KOREATRIZCON 2011, March 10-11, Dasan Hall, 18F, The Korea Economic Daily Building, Seoul, Korea

Engineering design education and TRIZ
- Experiences at Korea University -

March 2011

Kim, Kwon-Hee Prof.
Dept. Mech. Eng., Korea University

Design Courses in Mech. Eng. at Korea Univ.

Freshman	Sophomore		Junior		Senior	
2nd Term	1st Term	2nd Term	1st Term	2nd Term	1st Term	2nd Term
	Solid Mech. I	Solid Mech. II	Eng. Materials	Finite Element Method		Mech. Behavior of Materials
			Lab. I			
	Kinematics	Dynamics	Automatic Control	System Analysis	Microprocessor Programming	
			Vibration	Intro. Elect. Eng.	Robotics	
					Mechatronics	
	Manufacturing & Machine shop practice	Manufacturing & Machine shop practice		Computer Aided Design		Measurement
	Mechanical CAD	Mechanical CAD		Machine Element Design	Precision Engineering	Production Engineering
Design I		**Design II**	**Design IIIA**	**Design IIIB**	**Design IV**	**Research**
					MEMS	Optics
		Fluid Mech. I	Fluid Mech. II	Fluid Machinery	Bioengineering	Computational Fluid Mechanics
	Thermodynamics. I	Thermodynamics. II	Heat Transfer	Lab. II	Internal Combustion Engine	Applied Fluid Mechanics
				Refrigeration	Energy Engineering	Combustion
					Air Conditioning	Automotive Engineering
	Eng. Math. I	Eng. Math. II	CEO Lecture		Numerical Analysis	

Design I

- **For freshmen, 2nd semester, 1 credit unit**

- To foster motivation for engineering occupations.

  It is fun to find smart solutions to real problems!

- To convince each one's potential for creativity

  We are all creative!

Design II

- Sophomore, 2nd semester, 3 credit unit

- Introductory design course with standard industrial components.

- Design and build your own machine for competition under contest rules.

Design Competition

1996: Ping Pong Master	Collect and deliver ping pong balls
1997: Dead or Alive	Tug of war
1998: Stairway to Heaven	Overcoming stairways
1999: Never Down, Never Out	Robot Sumo
2002: Watch Out, Your Head!	Cap snatching
2003: Live and Let Die	Protect your balloons
2004: Die Another Day	Protect your balloons on a circle
2005: Pick'em and Run	Collecting tennis balls
2006: The Bridge over the Hell	Survive the competition on a shrinking platform
2007: Dance with the Flag	Grab the flag at the top of a stairway
2008: Pick up the balls	Collect the ping pong balls falling from above
2009: Ring the bells	Overcome the opponent and ring the bells
2010: Shoot them back	Send the golf balls back to the shooter's territory

Design IIIA/IIIB

- Junior, 1st & 2nd semester, 3 credit units
- Design of commercial products based on the customer needs
- Experience the product development process in industrial setting.

Scope of Activity

Topics change every year to maximize the creative potential of participants. Students experience a series of activities leading to the prototype design of commercial products such as

- Customer need identification
- Specifications
- Concept design
- Mockup modeling
- Analysis & Verification
- Prototype Design

Course Schedule

Week	Lectures	Practice
1	Schedules, creativity, brainstorming, case study, design note	
2	Teamwork & Meetings, Challenges, In-class Competition	Team launch, brainstorming
3	Customer Needs, Sketch Modeling	Idea Presentation
4	Patents and Intellectual Properties	Customer Needs Interview
5	Needs, Human Use & Function of Form	Sketch Modeling
6	Scheduling, Time Estimation, Specifications	Mock-up Modeling
7	Mock-up Review	Mock-up Modeling
8	Design Critique, Ethics, Product Architecture	Finalization of Team Design
9	Safety, System Engineering, Design for Assembly	Assembly Model & Specifications
10	In-Class Assembly Review	Prototyping
11-15	Technical Review, Debugging, Consulting Presentation Design, Product Development Economics, Marketing Examples	Prototyping, Final Presentation Practice, Final Peer Review
16	Final Design Competition	Lab Clean-up

Key Issues

- **Understanding the customers**
  the most important part leading to success

- **Accurate problem definition**
  outweighs all the following efforts

- **Creativity Tools**
  TRIZ, Biomimetics, Brainstorming

- **Engineering Tools**
  CAD/CAE, kinematics, structural analysis, design for assembly, materials and processing, robust design(Taguchi), etc.

- **Social Aspects**
  Patents, product liability, environment, recycling

Design IV

- Senior, 1st semester, 3 credit units
- Experience the product development process for business
- Understand entrepreneurship and learn how to convince your investors

Scope of Activity

Each team is to find business opportunities and experience a series of activities leading to the final business proposal to the investors. The activities include:

- Search for business opportunities
- Customer need identification
- Product design for business development
- Business proposal
- Presentation

Key Issues

- **Business opportunities**
  Look at the world in entrepreneurial perspectives
- **Design for business**
  Decide how to sell it before you design it
- **Understand monetary, real world issues**
  Finance, management, production & legal issues

TRIZ

- In Engineering Design Courses -

(IIIA: Product Design)

2010 PROJECT BRIEF

Adaptable Seat

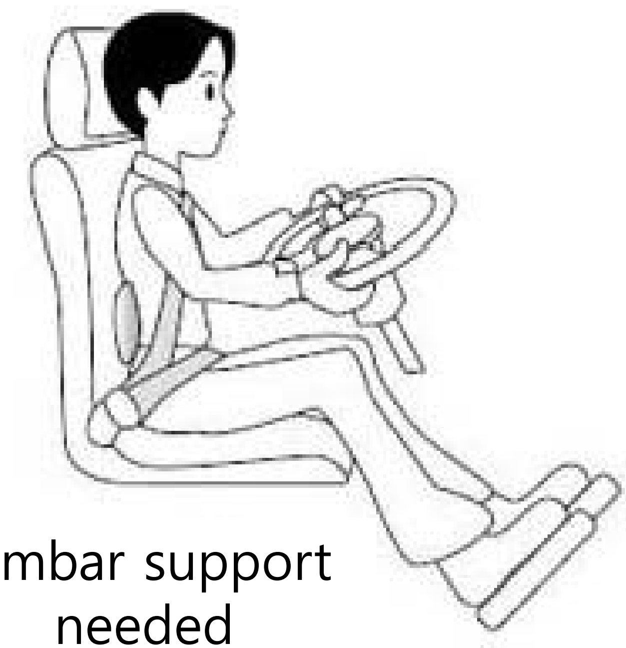
We have different sitting habits

Office

Slump/slouch | Forced upright | Poised/Relaxed

We have different sitting habits

Driving



lumbar support
needed

Upright posture

lumbar support
not needed

Comfort (relaxed) posture

We have different sitting habits

Home

Existing Products

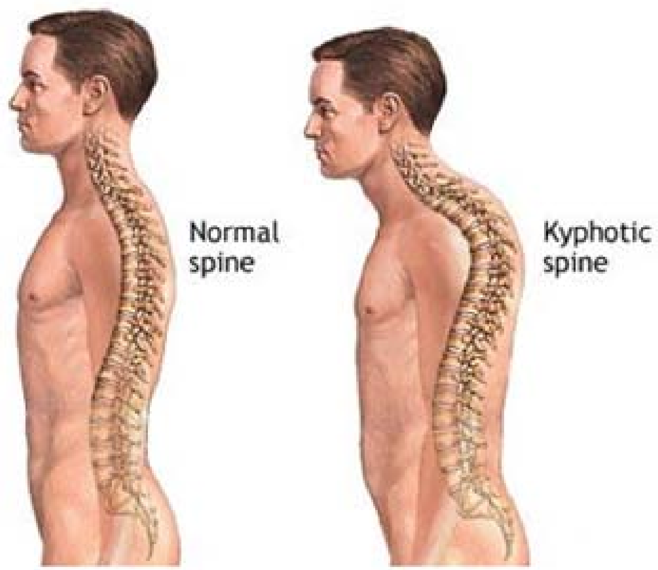
massage seat

automobile seats

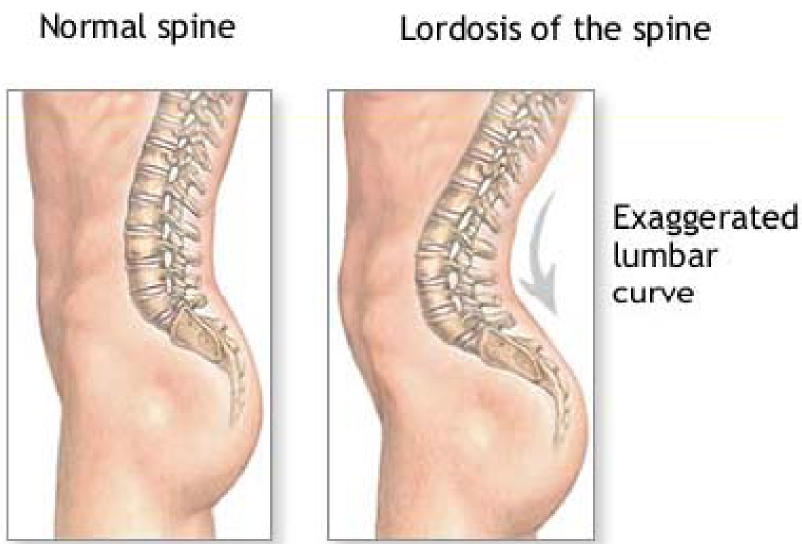
recliner

office chair

Not everybody has perfect spine



kyphosis
(척추후만)



lordosis
(척추전만)

Lordosis & Kyphosis

2010 Project

1. Your task is to develop a seat system for all sitting means (chair, sofa, driver seat, . . .).

2010 Project

2. The seat system is to conform to the physical conditions and various sitting habits

- Physical conditions
  body size, conditions of spine

- Sitting habits
  We need to change **postures** (comfort, correct and postures in between) at times. Staying in one posture for a long period is not good for us.
  We also want to change the **cushion stiffness** (soft, hard) according to the our muscle condition.

Feedback on

Sketch Model Review

April 6, 2010 – Week 6

Let’s think about fundamentals

Weight, posture and pressure

An object supporting human body – what are the essential properties?

Curvature of human body - dependent upon posture

Pressure distribution – dependent upon cushion material & shape, body weight and curvature

Let's think about fundamentals

Force and Deformation

The object supporting human body is deformed by body weight and curvature.

The local deformation of the object can be described by stress – strain relation of the object material.

Let's think about fundamentals

Coupling between pressure and stiffness

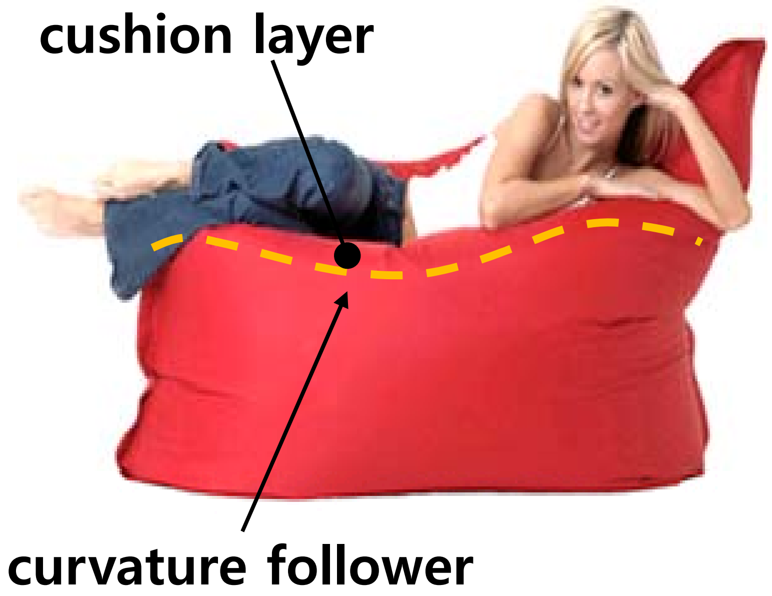
An elastic material deforms due to body weight and curvature and accordingly its stiffness changes throughout the body – support interface.

Each of us may want different stiffness. Due to the coupling between pressure and stiffness, an elastic one-piece body support will fail to offer stiffness independent from our body curvature.

Let's think about fundamentals

An ideal body support

An ideal body support will offer the interface stiffness regardless of your posture. This requires decoupling between posture and stiffness. It will be a key element in the design of body support.



Let's think about fundamentals

An ideal body support

- Curvature follower

  It is able to follow the body surface of the user with diverse postures. Once locked into one posture, it stays rigid enough to support the cushion on it until the next posture.

- Cushion layer

  The stiffness (or, softness if you will) can be chosen regardless of the follower construction.

Let’s think about fundamentals

An ideal body support

- Interface shear

  When the user changes his/her posture, there may develop friction between the body and the cushion. The shear prevents sliding and thus is necessary. At the same time excessive shear might induce discomfort while changing postures. You need to address this subtle problem with interface shear.

Feedback on
Mockup Reports

April 29, 2010 – Week 9

What are the keys of adaptable seat design?

Freedom to choose cushion stiffness

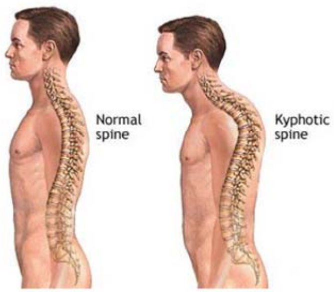
The users need different cushions depending on their physical conditions. Some users like softer cushions while others like harder cushions. **Conventional one piece cushion will not offer freedom in the choice of stiffness: harder cushions will not be able to follow the body surface.** Therefore, you need an **independent body surface follower**. With the follower, the cushion can take the form of thin sheet enabling bending and warping regardless of its stiffness(hard or soft).

What are the keys of adaptable seat design?

Body surface follower with sufficient degrees of freedom

The body surface follower should accommodate any posture and physical condition. Before and after the posture is taken, the follower needs to be released and locked at the will of the user.





What are the keys of adaptable seat design?

A release/lock mechanism for the follower

The user of the adaptable seat needs a way to release and lock the body surface follower so that he/she can change his/her posture. Before changing the posture, the user will release the locked follower. If carefully designed, the follower will not need any external power to comply with the changing posture. Once a new posture is taken, the user locks the follower.

Economic constraints

Optimization of body surface follower

For mass-produced consumer products such as chairs, the manufacturing cost is about **30% of retail price**. If the retail price is $200, then the manufacturing cost will be in the vicinity of $60-$80. You will have to **decide the retail price** of your product. Whatever the price, design optimization for cost control is an essential part of your task. Also you need to think about the **compatibility** of your back panel design **with the existing seats** if you decide to pursue greater market potential.

Geometric constraints

Optimized configurations of body surface follower – (1/5)

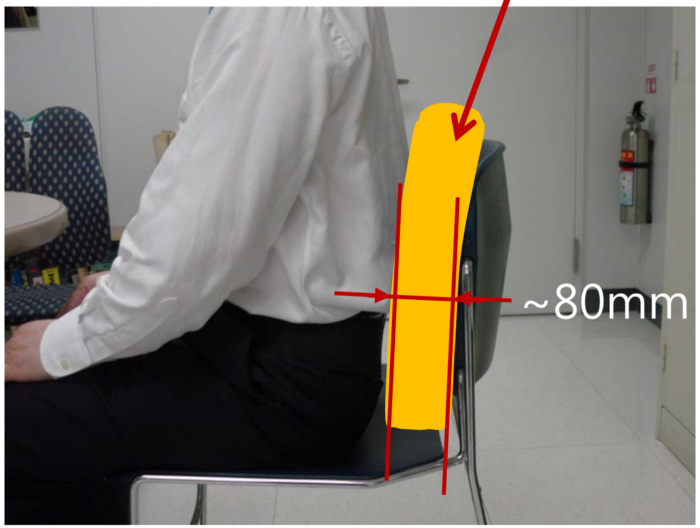
The back panel of an adaptable seat needs to be configured into the thickness range similar to conventional chairs - in the vicinity of 100mm.

Geometric constraints

Optimized configurations of body surface follower – (2/5)

If you can optimize the thickness of your back panel into the range of 80mm, the commercial potential of your design will be maximized.

A seat cushion with built-in body surface follower

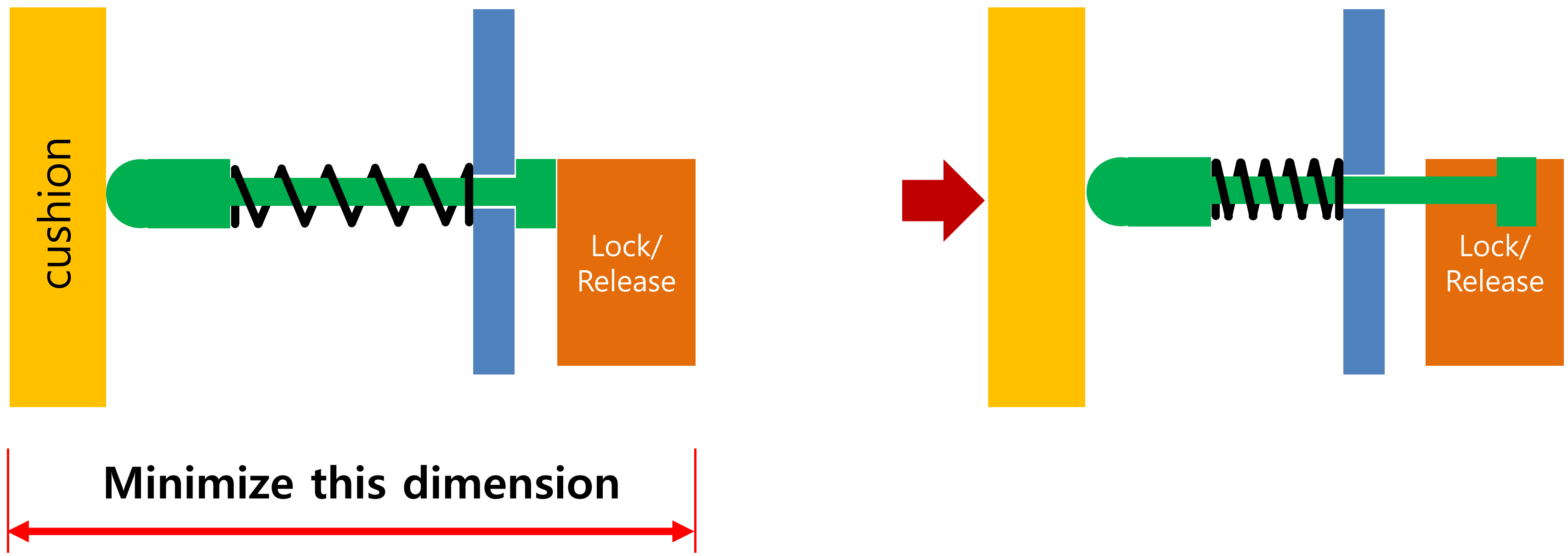


Geometric constraints

Optimized configurations of body surface follower – (3/5)

Most of your design adopt one of the following mechanism for body surface follower: mechanical, hydraulic, pneumatic or electromagnetic.

Mechanical follower

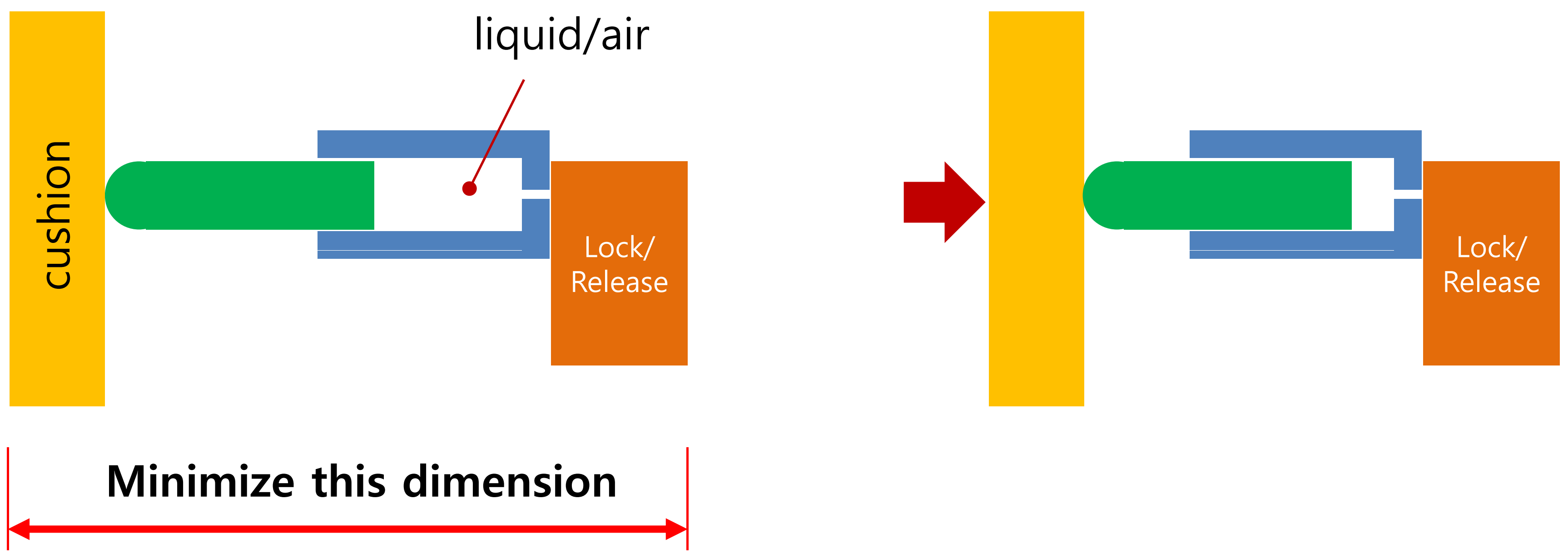


Geometric constraints

Optimized configurations of body surface follower – (4/5)

Most of your design adopt one of the following mechanism for body surface follower: mechanical, hydraulic or pneumatic.

Hydraulic/Pneumatic follower

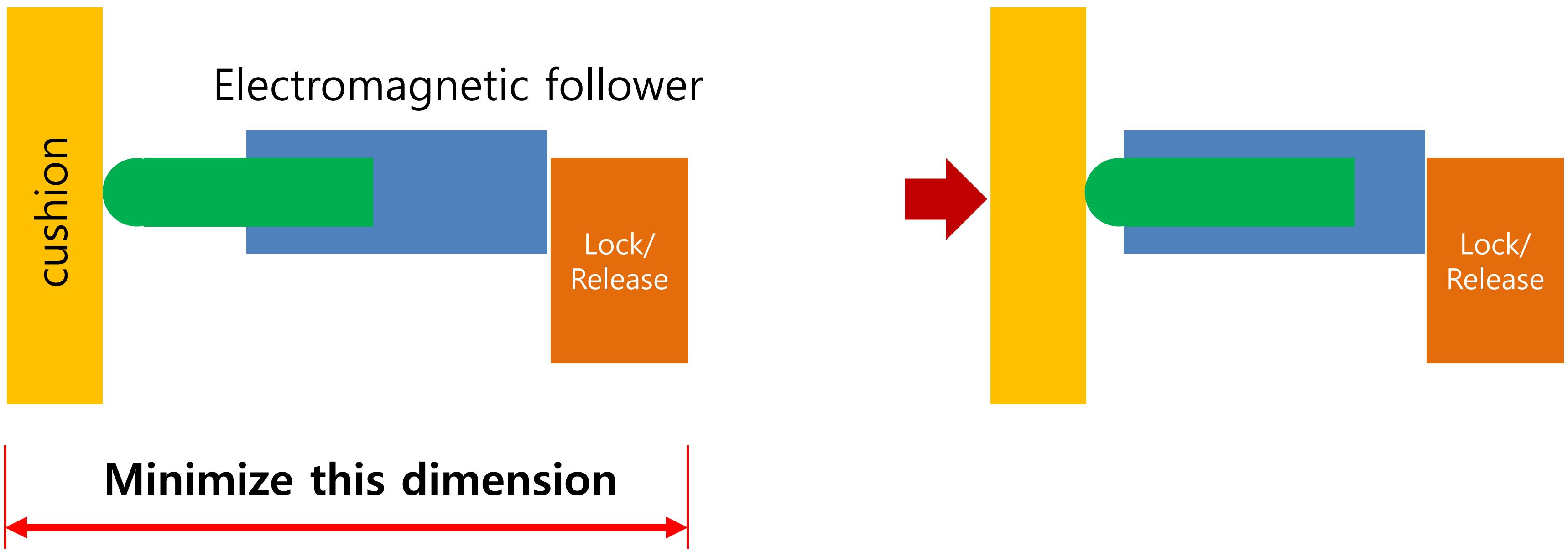


Geometric constraints

Optimized configurations of body surface follower – (5/5)

Most of your design adopt one of the following mechanism for body surface follower: mechanical, hydraulic or pneumatic.

Electromagnetic follower



How do you make it cheaper and thinner?

Beyond the current design

Making the body surface follower cheaper and thinner is a quite challenging task. Mere optimization of fixed configuration will not give you a solution.

For innovative solutions, try **TRIZ** approach – physical & technical contradiction analyses. To make the follower thinner, you need new arrangement of components. Try to use the available space with maximum efficiency. To make the follower cheaper, the mechanism should be very simple: fewer parts and ease of manufacturing. You need to revisit and work on the various engineering materials and the manufacturing processes you have studied.

Design guideline for term project

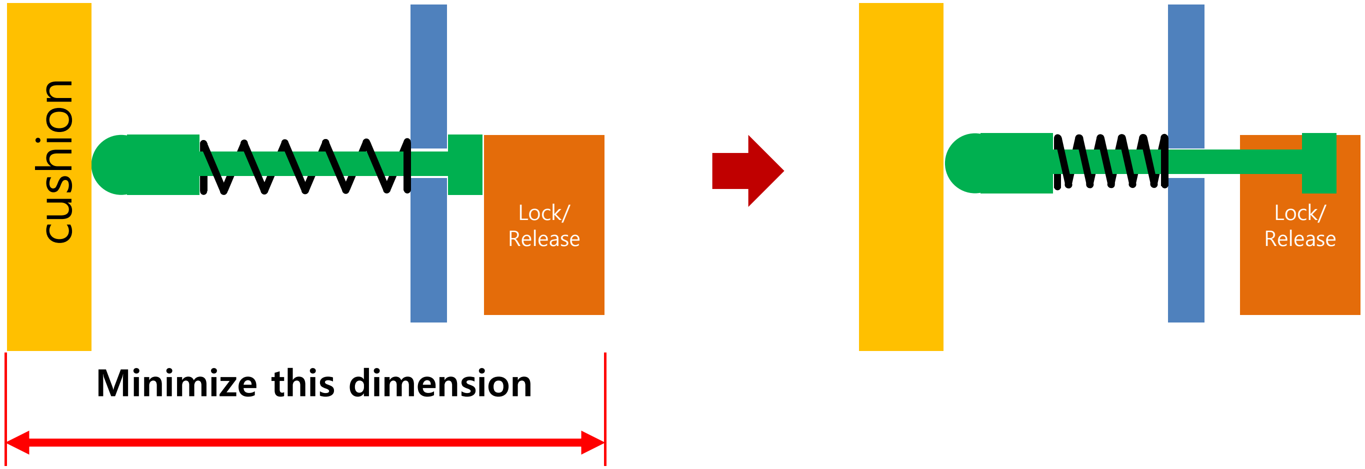
Body surface follower

Thursday May 6, 2010 – Week 10

The issue of this week

- Freedom to choose cushion stiffness
- **Body surface follower with sufficient degrees of freedom**
- A release/lock mechanism for the follower
- **Optimization with respect to economic and geometric constraints**

How do you make it thinner? – mechanical type



Conventional Optimization

Make the plunger head shorter
Making the spring fully collapsible
Minimize the thickness of lock/release mechanism

➡ Obvious limits in the spring and plunger length.
Complexity in the lock/release mechanism

How do you make it thinner? – mechanical type

Let’s try TRIZ

Physical Contradiction

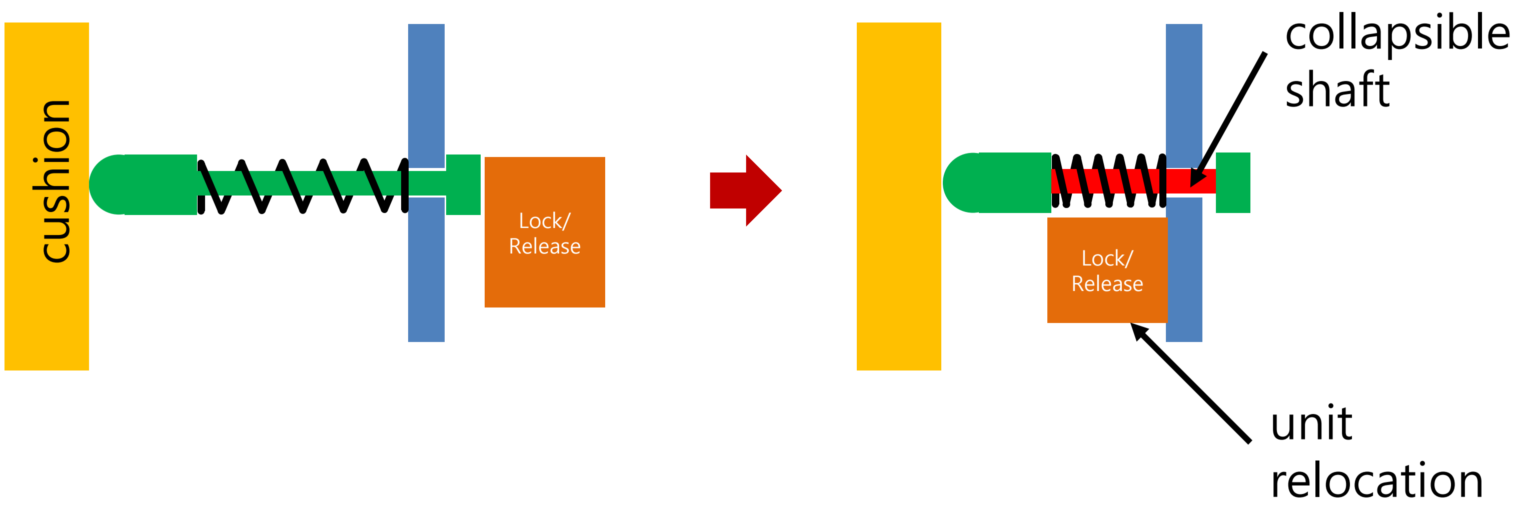
“The plunger & spring assembly need to be **longer** to accommodate greater range of users’ sitting posture and physical conditions”

“To increase the versatility of design, the plunger & spring assembly need to be **shorter**”

How do you make it thinner? – mechanical type

Physical Contradiction: separation principle

- In time
- In space
- Within a whole and its parts
- Upon conditions



How do you make it thinner? – mechanical type

Satisfied?

If not, try technical contradiction analysis

"You want make the follower and lock/release sub-assembly thinner"

Feature to Improve: length of moving object(3)

How do you make it thinner? – mechanical type

TRIZ technical contradiction analysis

"It tends to be more complex, more expensive with the new design"

Worsening Features:

Ease of manufacture	(32)
Device complexity	(36)
Productivity	(39)

How do you make it thinner? – mechanical type

Feature to Improve: length of moving object(3)

Worsening Features		Solution principles
feature	#	
Ease of manufacture	32	1, 29, 17
Device complexity	36	1, 19, 26, 24
Productivity	39	14, 4, 28, 29

How do you make it thinner? – mechanical type

Feature to Improve: ease of operation (33)

Solution principles (out of 40)		frequency
No.	Description	
1	**Segmentation**	**2**
4	Asymmetry	1
14	Spheroidality	1
17	Another dimension	1
19	Periodic action	1
24	Intermediary/Mediator	1
26	Copying	1
28	Mechanical substitution	1
29	**Pneumatics & hydraulics**	**2**

How do you make it thinner? – mechanical type

Solution Principles

Segmentation (1)

A. Divide an object into independent parts

B. Make an object sectional - easy to assemble or disassemble

C. Increase the degree of fragmentation or segmentation

→ You might get an idea or a clue depending upon your knowledge and experience

How do you make it thinner? – mechanical type

Solution Principles

Pneumatics & Hydraulics (29)

A. Use gas and liquid parts of an object instead of solid parts
e.g. inflatable, filled with liquids, air cushion, hydrostatic, hydro-reactive

→ Since we are now focusing on the mechanical type, let's think about this solution later.

How do you make it thinner? – mechanical type

Solution Principles

Asymmetry (4)

A. Change the shape or properties of an object from symmetrical to asymmetrical

B. Change the shape of an object to suit external asymmetries

C. If an object is asymmetrical, increase its degree of asymmetry

How do you make it thinner? – mechanical type

Solution Principles

Spheroidality (14)

A. Move from flat surfaces to spherical ones and from parts shaped as a cube (parallelepiped) to ball-shaped structures

B. Use rollers, balls, spirals

C. Go from linear to rotary motion (or vice versa)

D. Use centrifugal forces

How do you make it thinner? – mechanical type

Solution Principles

Another dimension (17)

A. Move into an additional dimension - from one to two - from two to three

B. Go from single storey or layer to multi-storey or multi-layered

C. Incline an object, lay it on its side

How do you make it thinner? – mechanical type

Do they offer any clue to you ?

Asymmetry (4)

A. Change the shape or properties of an object from symmetrical to asymmetrical

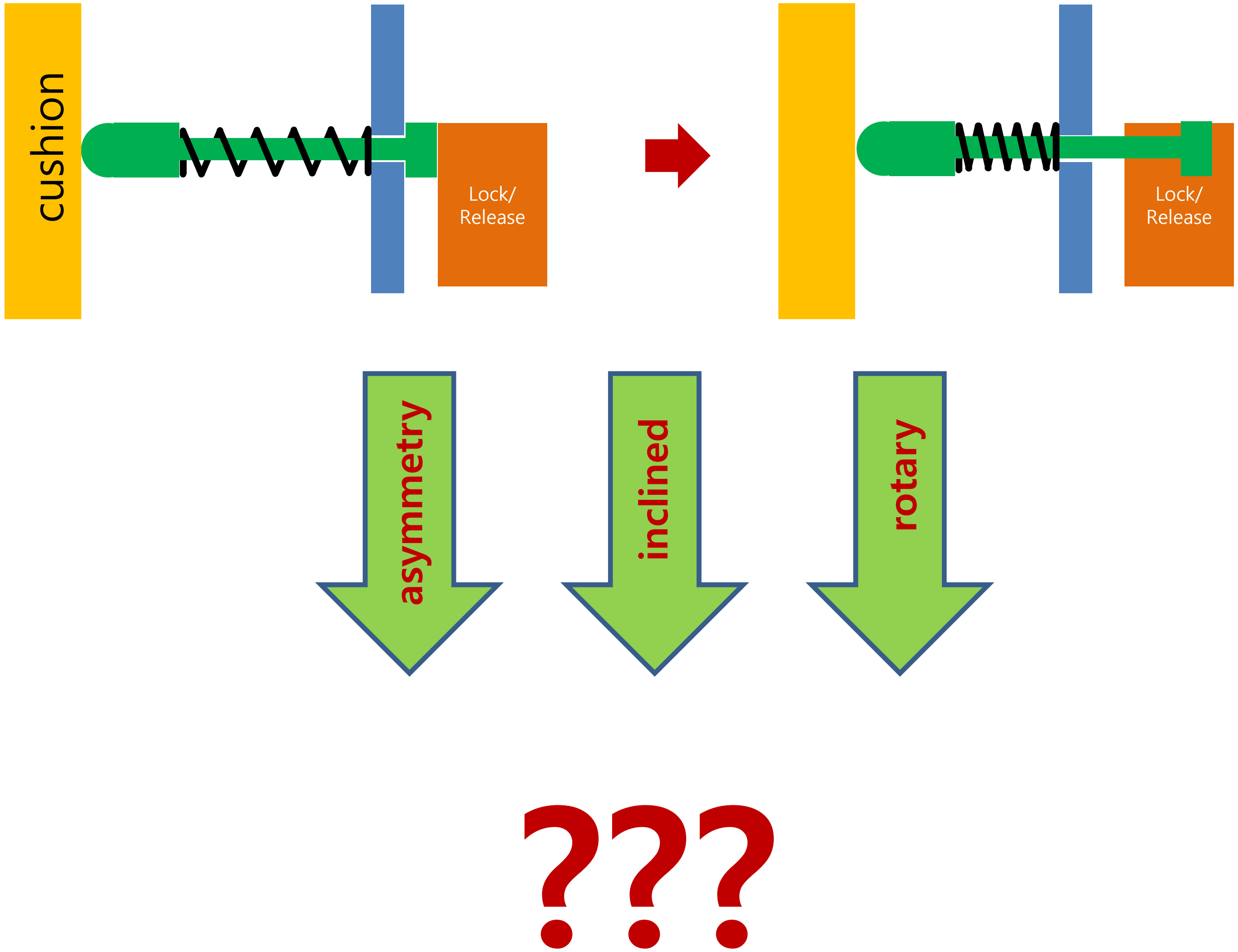
Spheroidality (14)

C. Go from linear to rotary motion (or vice versa)

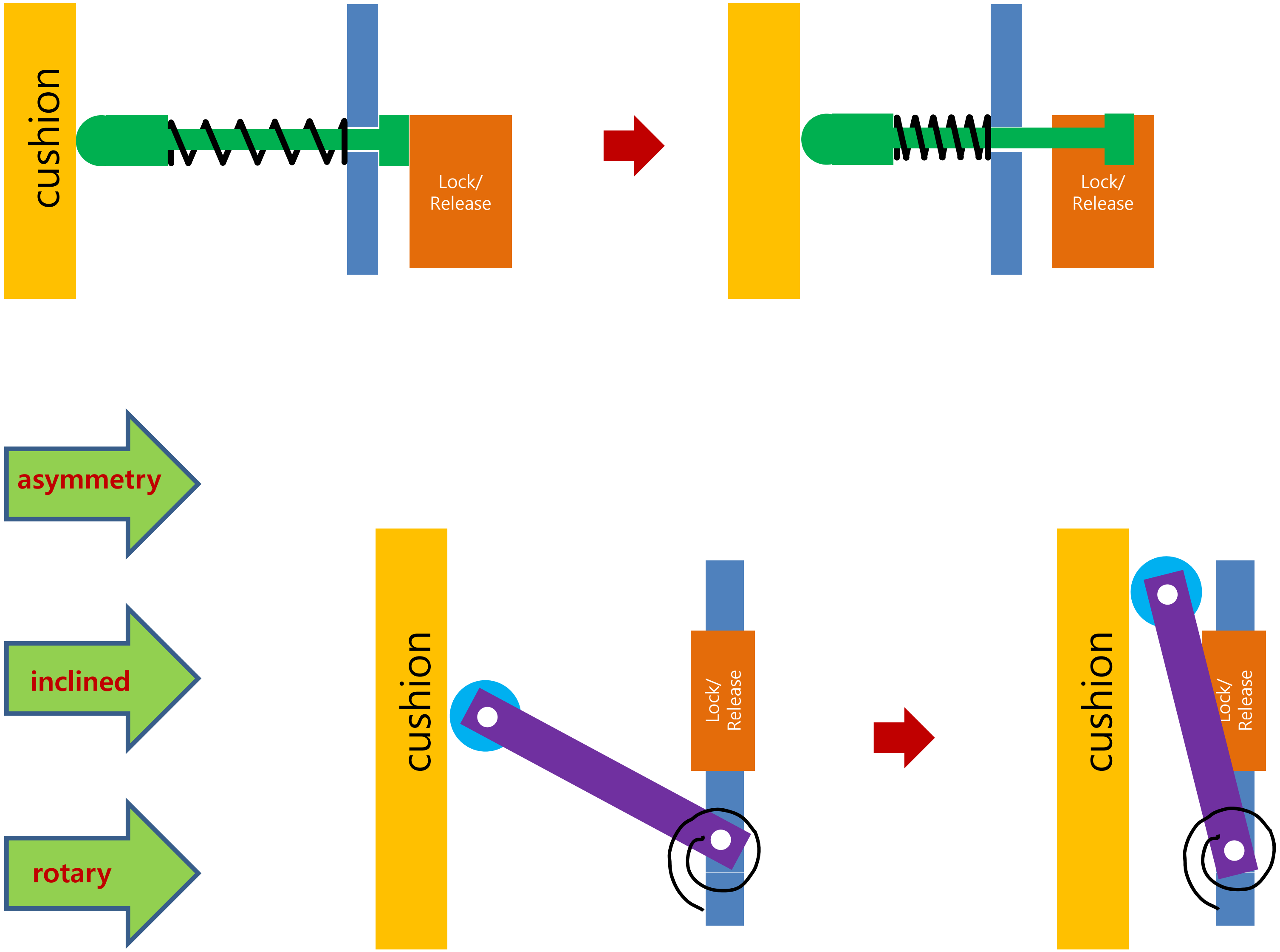
Another dimension (17)

C. Incline an object, lay it on its side

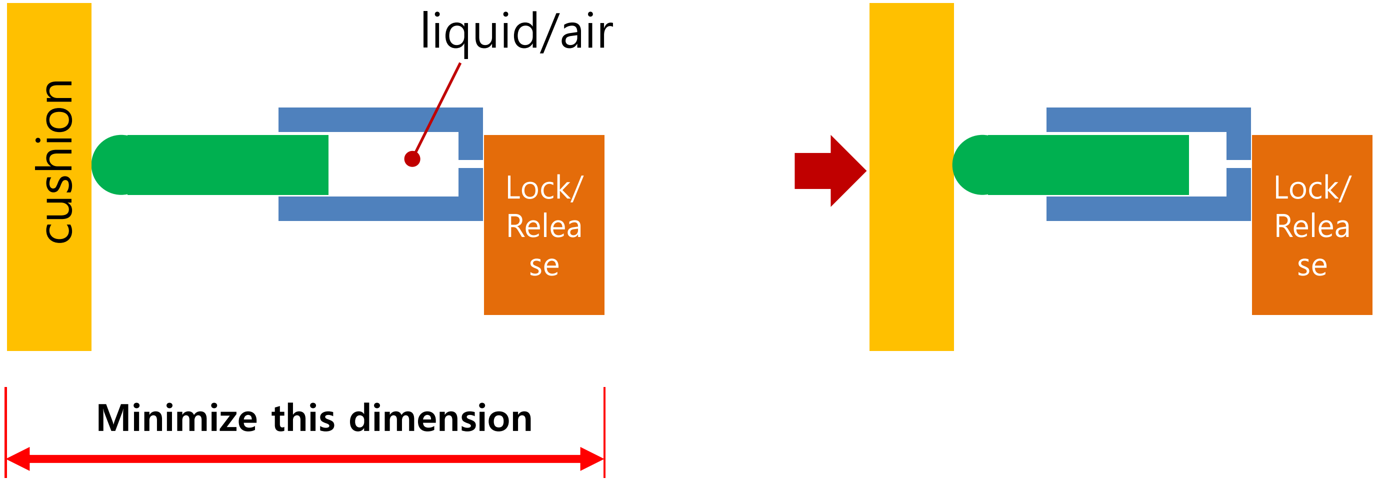
How do you make it thinner? – mechanical type



How do you make it thinner? – mechanical type



How do you make it thinner? – hydraulic/pneumatic types



Conventional Optimization

Make the cylinder and plunger head shorter
Minimize the thickness of lock/release mechanism

Obvious limits in the thickness reduction

How do you make it thinner? – hydraulic/pneumatic types

Let's revisit the contradiction analysis for the mechanical type

Feature to Improve: length of moving object(3)

Worsening Features		**Solution principles**
feature	#	
Ease of manufacture	32	1, 29, 17
Device complexity	36	1, 19, 26, 24
Productivity	39	14, 4, 28, 29

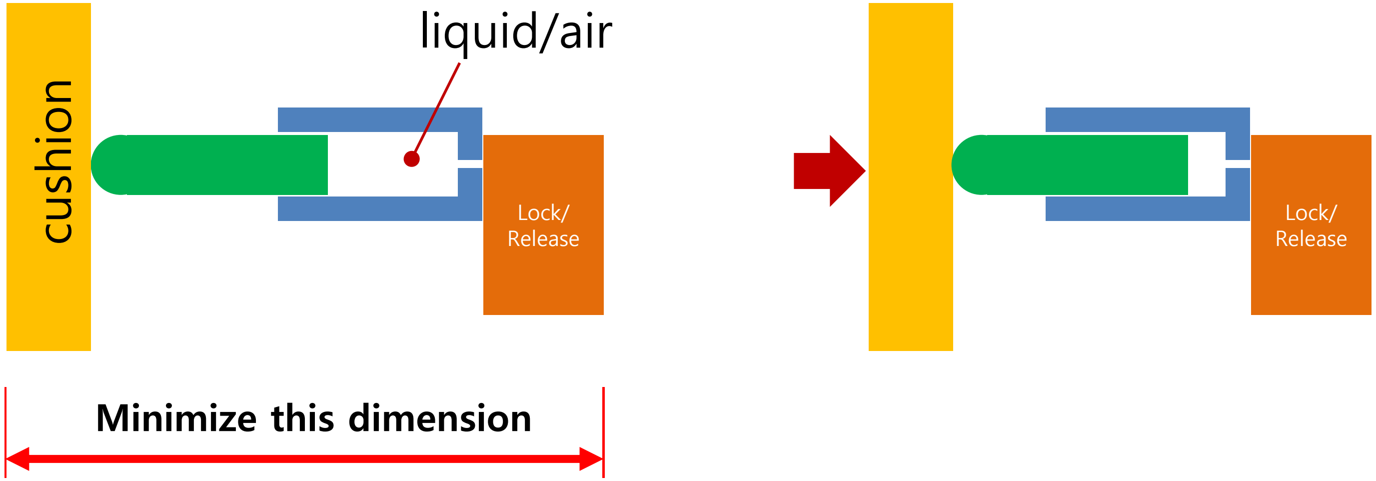
How do you make it thinner? – hydraulic/pneumatic types

Solution Principles

Pneumatics & Hydraulics (29)

A. Use gas and liquid parts of an object instead of solid parts
 e.g. **inflatable**, filled with liquids, **air cushion**, hydrostatic, hydro-reactive

How do you make it thinner? – hydraulic/pneumatic types

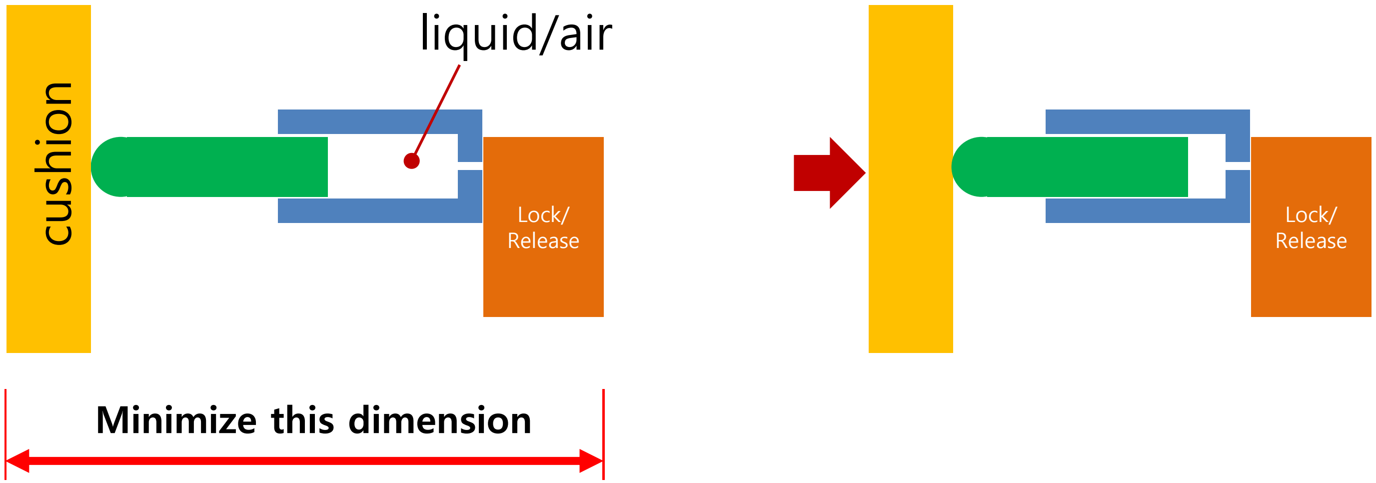


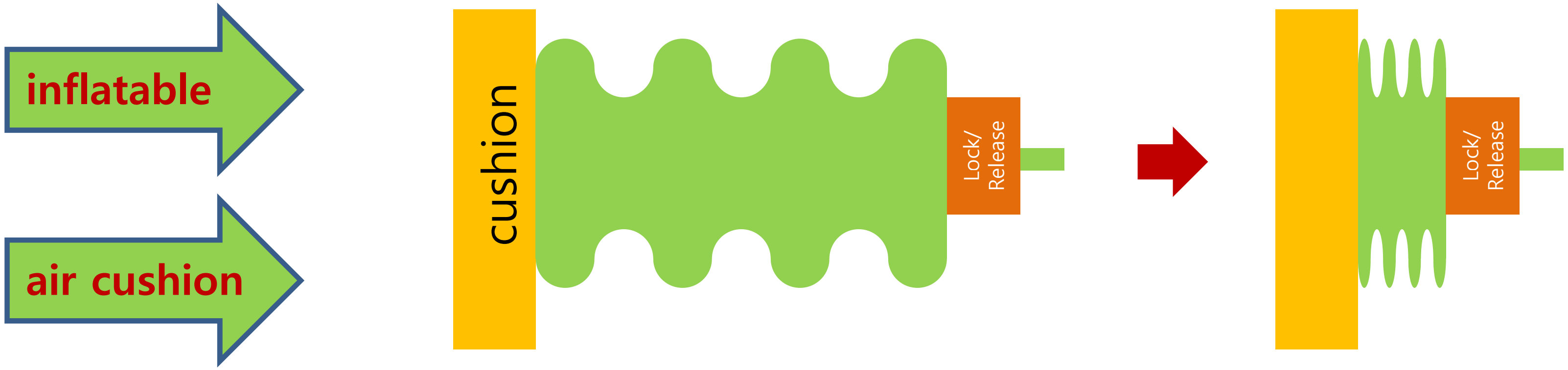
inflatable

air cushion

???

How do you make it thinner? – hydraulic/pneumatic types





You can try further for thinner collapsible structure
Also you can add a spring for follow-up action

Schedule for the next week

Once you achieve a progress with thinner layout of the follower unit, next step will be to make the lock/release mechanism thinner and economical.

Technical Review Report

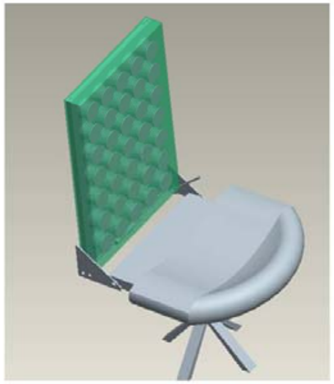
Tuesday May 20, 2010 – Week 12

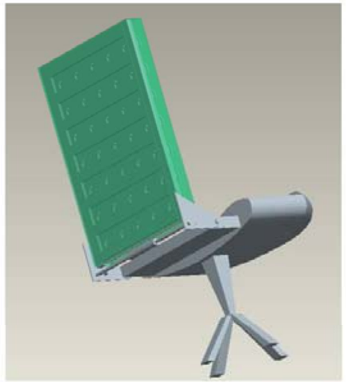
Bellows type

You need to accommodate reclining of the back support.

Team 3

Technical Review Report May 25, 2010

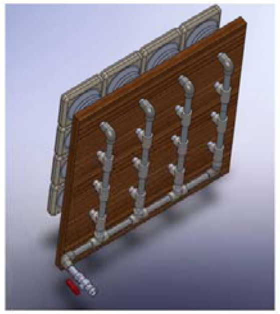


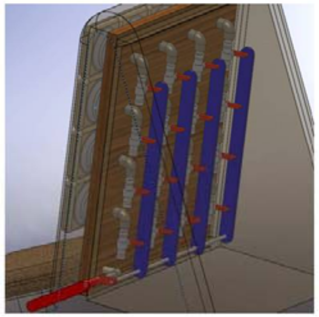


Change in design: individual locking – standard valves may work, but the assembly looks bulky.

Team 5

Technical Review Report May 25, 2010

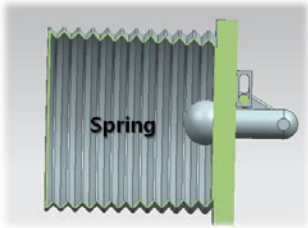


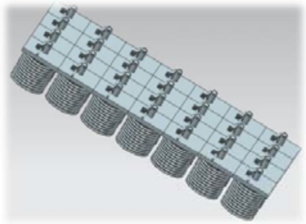


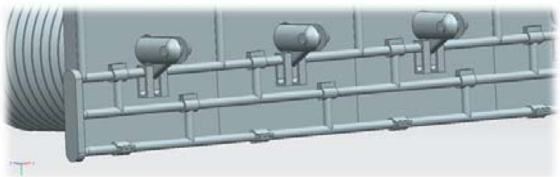
Locking mechanism: rubber ball head with solid shaft for axial stroke – how do you make it? Make sure that the shaft does not tilt and get jammed during the toggle action.

Team 6

Technical Review Report May 25, 2010



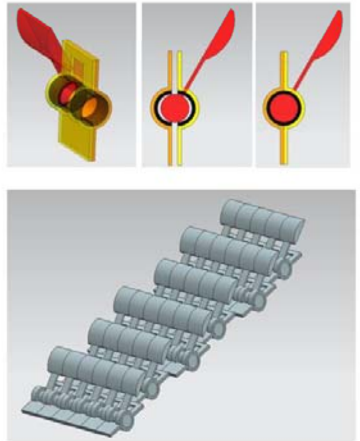




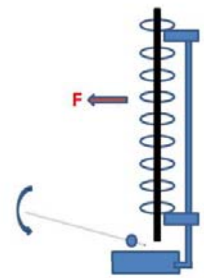
Linkage type

Foot operated brake – I do not fully understand the details.
Make sure that bend deflection is not induced to the structure by braking action.

Team 9



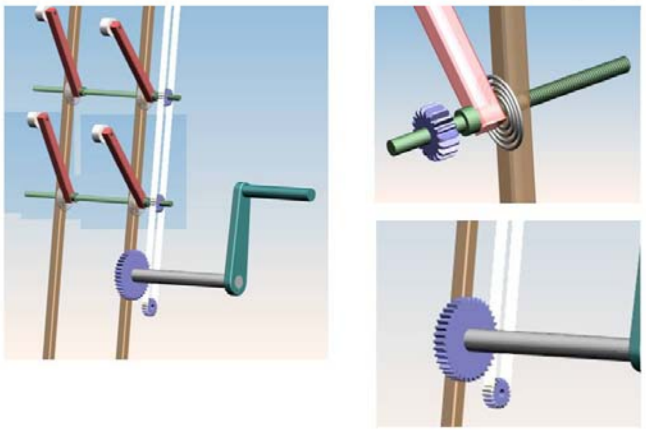
Week 3 May 15, 2010



A major design change - pivoted links with spiral springs and screw locking. Make sure that the springs are not damaged. What you need is not axial displacement but load.

Team 11

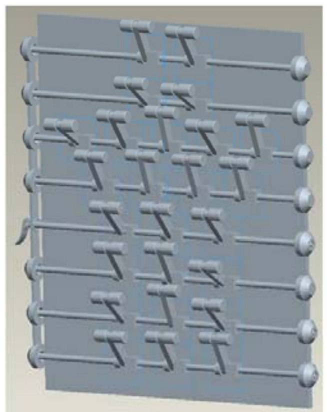
Week 3 May 15, 2010

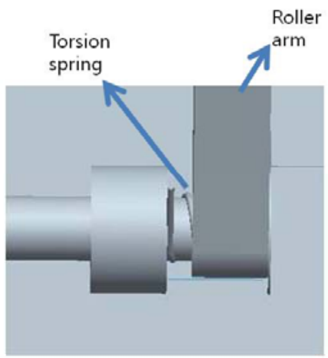


Design change from wedge to friction brakes. Make sure the torsion springs are not damaged during locking.

Team 14

Technical Review Report May 25, 2010





TRIZ in design courses

- Design IIIA for undergraduates

  TRIZ covered in lectures, quiz, in-class practice and guidelines for term project

- Theory of Mechanical Design for graduates

  TRIZ covered in lectures, quiz and term project guidelines

- Engineering Design for professionals

  Evening course for professional engineers
  TRIZ covered in lectures and term project guidelines

Experiences with TRIZ in classrooms

- Acquiring skills with TRIZ requires considerable efforts with practices

- Carefully planned teaching is important

  Level of invention
  Carefully planned failure – an essential process
  Proper timing for interruption with guidelines

- TRIZ experience should be fun & motivation process. The message should be "You are very creative".