compact and lightweight
Total cost	Expensive	Not so expensive (1/3〜1/2)

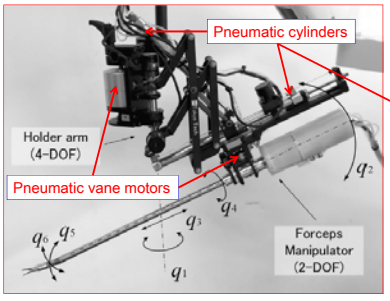


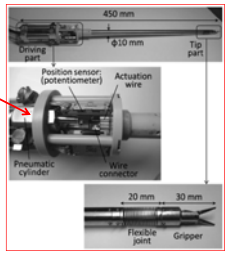
Pneumatic Surgical System

We are developing a surgery robot for a laparoscopic surgery (腹腔鏡手術).

By Tokyo Tech Research

Pneumatic Surgical System





Detail of forceps manipulator

Pneumatic driving system with 6 cylinders and 2 pneumatic vane motors: a holder arm with 4-DOF, a forceps manipulator with 2-DOF

Pneumatic Surgical System

We have achieved to make the system compact by adopting a pneumatic driving system.

By Tokyo Tech Research

Pneumatic Surgical System

We can control the position of the forceps tip with the accuracy of 0.1 mm.

By Tokyo Tech Research

Pneumatic Surgical System

We can estimate the contact force with the accuracy of 0.2 N.

By Tokyo Tech Research

Pneumatic surgery system

How to realize a bilateral control ? (more detail, more academic)

Kenji Kawashima et al., 'Development of a Master Slave Integrated Robotic Forceps with Pneumatic Actuator', Proc. of the 10th JFPS International Symposium on Fluid Power, 2017.10

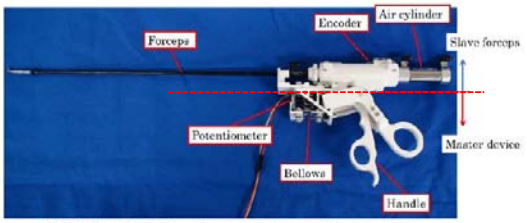


FIGURE 1. Master slave type robotic forceps with pneumatic actuators

Outline of master slave control:

1. The forceps (slave) can be driven by a pneumatic cylinder.
2. The grasping torque of forceps tip can be estimated by the values of the cylinder pressure and cylinder displacement.
3. The handle (master) is driven by an operator, and its opening angle can be measured by a potentiometer.
4. The grasping torque is displayed to the operator (forced to his/her fingers) with pneumatic bellows and the estimated grasping torque.

Grasping torque

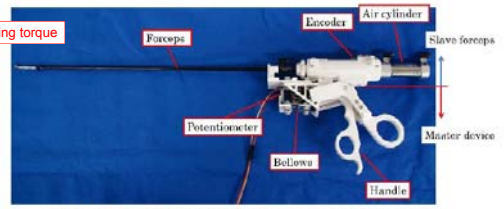


FIGURE 1. Master slave type robotic forceps with pneumatic actuators

Pneumatic circuit

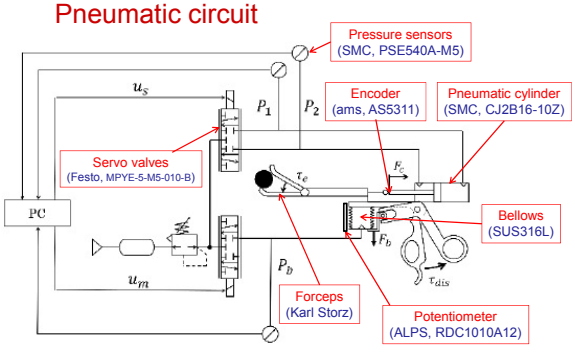


FIGURE 2. Pneumatic circuit of the robotic forceps

Whole bilateral control system

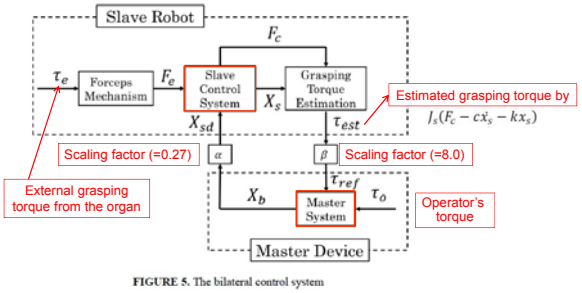


FIGURE 5. The bilateral control system

If the forceps tip grasps the organ, the external force Fe, which is the grasping force, is transformed to exert on the pneumatic cylinder. The slave robot estimates the grasping torque with the equation $J_s(F_c - cx_s^{\cdot} - kx_s)$.

Experimental results

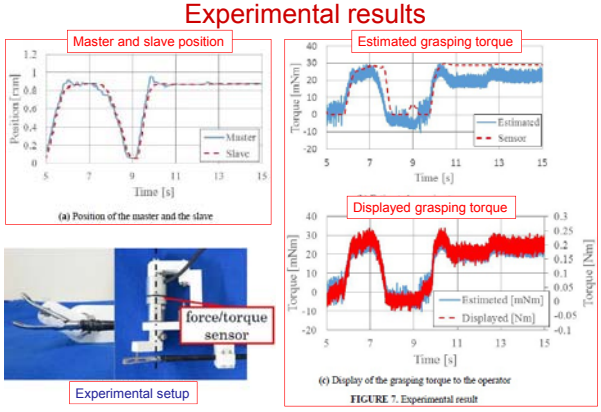


FIGURE 7. Experimental result

Pneumatic Surgical System

EMARO (Endscope Manipulate Robot) driven pneumatically which was develped and sold by the group of Tokyo Medical and Dental University, Tokyo Institute of Technology, Riverfield Inc. and Toray Engineering Co. Ltd.

Project of "Science of Soft Robots"

しなやかな身体、しなやかな動き、しなやかな知能

By http://softrobot.jp/

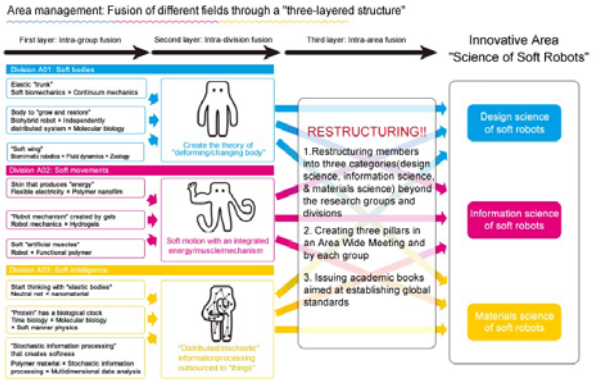
Science of Soft Robots

Since the dawn of history, advances in science and technology have pursued "power" and "accuracy." Initially, "hardness" in machines and materials was sought for reliable operations. In recent years, biological systems oriented toward "softness" have emerged simultaneously in diverse fields, including machinery, electronics, information processing, and materials science. This is not just a coincidence. In particular, there is a growing trend toward biomedical/human-centered science and technology.

2001–2014
Prof. at Okayama University
2014–present
Prof. at Tokyo Institute of Technology

Area manager: Professor Koichi Suzumori

p://softrobot.jp/



Science of Soft Robots

Image of future development / growth

Soft artifacts
ソフト人工物

Infrastructure of welfare / society
福祉・社会インフラ

Coexistence of caring / human
介護・人間共存

Research Interests

1972- Fluidics - Wall Attachment Fluidic Device

1986- Photo-Fluidic Interface and its application

2003- Pneumatic control component and Mechatronic system

Flexible pneumatic actuators, Wearable control valves, Flexible displacement sensors, their applications to robotic systems and rehabilitation devices

Pneumatic actuator has many advantages; high power ratio, compliance based on air compressibility, clean, light-weight and so on.

Flexible Pneumatic Actuator

Popular metal cylinder

The actuators required for a power assisted device and a rehabilitation device need to be flexible so as not to injure the human body.

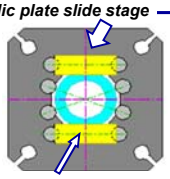
Flexible pneumatic cylinder

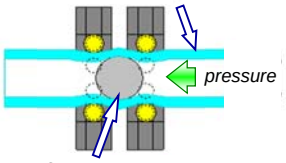
Motion when the stepwise pressure is applied to the cylinder. The tube is pushed and moving when the slide stage is fixed.

Flexible Pneumatic Cylinder
– Single ball type –

As a slide stage
Acrylic plate slide stage

As a cylinder & gasket
Flexible tube





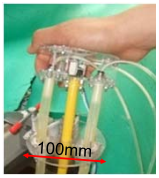
Brass roller(φ4mm) ×2
Set on the inner bore of the stage to press & deform the tube

Steel ball(φ9mm)
As a cylinder head

The operating principle:

When a supply pressure is applied to one side of the cylinder, the inner steel ball is pushed. And they push the rollers and move the slide stage. When the slide stage is fixed, the tube is pushed.

Applications of Flexible Pneumatic Cylinder
- Robot Arm and Spherical Actuator -

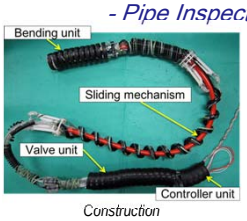


Robot arm

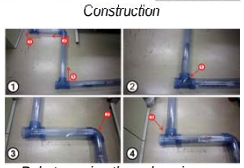
Spherical actuator

	Robot arm	Spherical actuator
Size	φ100×300 mm	φ160×170 mm
Mass	380 g	300 g
D.O.F	3	2
Bending, Expanding	45°, 160 mm	120°, 0 mm
Control	Need a model	Easier
How to use	Fixed on the table	Portable

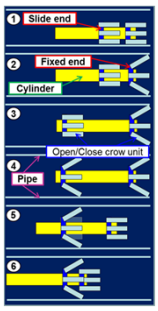
Applications of Flexible Pneumatic Cylinder
- Pipe Inspection Robot -



Construction

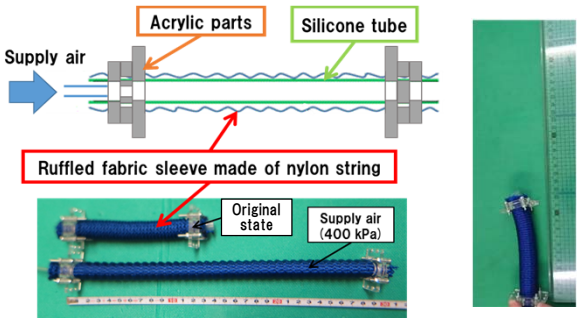


Robot passing through a pipe



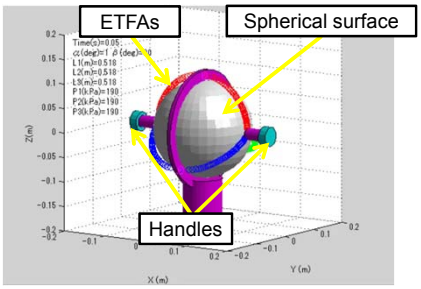
Operating principle

Extension Type Flexible Actuator (ETFA)



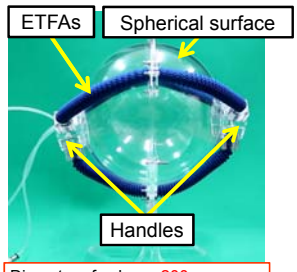
Application of ETFA
- Rehabilitation Device for Upper Arm -

Image video for development



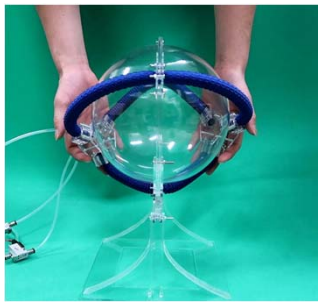
Application of ETFA
- Rehabilitation Device for Upper Arm -

Experiment by tested robot



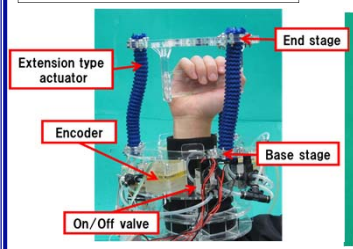
Diameter of sphere: 200 mm
Original length of ETFA: 170 mm

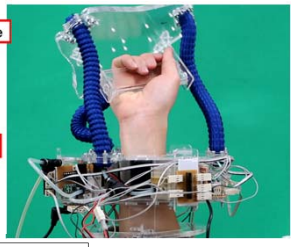
Movement



Applications of ETFA
- Rehabilitation Device for Wrist -

Experiment of tested device





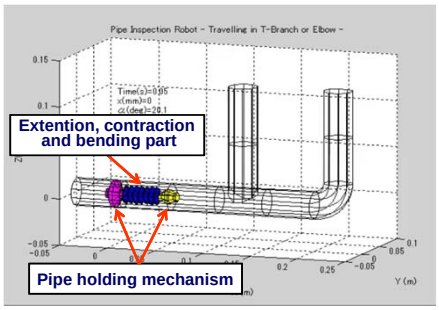
Construction

Outer diameter: 200 mm
Length: 260 mm
Mass: 1.4 kg

Movement

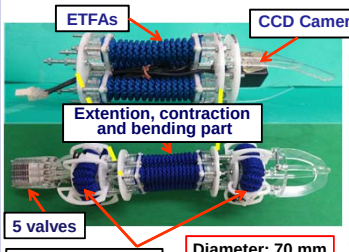
Application of ETFA
- Pipe Inspection Robot -

Image video for development



Application of ETFA
- Pipe Inspection Robot -

Experiment by tested robot

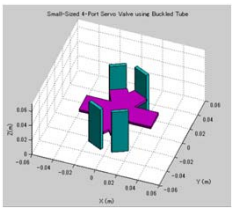


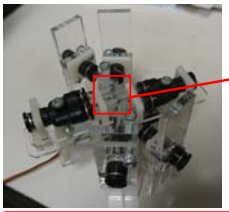
Movement

Diameter: 70 mm
Length: 300 mm
Mass: 0.43 kg

Small-sized Servo Valve using Buckled Tubes

Construction of 4-port servo valve



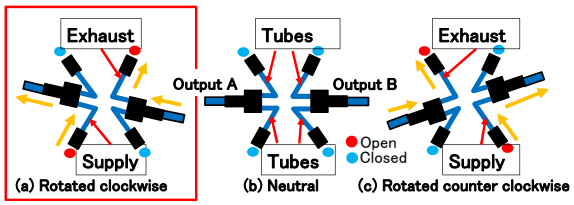


Buckled tube

Size :90 × 79 × 53 mm Mass : 73g

The valve consists of a RC servo motor, two Y-shaped one-touch connecters, four one-touch connecters, four buckled soft polyurethane tubes and a rotational disk with connecter holders.

Operating principle of 4-port servo valve



When the servo motor rotates clockwise,

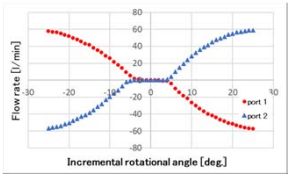
the bending angles of right side supply buckled tube and left side exhaust buckled tube are decreased. At the same time, the bending angles of left side supply buckled tube and right side exhaust buckled tube are increased.

Consequently,

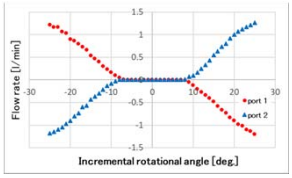
the fluid is supplied into output A, and the fluid is exhausted from output B.

Characteristics of 4-port servo valve

– Relation between rotational angle and flow rate –



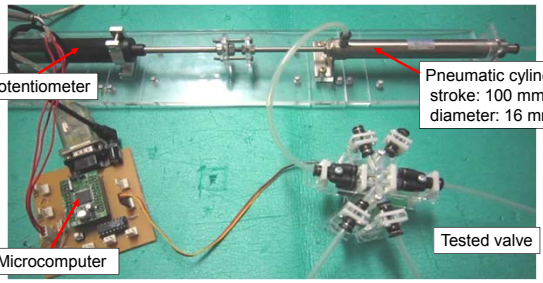
Working fluid: **Air**
Supply pressure : 500 kPa



Working fluid: **Tap water**
Supply pressure : 250 kPa

It is said that the tested valve can be used in both pneumatic and water hydraulic driving system as a servo valve.

Position control of a cylinder using tested valve



The position of the cylinder can be controlled by the tested valve.

Summary

1) ***Okayama** and **Okayama University of Science** are introduced with interest and humor.*
2) *Current status of **pneumatic industry** in Japan is explained briefly. Especially, the activity of **SMC Corp.** and an interesting idea are introduced.*
3) *As a **new technology** in Japan, two research projects are introduced. One is a **pneumatic surgical system** being developed by Prof. Kawashima at Tokyo Medical and Dental University et al. Another is '**Science of Soft Robot**' being studied by Prof. Suzumori and 35 researchers.*
4) *Our research projects are introduced. Especially, two types of **flexible pneumatic actuator** and a small-sized **servo valve** and their applications are explained.*

Please come to Okayama and OUS