

# **Concept Development of a Variable Compression Ratio Engine Using TRIZ**

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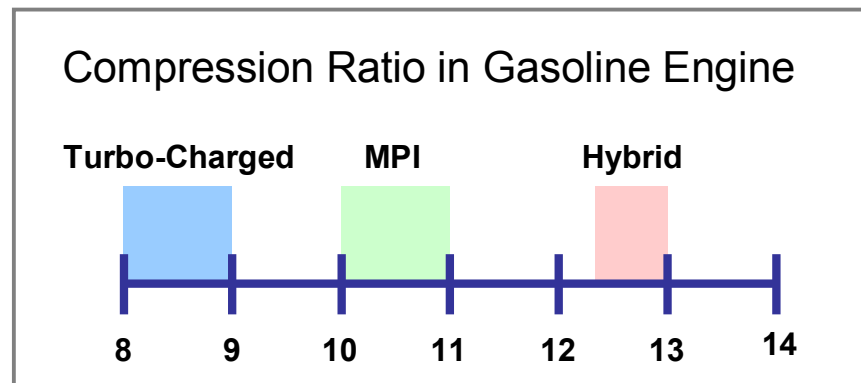
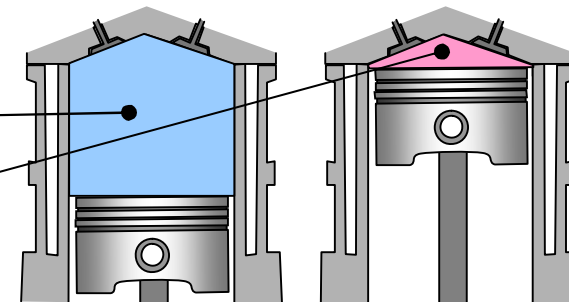


## ■ Research Target in this Study

Develop “**Variable Compression Ratio engine**”

### ● What is “Compression Ratio”?

$$\text{Compression Ratio} = \frac{\text{Maximum Cylinder Volume}}{\text{Minimum Cylinder Volume}}$$



If compression ratio becomes large,  
then **thermal efficiency increases**,  
But, **engine power decreases due to Knocking**

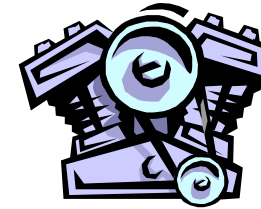
**Technical Contradiction  
in a Conventional Engine**

# Variable Compression Ratio Engine

## ■ Solution of Technical Contradiction

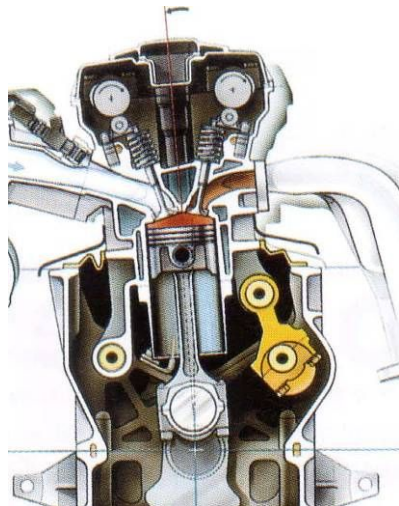
Low Load & Speed : High C/R → Engine Efficiency ↑

High Load & Speed : Low C/R → Engine Power ↑

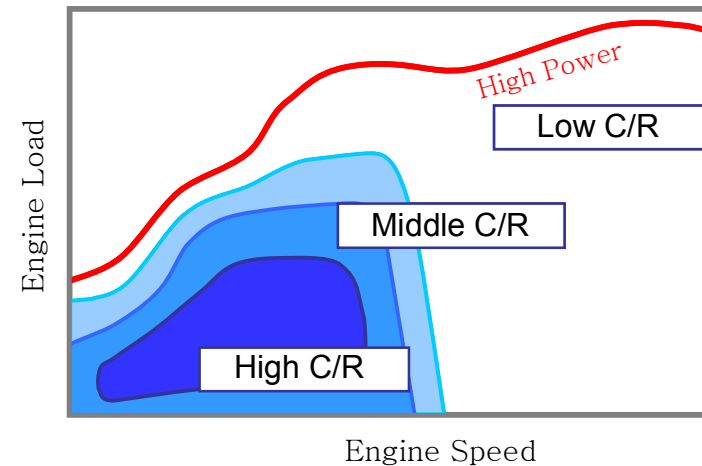


## → Separation in Time: Variable Compression Ratio Engine

: Compression ratio of the engine can be controlled at each engine operation condition



SAAB VCR engine



# Variable Compression Ratio Engine

## ■ Effect of Variable Compression Ratio

VCR+Turbo Engine improves 20~30% of Fuel Consumption in comparison with the same power of NA Engine.

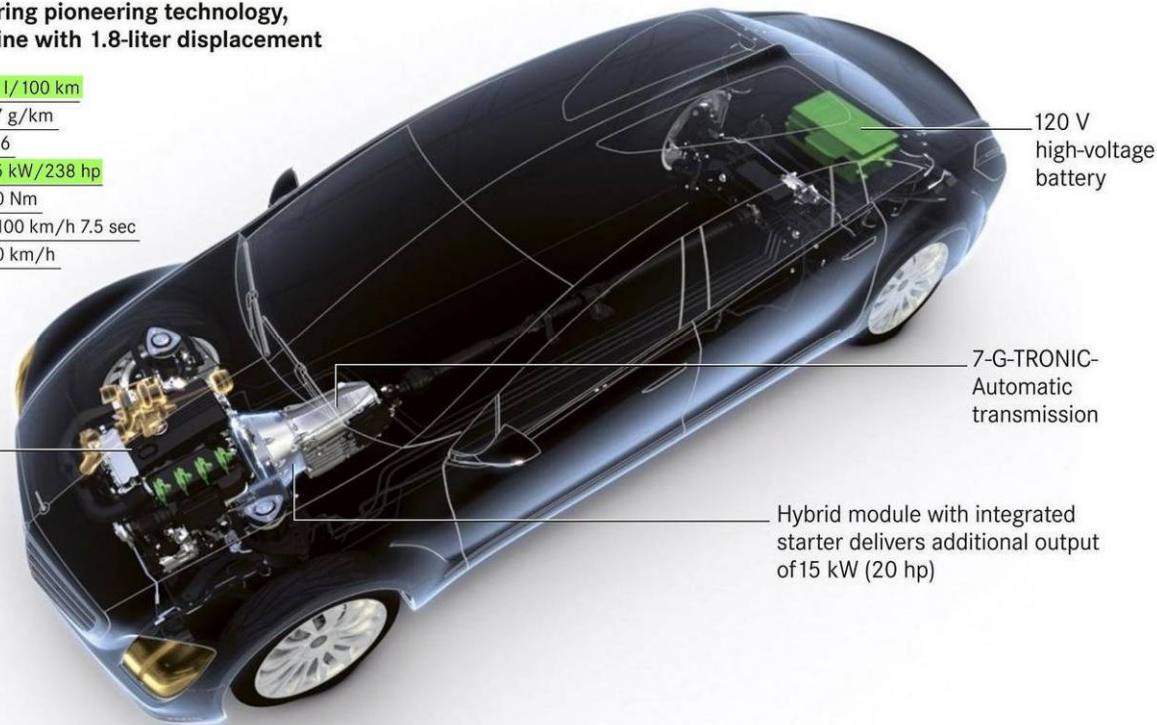
### Mercedes-Benz F 700 DIESOTTO

Combustion engine featuring pioneering technology,  
4-cylinder DIESOTTO-engine with 1.8-liter displacement

Consumption:	5.3 l/100 km
CO <sub>2</sub> emissions:	127 g/km
Emission controls level:	EU 6
Rated power DIESOTTO:	175 kW/238 hp
Max. torque:	400 Nm
Acceleration:	0-100 km/h 7.5 sec
Top speed (limited):	200 km/h

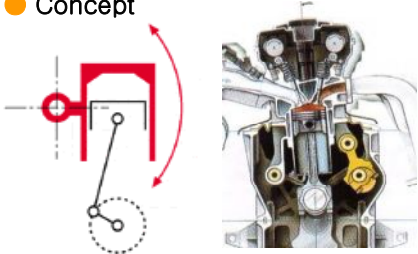
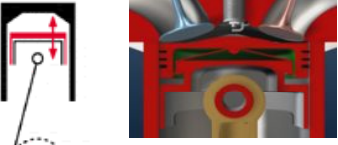
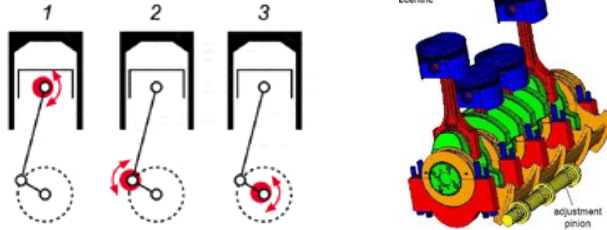
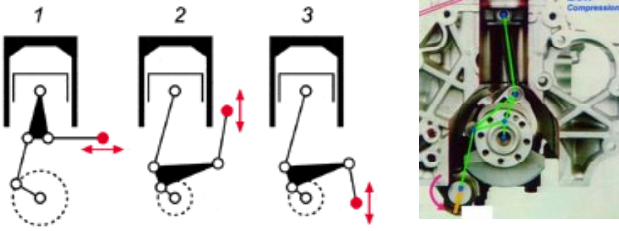

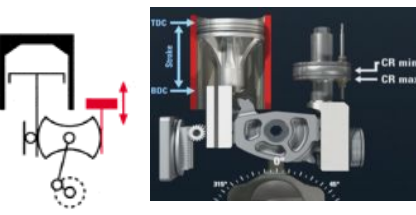
#### Additional fuel-saving features

- Two-stage turbocharger
- Direct gasoline injection
- Variable compression ratio
- Controlled auto ignition



➡ 1.8 Liter DiesOtto Engine generates “239HP & 18.9km/L”

## ■ Bench Marking on Previous VCR Engines

<p><b>Articulated Cylinder Head</b></p> <p>● Concept</p>  <p>Saab</p>	<p><b>Hydraulic Piston</b></p> <p>● Concept</p>  <p>Ford</p>	<p><b>Eccentric Bearing</b></p> <p>● Concept</p> <p>1 2 3</p>  <p>Piston pin Crank pin Main journal</p> <p>FEV</p>
<p><b>Multi-Link Rod-Crank</b></p> <p>● Concept</p> <p>1 2 3</p>  <p>Nissan / PSA</p>	<p><b>Additional Piston</b></p> <p>● Concept</p>  <p>Volvo / Ford</p>	<p><b>Gear-Based</b></p> <p>● Concept</p>  <p>MCE-5</p>

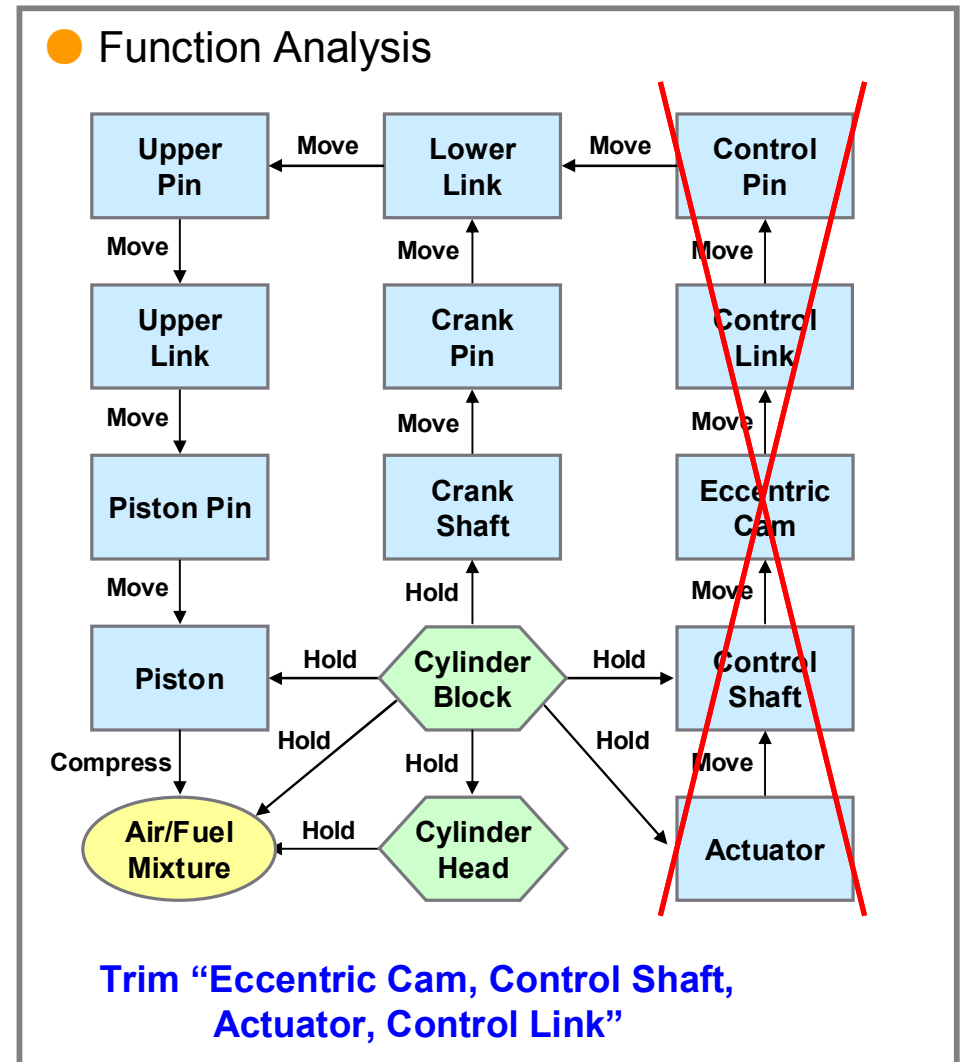
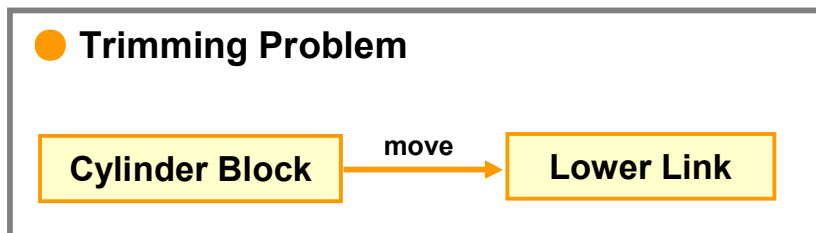
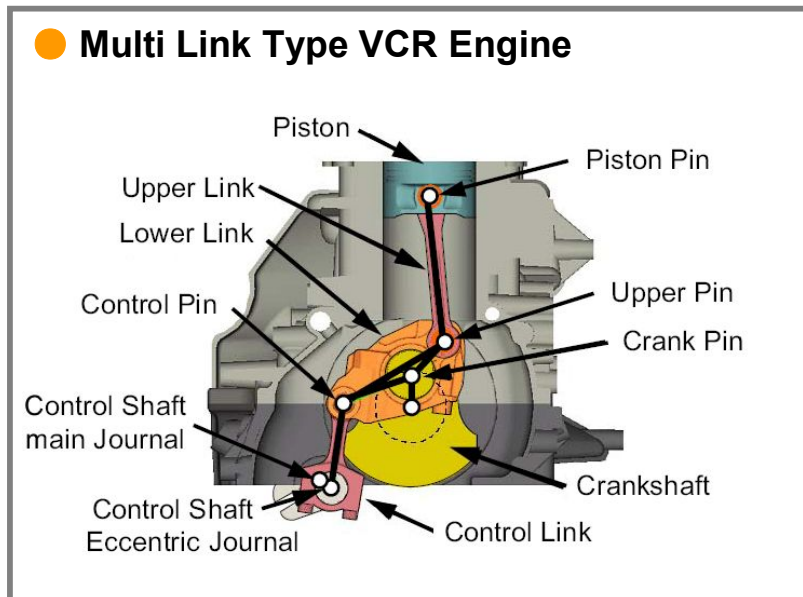
➡ Multi-Link Type is superior to others from viewpoint of mass-production.

Problem: Patent Infringement

➡ Patent Circumvention Using TRIZ

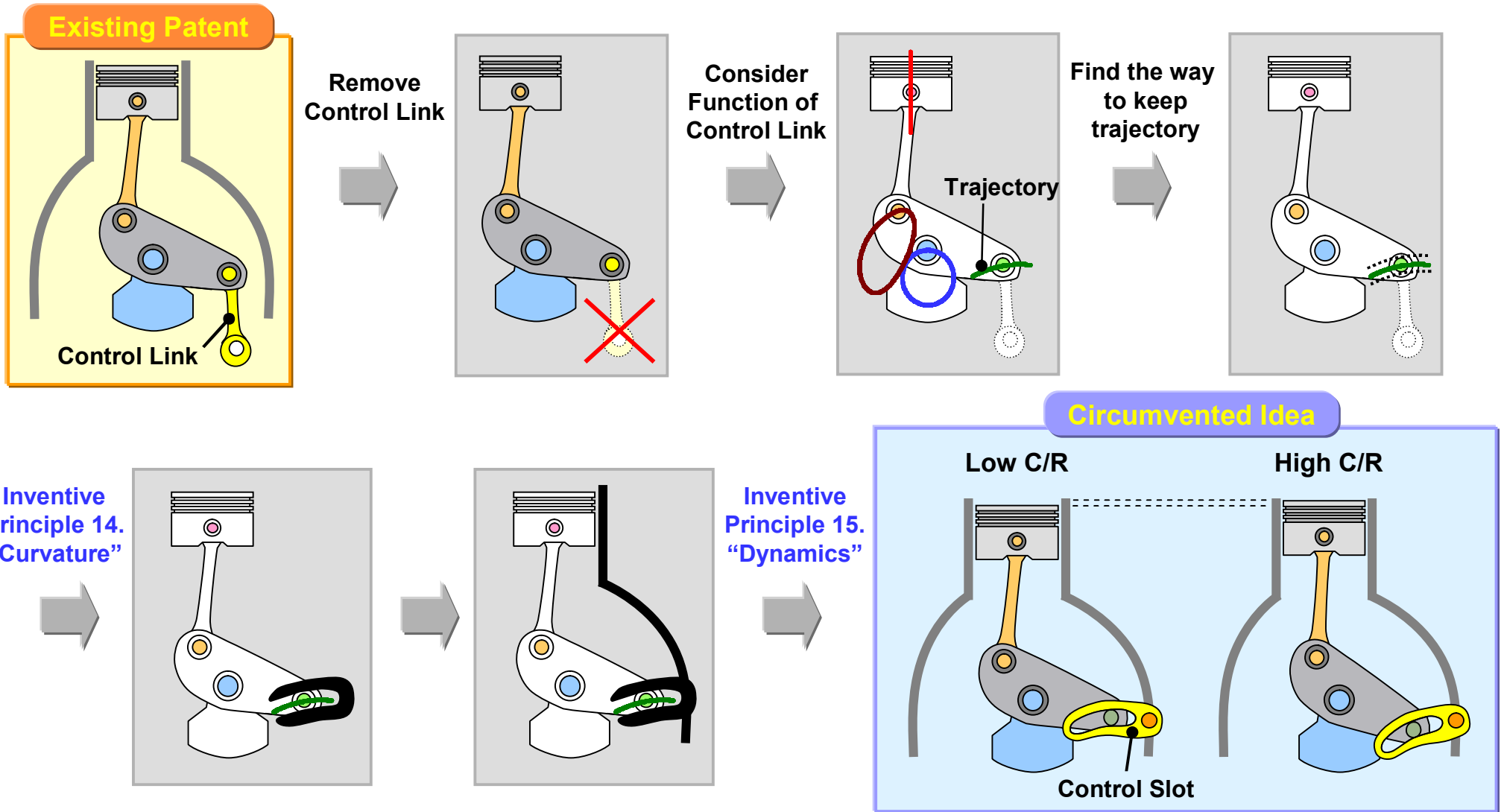
# IDEA-1: Patent Circumvention

## ■ Patent Circumvention Using Trimming

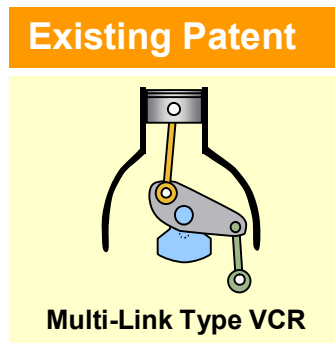


# IDEA-1: Trimming

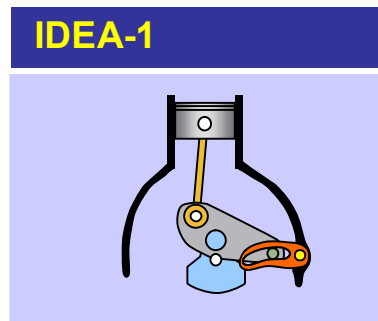
## Idea Generation from Trimming Problem



## ■ Result of Idea Generation (Step1)



Circumvent  
Patent  
→  
**Trimming**



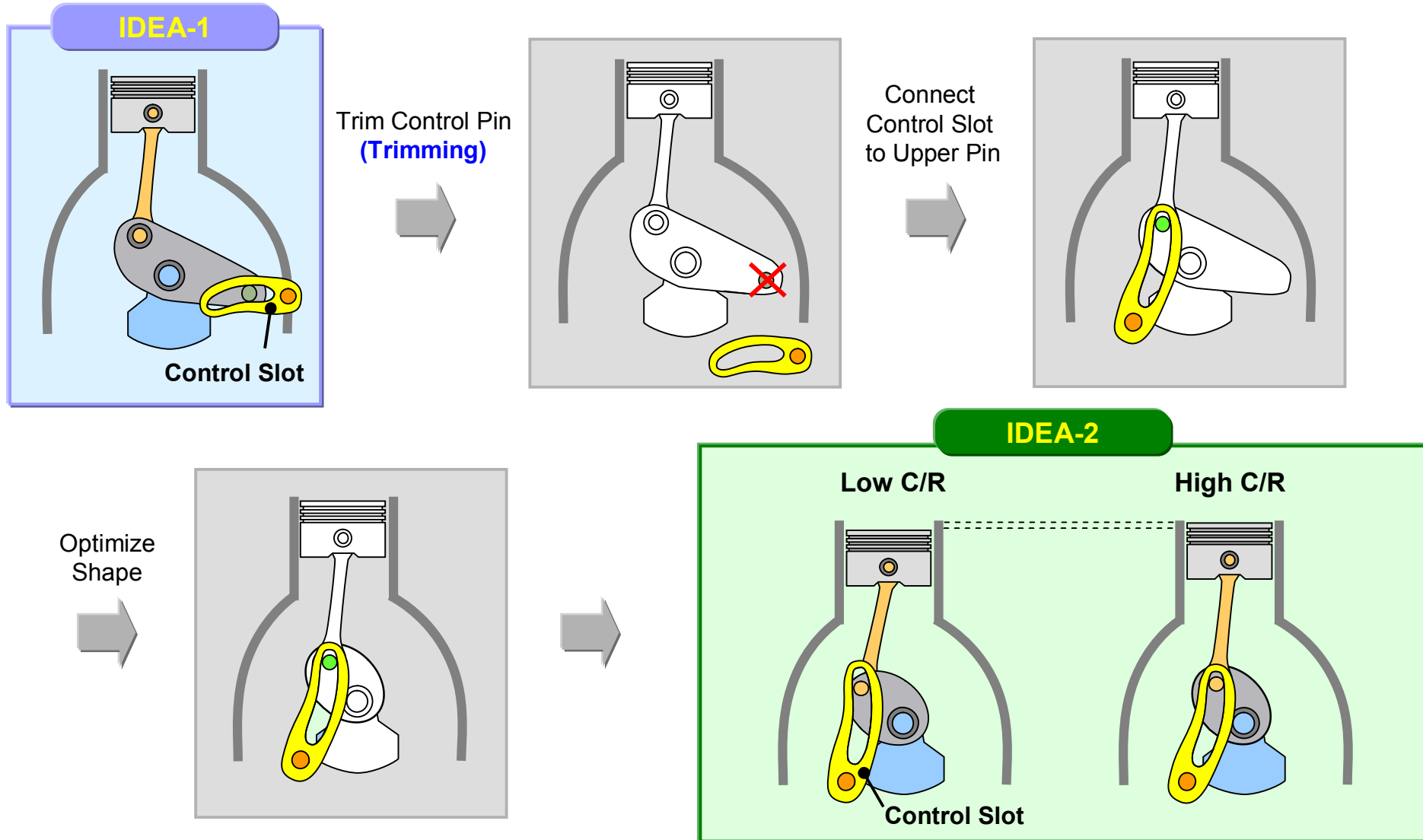
Strengthen  
Idea  
→  
**Antidote**



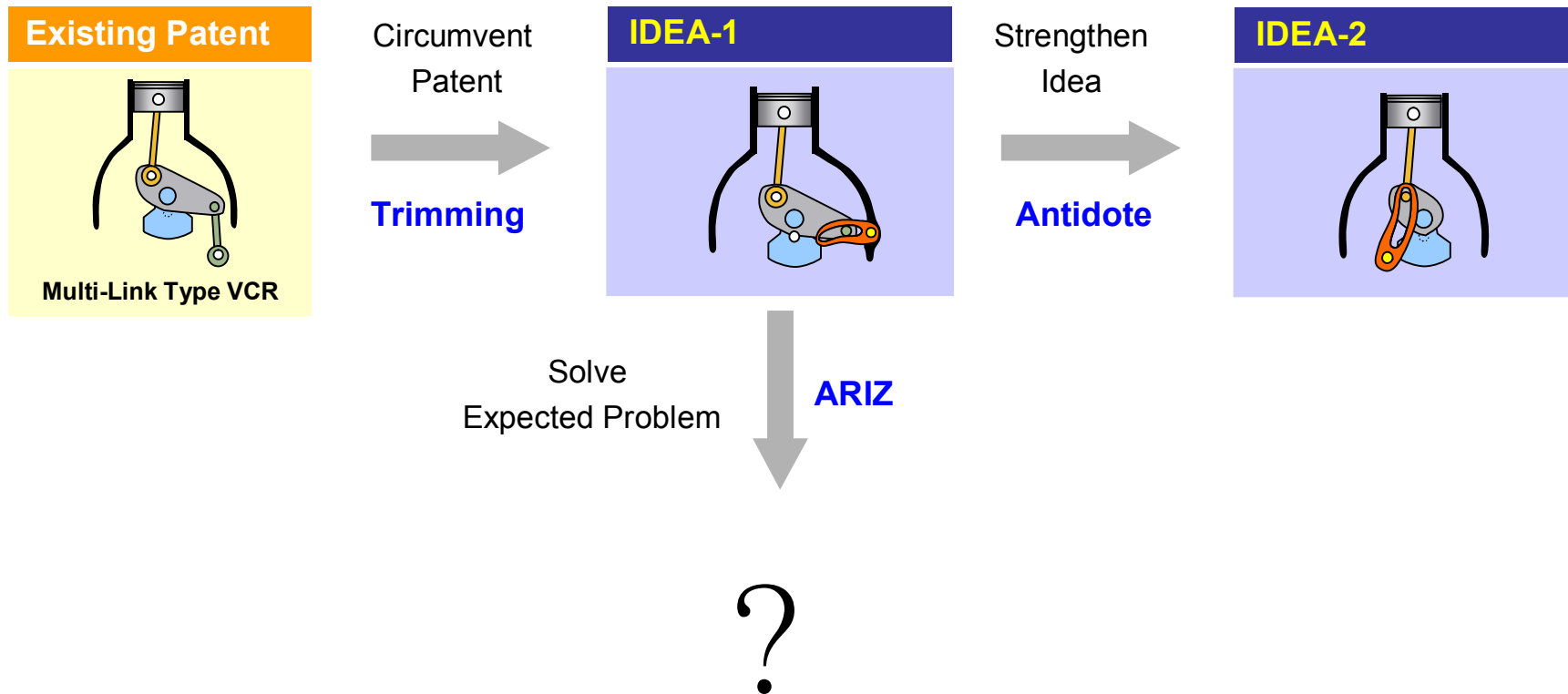


# IDEA-2: Antidote Strategy

## ■ Circumvent IDEA-1 again to strengthen idea (Antidote Strategy)

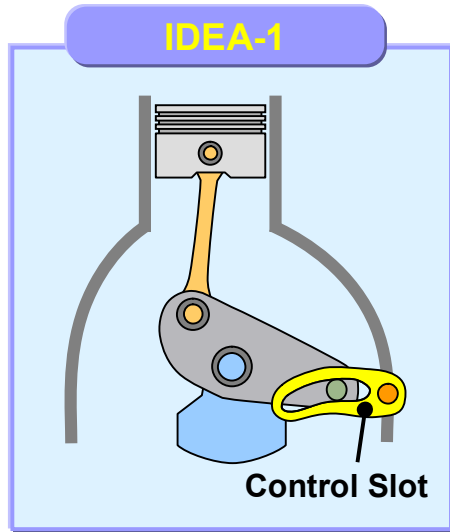


## ■ Result of Idea Generation (Step2)



# IDEA-3: Expected Problem of Control Slot

## ■ Solve Expected Problem Using ARIZ



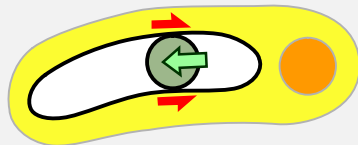
“Control Slot” is introduced to IDEA-1

➔ What is expected problem of control slot?

1. What is a proper clearance between Control Slot and Control Pin?
2. Machining Problem: How to machine control slot uniformly?
3. How much is a slot deformed by thermal expansion?
4. ...

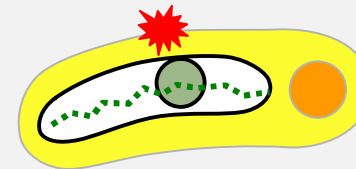
Use ARIZ

● When the clearance is small



Control slot guides control pin well,  
but friction becomes large.

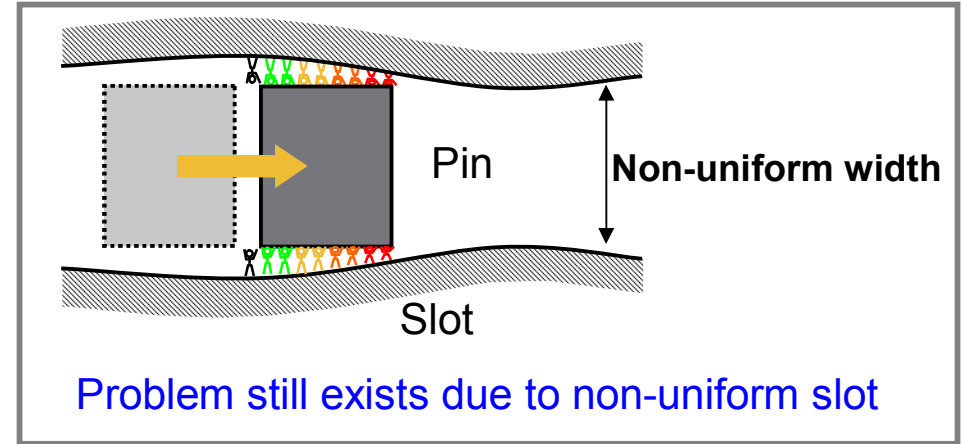
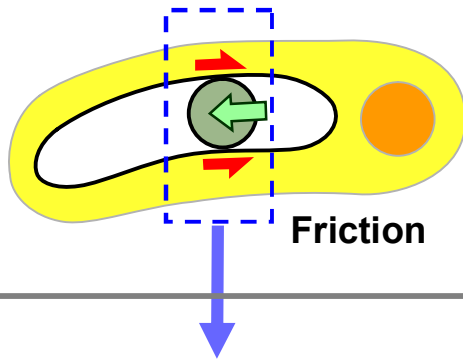
● When the clearance is large



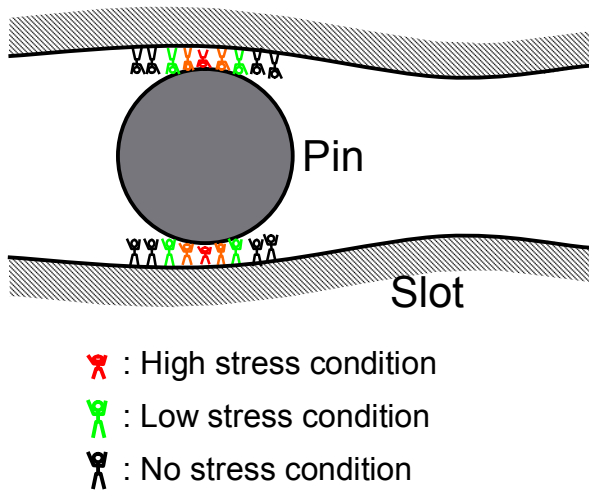
Friction will be reduced,  
but control slot cannot guide pin well.

# IDEA-3: ARIZ

- When clearance is small (Minimal Change)

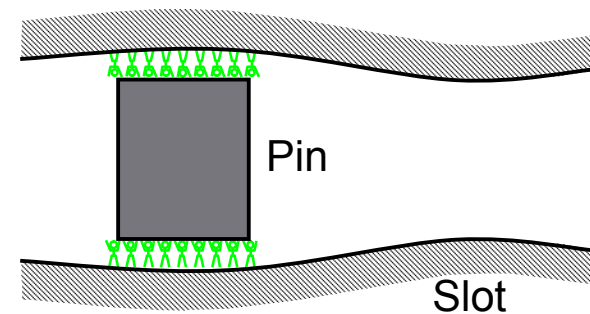


- Small Smart People



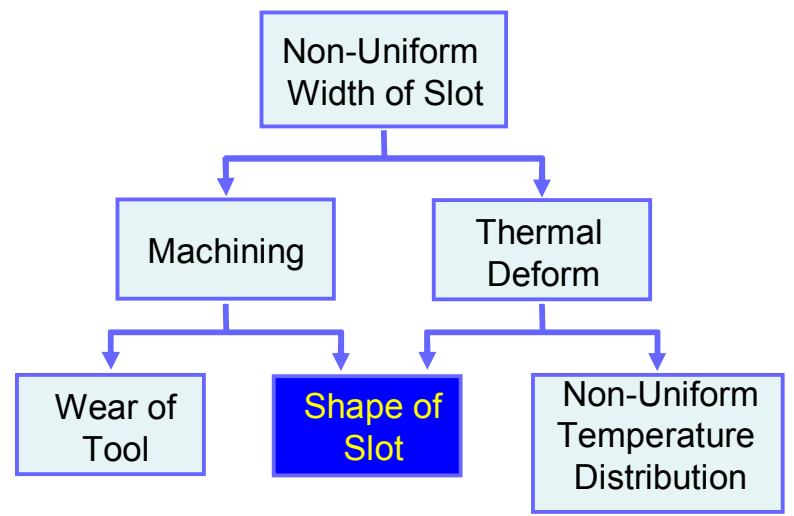
➡  
Increase  
Contact Area

- Change Shape of Control Pin

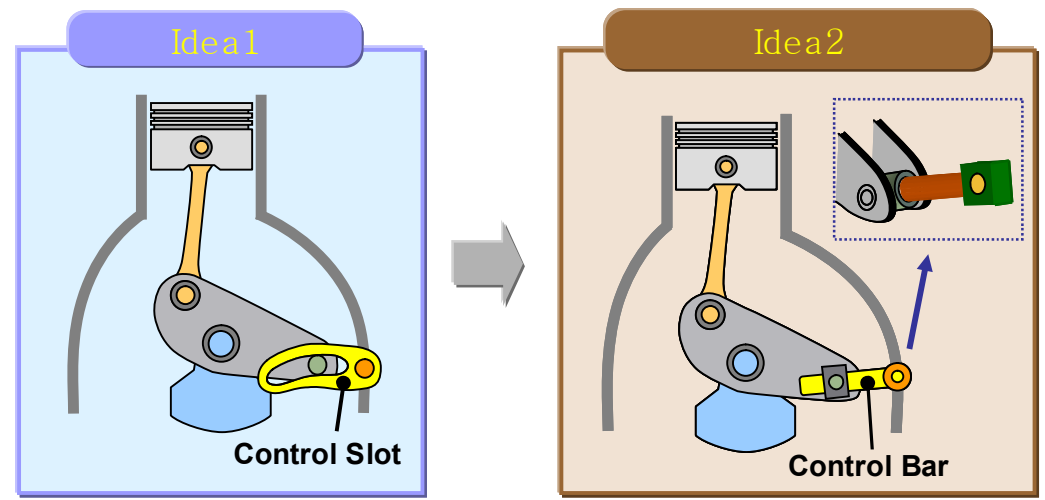
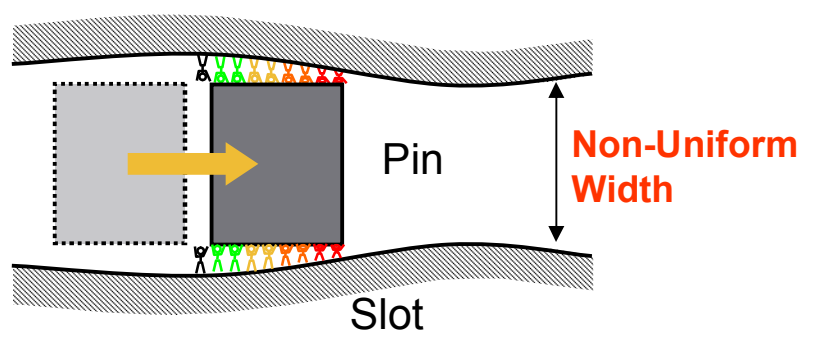


# IDEA-3: ARIZ

## ● Cause Effect Chain Analysis

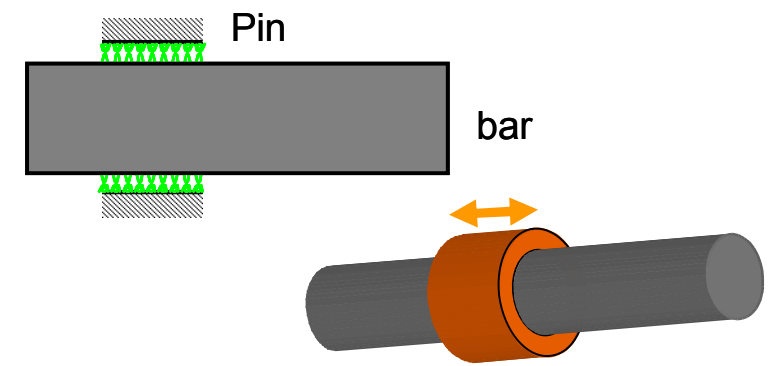


## ● Change shape of slot



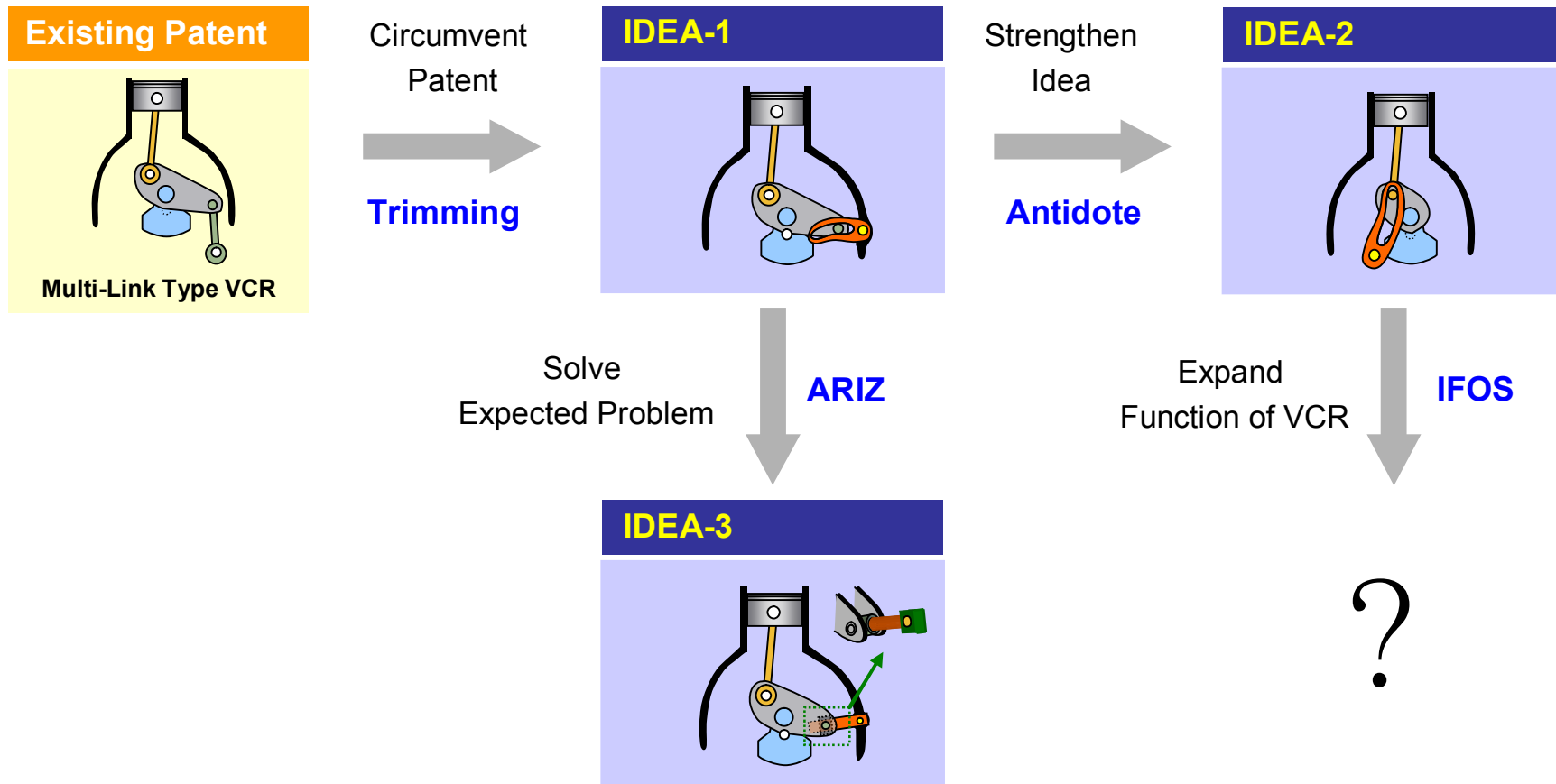
➡  
Inventive Principle 13.  
"The Other Way Round"

## ● Replace control slot with control bar

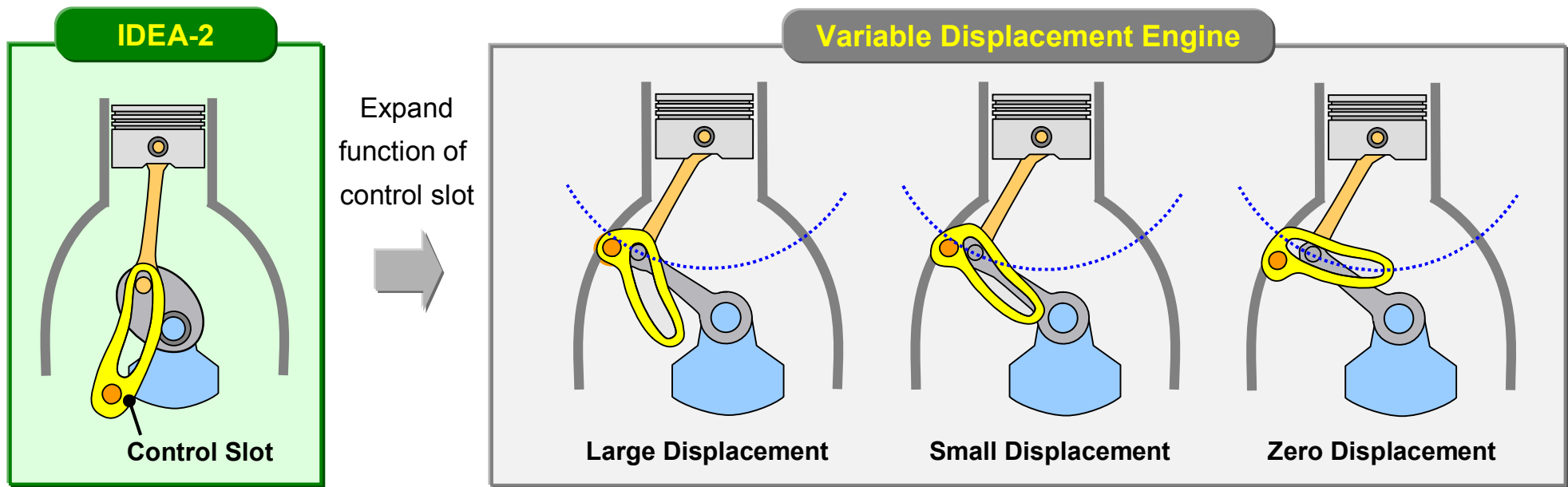


# Idea Generation Using TRIZ

## Result of Idea Generation (Step3)



## Expand function of Control Slot to Other Application (IFOS: Inverted Function-Oriented Search)



Variable **Compression Ratio** Engine  
Using Control Slot

Variable **Displacement** Engine  
Using Control Slot

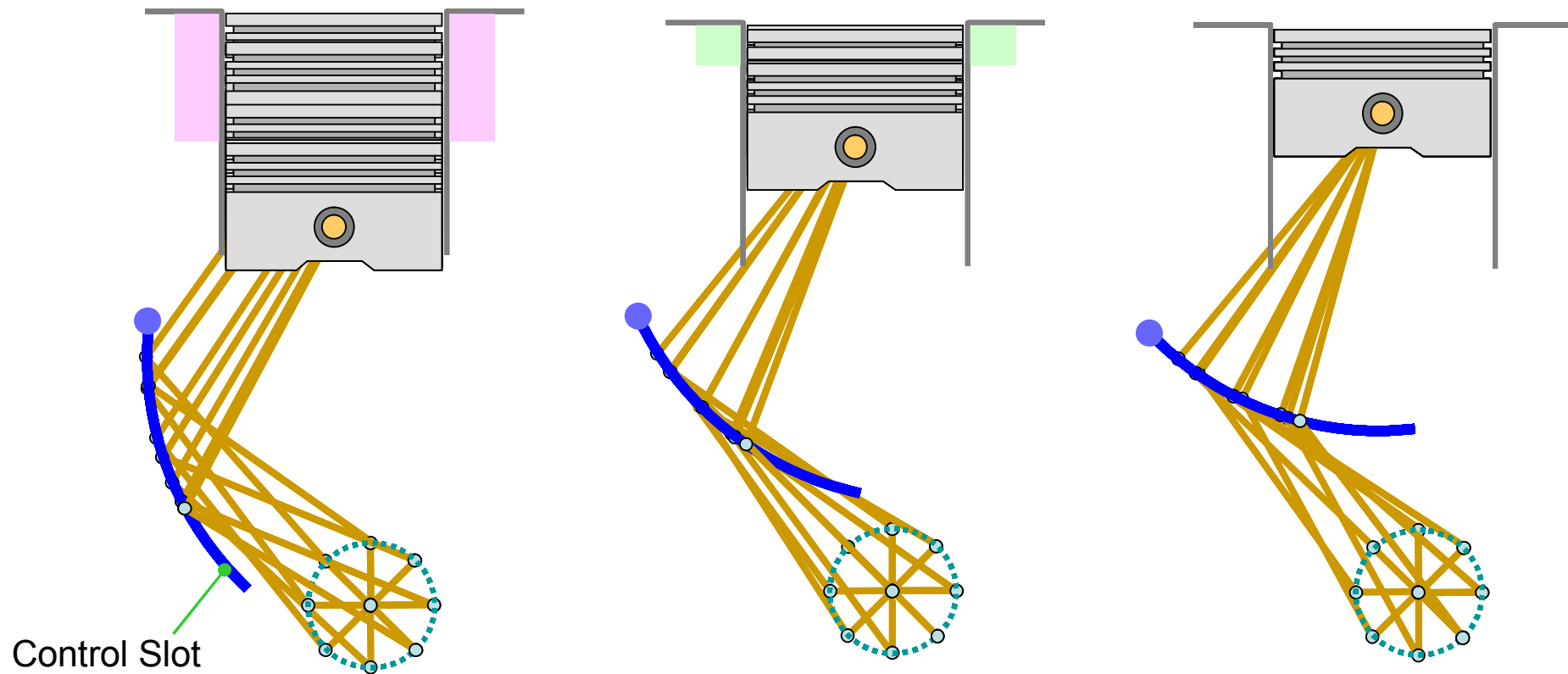
# IDEA-4: Variable Displacement Engine Using Control Slot

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● Large Displacement

● Small Displacement

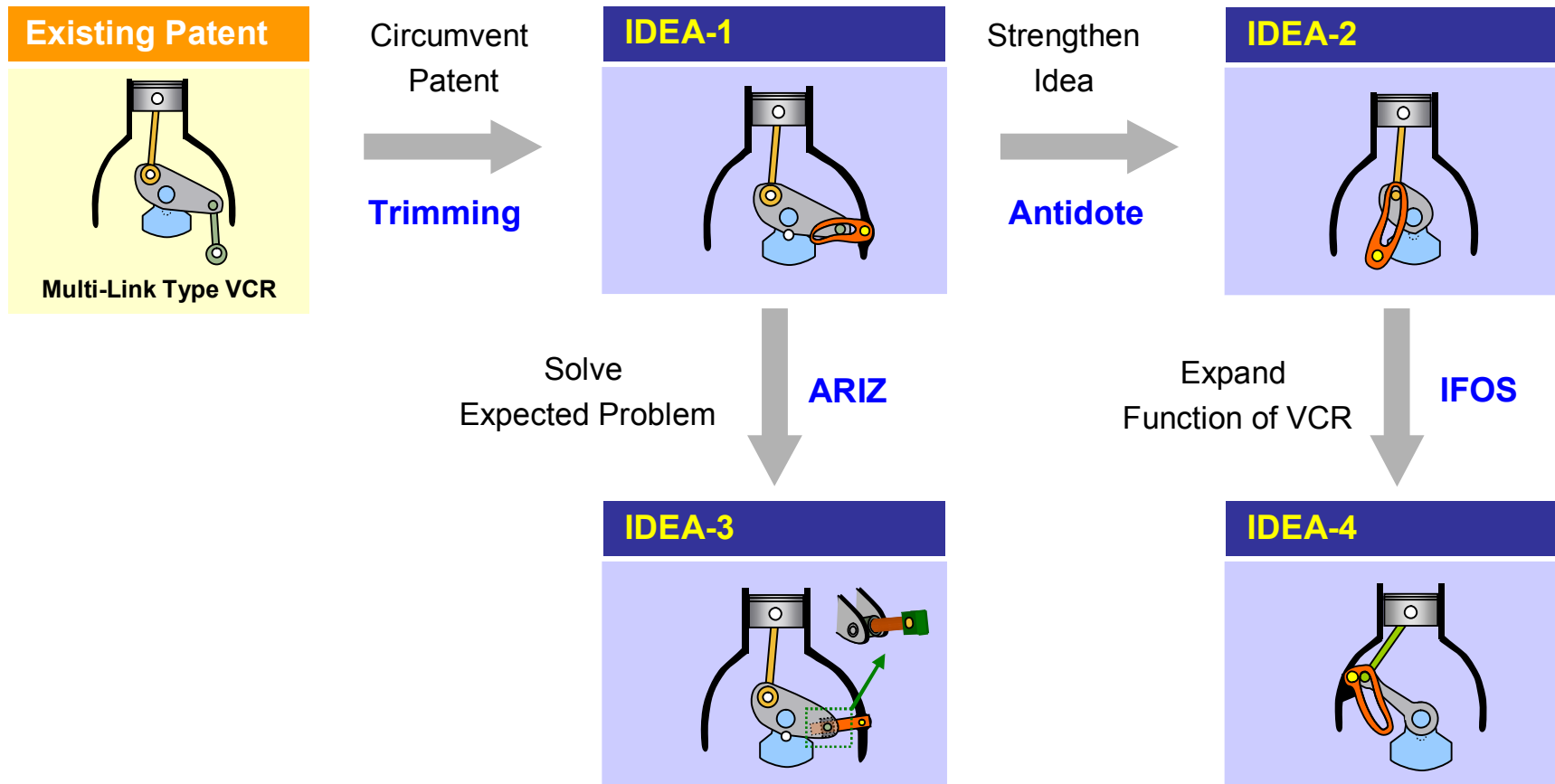
● Zero Displacement





# Idea Generation Using TRIZ

## Result of Idea Generation (Step4)



- Variable compression engine itself is one of good examples of “Separation in Time”, and it can maximize engine power and fuel economy.
  
- In this study, TRIZ is applied to develop new concept of VCR engine. Various tools of TRIZ have been used in this study:
  - “Function Analysis” is applied to analyze previous VCR models.
  - “Trimming” makes new contradiction.
  - “Antidote Strategy” strengthens circumvented idea.
  - “ARIZ” gives a solution to the expected problem.
  - “IFOS” expands control slot to other applications.
  
- Finally, several concepts of VCR engine have been obtained successfully.