

# Molding products with Cooling pipe

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성지환

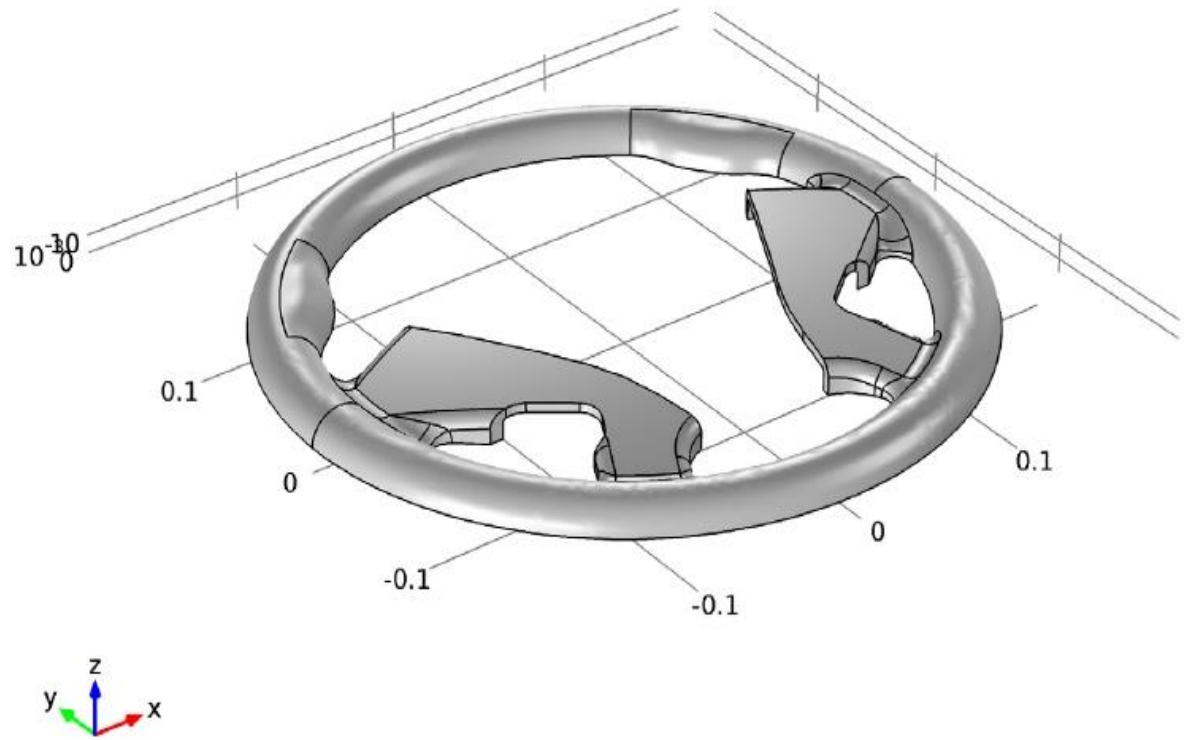
# contents

- ◉ Subject
- ◉ Methodology
- ◉ Study Result

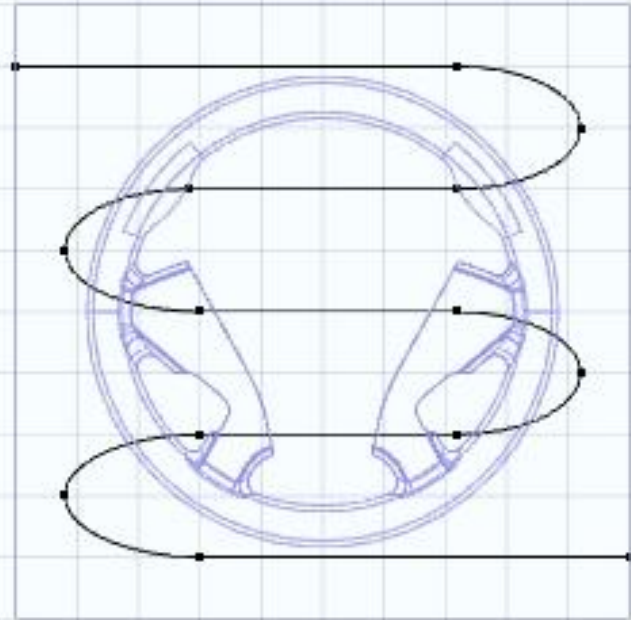


# Subject (간략화)

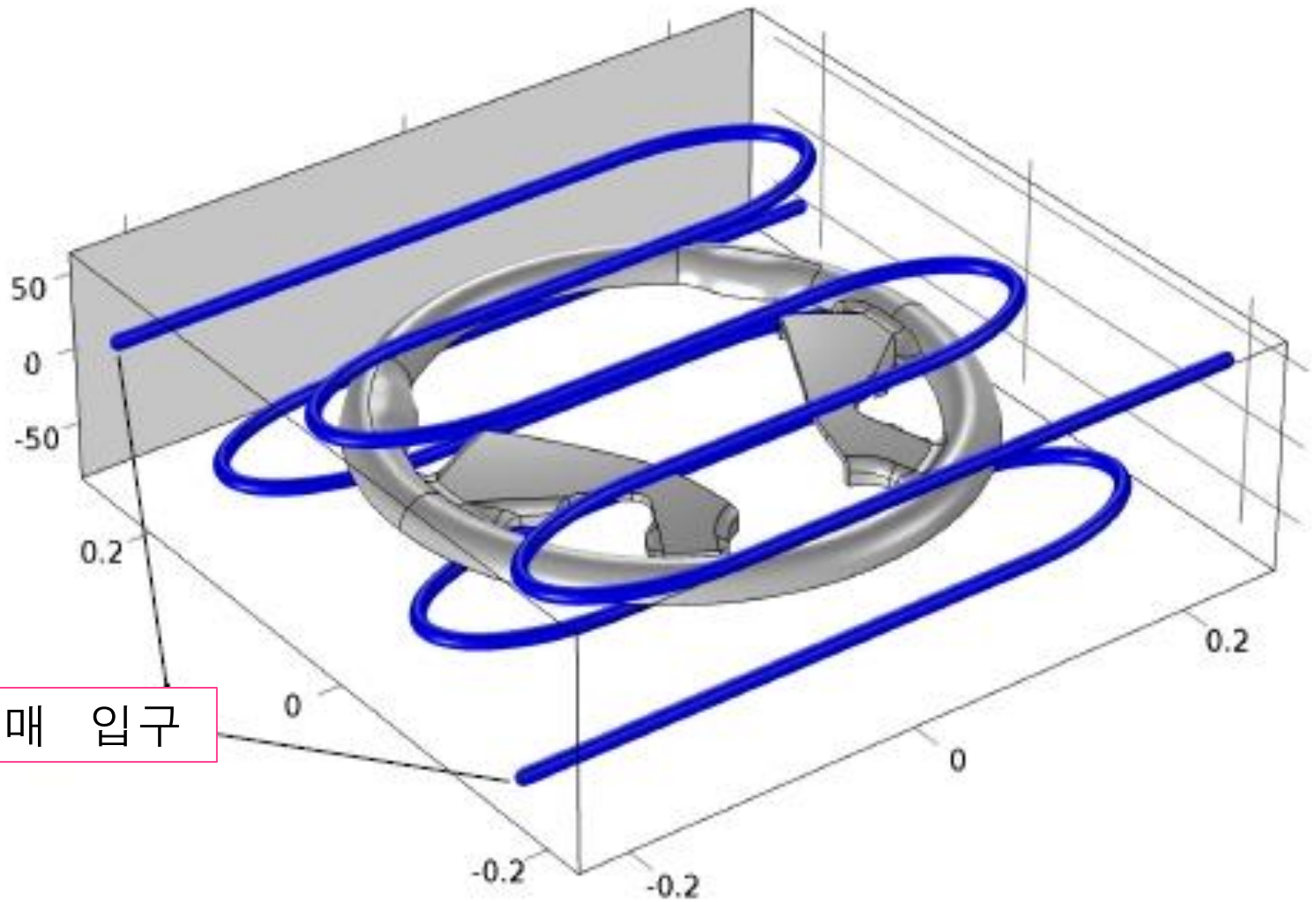
핸들 상반부분의 그립 분석



# Subject (간략화)



# Subject (간략화)



냉매 입구

# Methodology

# <Pipe & Mold 부여조건>

- Heat Transfer in Pipes
- 냉매의 이동
- Wall heat transfer
- Non- isothermal Pipe Flow



- ◉ Heat outflow
- ◉ Material
- ◉ Model geometry

# Model Set up

The screenshot displays the COMSOL Multiphysics Model Builder interface. The left pane shows a tree of physics models. The 'Heat Transfer' folder is expanded, and 'Heat Transfer in Solids (ht)' is selected. Below the tree, the 'Selected physics' section lists 'Non-Isothermal Pipe Flow (nipf2)' and 'Heat Transfer in Solids (ht2)'. The 'Dependent variables' section shows 'Temperature' set to 'T4' and 'Surface radiosity' set to 'J2'.

**Model Builder Tree:**

- Turbulent Flow
  - Non-Isothermal Pipe Flow (nipf)
- High Mach Number Flow
- Rarefied Flow
- Particle Tracing for Fluid Flow (fpt)
- Fluid-Structure Interaction (fsi)
- Heat Transfer
  - Heat Transfer in Solids (ht)
  - Heat Transfer in Fluids (ht)
  - Heat Transfer in Porous Media (ht)
  - Bioheat Transfer (ht)
  - Heat Transfer in Thin Shells (htsh)
- Conjugate Heat Transfer
- Radiation
- Electromagnetic Heating
- Heat Transfer in Pipes (htp)
- Plasma

**Selected physics:**

- Non-Isothermal Pipe Flow (nipf2)
- Heat Transfer in Solids (ht2)

**Dependent variables:**

- Temperature: T4
- Surface radiosity: J2

The screenshot shows the 'Model Setup' section of the software. It contains three radio button options: 'Stationary', 'Time Dependent', and 'Custom Studies'. The 'Time Dependent' option is selected.

**Model Setup:**

- Stationary
- Time Dependent
- Custom Studies

# Parameter, variable 지정

Parameters

| Name        | Expression | Value    | Description               |
|-------------|------------|----------|---------------------------|
| T_init_mold | 473,15[K]  | 473,15 K | Initial temperature, mold |
| T_coolant   | 288,15[K]  | 288,15 K | Steady-state inlet tem... |
|             |            |          |                           |
|             |            |          |                           |
|             |            |          |                           |

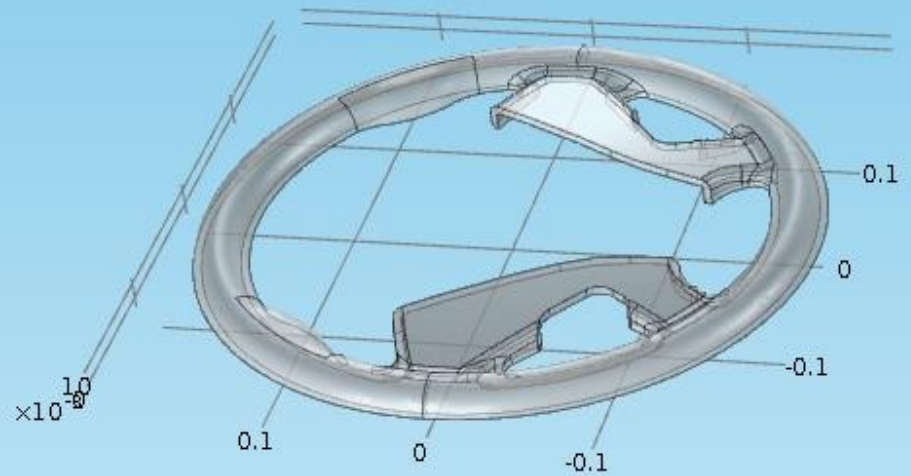
Variables

| Name    | Expression  | Unit | Description             |
|---------|---|------|-------------------------|
| T_inlet | $T\_coolant + (T\_init\_mold - T\_coolant) \dots$ | K    | Ramped inlet tempera... |
|         |   |      |                         |
|         |   |      |                         |
|         |   |      |                         |
|         |   |      |                         |

# CAD파일 불러오기



CAD에서 작성후 Comsol에서 축척 맞춘 후 mphbin 파일로 저장했음



# Dialog Box 생성

(사용자로부터 인터페이스에서 입력을 받아들이기 위해 표시되는 임의의 장치)

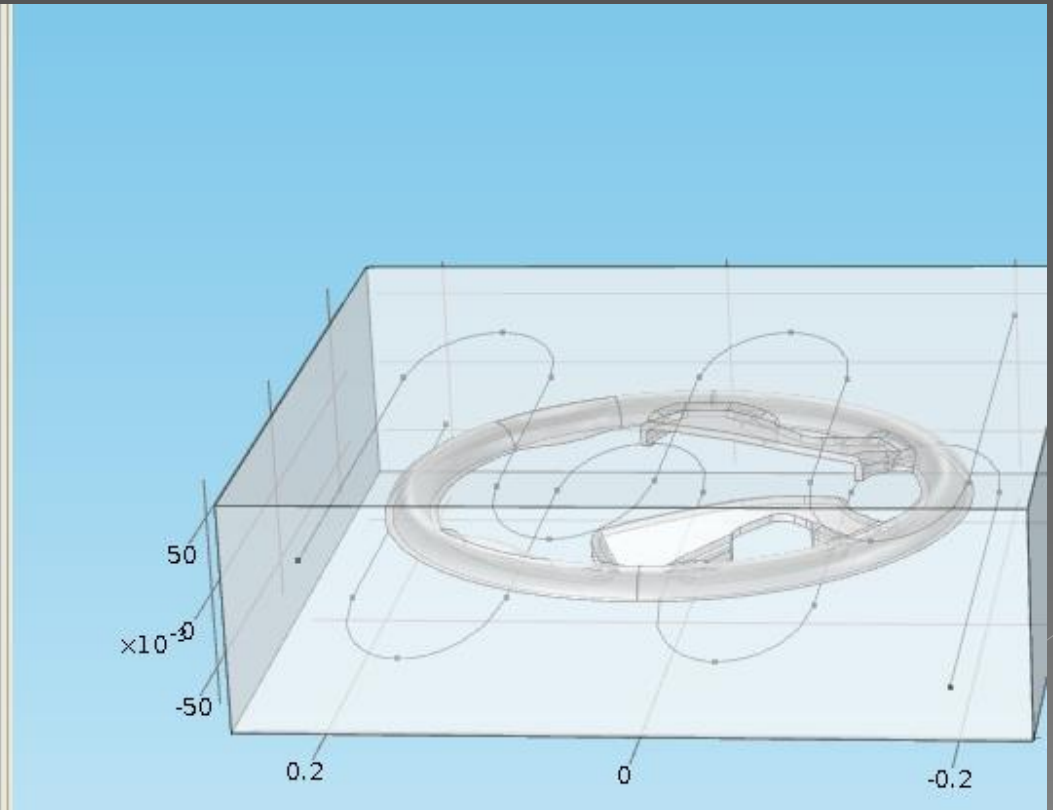
▼ Object type  
Type: Solid

▼ Size and Shape  
Width: 0,5 m  
Depth: 0,5 m  
Height: 0,15 m

▼ Position  
Base: Center  
x: 0 m  
y: 0 m  
z: 0 m

▼ Axis  
Axis type: Cartesian  
x: 0  
y: 0  
z: 1

▼ Rotation Angle



# Work plane에서 cooling pipe 작성

## Work Plane

Plane type:

Quick

Plane:

xy-plane

z-coordinate:

4e-2

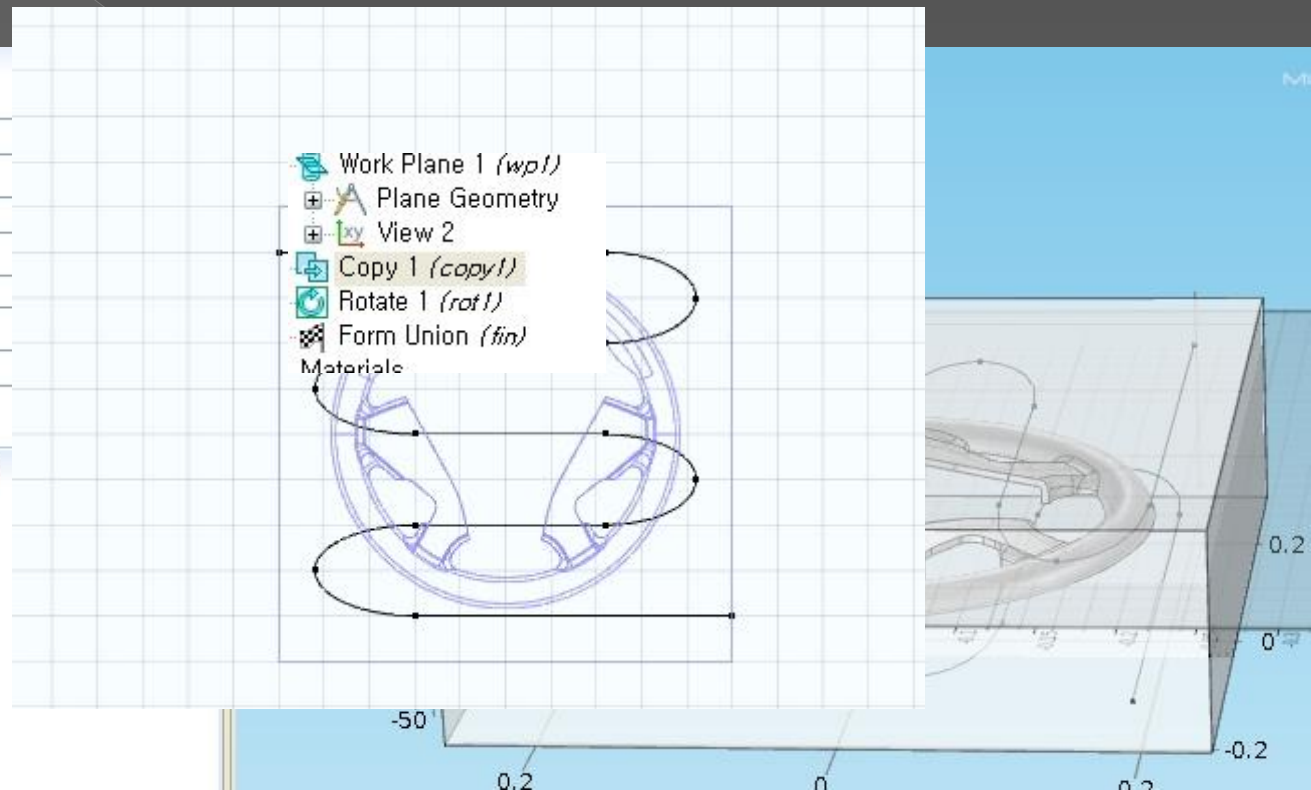
3D projection:

Entire 3D geometry

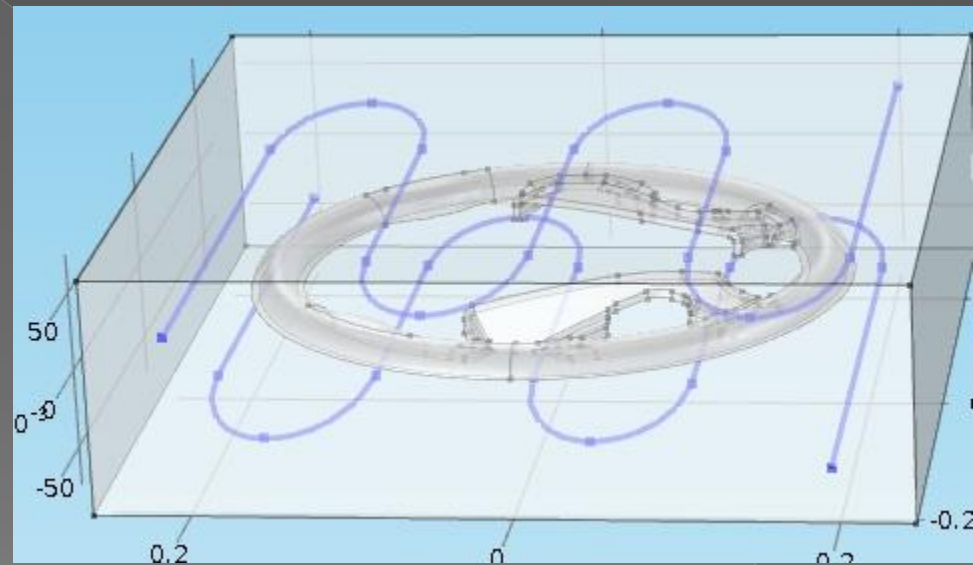
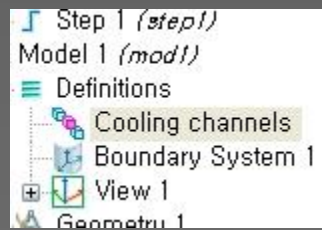
Draw on work plane in 3D

## Selections of Resulting Entities

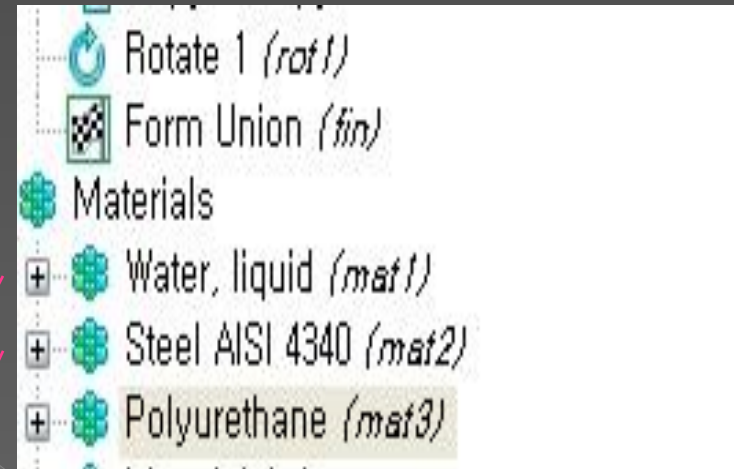
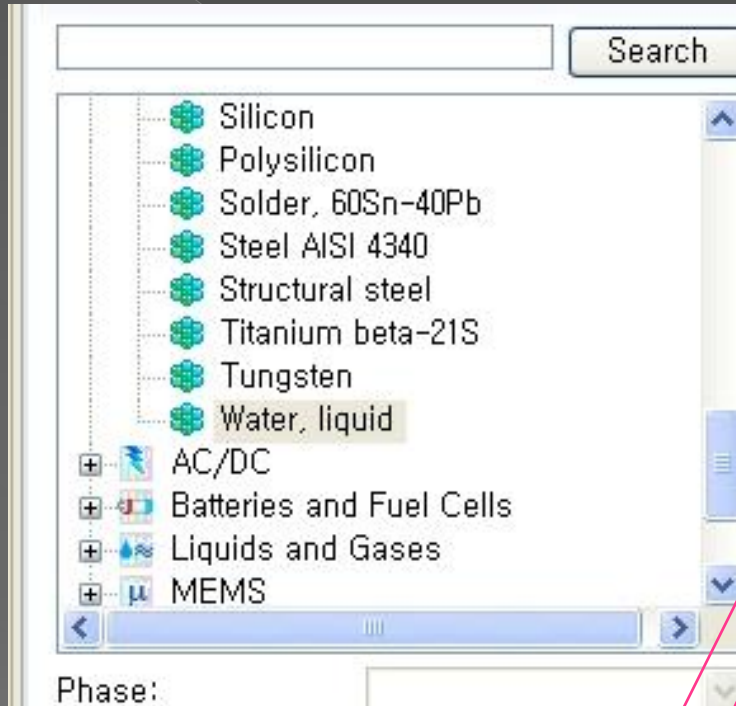
Create selections



# Definition에 cooling pipe 추가



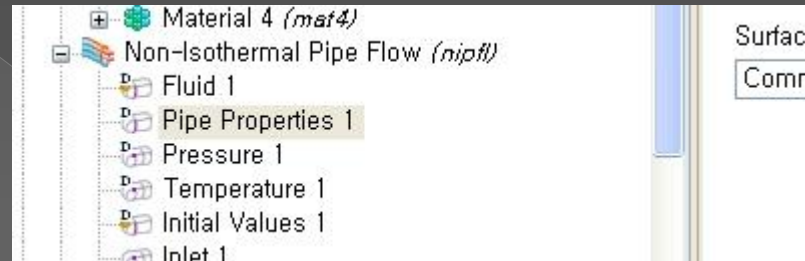
# Material 설정



| Property                        | Name | Value | Unit    |
|---------------------------------|------|-------|---------|
| ✓ Thermal conductivity          | k    | 0,32  | W/(...) |
| ✓ Density                       | rho  | 1250  | kg/...  |
| ✓ Heat capacity at constant ... | Cp   | 1540  | J/(k... |



# Cooling pipe 의 특성 직접 작성



Equation

Pipe Shape

Round

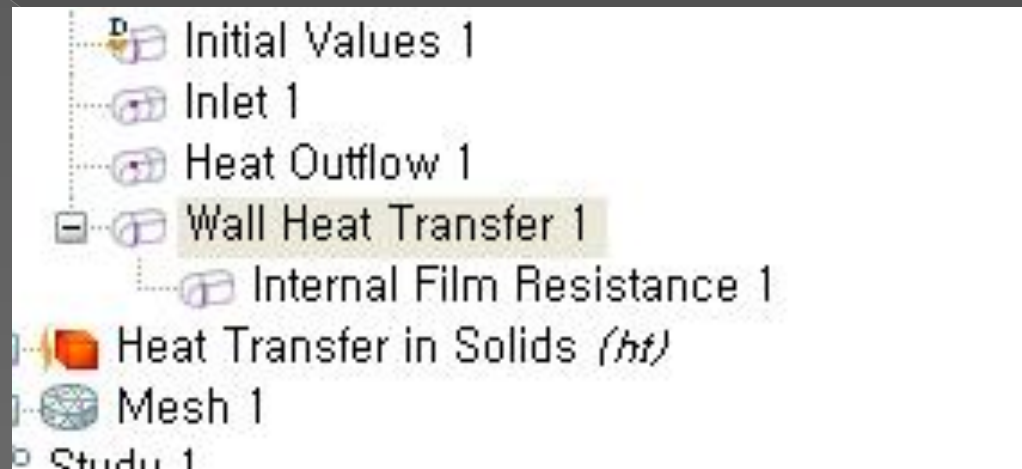
Inner diameter:  
 $d_i$  1[cm] m

Flow Resistance

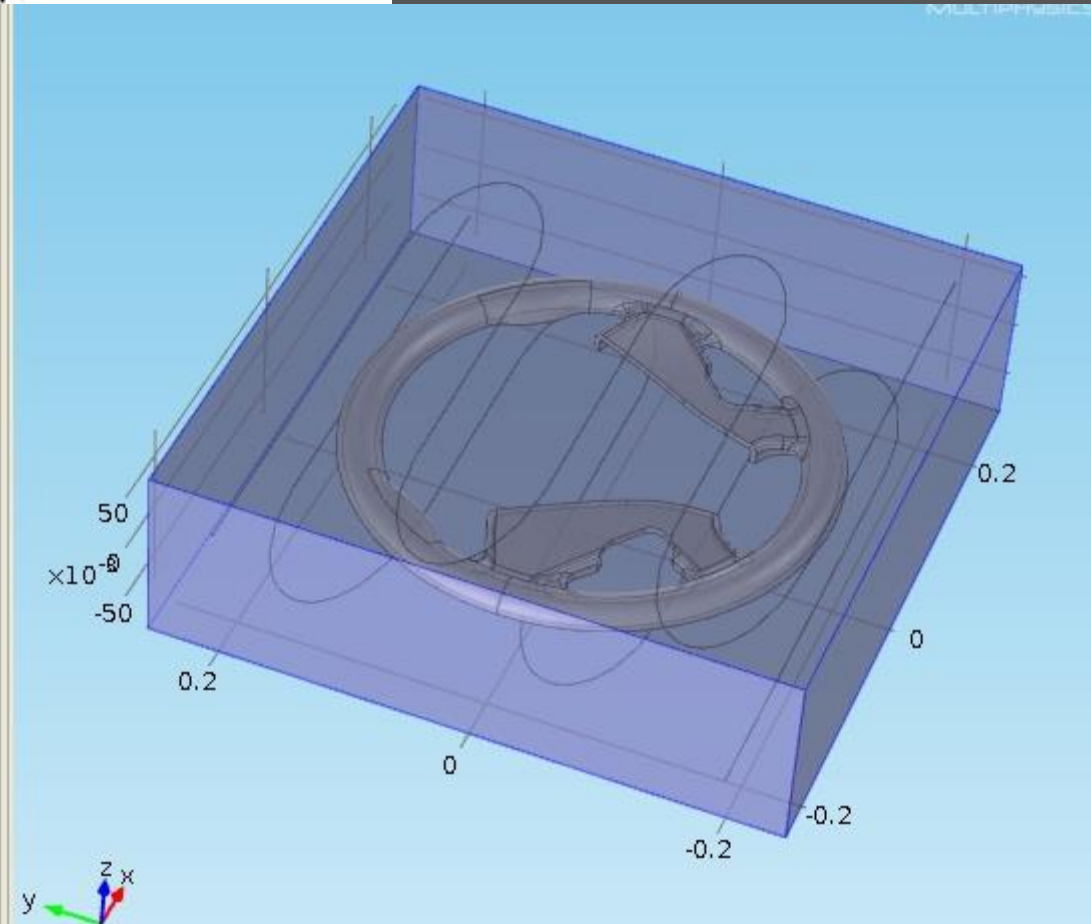
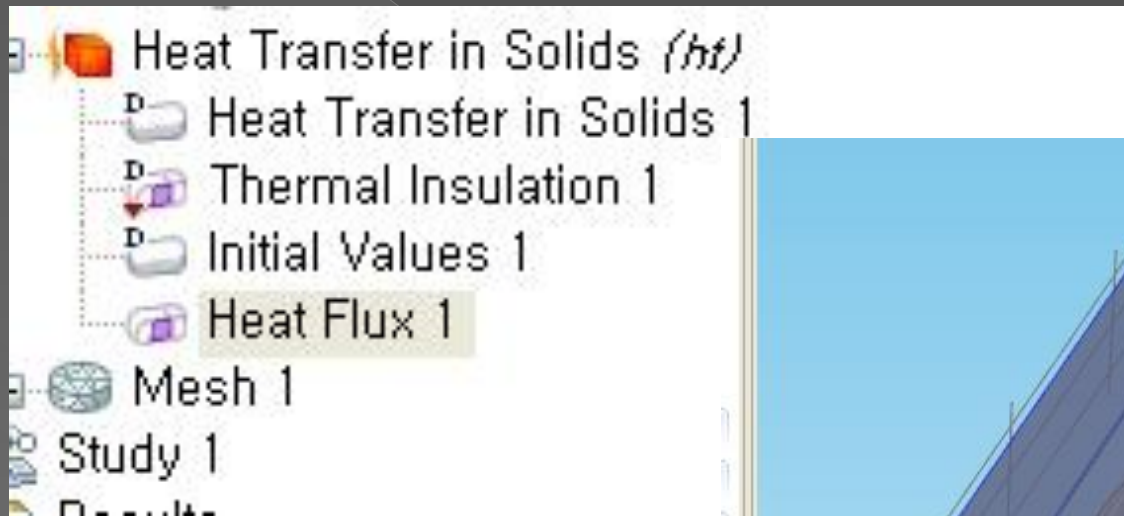
Friction model:  
Churchill

Surface roughness:  
Commercial steel (0,046 mm)

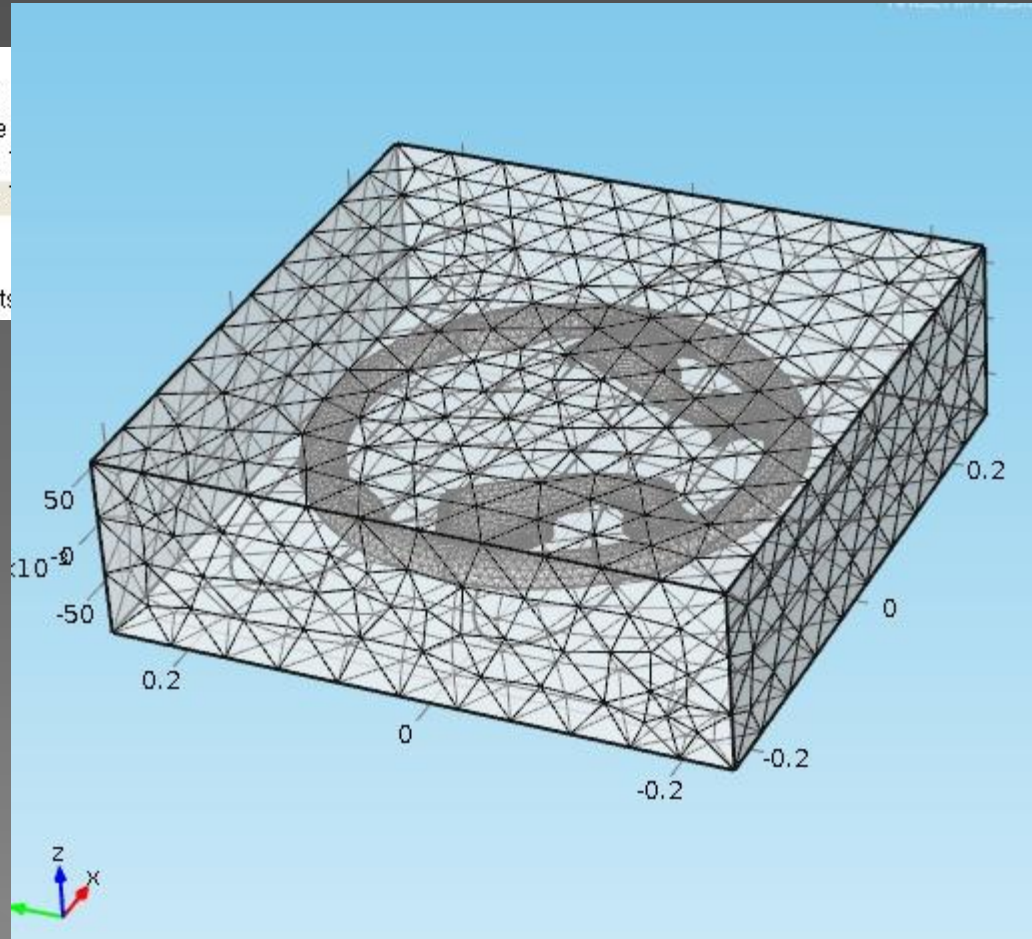
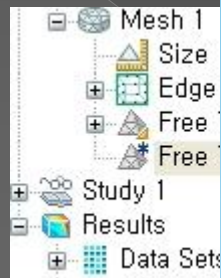
# 파이프 내부의 저항 직접작성



# 열 유속을 알기 위해 dialog box 를 선택



# Mesh 생성



# 시간 범위 설정

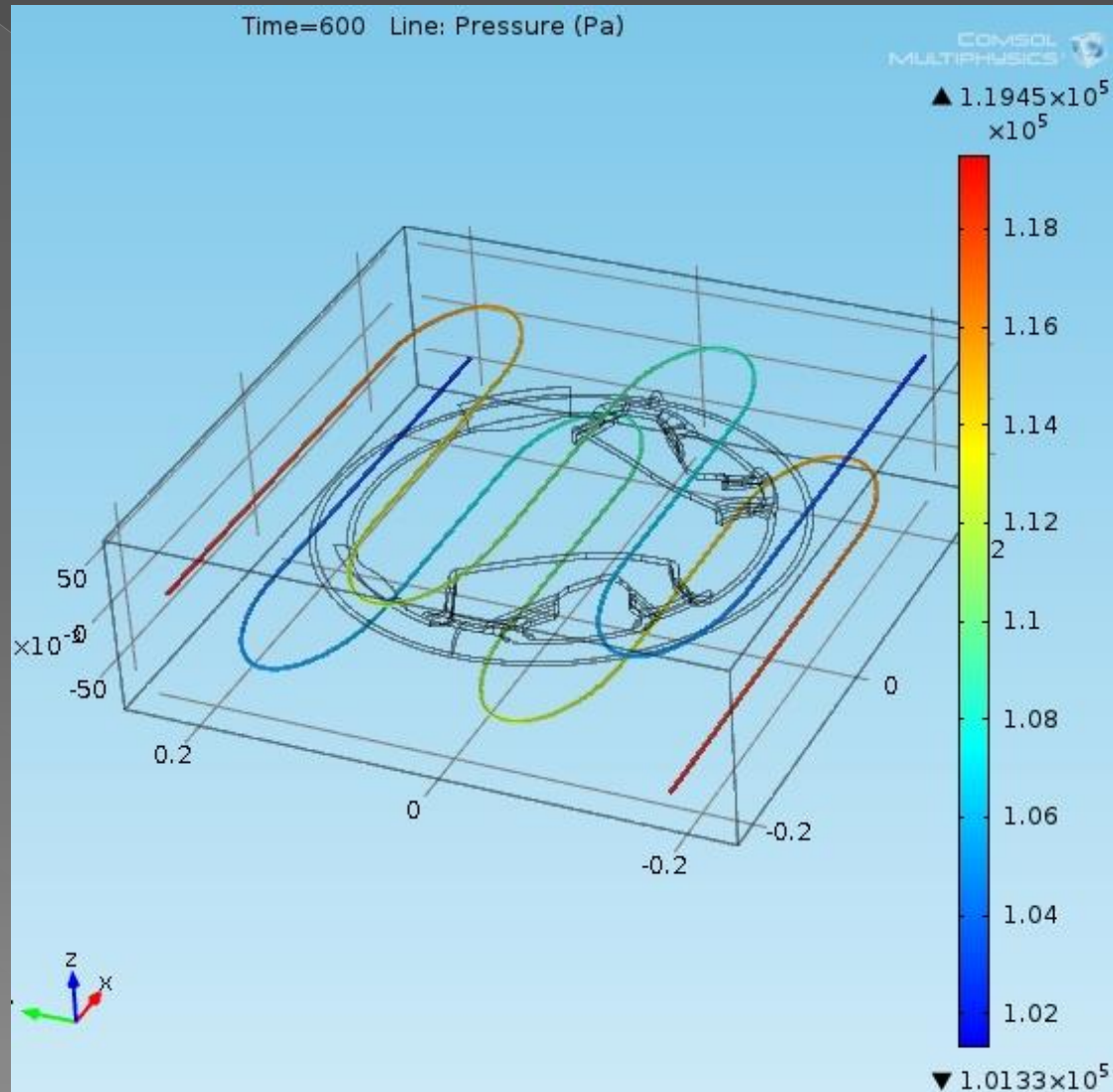
▼ Study Settings

Times:  s

Relative tolerance:

# Study Result

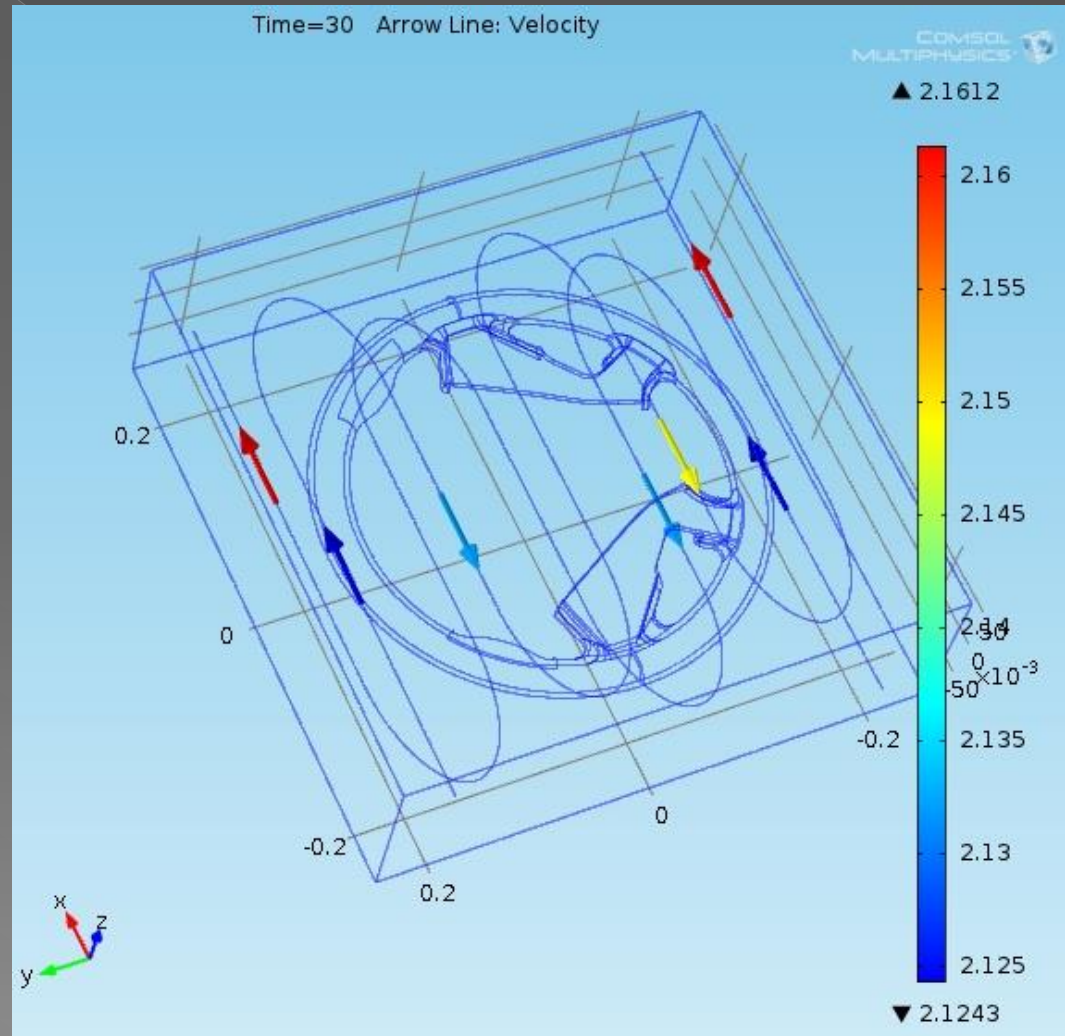
# 10분 후 cooling pipe에 압력 분포





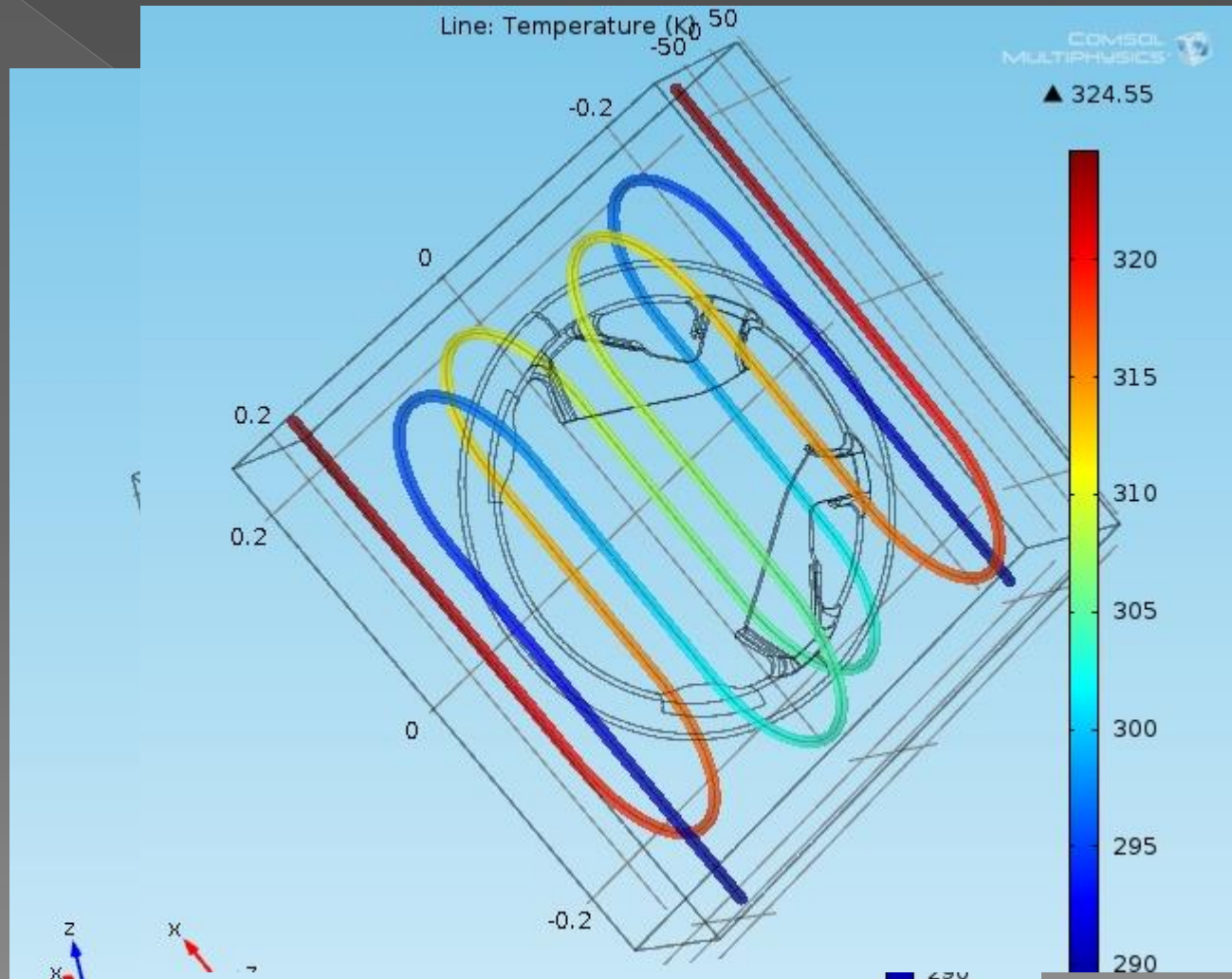
# 30초에 파이프에 흐르는 냉각수의 속도

측정 결과  
시간 흘러도  
별 차이 없음

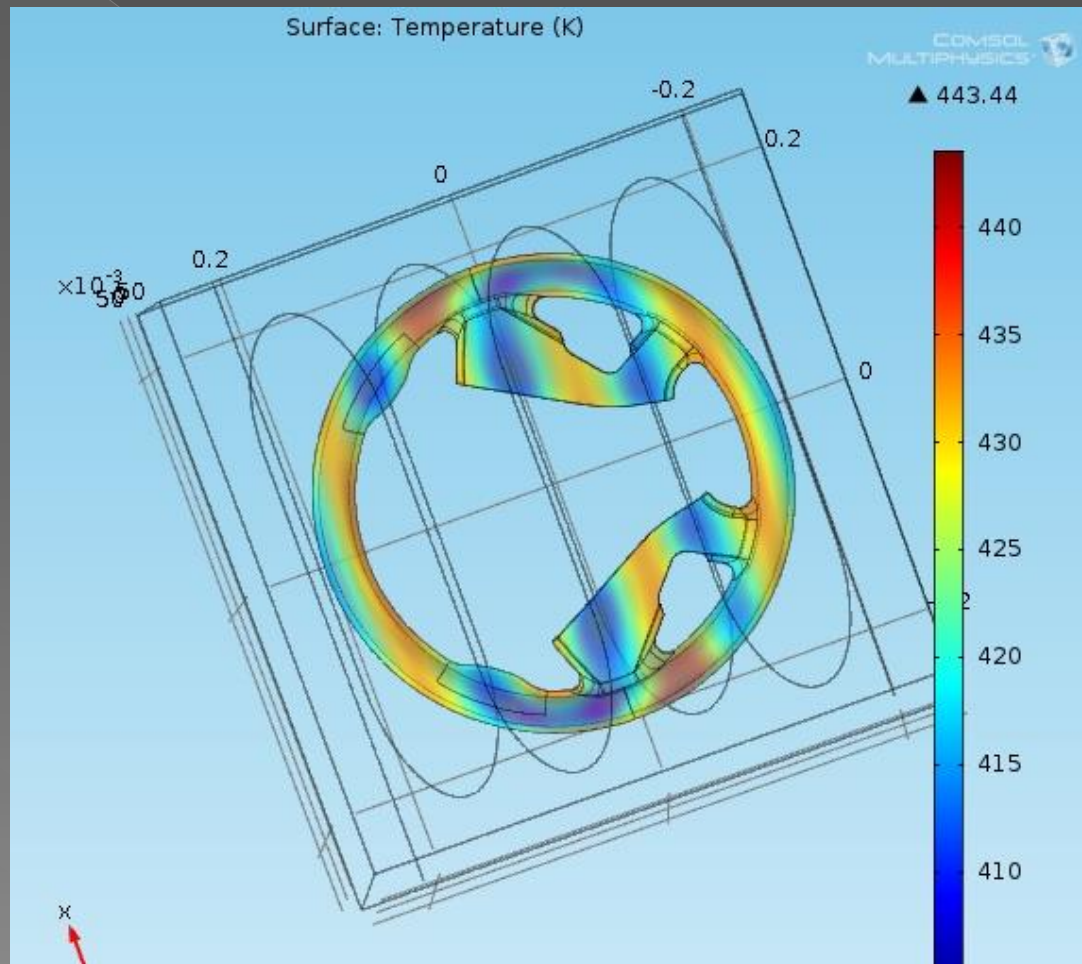




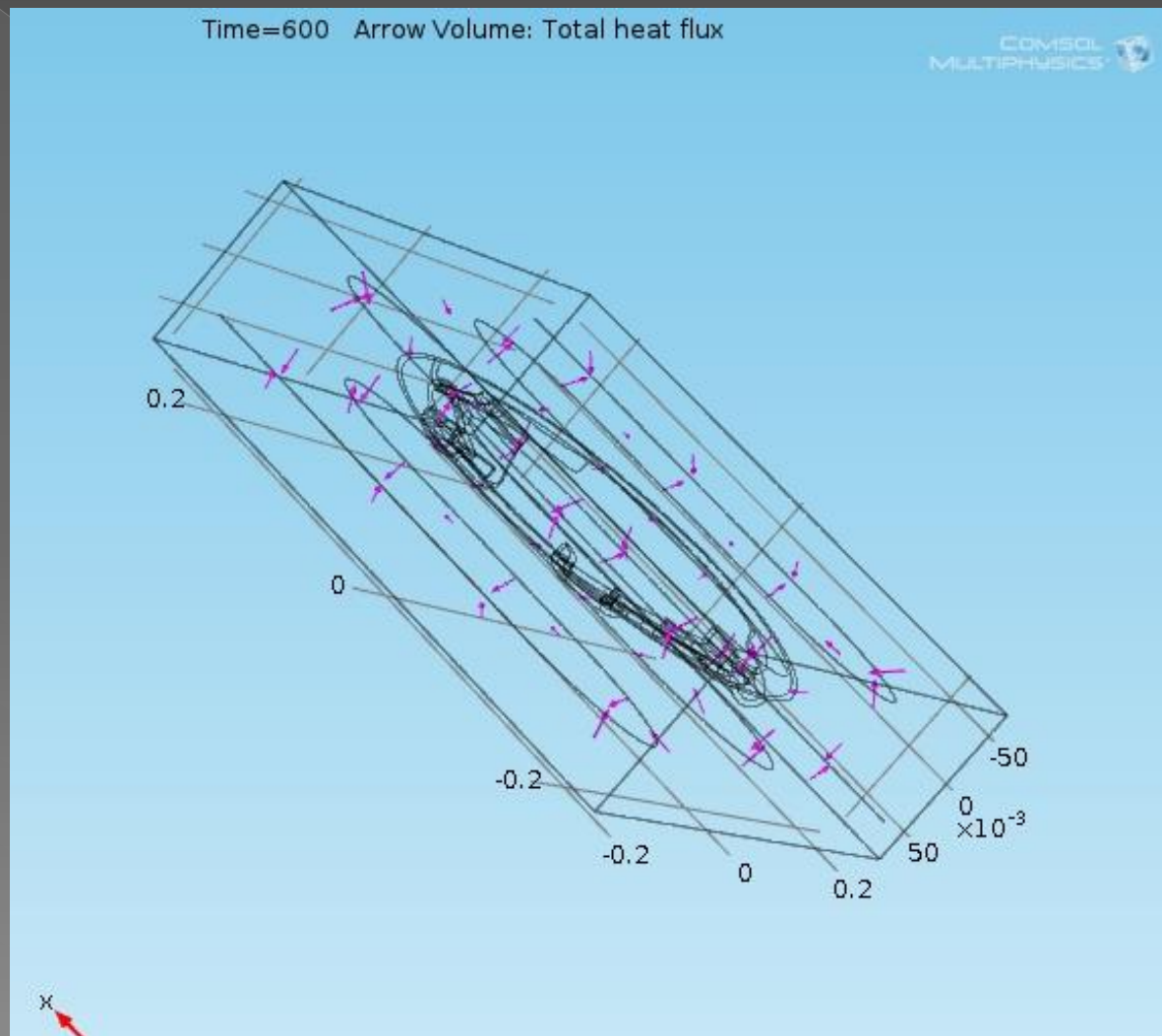
# 파이프에 냉각수 온도 변화분포



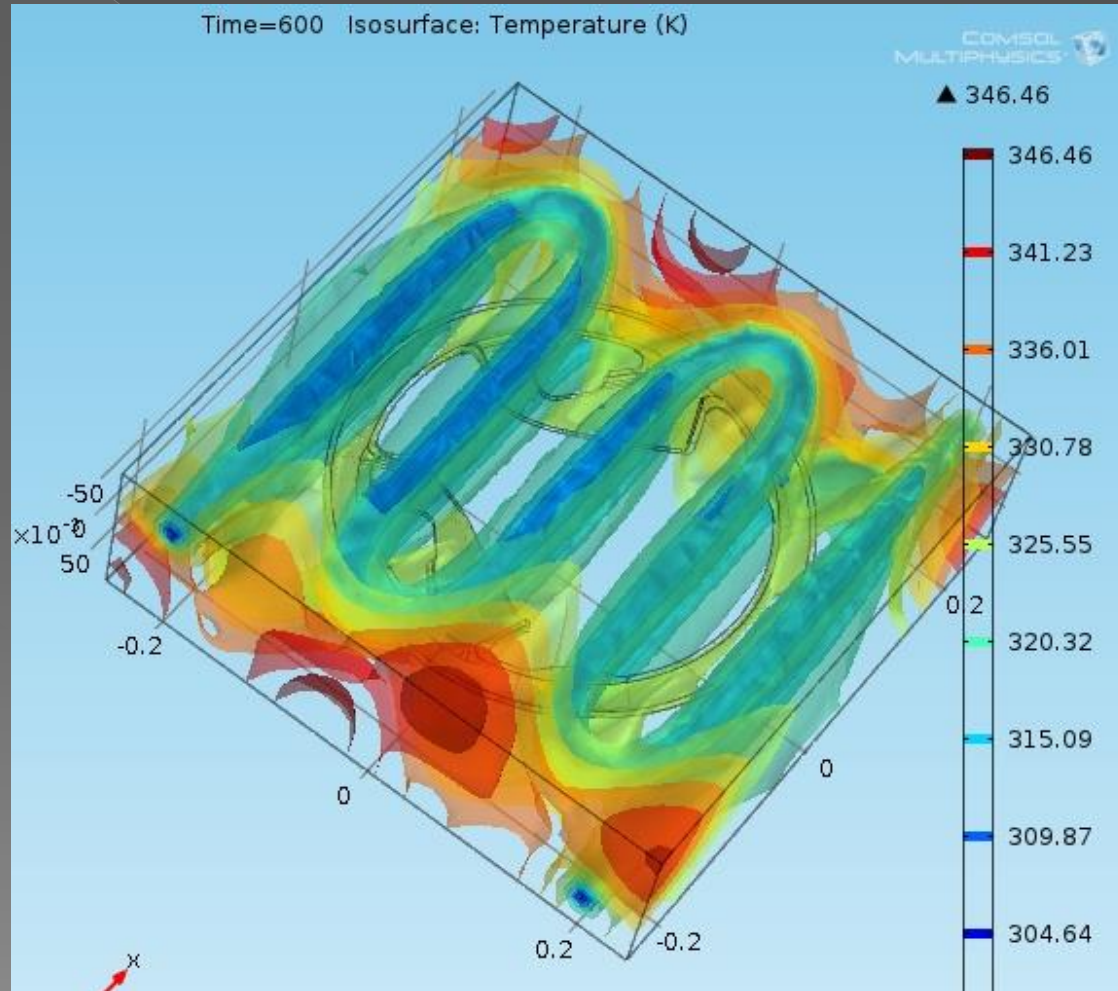
# Mold product의 온도 분포



# Heat flux 파이프로 향하는 것 관찰 가능

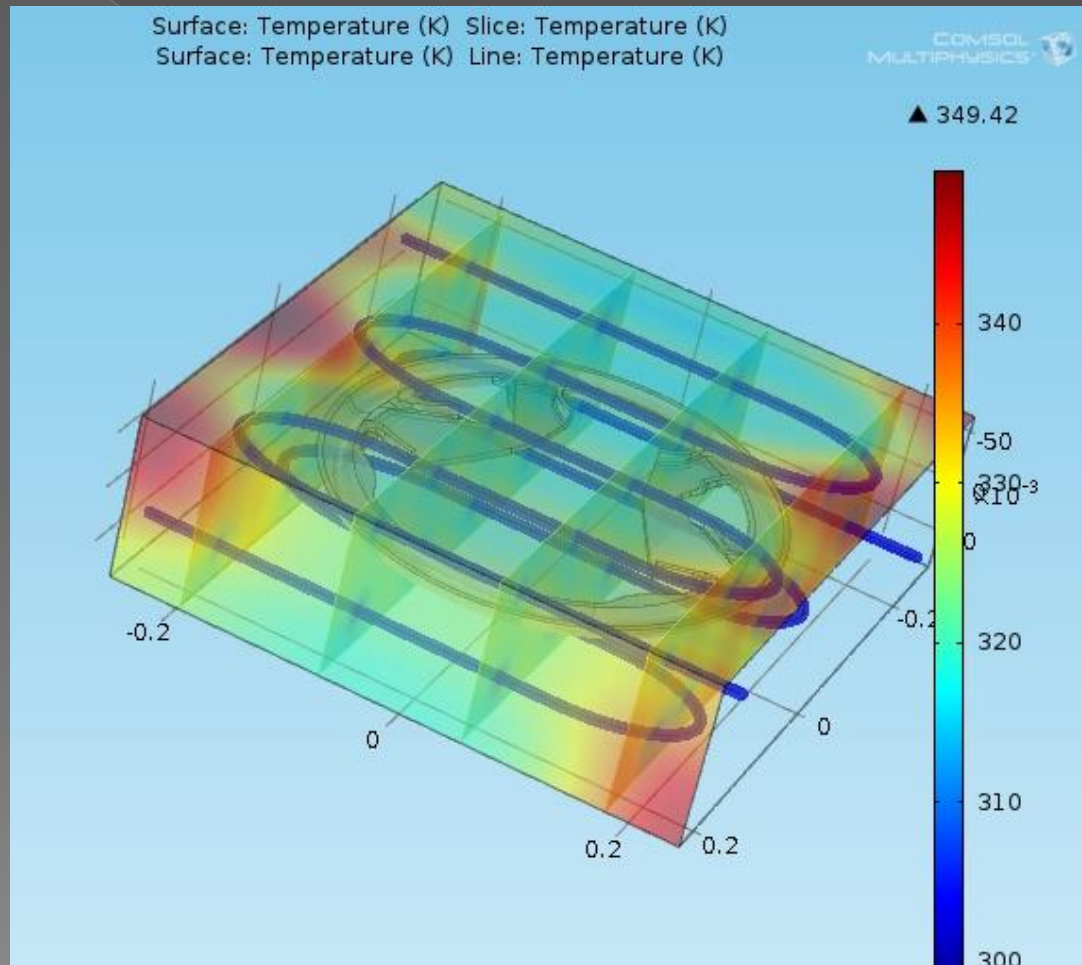


# 등위면으로 본 온도 그래프



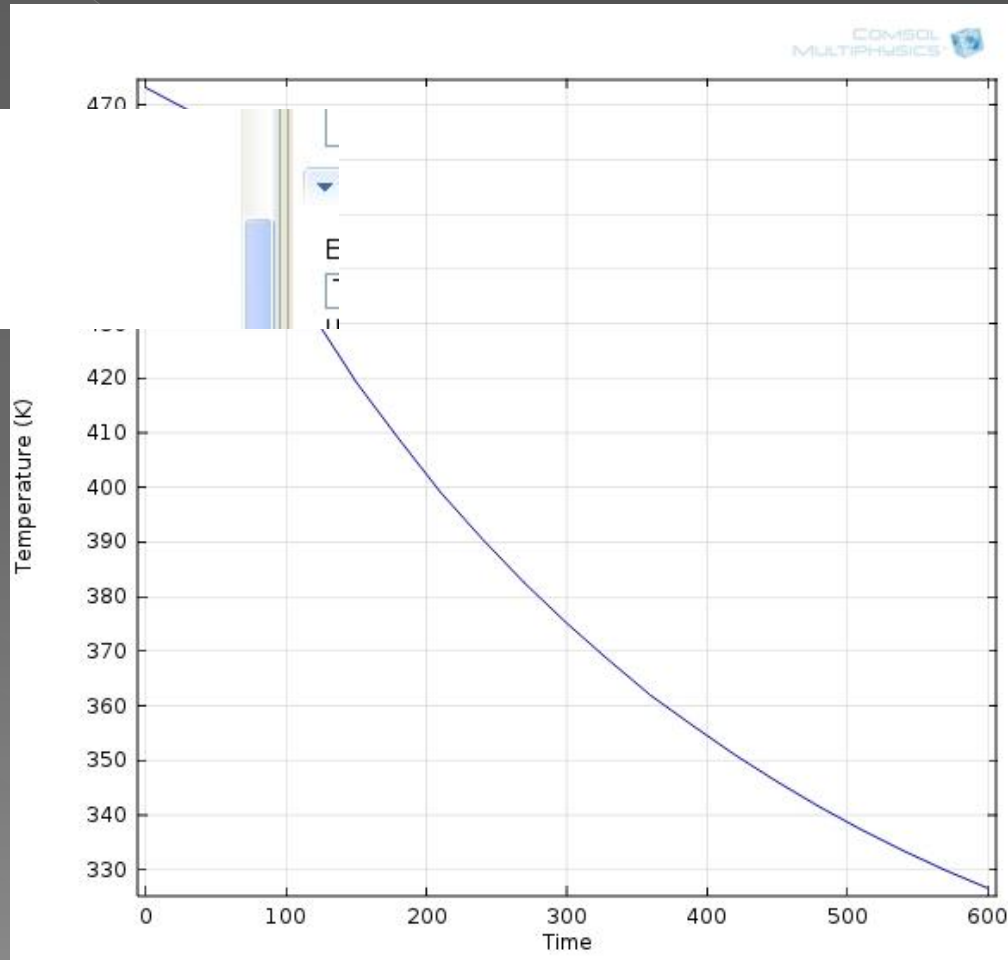


# 강철 mold block을 쳐냈을 때의 온도 분포 (block을 세워놓고 온도 분포의 변화가 있나를 살펴봄)

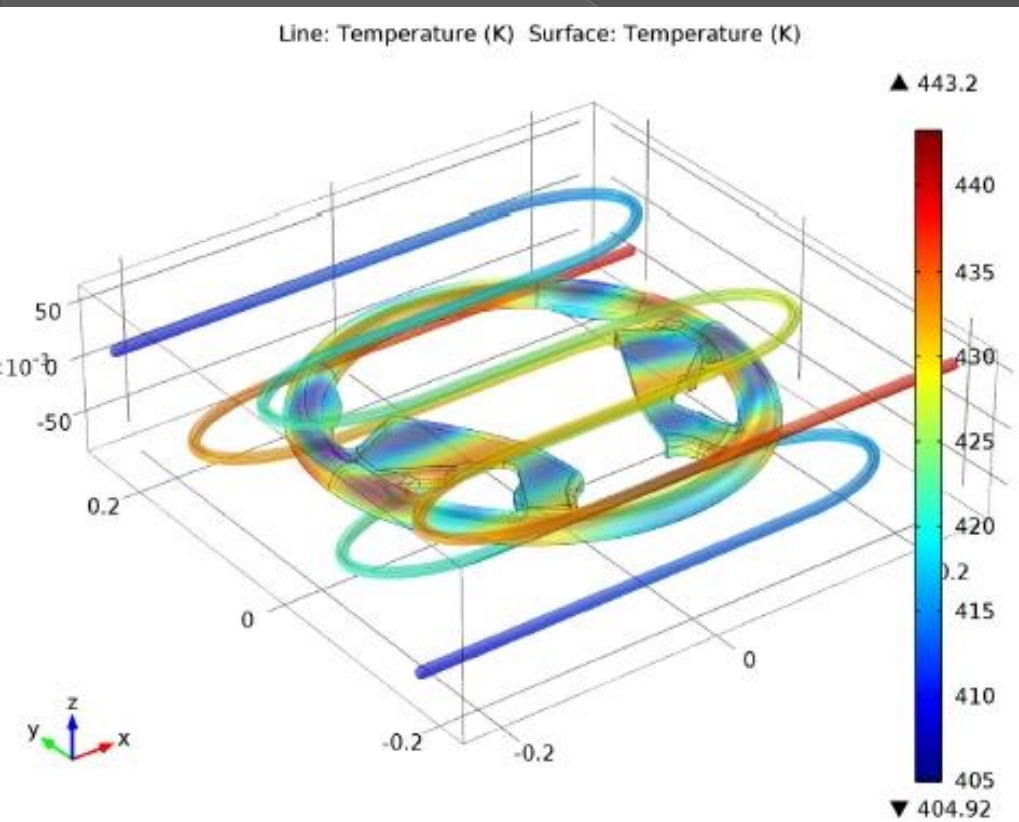


# 시간에 따른 평균 온도 분포

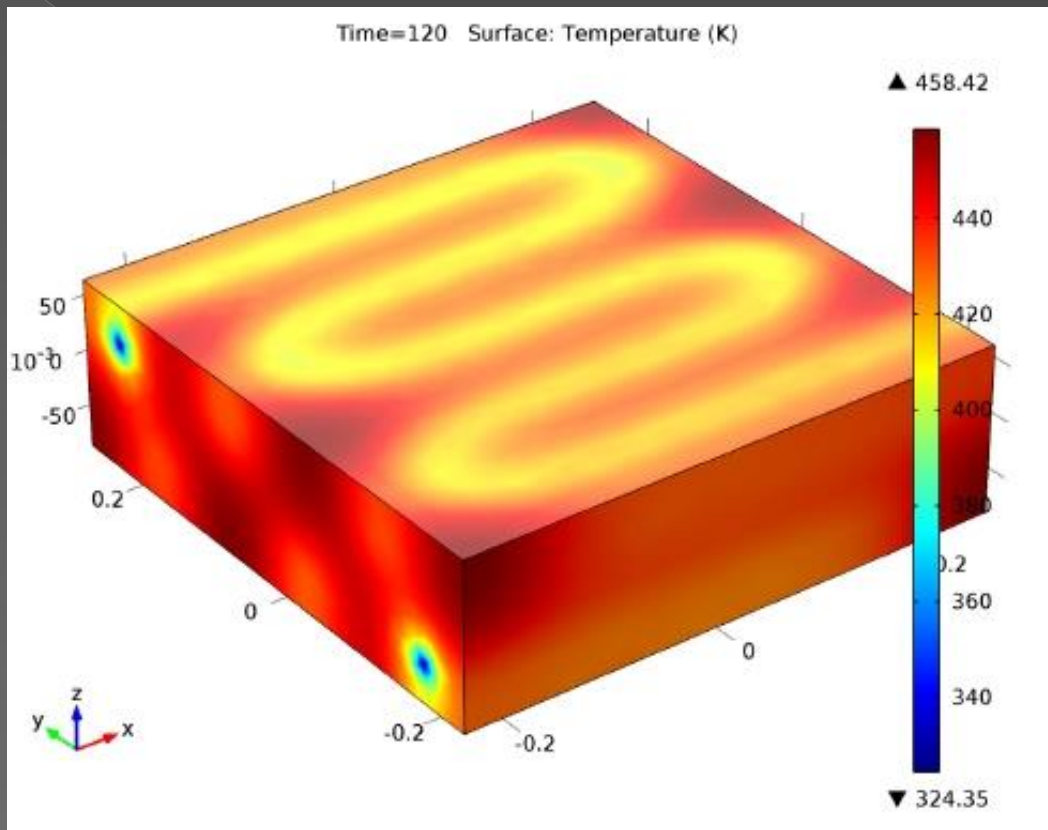
- Solution 2
- Solution 3
- Derived Values
  - Volume Average 1
- Tables
- Pressure
- Velocity



폴리우레탄 핸들 모델에 473K 온도, 10L/min의 냉각수 속도, surface roughness 46 $\mu$ m 초기조건을 부여함.

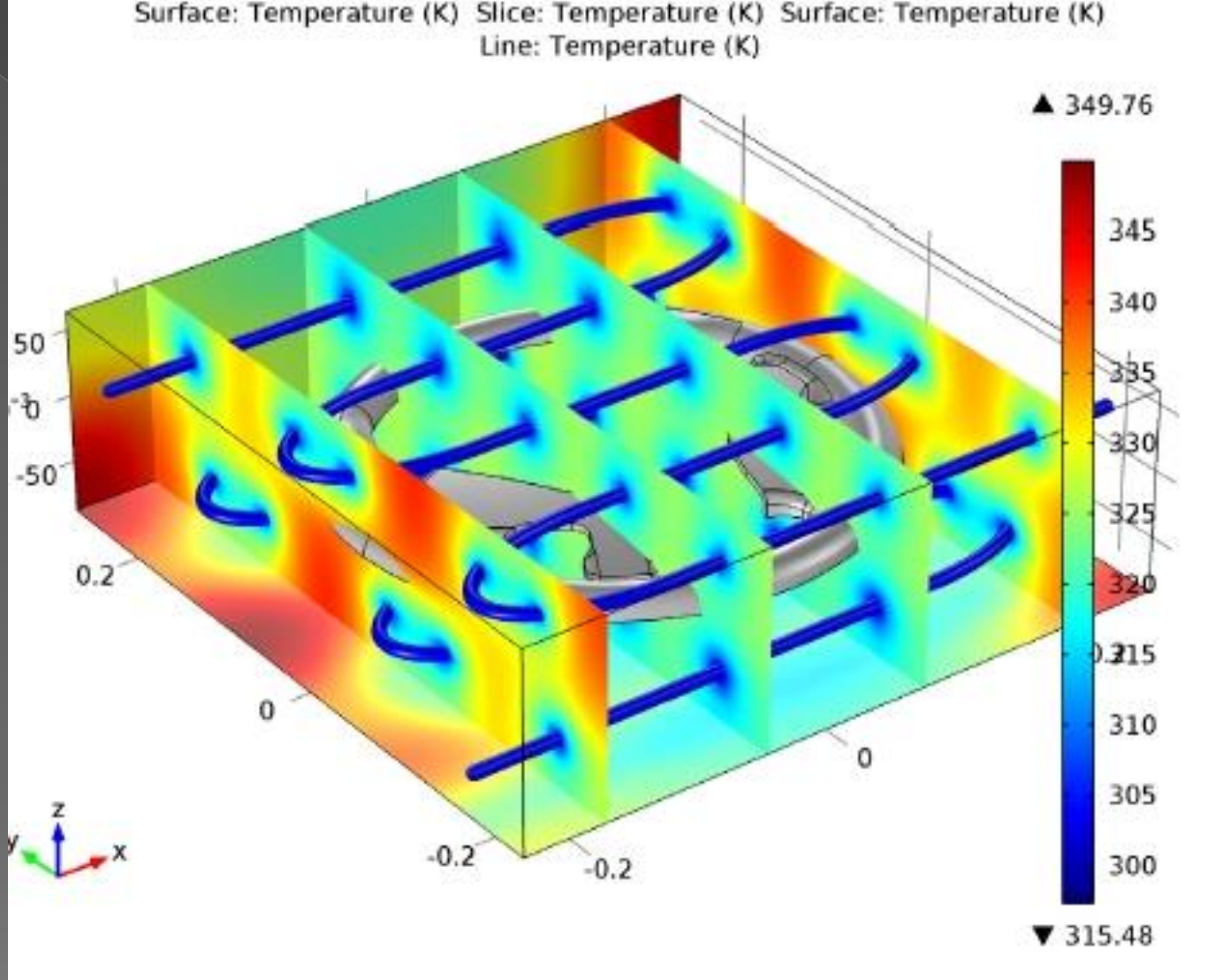


2분 후에 대략 최고 온도 지점과 최저 온도 지점이 40도 정도 차이남.



2분 후 surface graph. Dialog box 에 cooling channel 의 온도 형상이 그대로 드러난다.





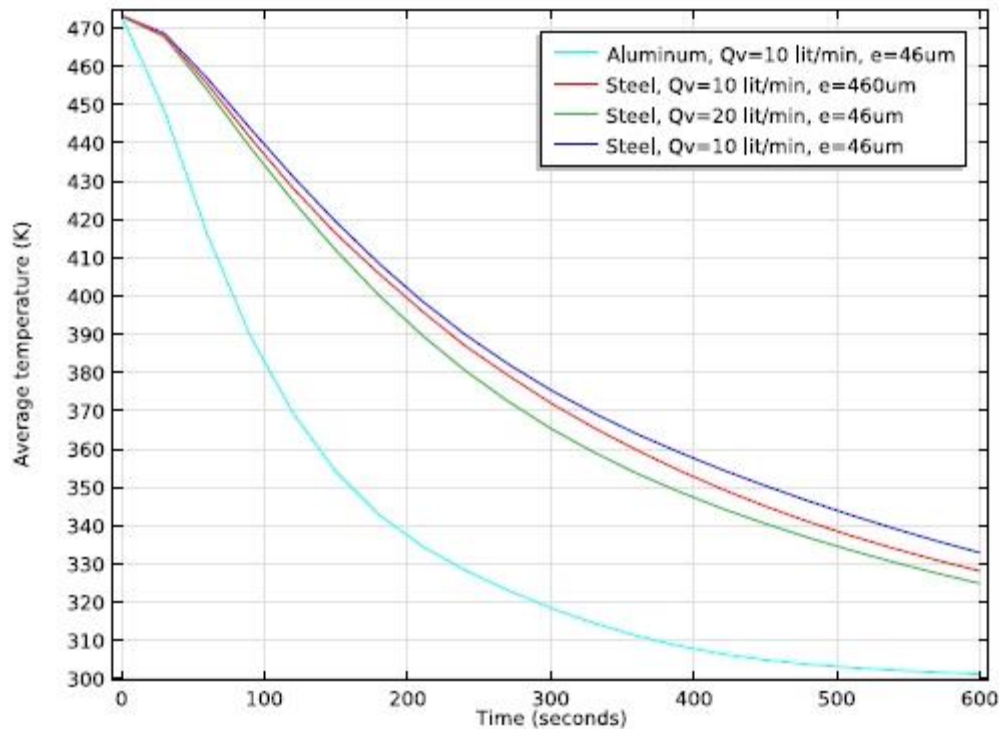
10분 냉각이 완료된 후에 (0,0,0) 중심부분이 333K였다.  
 냉각수 출입 부분이 다른 boundary 보다 20K 정도 높은 것도 관측할 수 있었다.

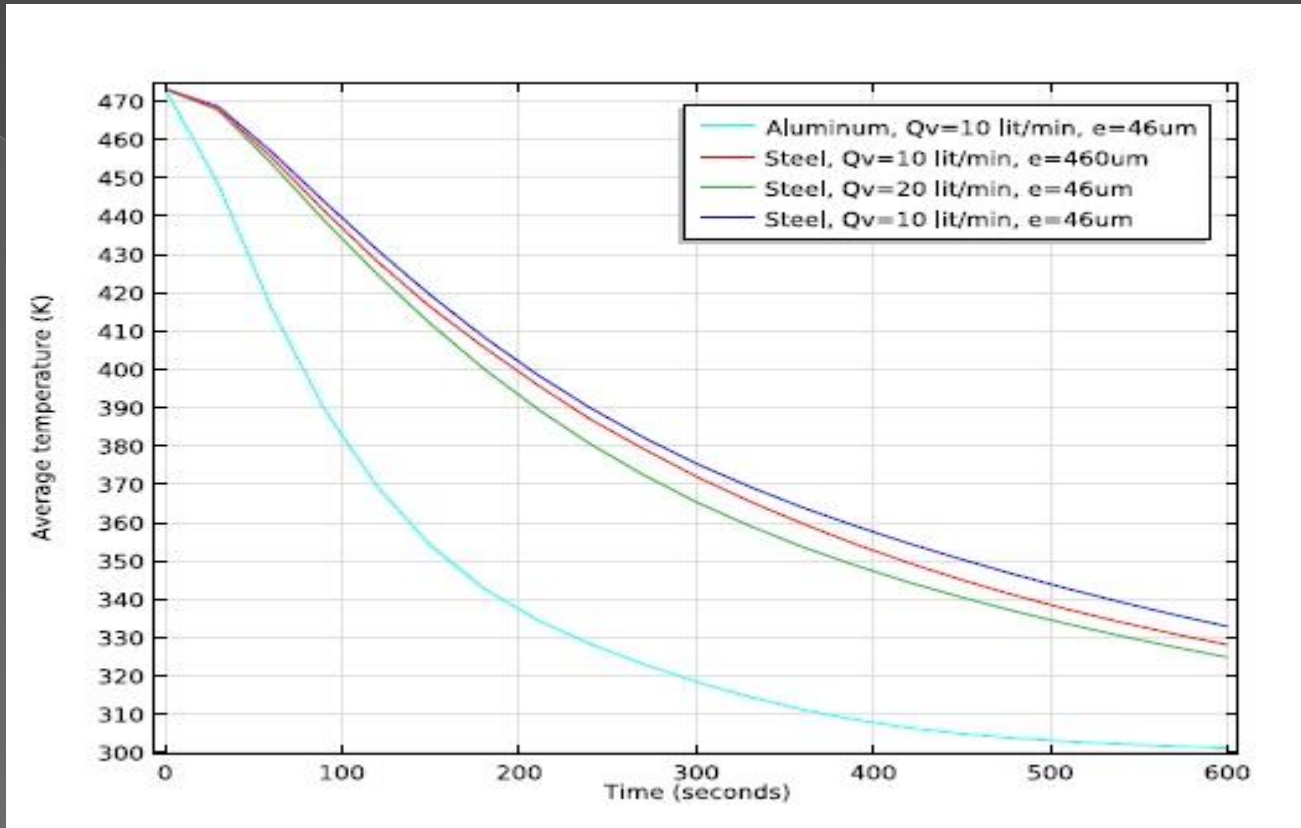
- 냉각 시간에 영향을 끼치는 인자를 확인하기 위해 추가 실험을 해보았다.

Cooling condition 에서 영향을 끼치는 또 다른 인자가 있을까 찾아보았는데 냉각수의 유속, 파이프 내부의 roughness, mold 소재 등이 있었다.

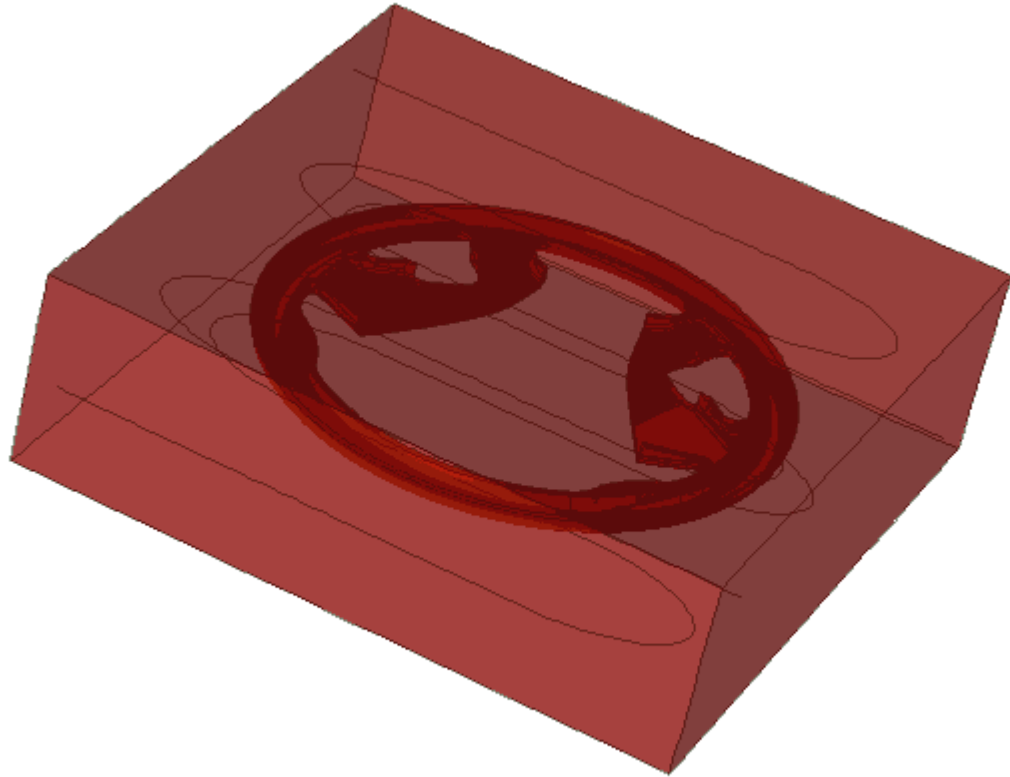
<출처: *Fundamentals of Heat and Mass Transfer (5th ed.)*. Hoboken: Wiley.>

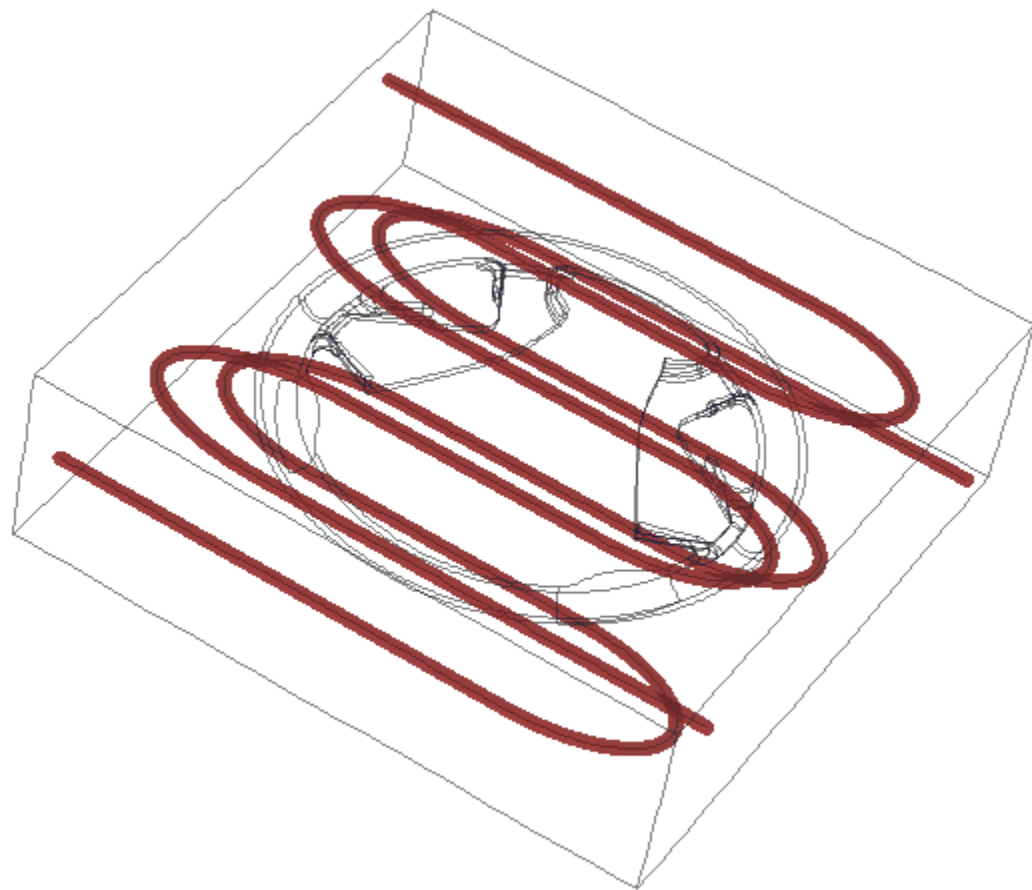
| Mold Material | water flow rate(L/min) | surface roughness(MM) | 10분후 T (K) |
|---------------|------------------------|-----------------------|------------|
| Steel         | 10                     | 0.046                 | 333        |
| Steel         | 20                     | 0.046                 | 325        |
| Steel         | 10                     | 0.46                  | 328        |
| Aluminium     | 10                     | 0.046                 | 301        |

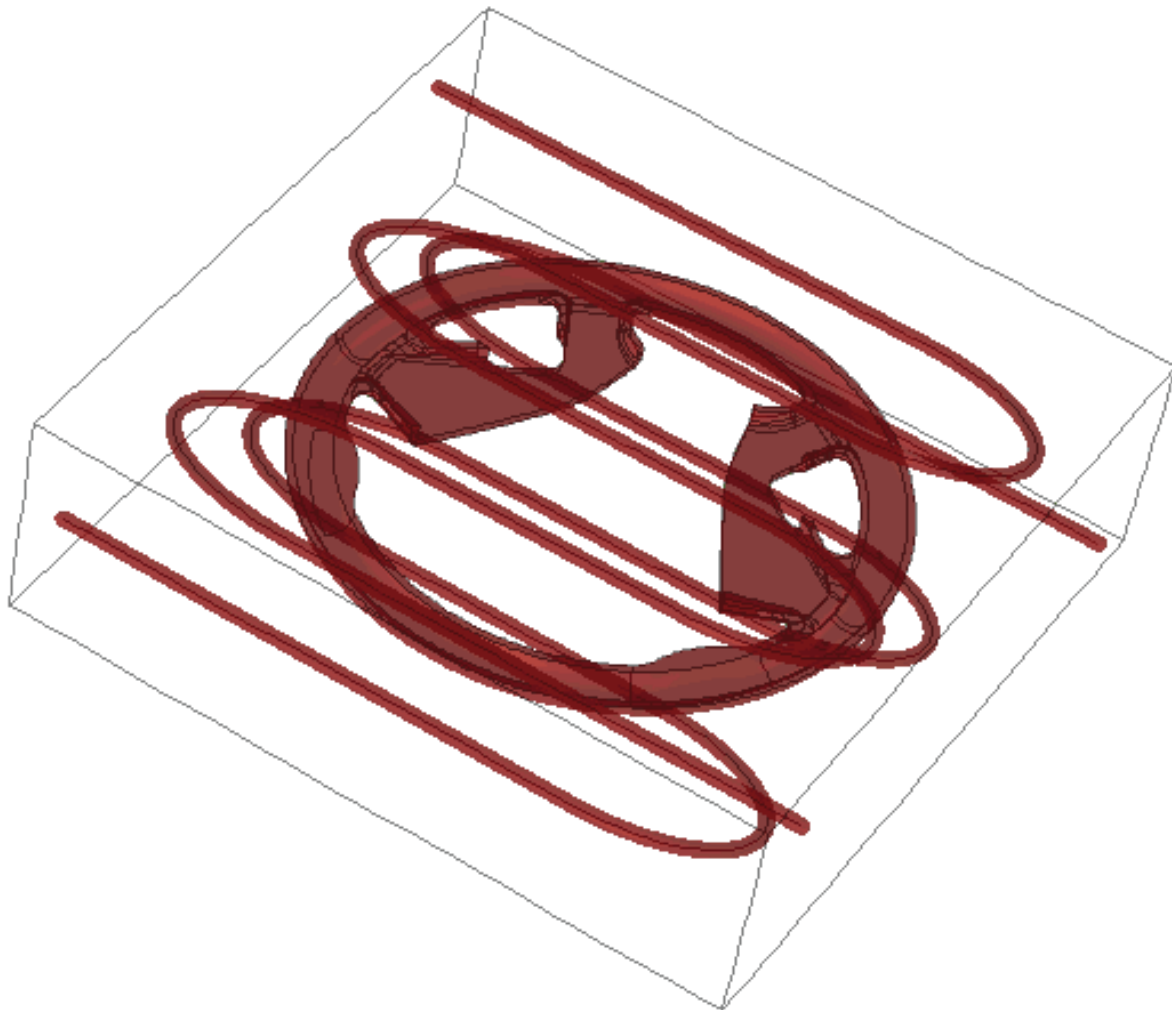


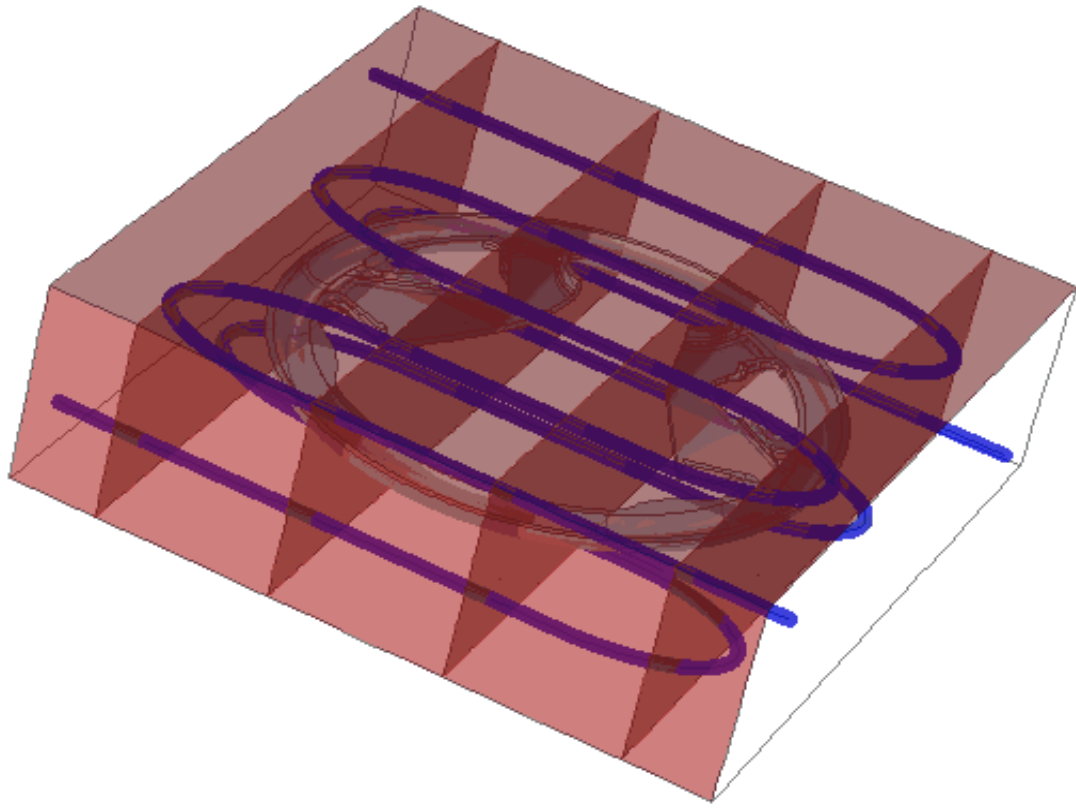


위의 그래프로부터 340K 가 목표하는 온도라고 가정하면 ,  
**Cooling time**이 Mold material을 바꿨을 경우 67%  
 Flow rate을 바꿨을 경우 17%  
 Surface roughness를 바꿨을 경우 11% 감소한다.



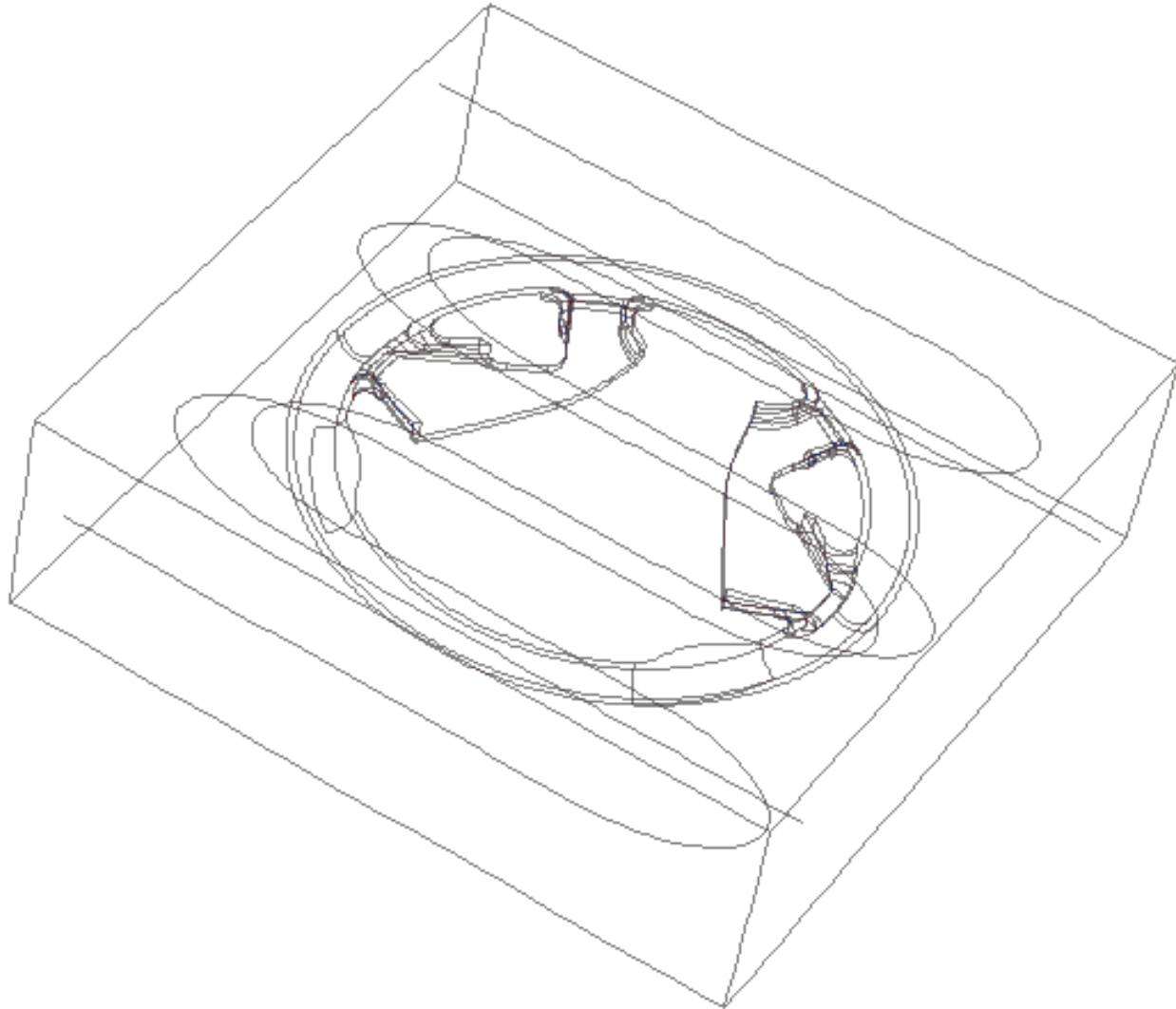








isothermal



Thank you for  
listening!