Analysis of the Effectiveness of Thermal Shroud on the Thermal Deformation of a Gun Barrel

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INTRODUCTION

- The general
  - ✓ Accuracy is well known as one of the main performance of a tank gun.
  - ✓ Factors to affect the accuracy
    - gun, fire control system, ammunition, gunner, etc.
  - ✓ In the case of gun, the centerline profile of the bore affects the in-bore movement, and exit state of the projectile, and finally its flight path to target.
  - ✓ Factors to vary the centerline of the bore
    - sagging from the weight of a gun barrel itself
    - machining error (straightness, wall thickness)
    - deformation by internal or external heat source

INTRODUCTION

□ Thermal deformation principles of gun barrel

Heat flux from solar radiation, wind, rain

Heat flux from the bore in firing

↓

Uneven heating or cooling of gun barrel

↓

Cross sectional temp. difference of gun barrel

↓

Thermal deformation of gun barrel

↓

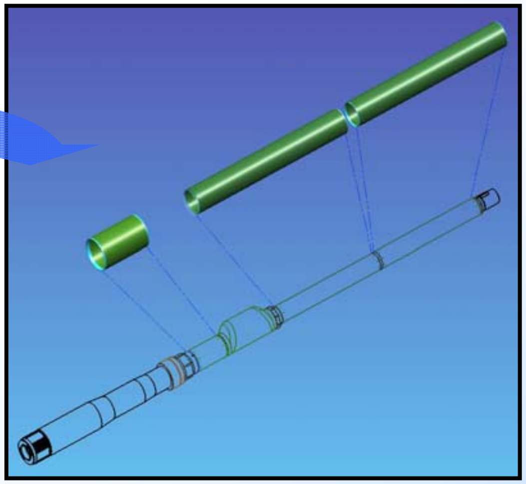
The degradation of accuracy of gun system

❖ This presentation does not include the analysis related to heat flux from the bore in firing.

INTRODUCTION

□ Requirement of thermal shroud design

- ✓ To minimize the deformation of gun barrel by heat
- ✓ To have light-weight structure



□ Purpose & Scope of the research

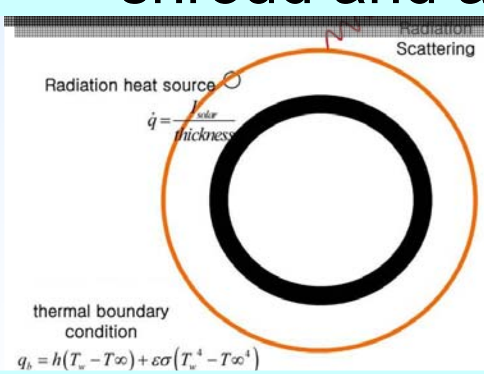
- ✓ To evaluate the effectiveness of thermal shroud
- ✓ To study the effect of design parameters

ANALYSIS

□ Outline

Flow Field Analysis (FLUENT)

- to predict the heat transfer coef. at the outer wall of thermal shroud
- to calculate the temp. of a gun barrel, thermal shroud and air gap in between the two



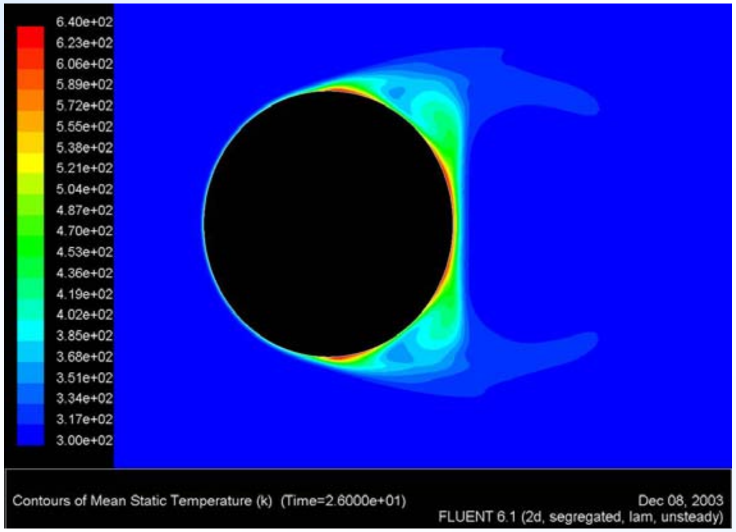
Data Mapping Scheme : transferring CFD results to stress analysis

Thermal Stress Analysis (ABAQUS)

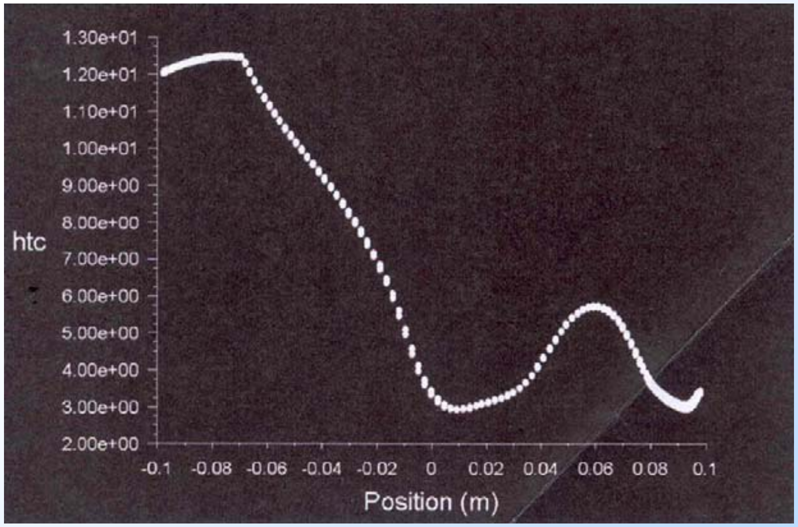
- to calculate the deformation of a gun barrel and the gun muzzle movement

ANALYSIS

- □ Prediction of the heat transfer coef. at the outer wall of thermal shroud
  - ✓ wind velocity. : 0.5 m/s, heat input : constant
  - ✓ Calculation Eq. : $h = \dfrac{Q}{\bar{T}_{wall} - T_{\infty}}$



Average temperature



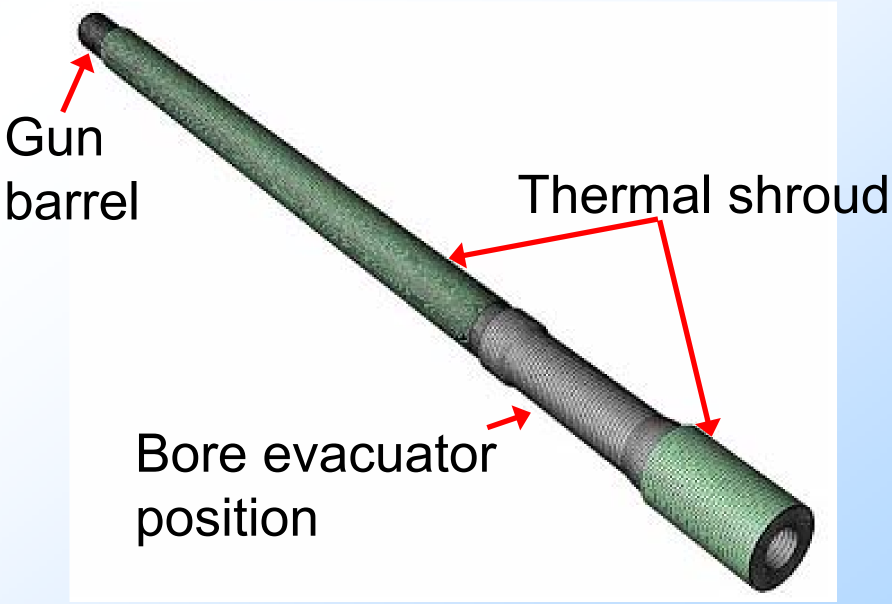
Average heat transfer coef.

ANALYSIS

- Material properties

Properties	Thermal shroud	Gun barrel
Density(kg/m³)	2,540	7,850
Conductivity(W/m-k)	1.0344	44.5
Specific heat(J/kg-k)	795.5	475

- Mesh model of gun barrel with thermal Shroud



ANALYSIS

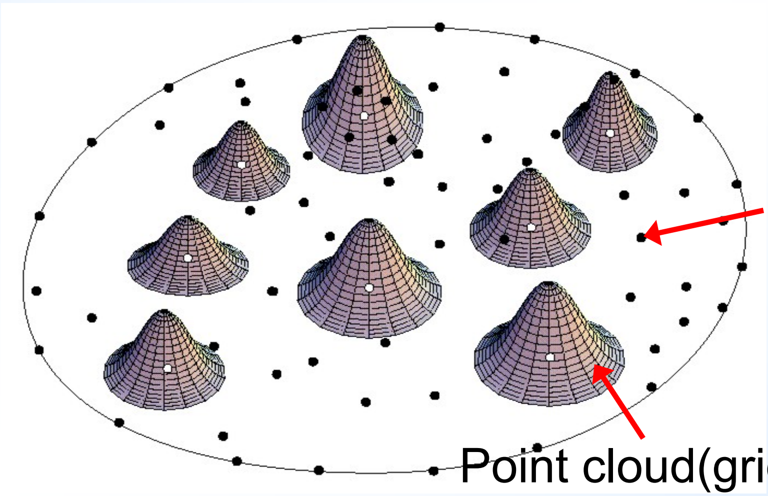
- Geographic conditions for analysis
  - ✓ Latitude 35° north, longitude 127° 30' east
  - ✓ Solar radiation energy in Summer(21, Aug.)

Case	Hour	Solar radiation energy(W/m^2)		Wind vel. (m/s)
		direct	diffuse	
A	7 a.m.	427.6	52.2	0.5
B	9 a.m.	792.4	96.7	0.5
C	12 a.m.	883.4	120.1	0.5
D	3 p.m.	850.6	103.8	0.5
E	5 p.m.	695.5	84.9	0.5
F	12 a.m.	883.4	120.1	3.0

- ✓ Orientation of a gun barrel to south
- ❖ Unless stated, analysis conditions refer to Case C

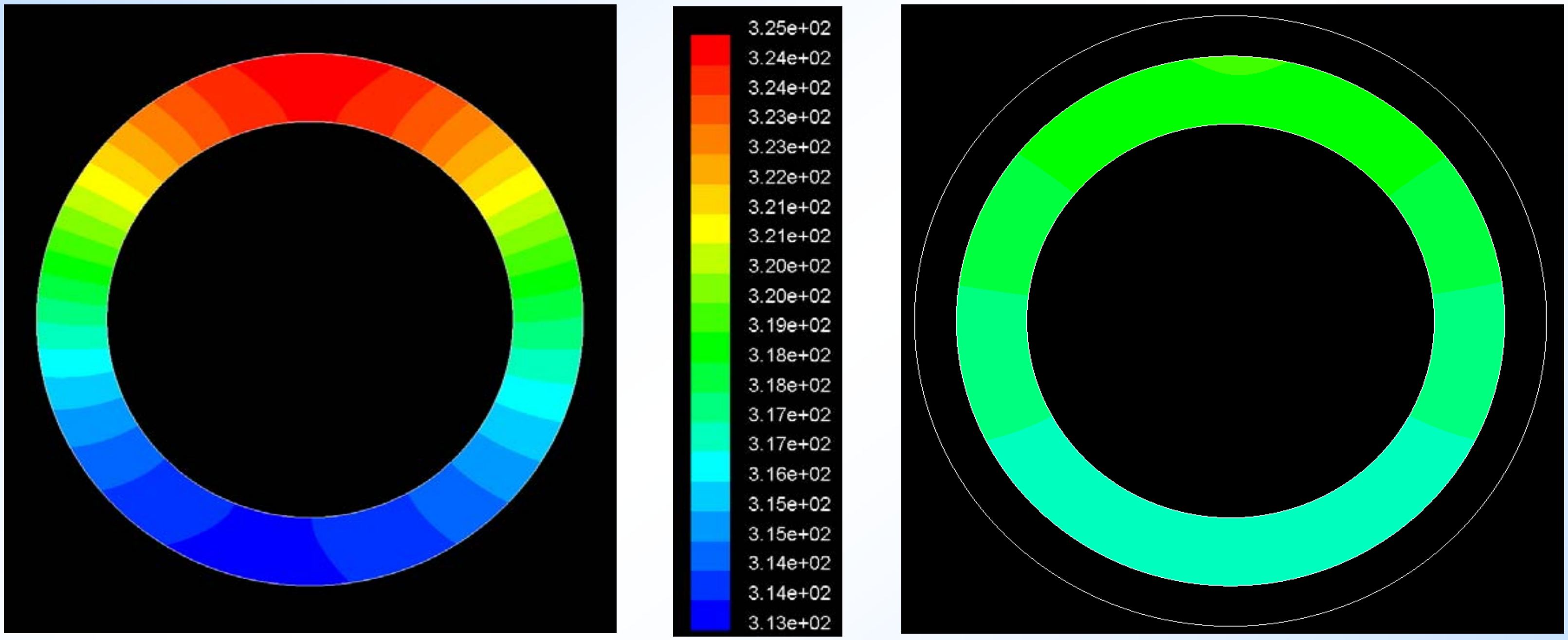
ANALYSIS

- Development of a coupled scheme for data mapping
  - ✓ Need to transfer the temperature results of fluid flow analysis to the thermal stress model
  - ✓ To solve the mapping problem according to different mesh system each other
  - ✓ Applied the point clouds concept



ANALYSIS

- A cross sectional wall temp. of gun barrel

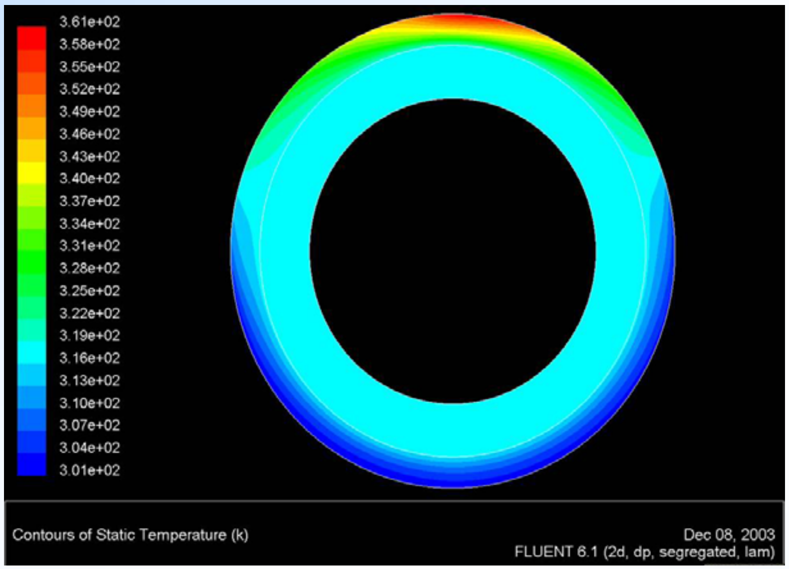


Wall temp. without thermal shroud (Max. T: 52°C, ΔT : 12°C)

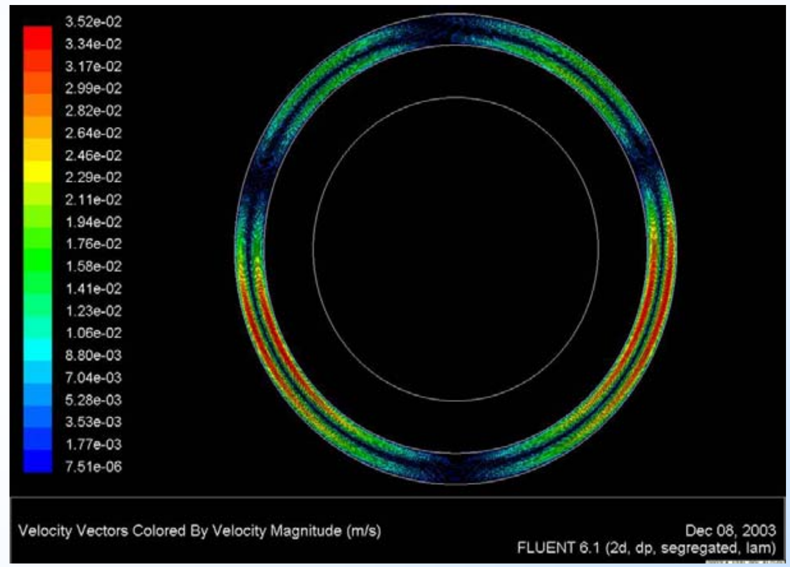
Wall temp. with thermal shroud (Max. T: 46°C, ΔT : 3°C)

ANALYSIS

□ Temp. and flow characteristics of air layer by thermal shroud



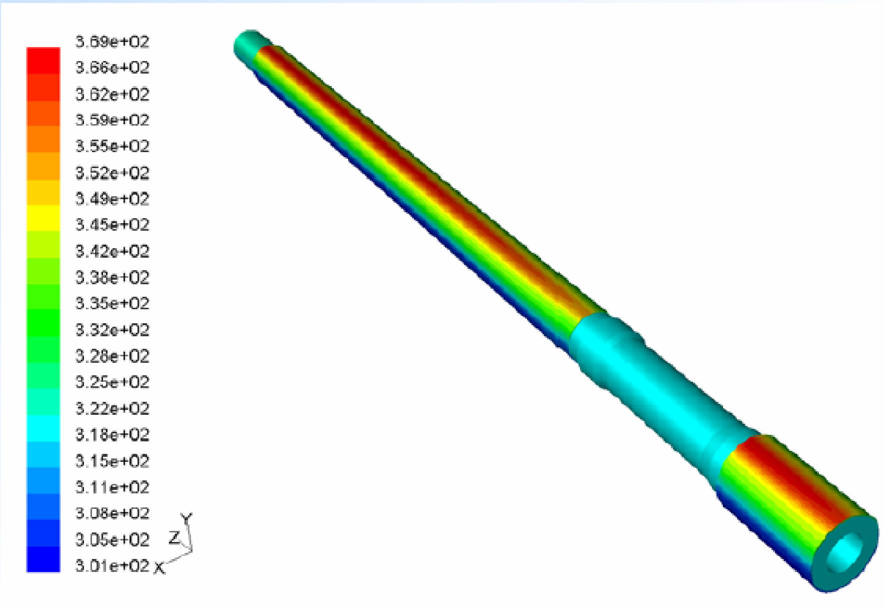
Temp. distribution of air layer
(ΔT : approx. 60 °C)

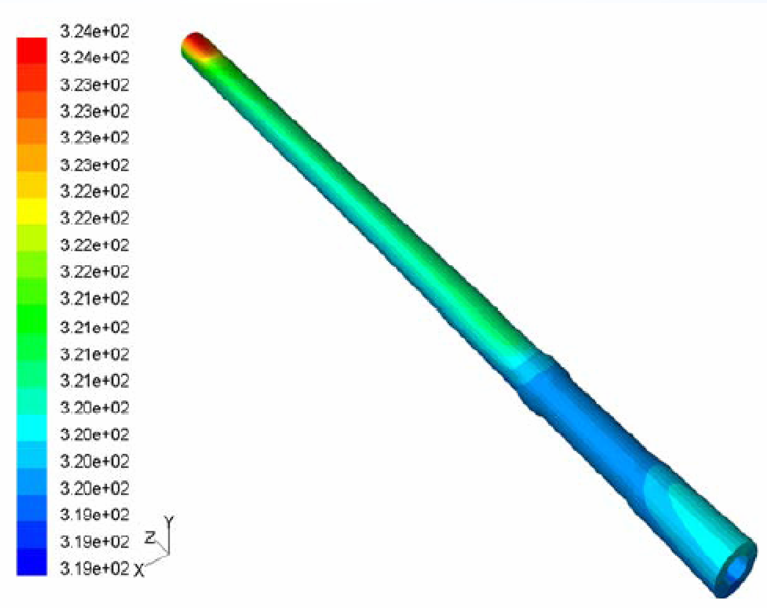


Vel. distribution of air layer
(Max. Vel. : 3.5 cm/s)

ANALYSIS

- Longitudinal wall temp. of thermal shroud and gun barrel



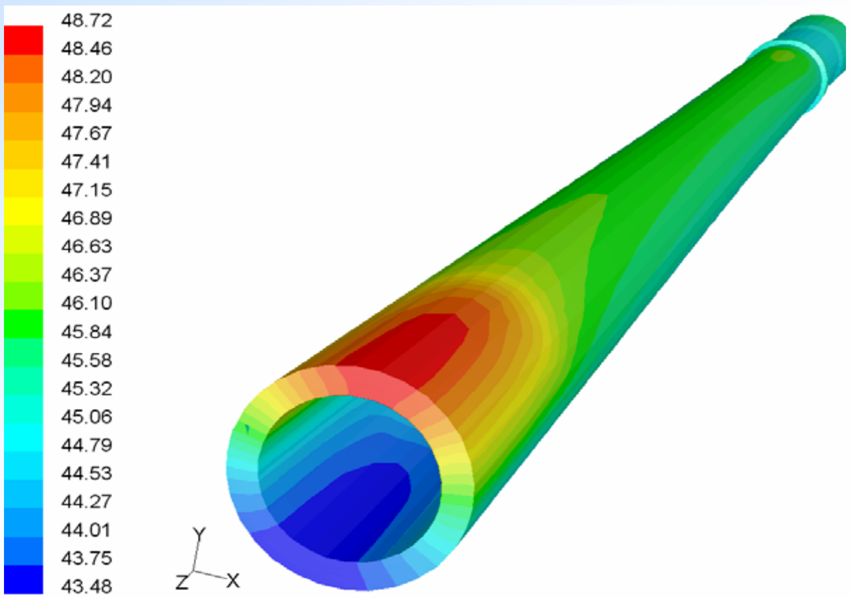


Max. T : 98.0 ° C
Min. T : 23.4 ° C

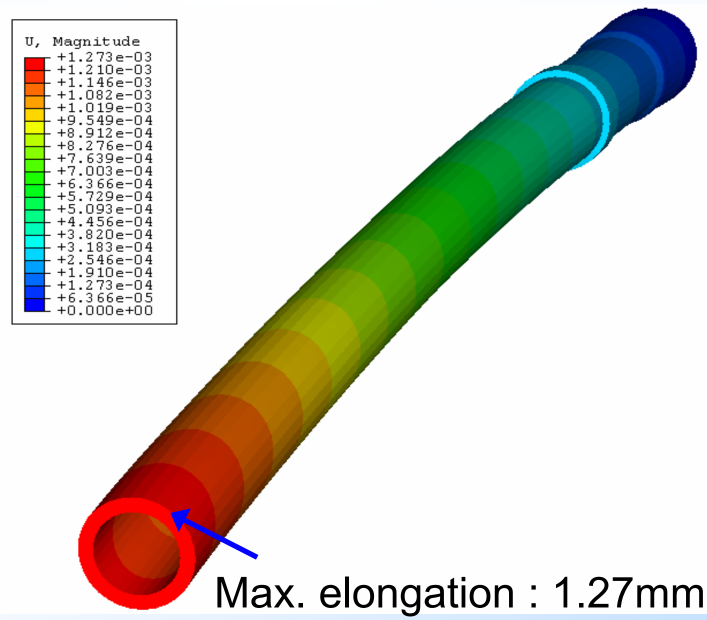
Max. T : 48.7 ° C
Min. T : 43.5 ° C

ANALYSIS

□ Longitudinal temp. distribution and thermal deformation of gun barrel with thermal shroud



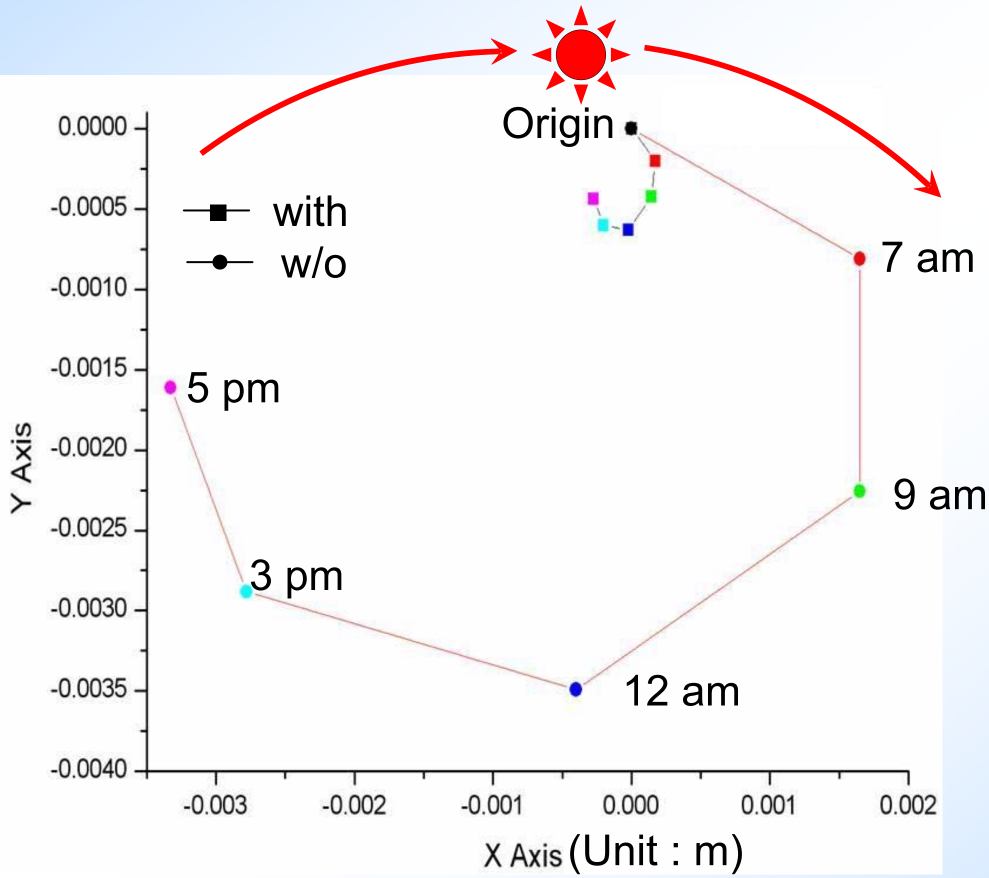
Temp.(°C) distribution



Thermal deformation(m)

ANALYSIS

- Comparison of the movement of gun muzzle with or without thermal shroud



The effectiveness of the thermal shroud is proved by analysis.

DESIGN PARAMETERS STUDY

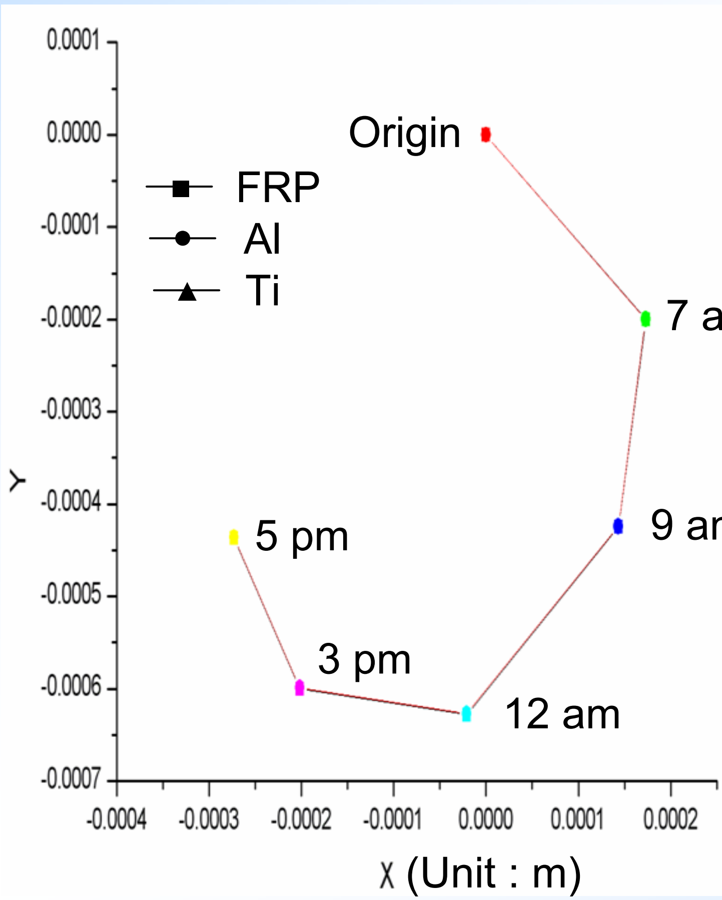
- □ Materials of thermal shroud

Properties	FRP	Al	Titanium
Density(kg/m³)	2,540	2,719	4,850
Conductivity(W/m-k)	1.0344	202.4	7.44
Specific heat(J/kg-k)	795.5	871	554.25

- □ Wall thickness of thermal shroud
  - ✓ 5mm
  - ✓ 10mm
- □ Radial gap between thermal shroud and gun barrel
  - ✓ 1.0L
  - ✓ 1.5L

DESIGN PARAMETERS STUDY

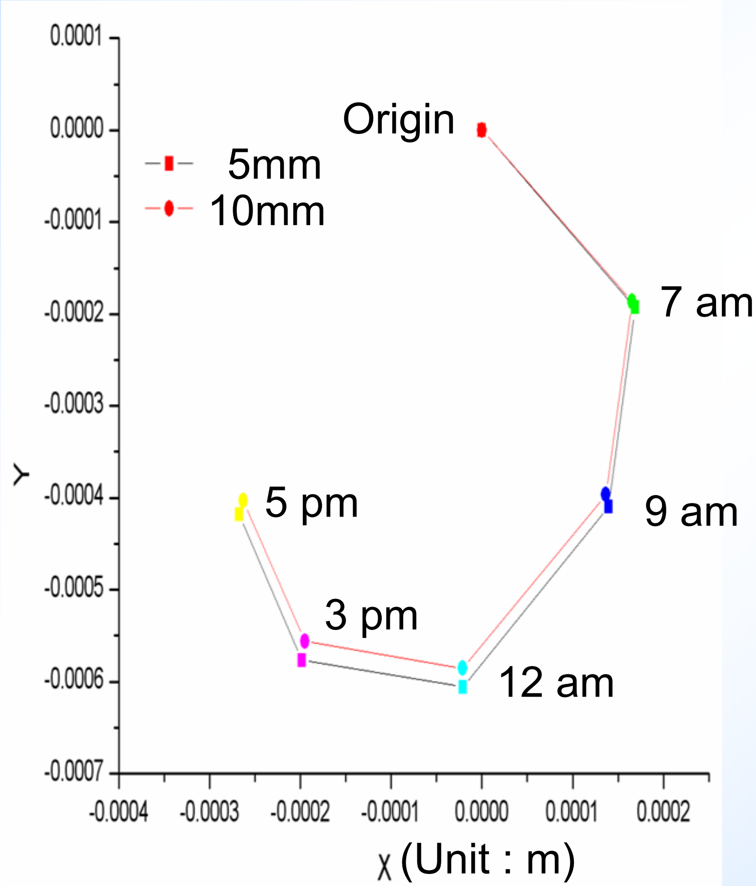
- Comparison of the movement of gun muzzle relating to materials



✓It is shown that the material does not almost influence the effectiveness of thermal shroud.
✓Aluminum has the shortest time in thermal equilibrium

DESIGN PARAMETERS STUDY

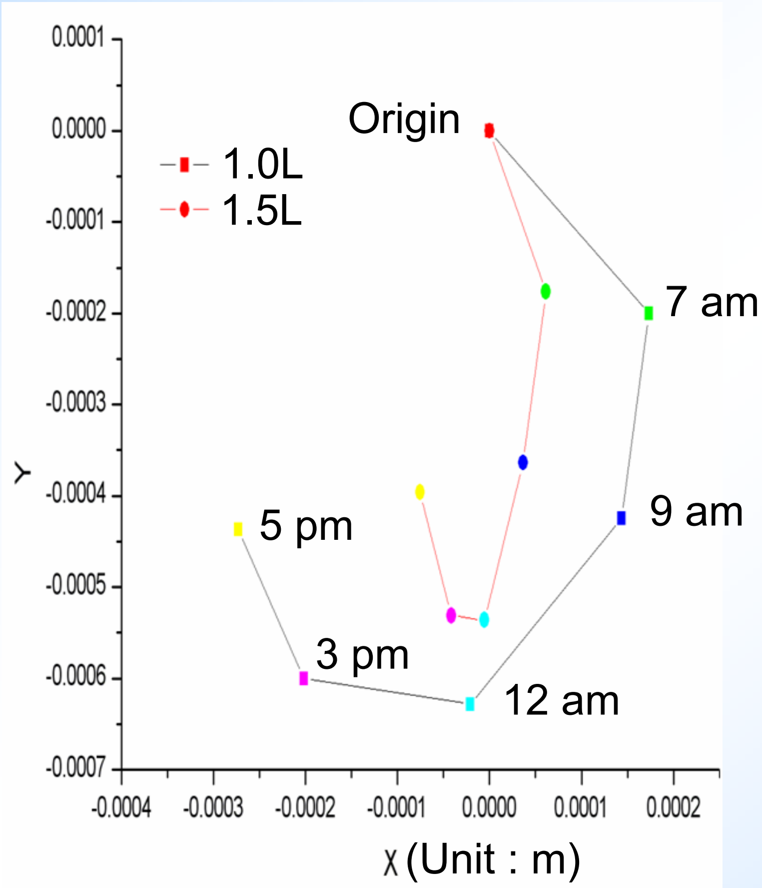
- □ Comparison of the movement of gun muzzle relating to wall thicknesses



It is shown that the wall thickness does not influence the effectiveness so much.

DESIGN PARAMETERS STUDY

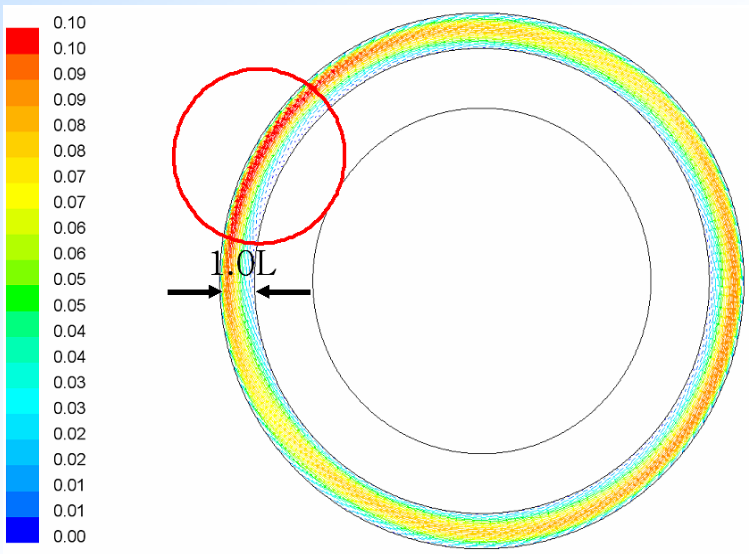
- Comparison of the movement of gun muzzle relating to radial gaps

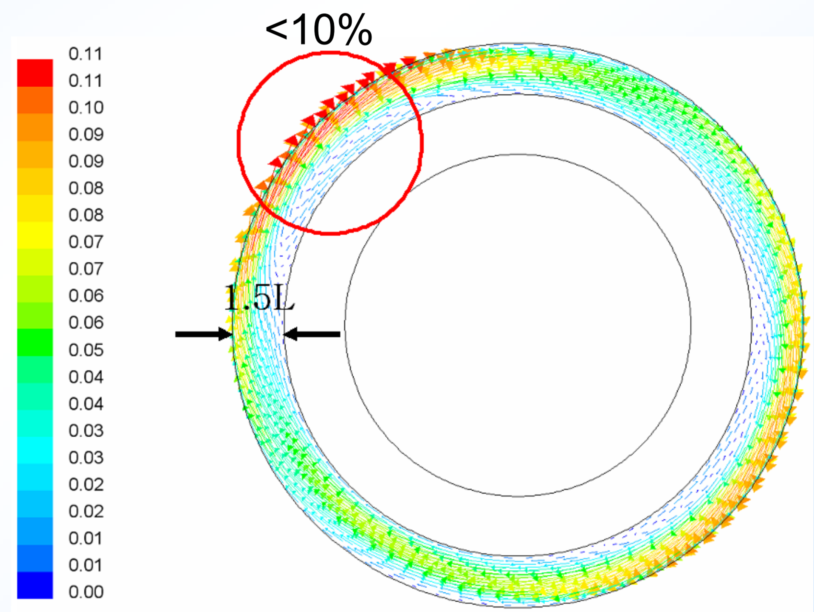


It is shown that a gap is a major parameter in designing the thermal shroud.

DESIGN PARAMETERS STUDY

- Consideration of radial gap’s effects
  - ✓ Velocity vector(at 9 a.m.)



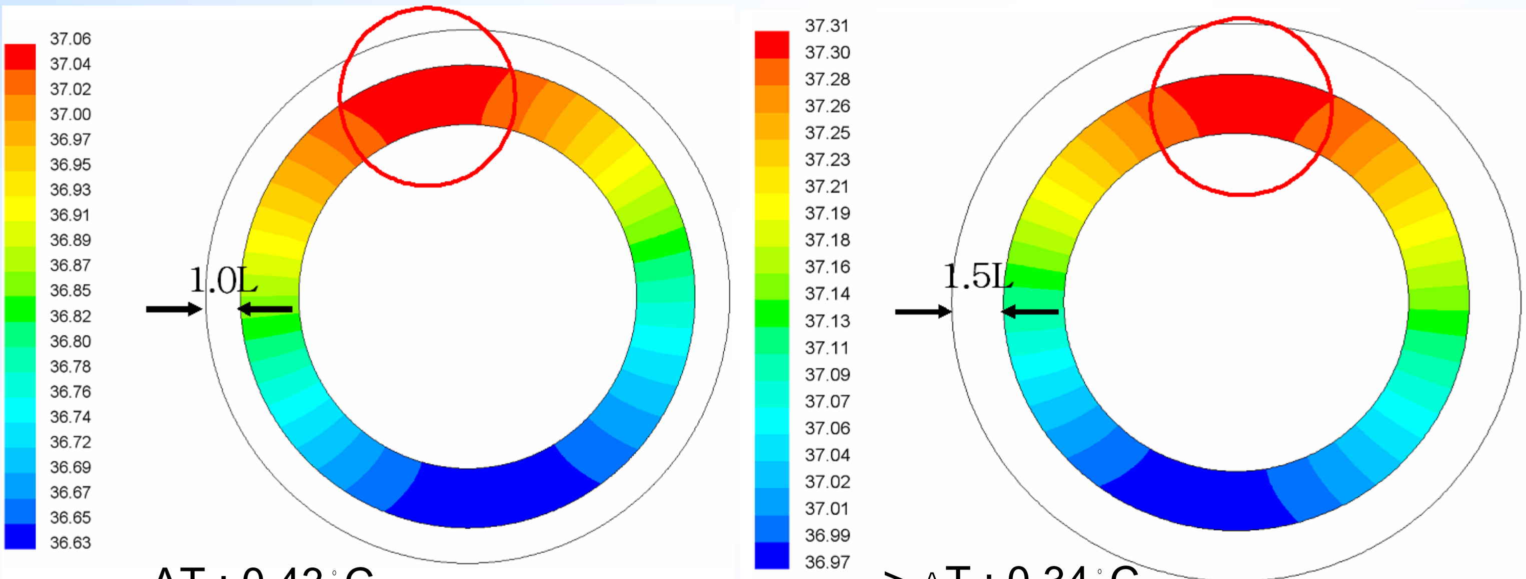


It is shown that the gap increment makes the flow velocity of air layer faster, and the wall temp. of gun barrel in more equilibrium.

DESIGN PARAMETERS STUDY

□ Consideration of radial gap's effects(cont.)

✓ Wall temp. distribution of gun barrel(at 9 a.m.)

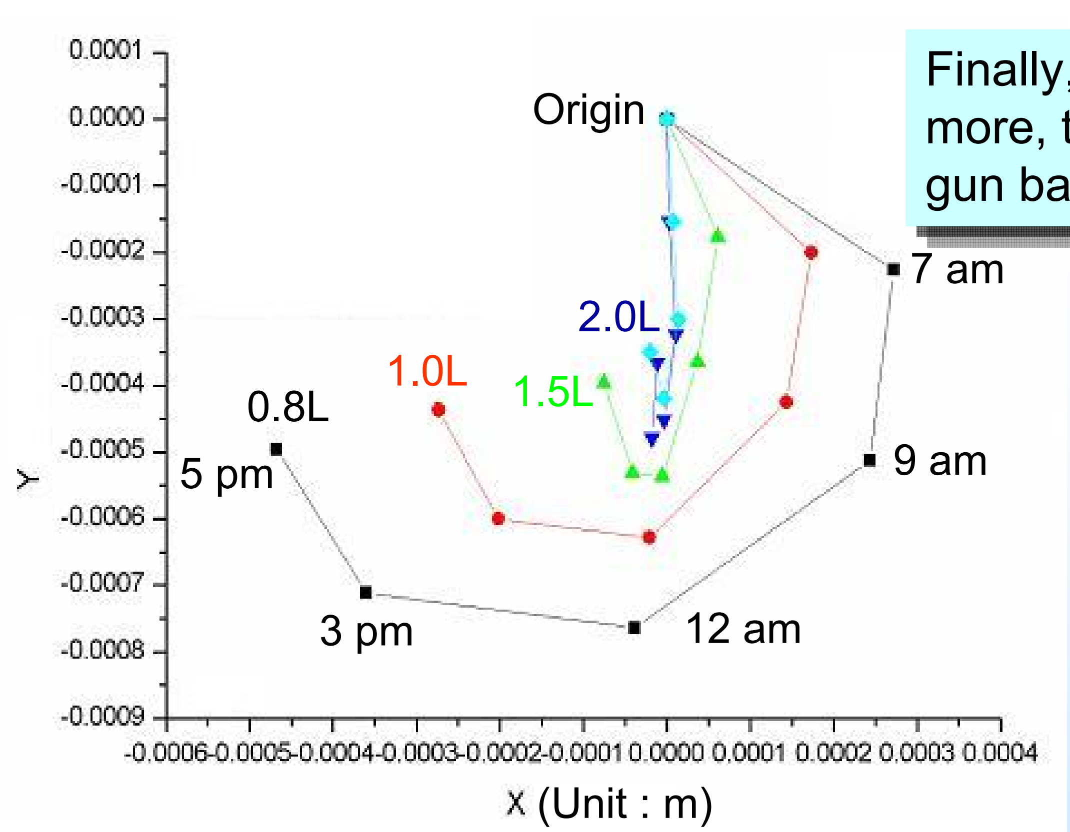


ΔT : 0.43°C > ΔT : 0.34°C

It is shown that the wall temp. difference of gun barrel becomes on the decrease.

DESIGN PARAMETERS STUDY

- □ Consideration of radial gap's effect(cont.)
  - ✓ Validation examination by various gap sizes

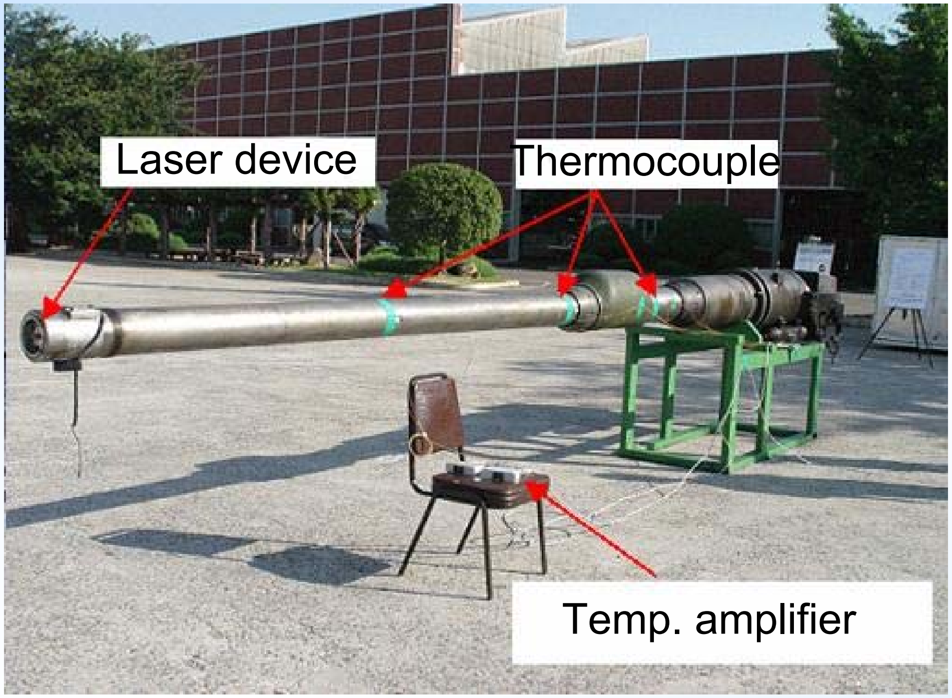


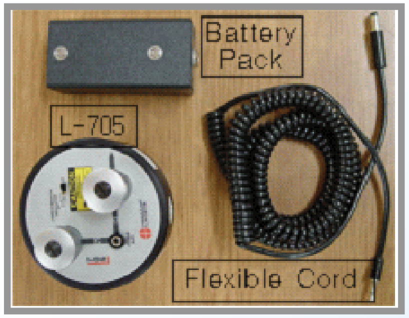
Finally, as the gap increases more, the deformation of a gun barrel decreases.

TEST RESULTS

□ Validation of analysis by non-firing test

✓ test scene and apparatus





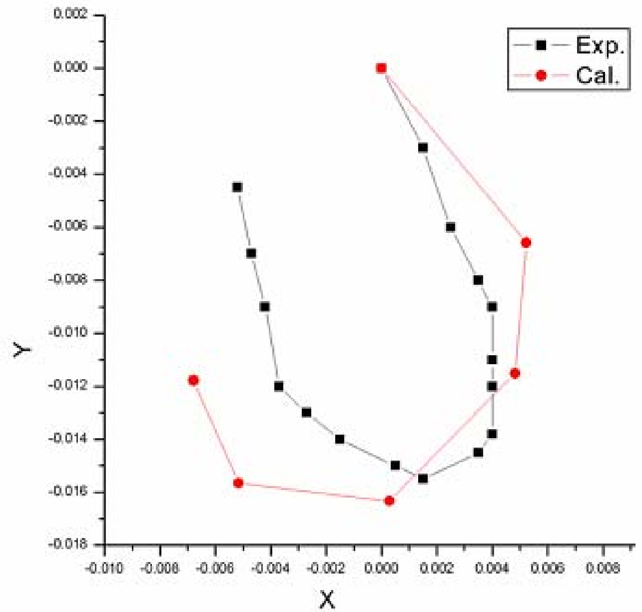
✓ Target range : 20m

TEST RESULTS

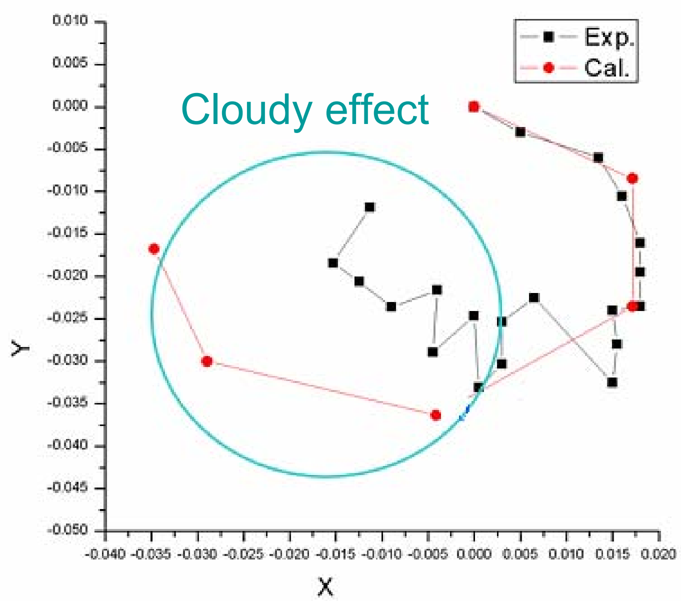
□ Validation of analysis by non-firing test(cont.)

✓ Comparison of the results by non-firing test with the calculation results according to test ambient conditions

❖ All values are at a distance of 20m from gun muzzle.



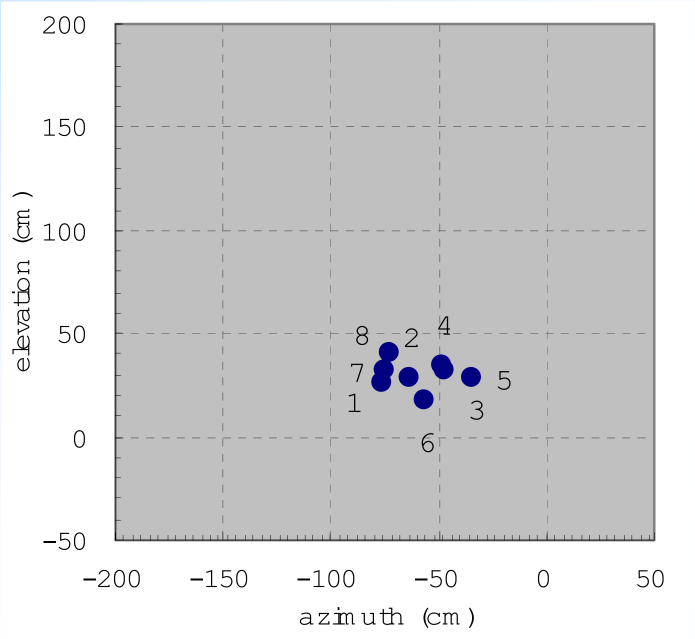
With thermal shroud



Without thermal shroud

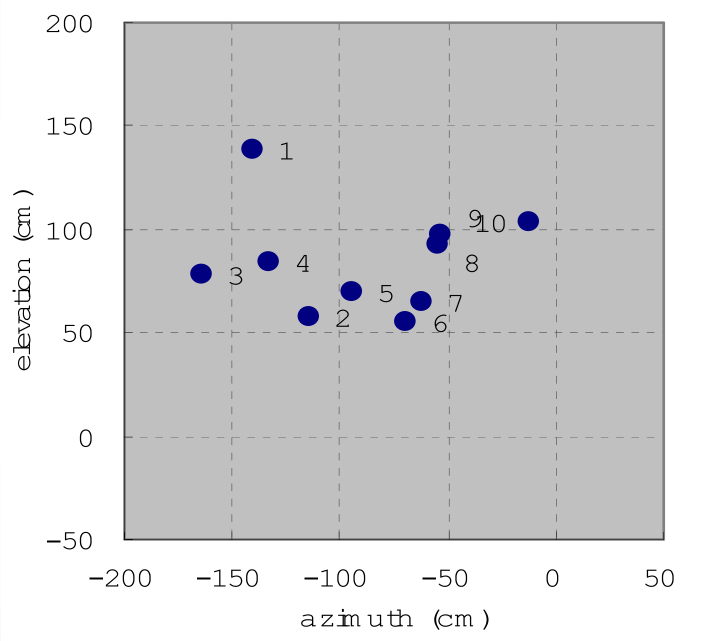
TEST RESULTS

- Real firing test results
  - ✓ Target range : 1km



Max. ΔT at the outer of gun barrel : 2.0°C

With thermal shroud



Max. ΔT at the outer of gun barrel : 10.5°C

Without thermal shroud

DISCUSSION AND CONCLUSIONS

- An attempt was made to evaluate the effectiveness of thermal shroud, and to study the effect of design parameters by analysis.
  - ✓ A coupled scheme that transfers the results of fluid flow analysis to the thermal stress analysis has been developed.
  - ✓ The effectiveness of the thermal shroud has been verified.
  - ✓ The gap between the thermal shroud and gun barrel is a major parameter in designing.
  - ✓ The thermal deformation of a gun barrel decreases, as the gap increases.

- This analysis is thought to be good, comparing calculation results with test results.

- The results of this study will be helpful to design the thermal shroud.

END OF PRESENTATION

QUESTION?

THANK YOU

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