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인덕션 히팅 해석의 최신 기술 (Induction Heating)

2015.05.13

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Induction Heating & RHCM(Steam해석)

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- 급열급냉(Rapid Heat & Cool Molding)의 이란?

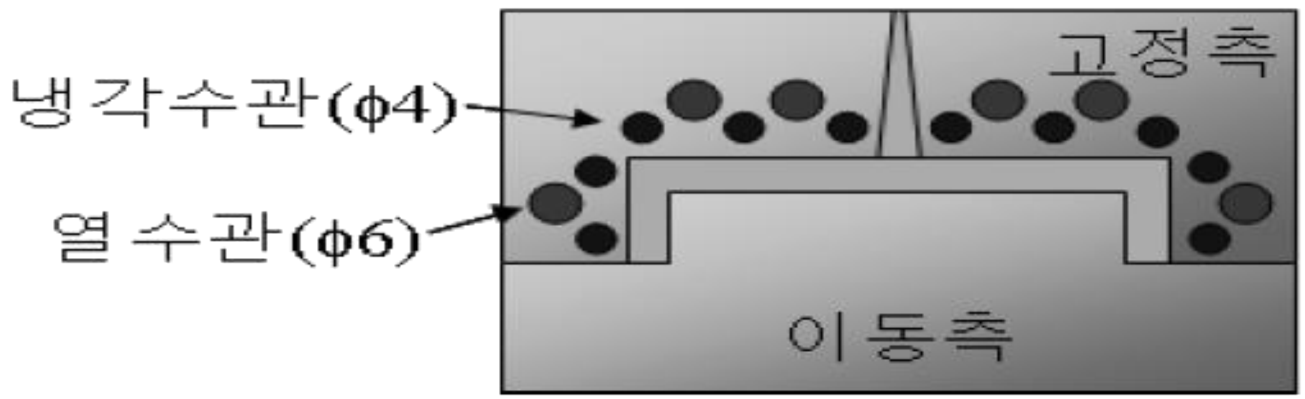
- **RHCM 공정**의 기본 원리는 수지가 금형 내부로 주입이 될 때 **금형 온도를 급속 가열하여** 열변형 온도 이상을 유지하고, **보압 및 냉각 공정에서**는 제품의 고화를 촉진하기 위하여 **금형의 온도를 급격히 떨어뜨리는 방식**이다.

- 주요 목적은 **제품의 외관 특성(웰드라인, 고광택)을 개선**하고자 하는 성형가공 기술이다.

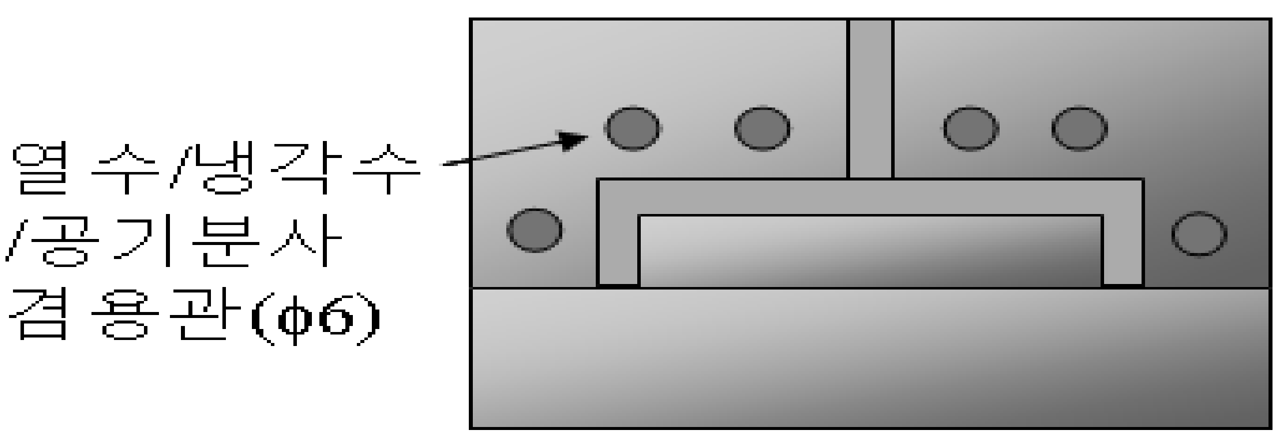
Induction Heating & RHCM(Steam해석)

- 급열급냉(Rapid Heat & Cool Molding)의 종류

RHCM (Rapid Heat & Cool Molding)



열수관과 냉각수관이 분리 열효율측면에서 매우 비효율적



열수/냉각수/공기분사 겸용관을 이용 – **Moldflow RHCM 해석**

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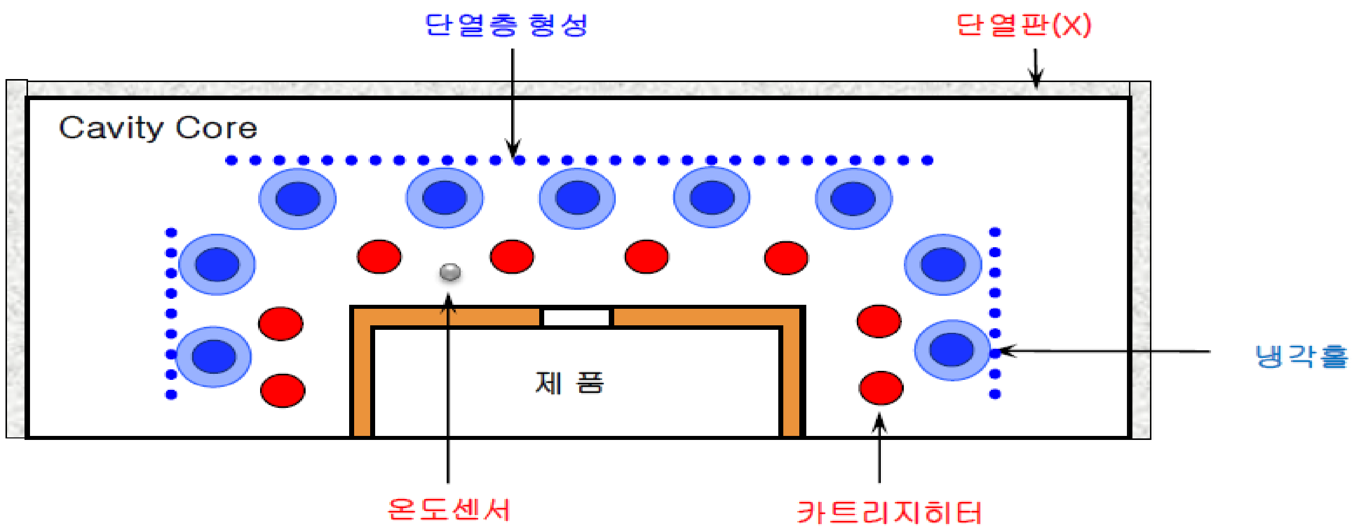
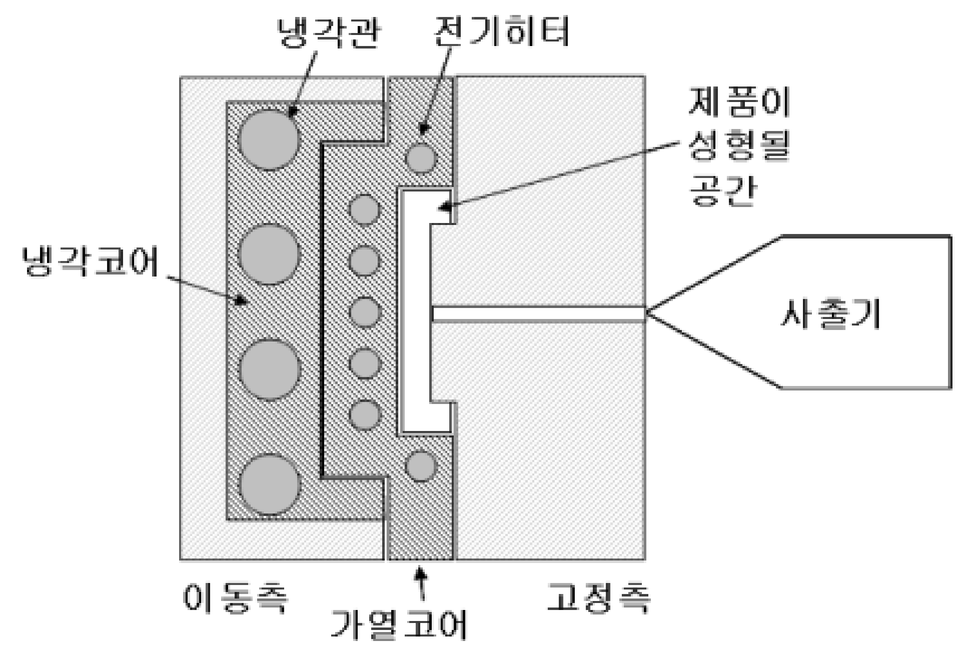
- 급열급냉(Rapid Heat & Cool Molding)의 종류

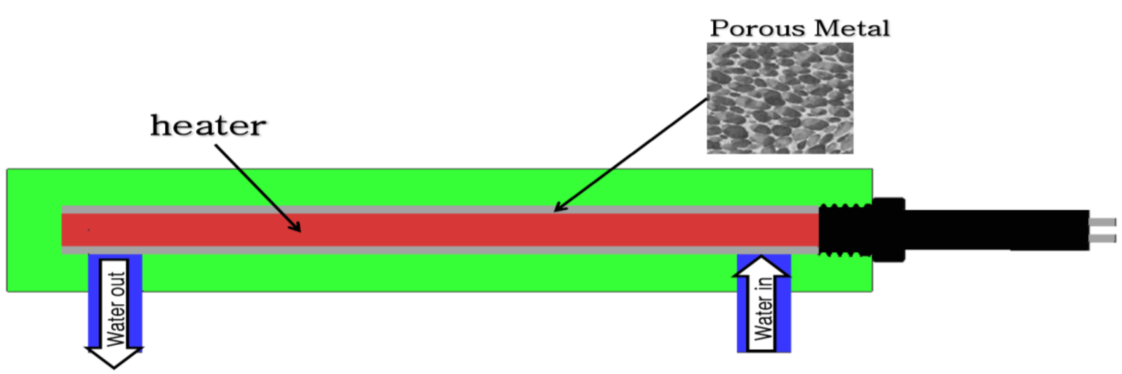
Electricity RHCM Mold



E-Mold



F-Mold



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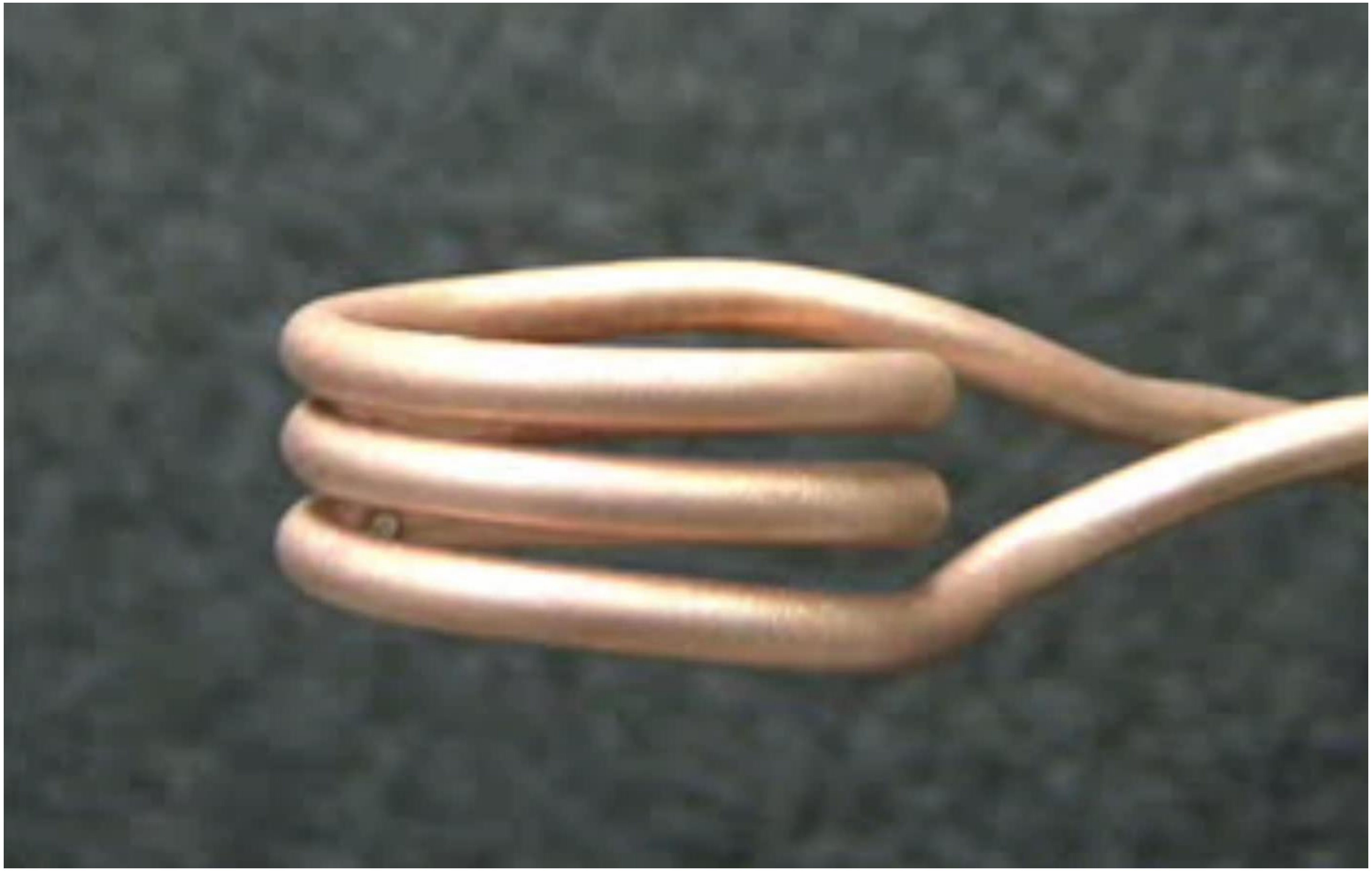
- Induction Heating 소개



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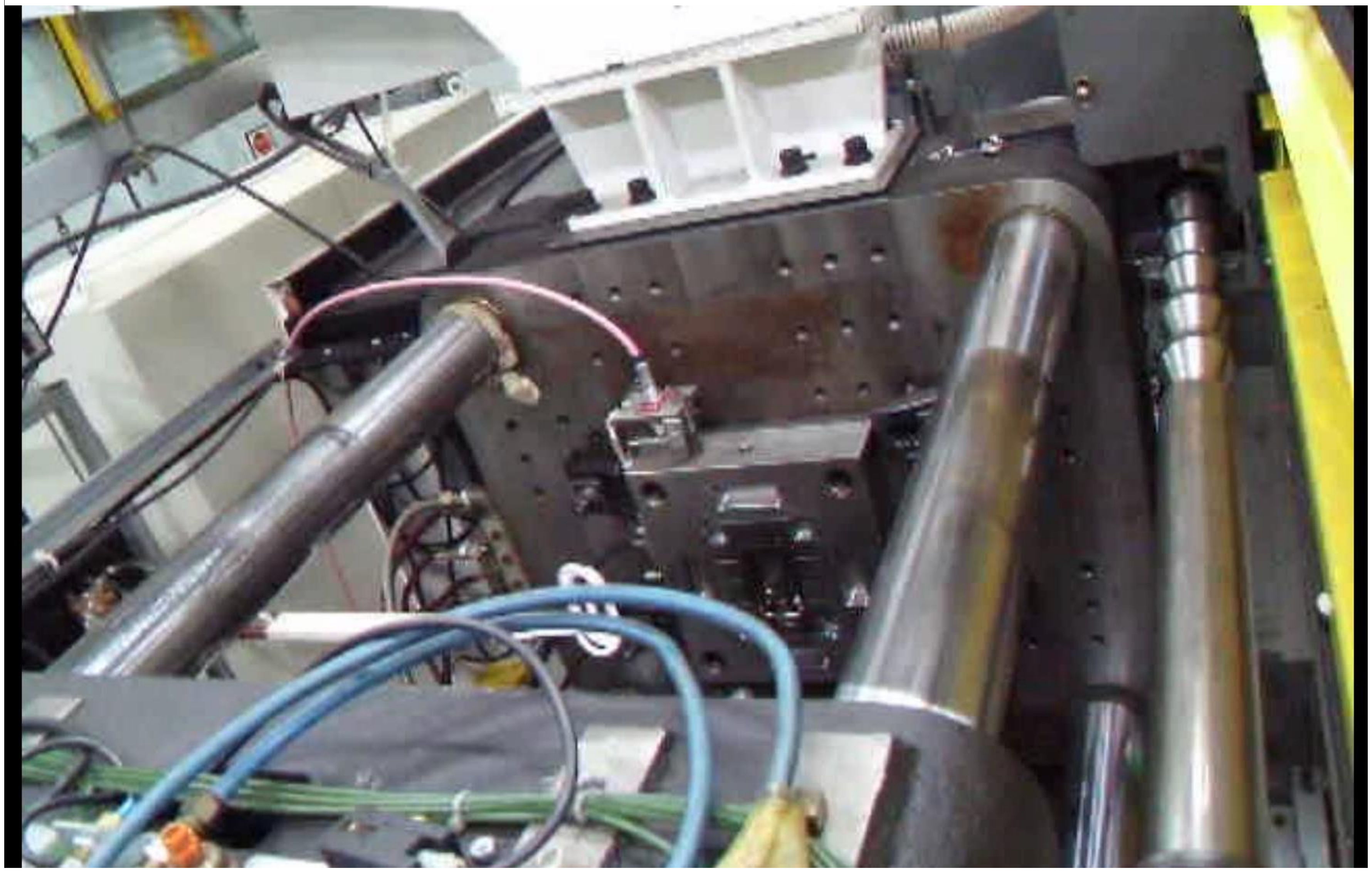
- Induction Heating 소개



http://www.hl-hf.com/index.htm

목표

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At the end of this class, you will be able to:

- Induction Heating 해석 방법을 익힘
  - 전기저항력의 개념은 알게 됨.
  - 투자율 or 상대투자율의 개념을 알게 됨.

- Induction Heating의 해석결과 확인

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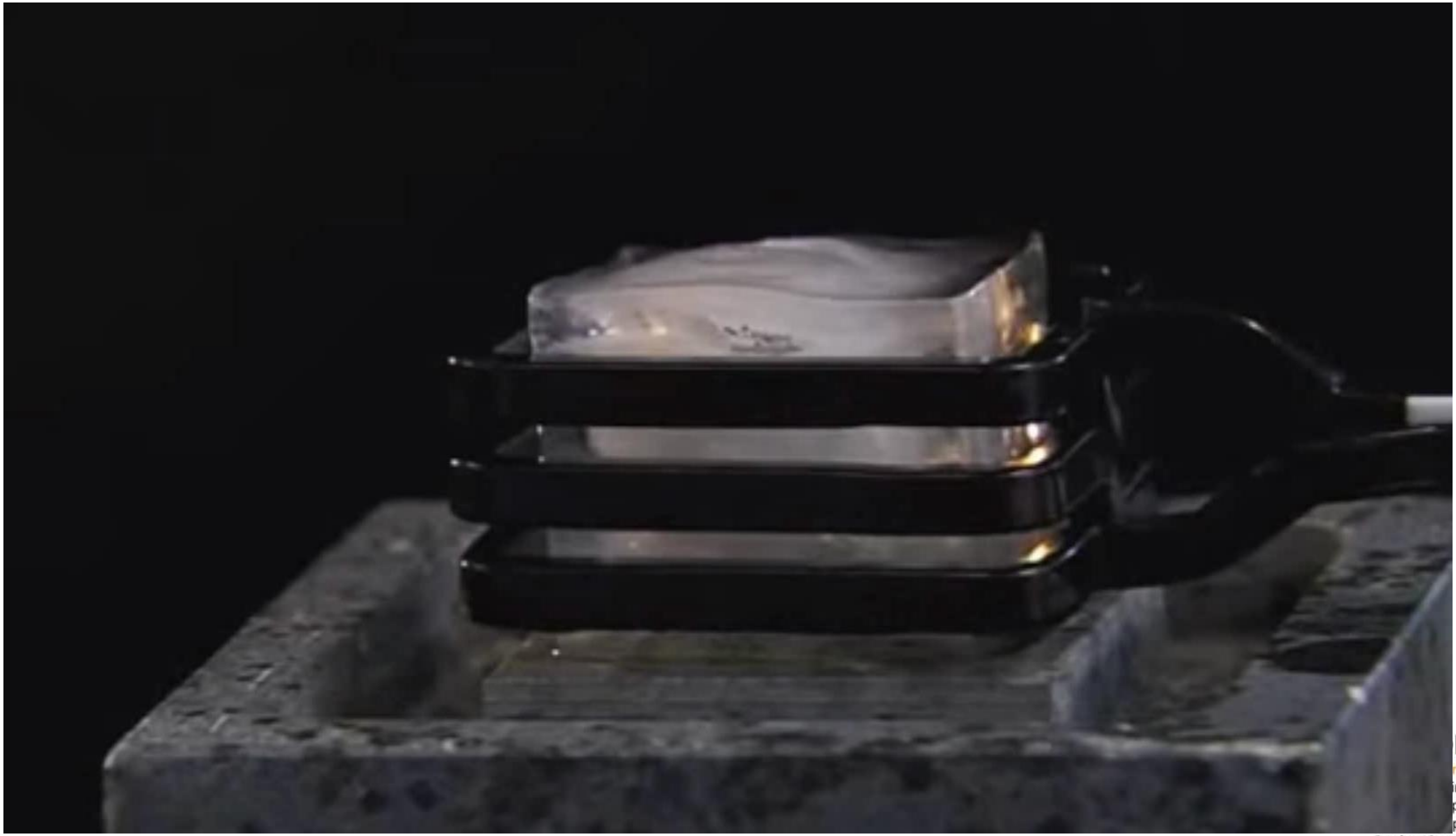
Induction Heating 해석 소개

1. Induction Heating 의 예

Induction Heating 해석 소개

1. Red-hot ice cube by induction heating



Induction Heating 해석

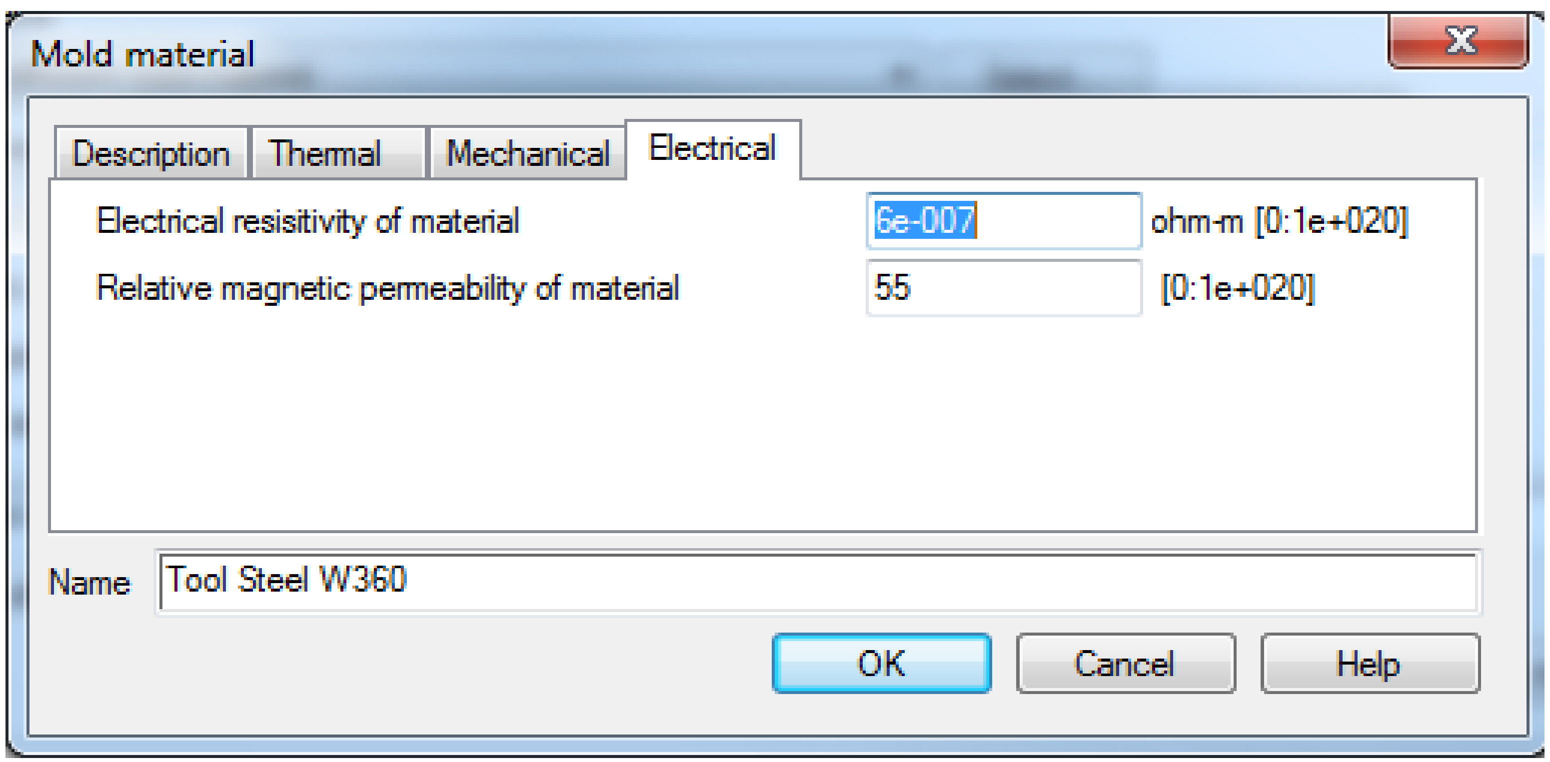
Induction Heating 해석 이론

1. Electrical 이란?

Electrical resistivity of material(단위: ohm-m)

재료의 전기저항률: 단위 길이를 갖는 물체 또는 어떤 물체의 단위 용적(1cm^3)의 전기저항

Relative magnetic permeability of material
재료의 상대 투자율



Induction Heating 해석 이론

1. 재료의 전기저항률(Electrical resistivity of material)이란?

어떤 물체가 전기를 흐름성을 비교하기 위한 물성수치(단위: Ωm)

→ 전기저항률이 낮을수록 전기는 흐르기 쉽다.

금속
Metals (Ωm)

- Steel,low carbon $142e^{-8}$
- Titanium $42.0e^{-8}$
- Platinum $10.60e^{-8}$
- Nickel $6.84e^{-8}$
- Aluminum $2.65e^{-8}$
- Gold $2.35\sim2.65e^{-8}$
- Copper $1.67\sim2.65e^{-8}$
- Silver $1.59e^{-8}$

반도체
Semiconductors

- GaAs
- Silicon (pure)
- Silicon (.0025 ohm-cm)
- Silicon Dioxide (amorphous)
- Silicon Nitride .16 - .33
- Silicon Carbide

절연체
Insulators

- Air
- Diamond
- Epoxy
- Glass
- water
- Liquid Nitrogen(77K)
- Liquid Argon(85K)

전기저항률참고: http://www.reade.com/Particle_Briefings/elec_res.html
http://www.matweb.com/

Induction Heating 해석 이론

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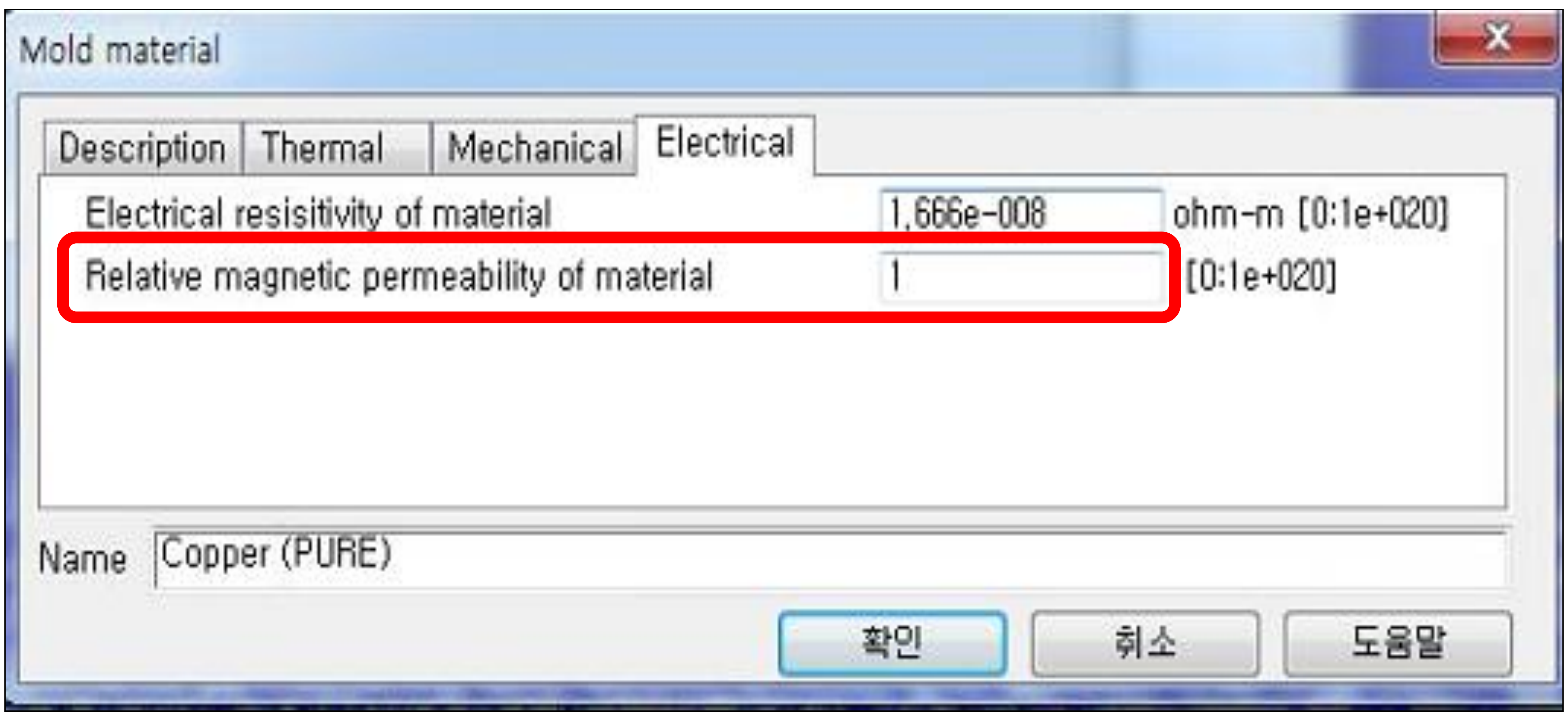
1. 재료의 **상대 투자율**
   (**Relative magnetic permeability** of material)?

magnetic permeability = 투자율 = 透 투과하다(투) 磁 자석(자) 率 비율(율)

상대 투자율 μ_r = **물질의 투자율** μ / **진공의 투자율** μ_0



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Induction Heating 해석 이론

1. 재료의 **상대 투자율**
   (**Relative magnetic permeability** of material)?

상대 투자율 = **물질의 투자율 / 진공의 투자율**

물질 투자율

물질의 자기적 성질을 나타내는 양

물질의 종류에 따라 달라진다.

강자성체 > 1 (철, 코발트, 니켈 종류의 원소 또는 합금)

상자성체 = 1 (산화알미늄…)

반자성체 < 1 (구리, 안티몬, 물…)

진공 투자율

물질이 진공 환경에서 자기적 성질을 나타내는 양

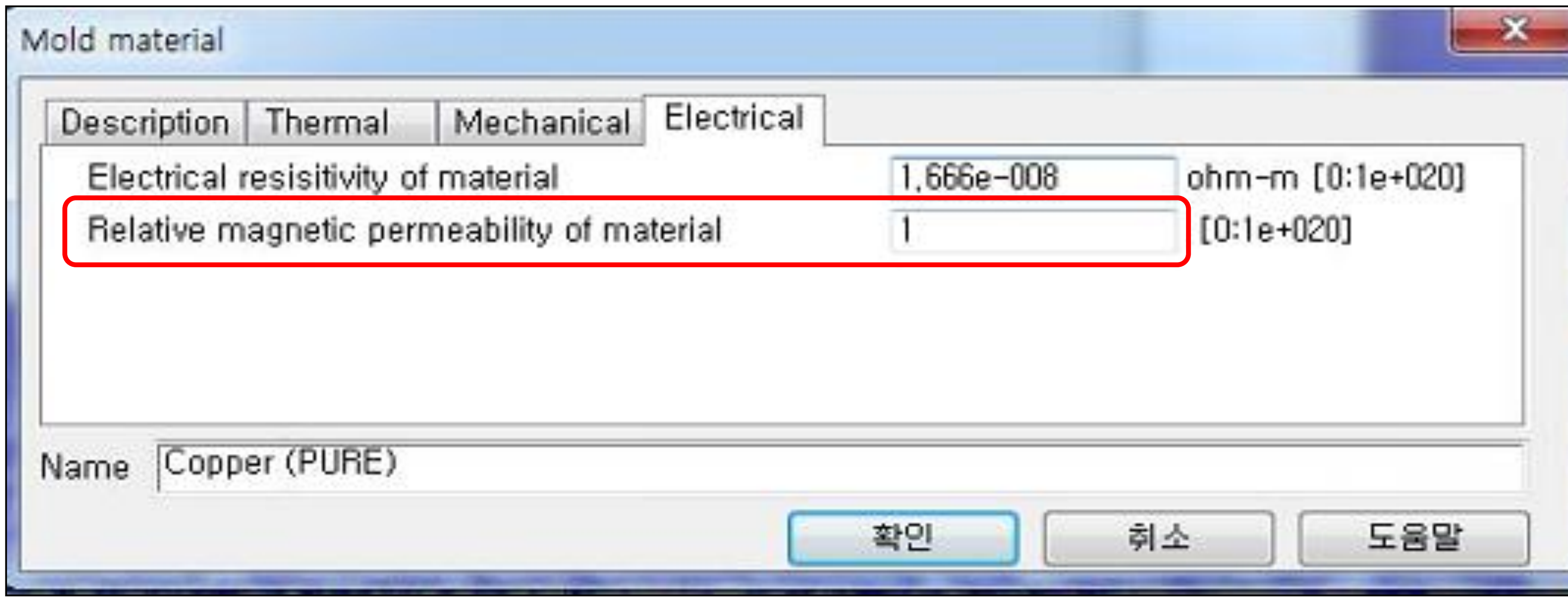
매우 작은 값으로 거의 0에 가깝다. (μ진공 = $4\pi \times 10^{-7} \approx 1.26 \times 10^{-6}$ $H \cdot m^{-1}$)

자기장: 자석이나 전류, 변화하는 전기장 등의 주위에 자기력이 작용하는 공간.

Induction Heating 해석 이론

1. 재료의 **상대 투자율**

(**Relative magnetic permeability** of material)?



이하

.26×10^{-6} H·m^{-1})

$$\text{구리의 상대 투자율} = \frac{\text{순수 구리의 투자율}(H\cdot m^{-1})}{\text{진공의 투자율}(H\cdot m^{-1})}$$

$$= \frac{1.2566368\times10-6}{4\pi\times10-7} = 0.999999791955 ≒ 1$$

자기장의 세기 H [단위(A/m)]
재료의 투자율 확인 : http://en.wikipedia.org/wiki/Permeability_(electromagnetism)
자기장: http://ko.wikipedia.org/wiki/%EC%9E%90%EA%B8%B0%EC%9E%A5

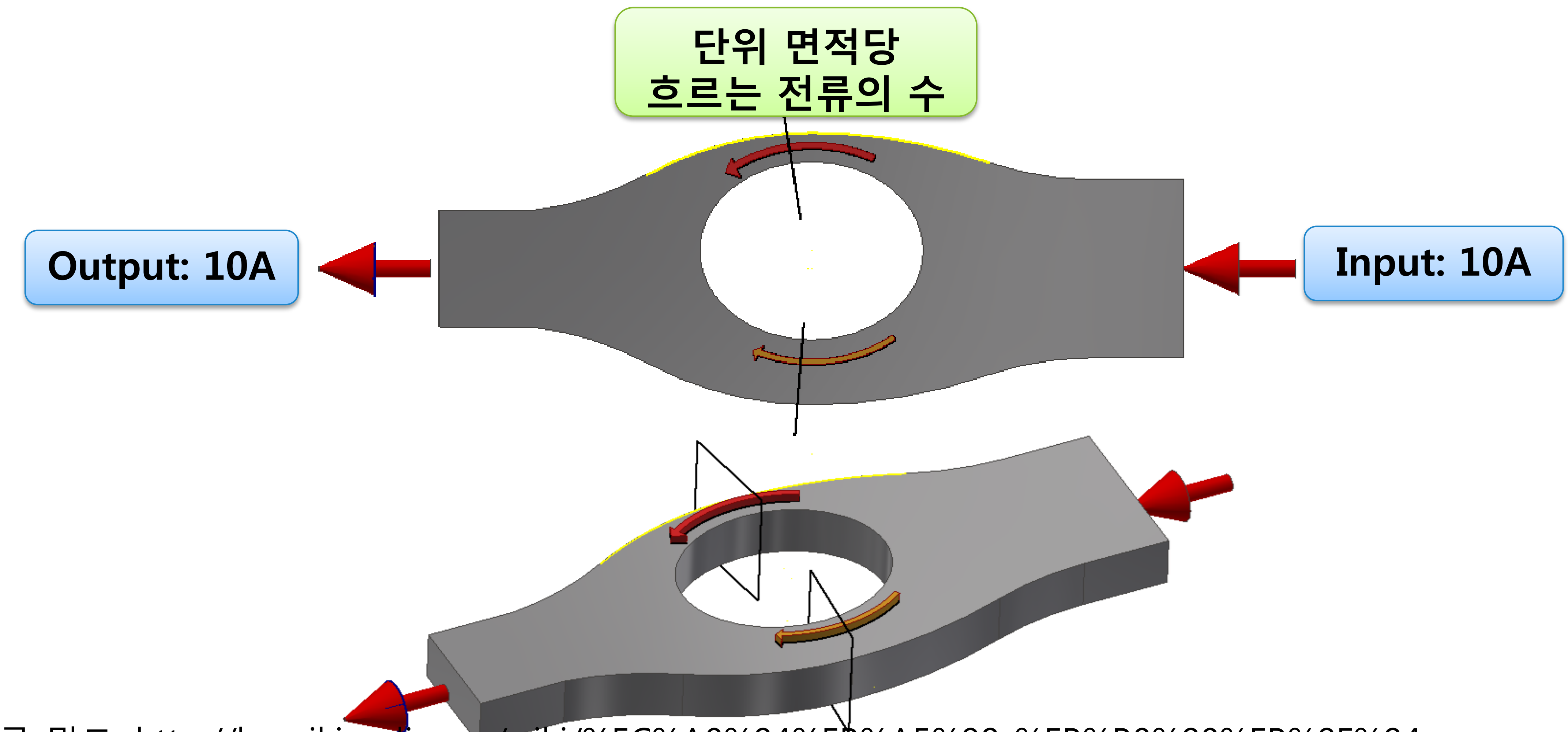
Induction Heating 해석 이론

1. 재료의 상대 투자율
   (Relative magnetic permeability of material)?

자력선속밀도: 단위 면적을 수직으로 지나는 자기력선의 수, 이를 자속밀도
Wb/m² = N/(Am) [단위: 국제단위계 가우스(G), CGS 테슬라(T)]

전류 밀도 = $\frac{A}{m^2}$ ∝ 자속 밀도 = $\frac{Wb}{m^2}$

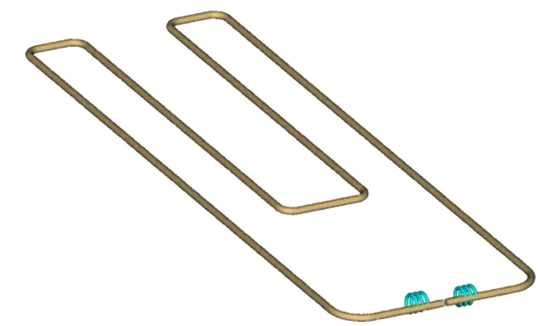
단위 면적당 흐르는 전류 ∝ 단위 면적당 흐르는 자기력

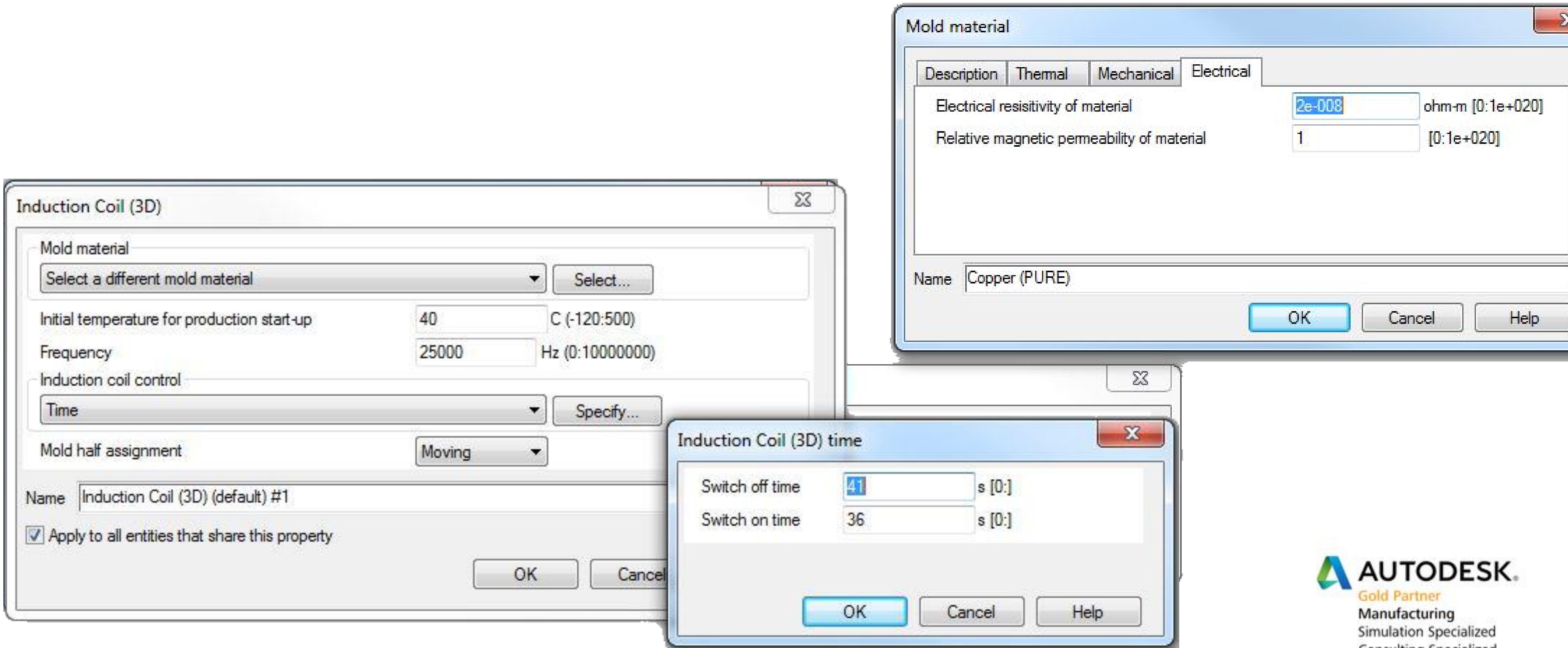


전류 밀도: http://ko.wikipedia.org/wiki/%EC%A0%84%EB%A5%98_%EB%B0%80%EB%8F%84

Induction Heating 해석 이론

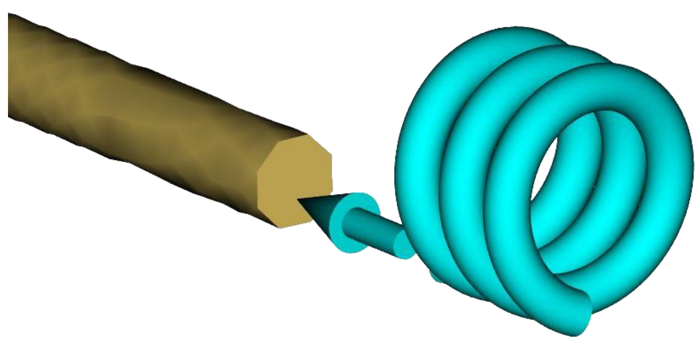
1. Elemental properties는 Coil로 지정 해야 함.
   유도가열을 목적으로 하는 coil은 동을 추천

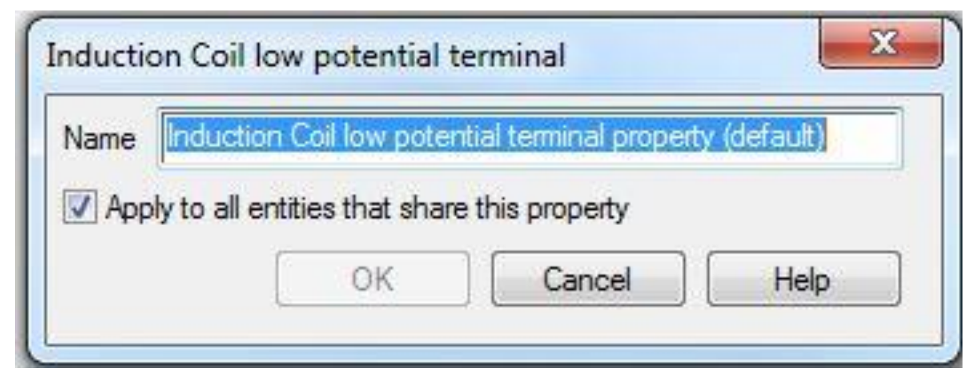


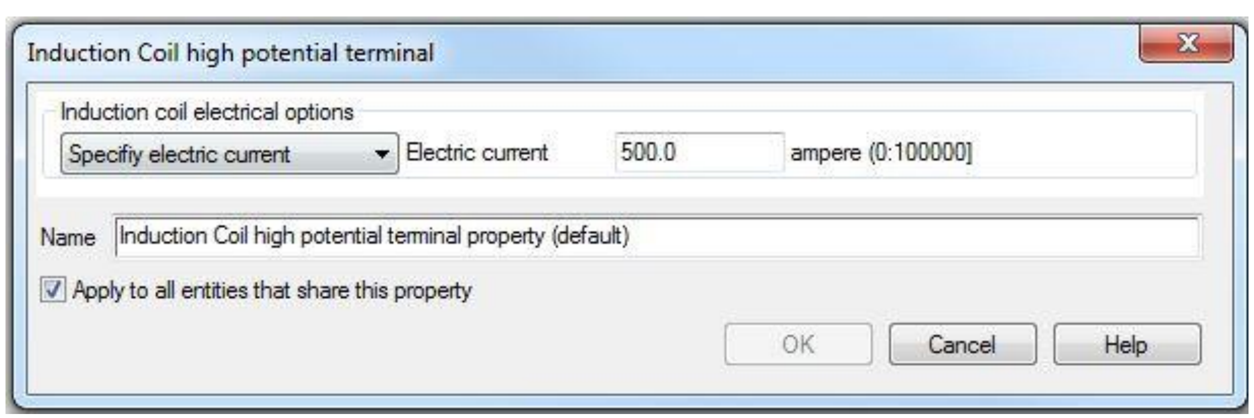


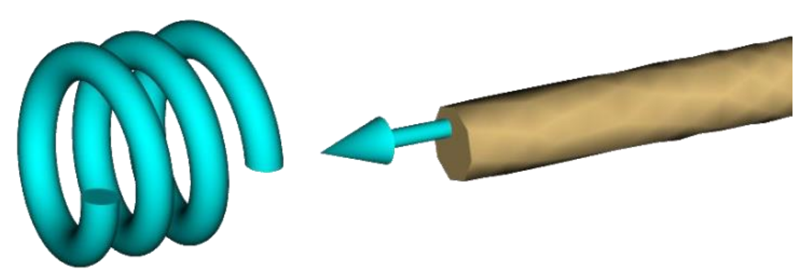
Induction Heating 해석 이론

1. 전류 또는 전압의 크기 지정.(전류의 방향)









Induction Heating 해석 이론

- Induction heating 해석에서 신뢰도를 높이기 위한 도체의 매싱 기법
- 유도전류의 86%가 도체 표면 레이어에 집중되어 있음.

- (최외곽 표면층의 두께) $\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$

  f: 발전기의 주파수(s^{-1}),
  μ : 재료의 투자율($H \cdot m^{-1} = kg \cdot m^{2} \cdot s^{-2} \cdot A^{-2} \cdot m^{-1}$) ,
  σ : 재료의 전기 전도율 ($S \cdot m^{-1} = kg^{-1} \cdot m^{-2} \cdot s^{3} \cdot A^{2} \cdot m^{-1}$)

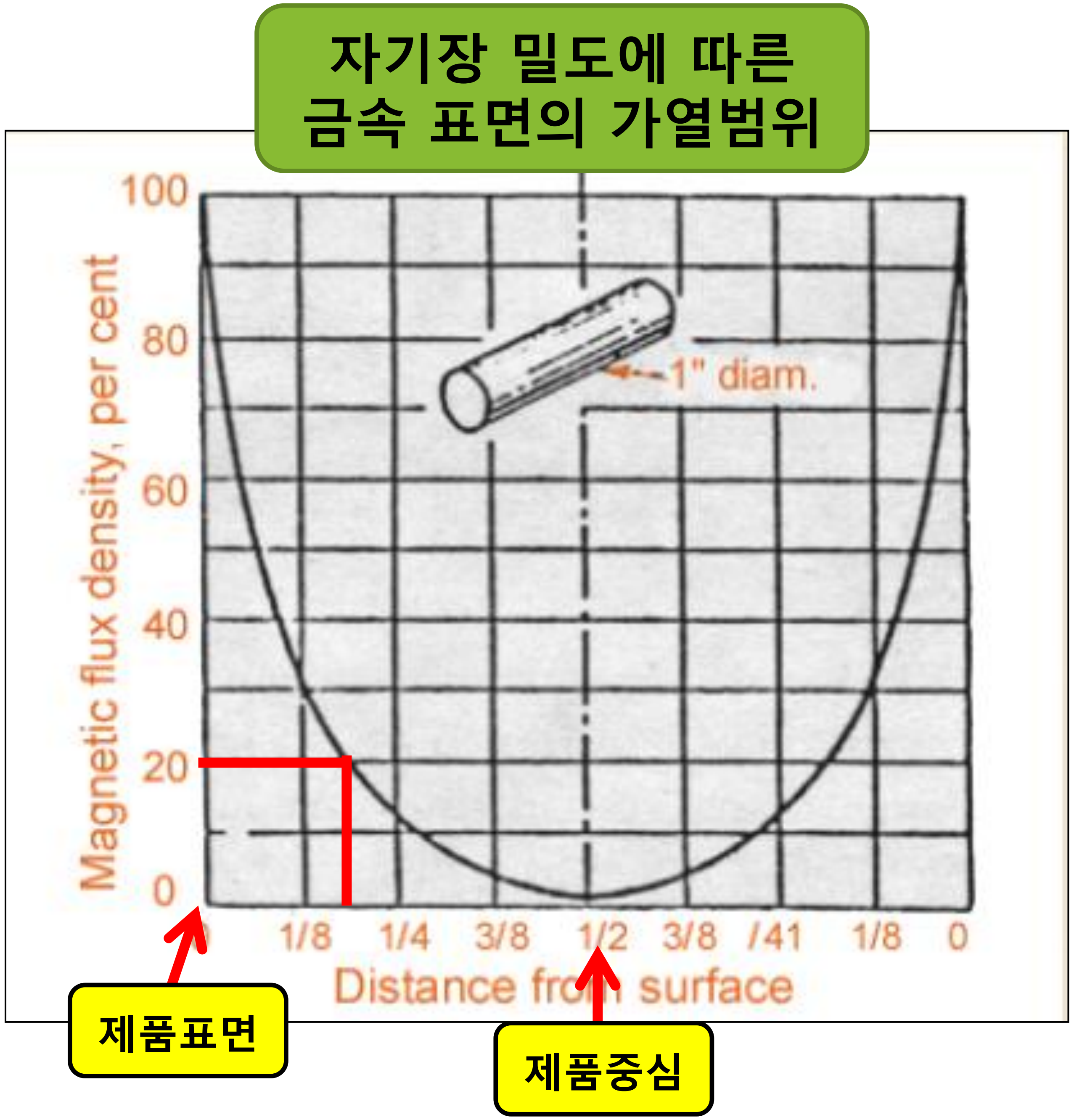
- $\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} = 1/\sqrt{\pi\,(s^{-1})(kg\,m^{2}\,s^{-2}\,A^{-2}\,m^{-1})(kg^{-1}\,m^{-2}\,s^{3}\,A^{2}\,m^{-1})}$ =m

- 도움말 참고« meshing guidelines for induction heating »

유도단위 : http://terms.naver.com/entry.nhn?docId=1661982&cid=42330&categoryId=42330

Induction Heating 해석 이론

- 해석 신뢰도를 높이기 위해 Mold Insert(가열체)의 1st layer 두께는 δ(델타) 가 중요한 이유는?



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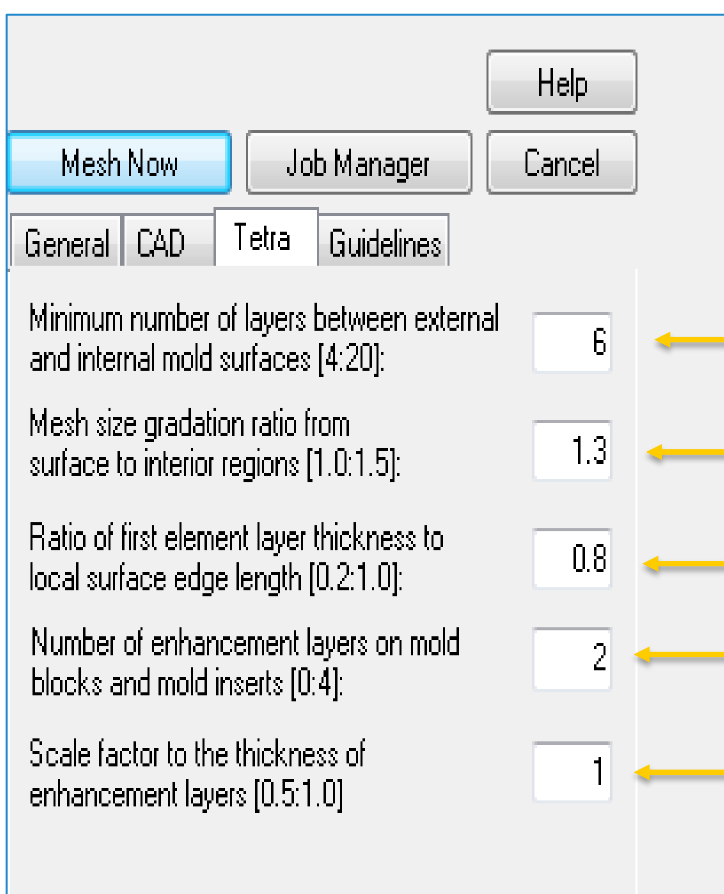
Induction Heating 해석 이론

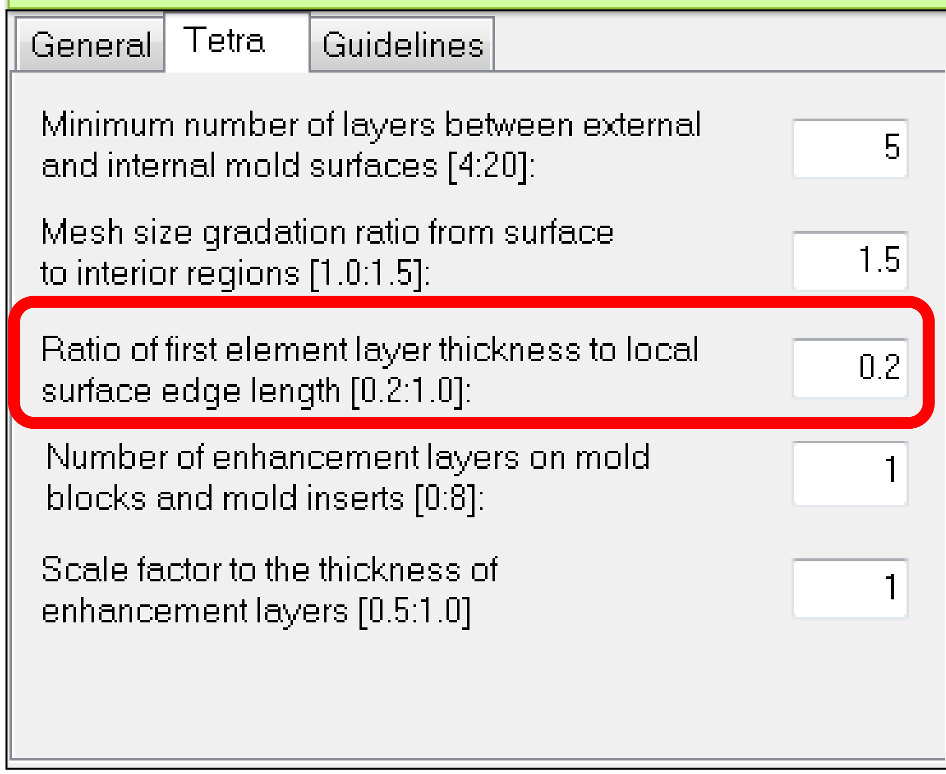
- Meshing 고려대상
  - Mold Insert(가열체)
- Mold Insert(가열체)표면 Mesh size
  - $mesh\ size = \frac{\delta}{0.8}$
- Mold Insert(가열체)의 1st layer 두께는 δ(델타) 로 지정
- 표면부위는 4 Layer를 추천함.

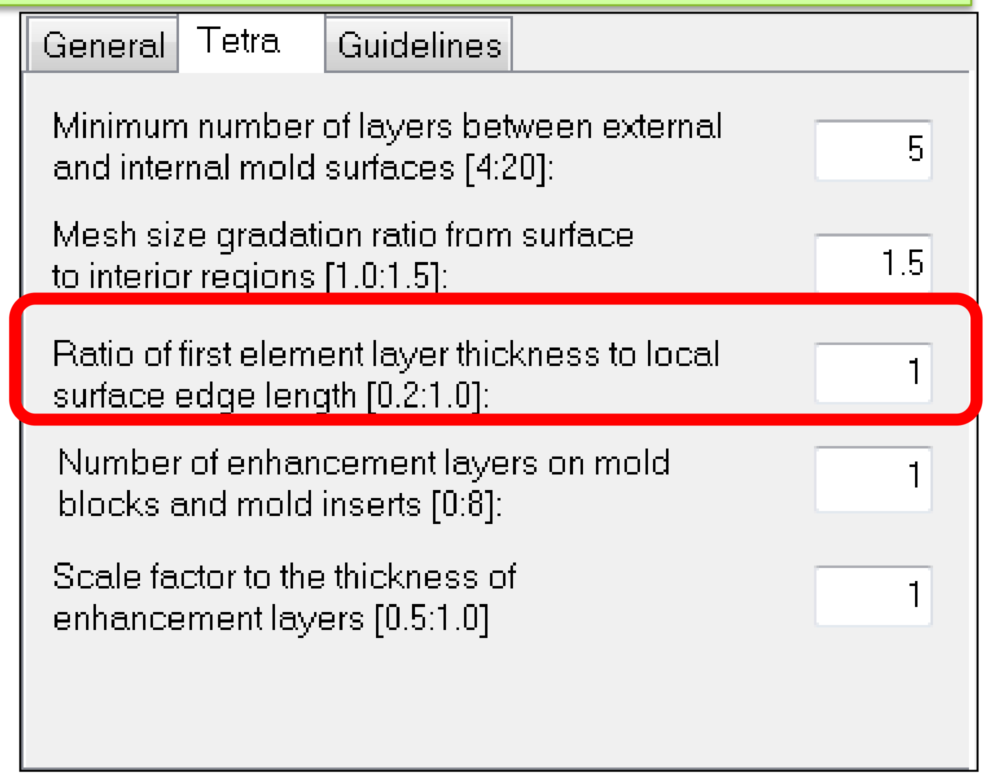


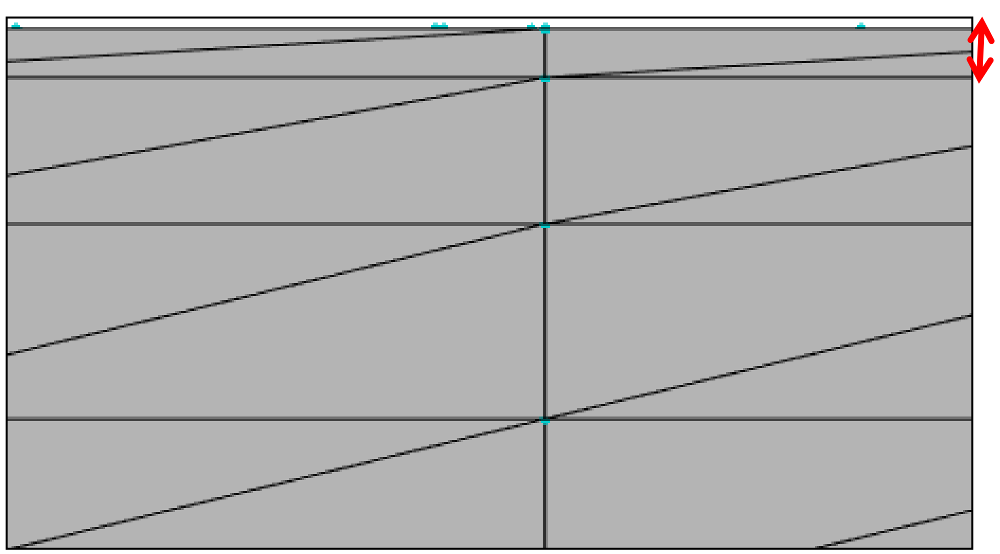
- 표면에서 중심까지의 Layer 수(6-Layer 생성)
- 표면에서 중심까지의 두께 증가비율(1.3배로 증가)
- 1st Layer 두께 사이즈(1st layer 두께 0.8mm)
- 1st Layer 두께의 개수 결정(1st layer 0.8mm가 2개)
- 1st Layer 두께 사이즈에 Scale 적용
  Ex) 1st layer 0.8mm 일때 0.5를 입력하면 0.4mm 두께

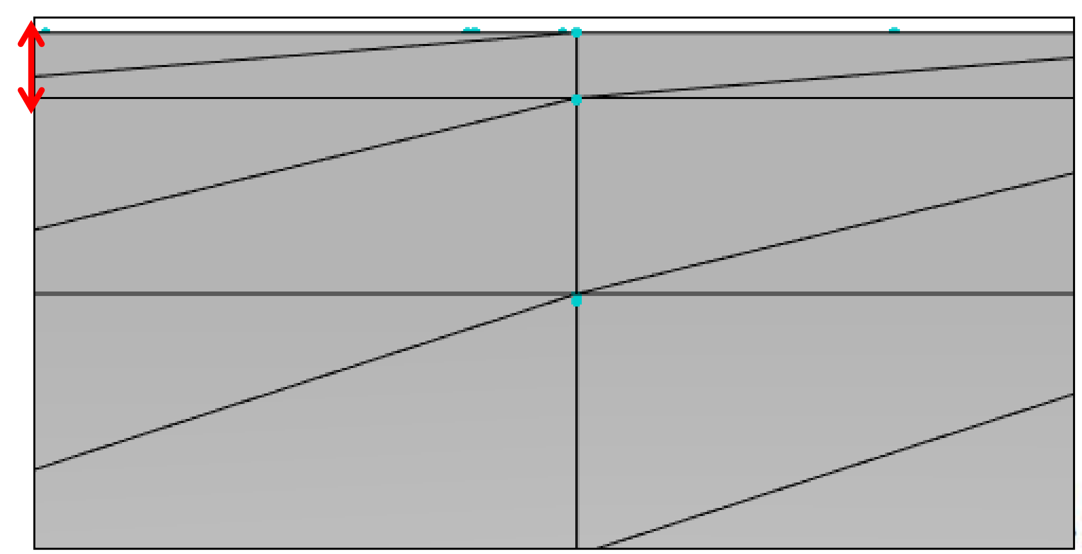
Induction Heating 해석 이론

1st Layer 두께 사이즈(1st layer 두께 0.2mm / 1mm)









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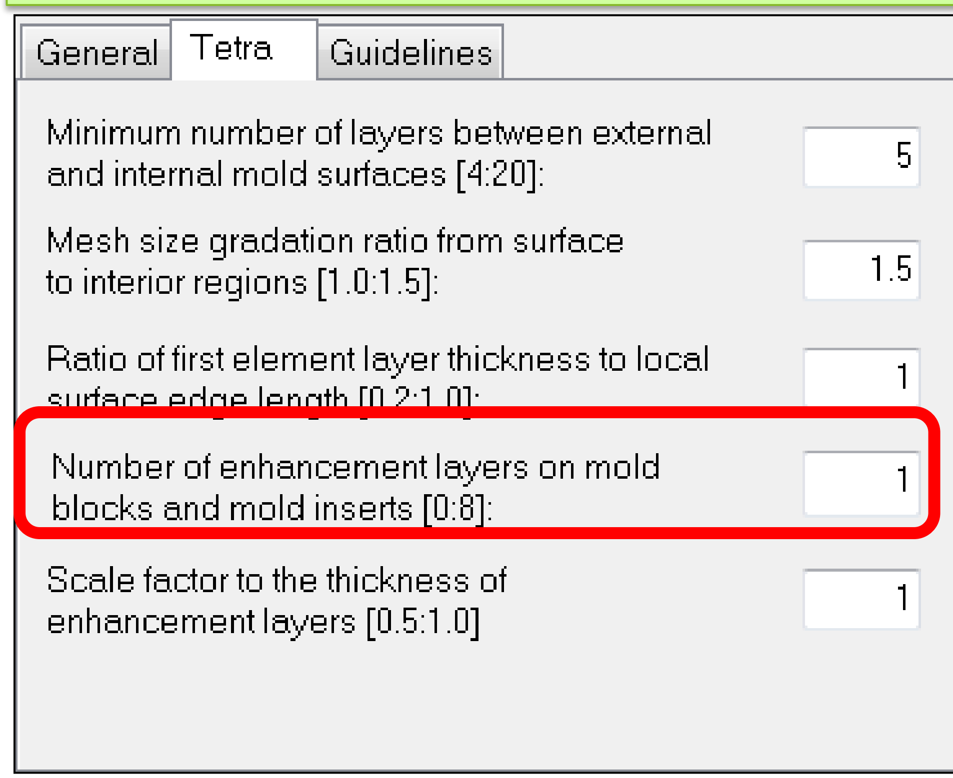
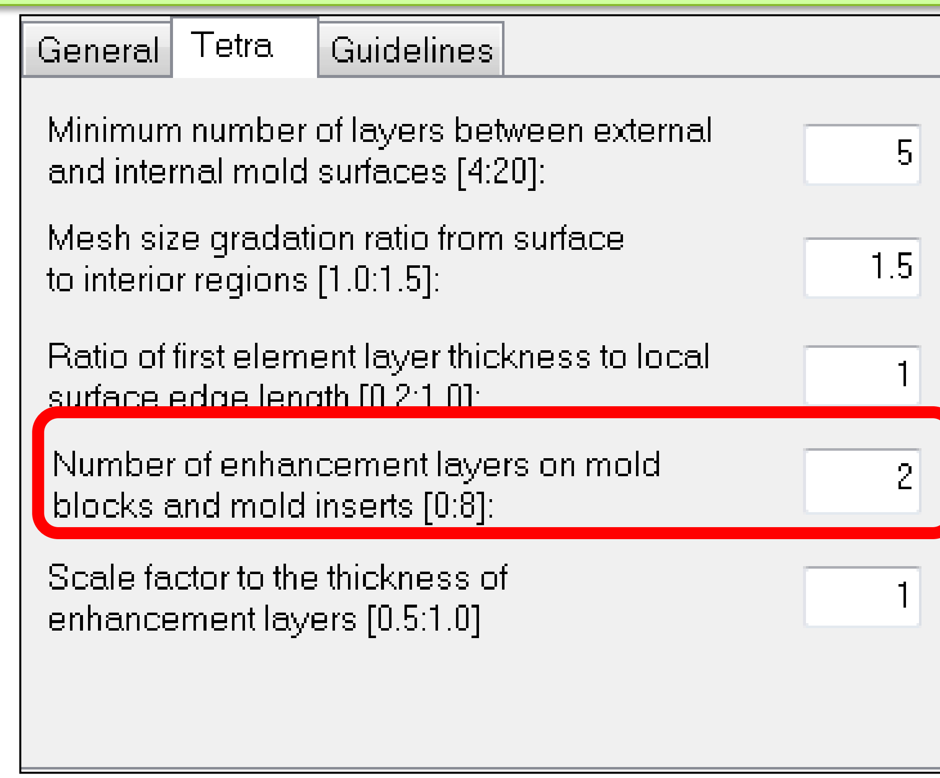
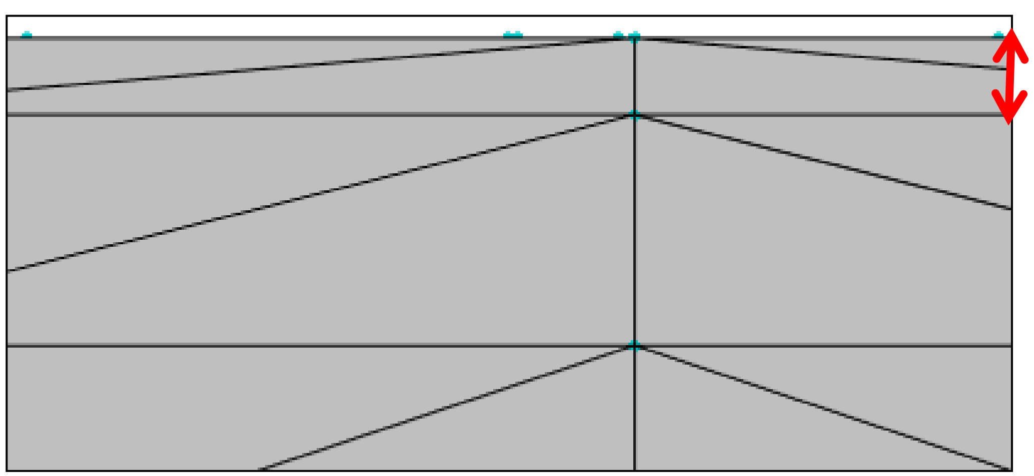
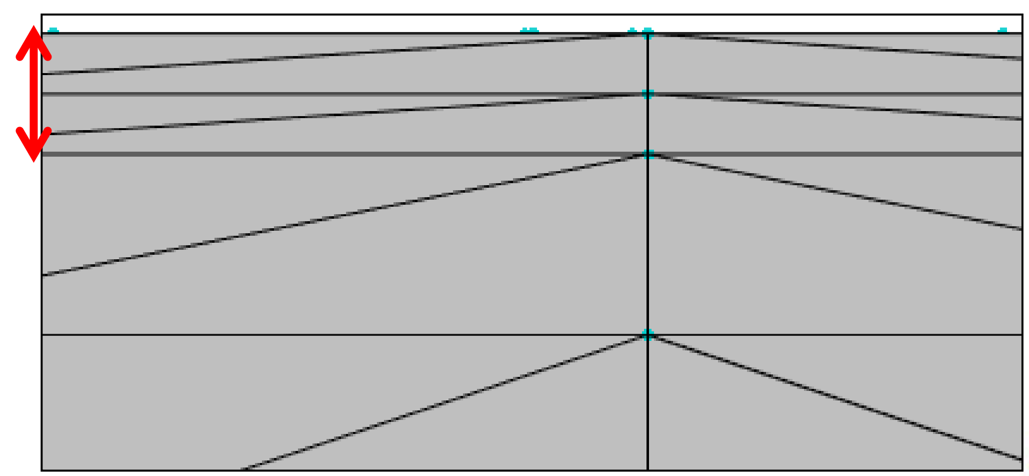
Induction Heating 해석 이론

1st Layer 두께의 개수 결정(1st layer 1mm가 1개 / 2개)



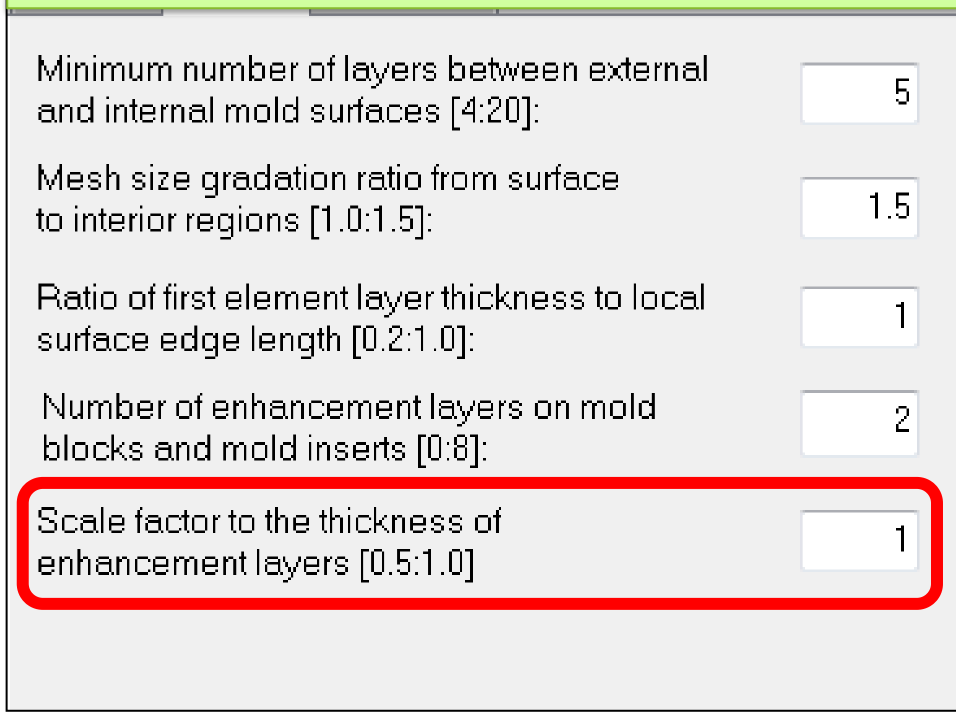


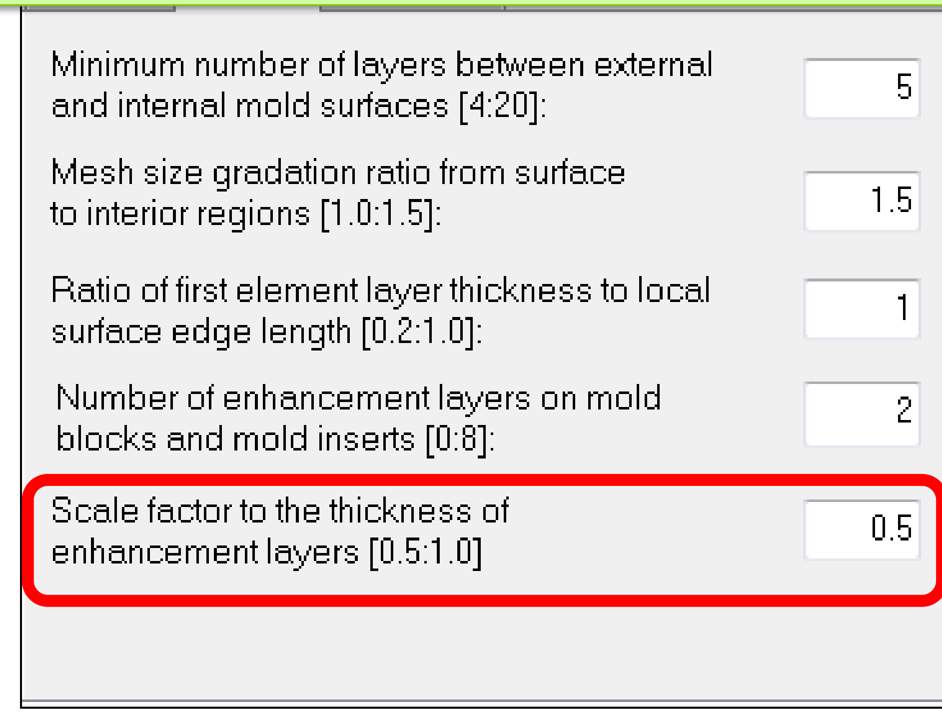


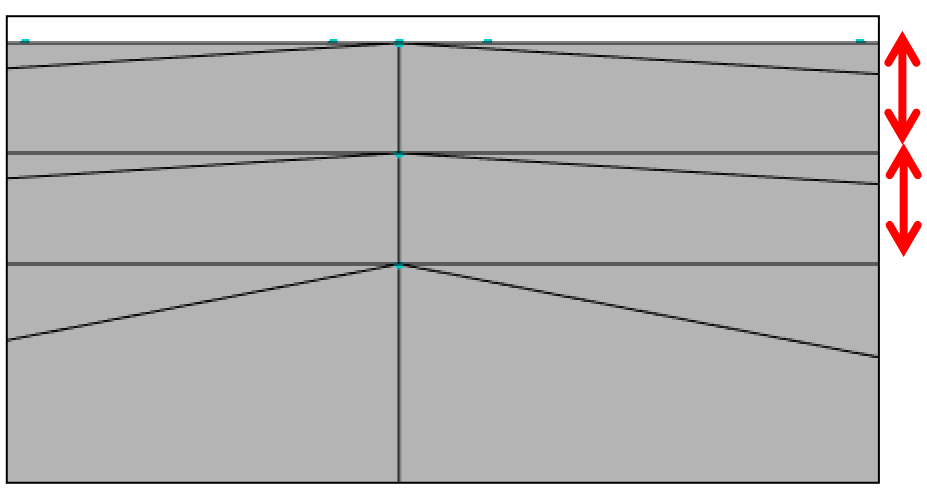


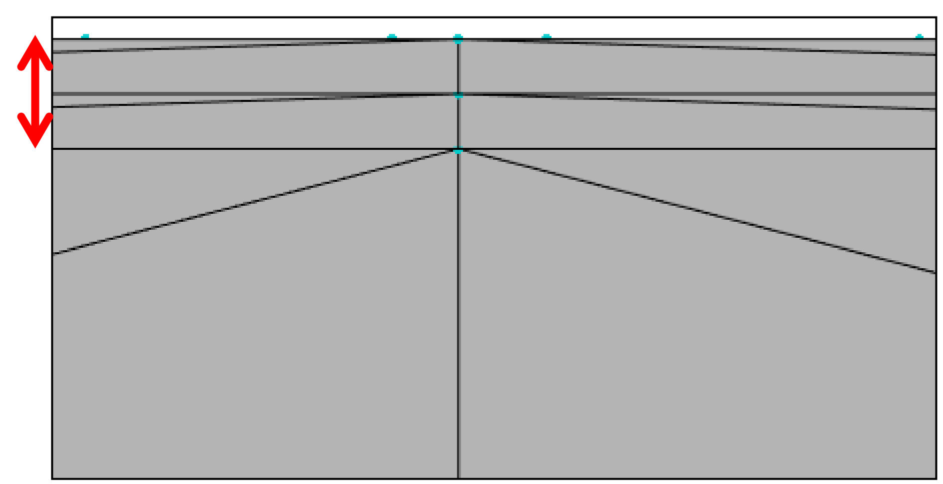
Induction Heating 해석 이론

1st Layer 두께 사이즈에 Scale 적용
Ex) 1st layer 1mm 일 때 1 / 0.5



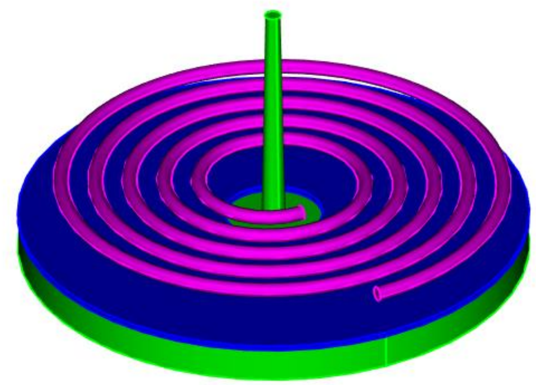


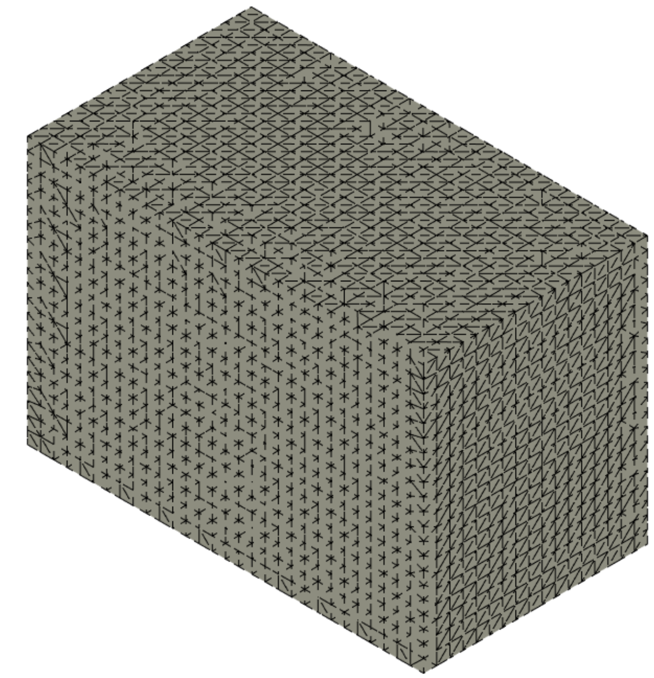




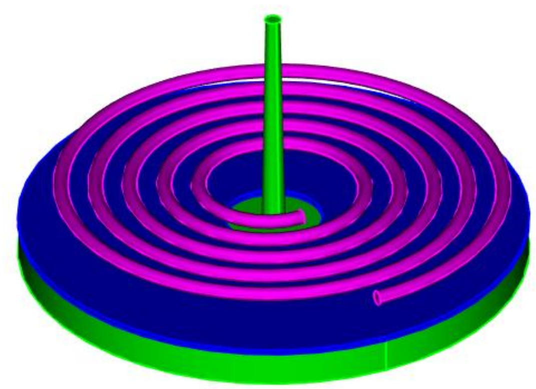
Induction Heating 해석 실습

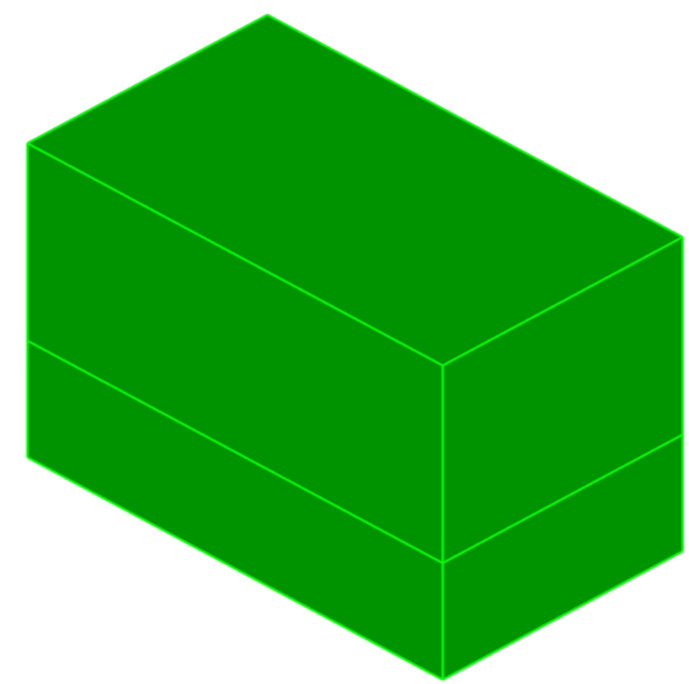
1. Mold Surface Wizard(FEM)
   1. 제품 모델링
   2. Runner 모델링 (Beam or 3D CAD)
   3. Channel 모델링 (Beam)
   4. Coil 모델링(3D CAD)
   5. Insert 모델링(3D CAD)





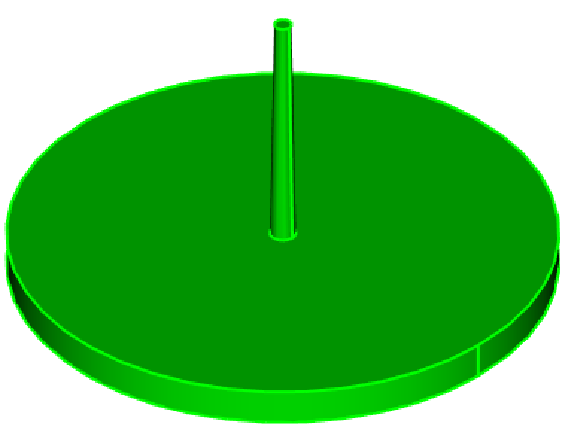
2. Mold Block(FEM)
   1. 제품 모델링
   2. Runner 모델링 (Beam or 3D CAD)
   3. Channel 모델링 (Beam)
   4. Coil 모델링(3D CAD)
   5. Insert 모델링(3D CAD)
   6. **금형 모델링 (3D CAD)**

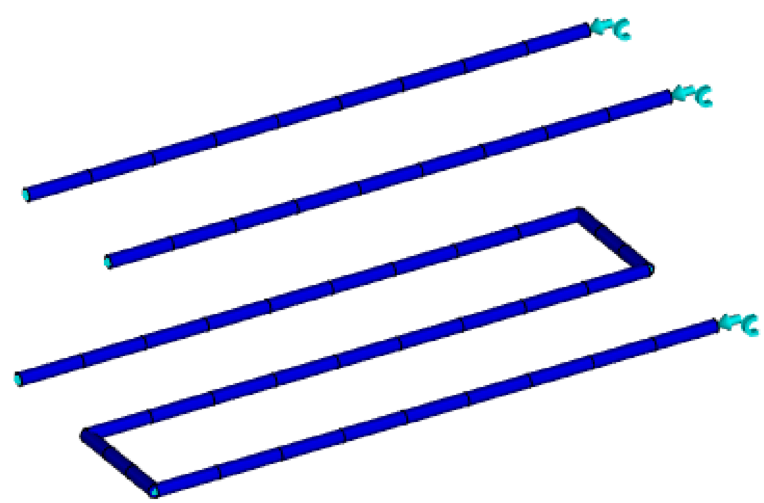


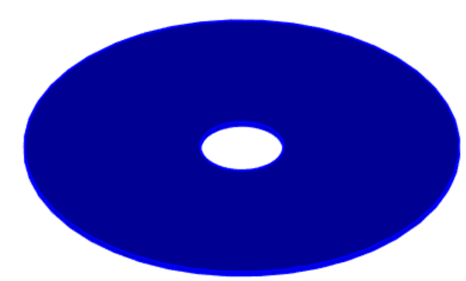


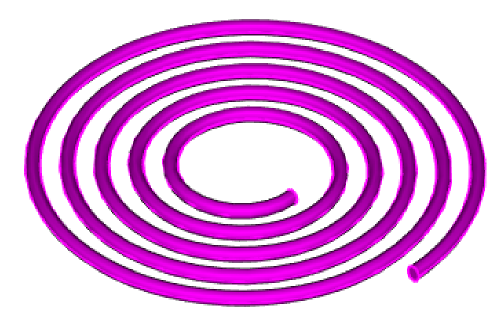
Induction Heating 해석 실습

- 제품 모델링
- Runner 모델링 (Beam or 3D CAD)
- Channel 모델링 (Beam)
- Coil 모델링(3D CAD)
- Insert 모델링(3D CAD)



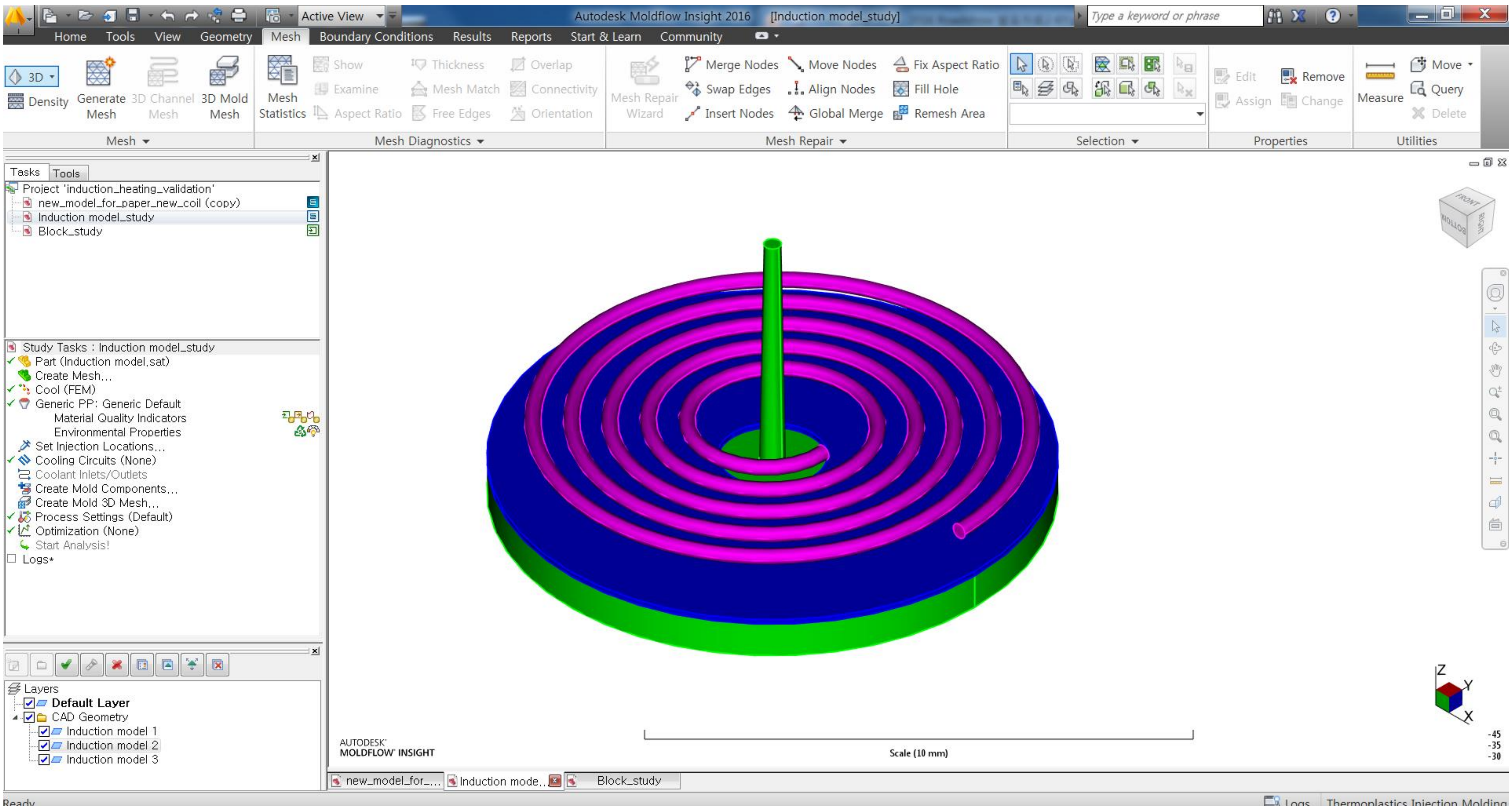






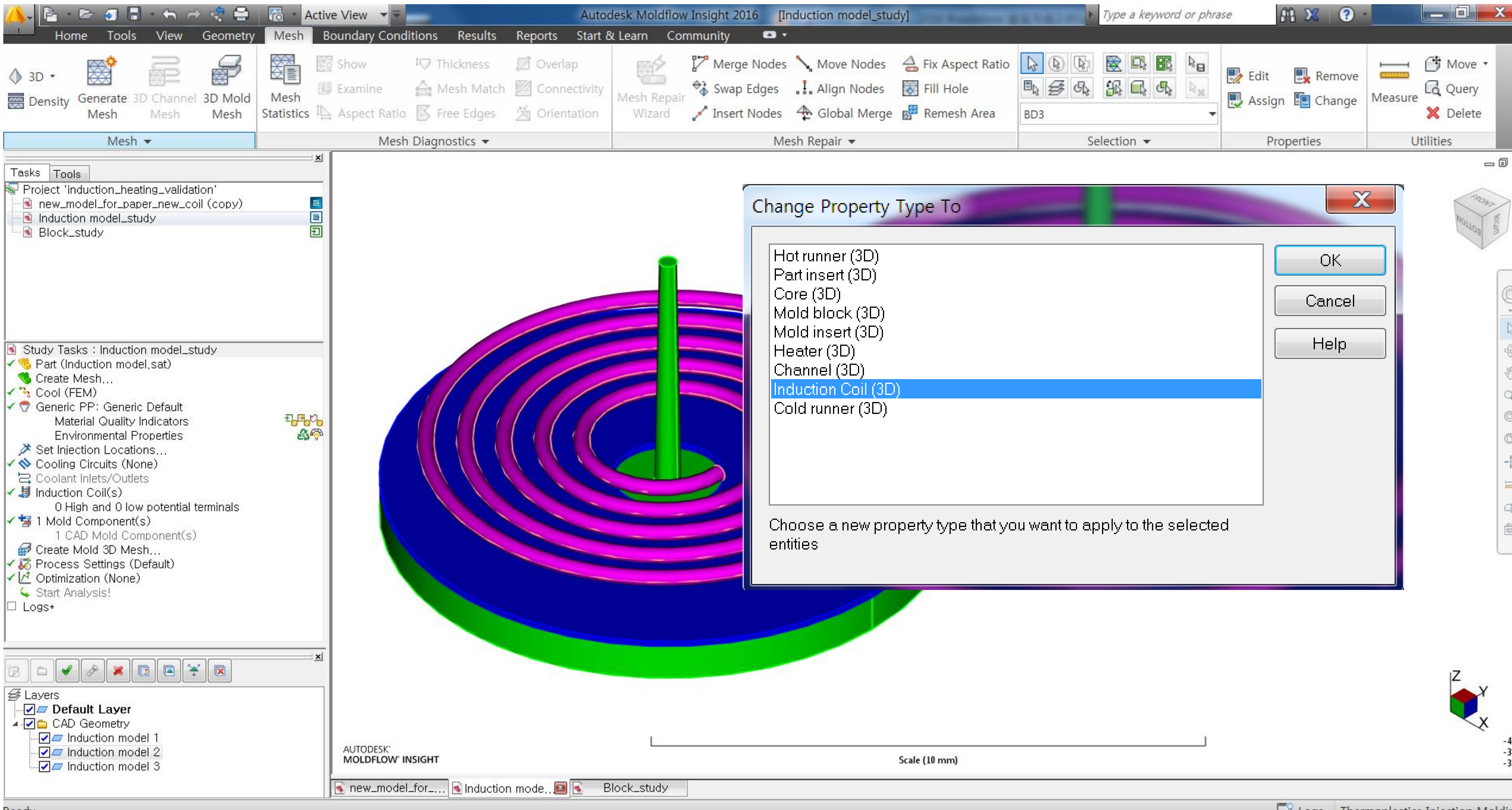
Induction Heating 해석 실습

- 제품, Runner, Coil, Mold insert - Import



Induction Heating 해석 실습

- Induction Coil 로 속성 설정



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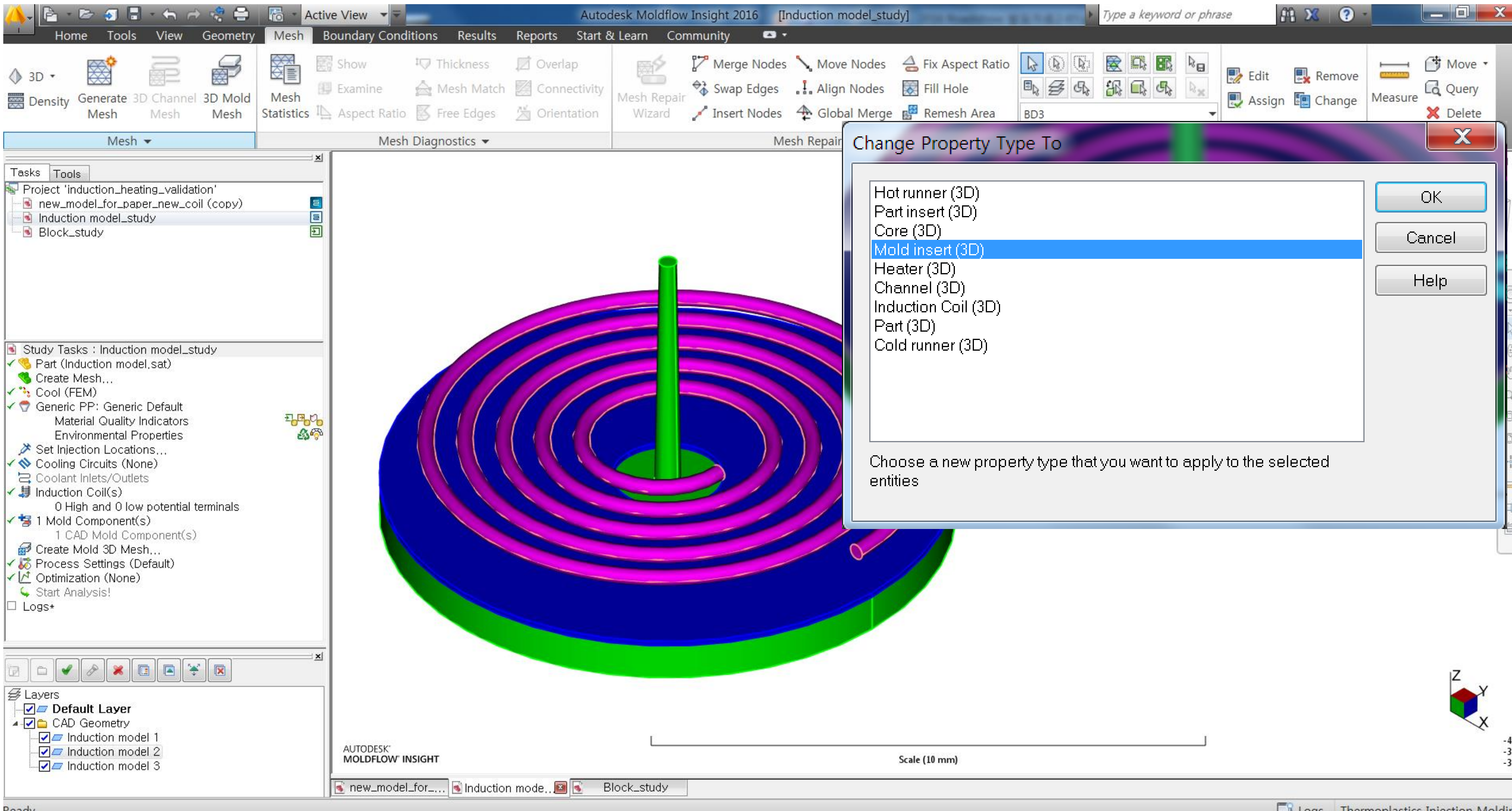
Induction Heating 해석 실습

- Mold insert 로 속성 설정



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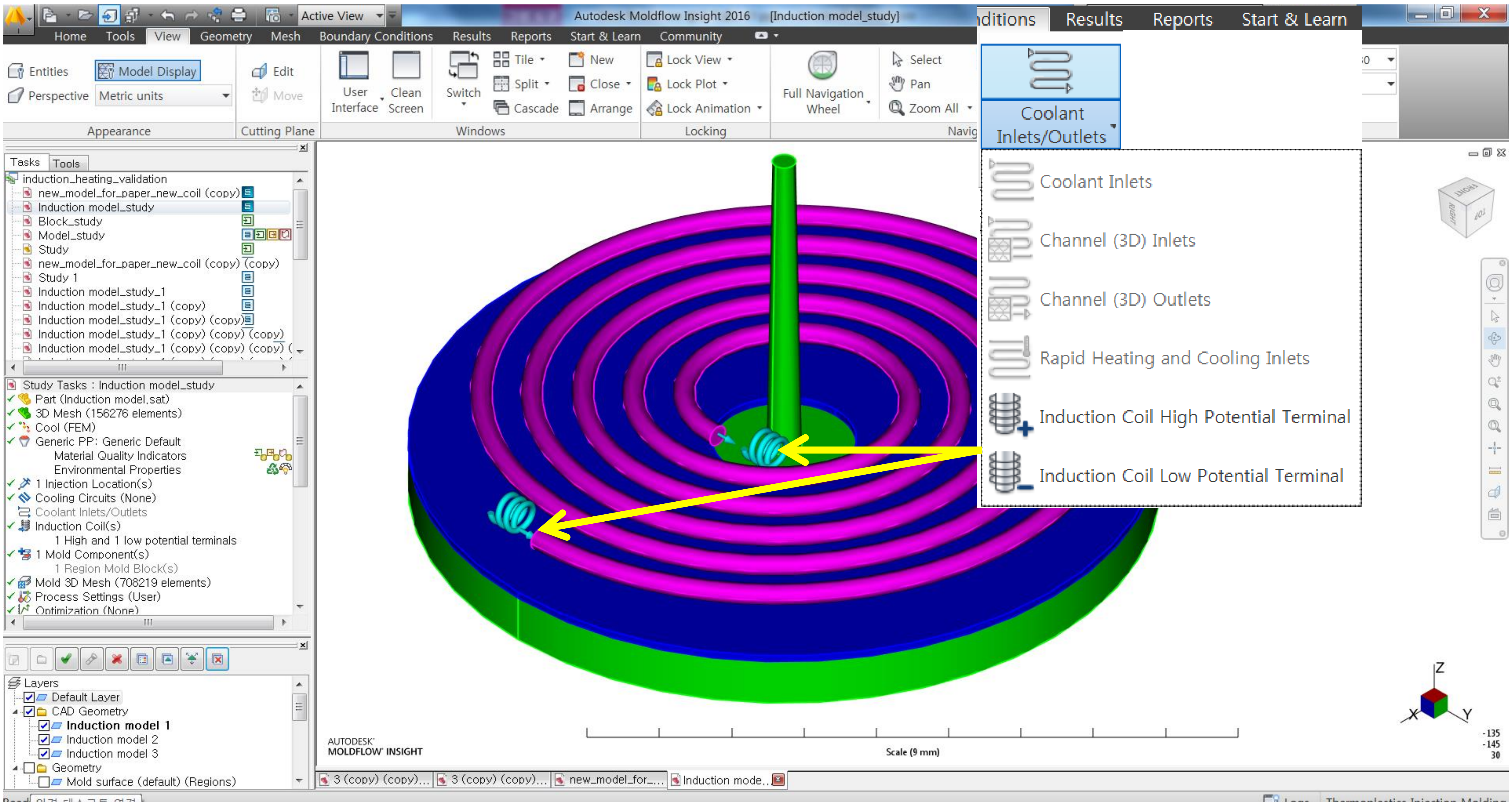
- Induction Coil High/Low Potential Terminal 설정(Boundary Condition)



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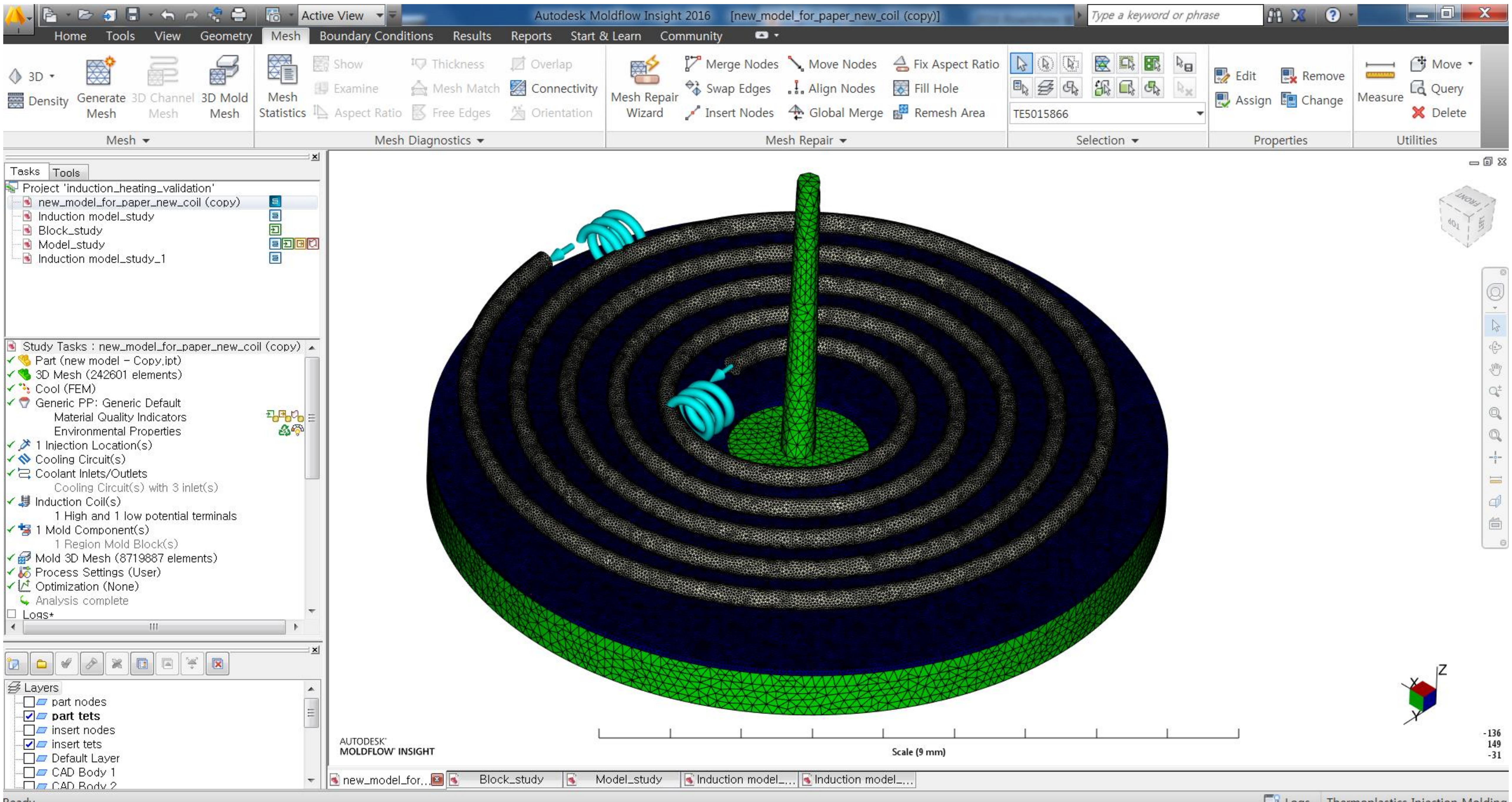
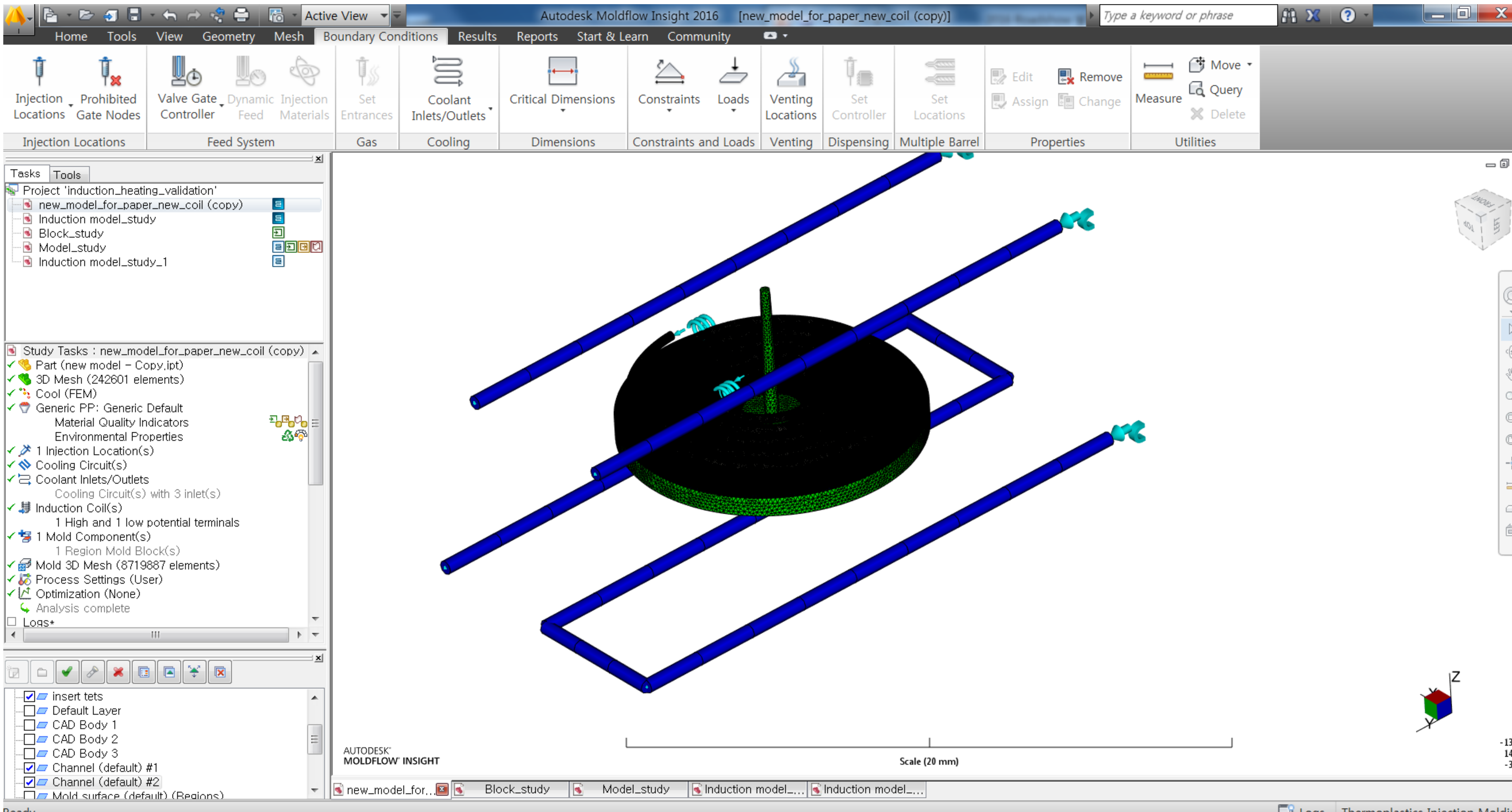
Induction Heating 해석 실습

- Induction Coil Mesh 생성



Induction Heating 해석 실습

- Channel Beam Mesh 생성



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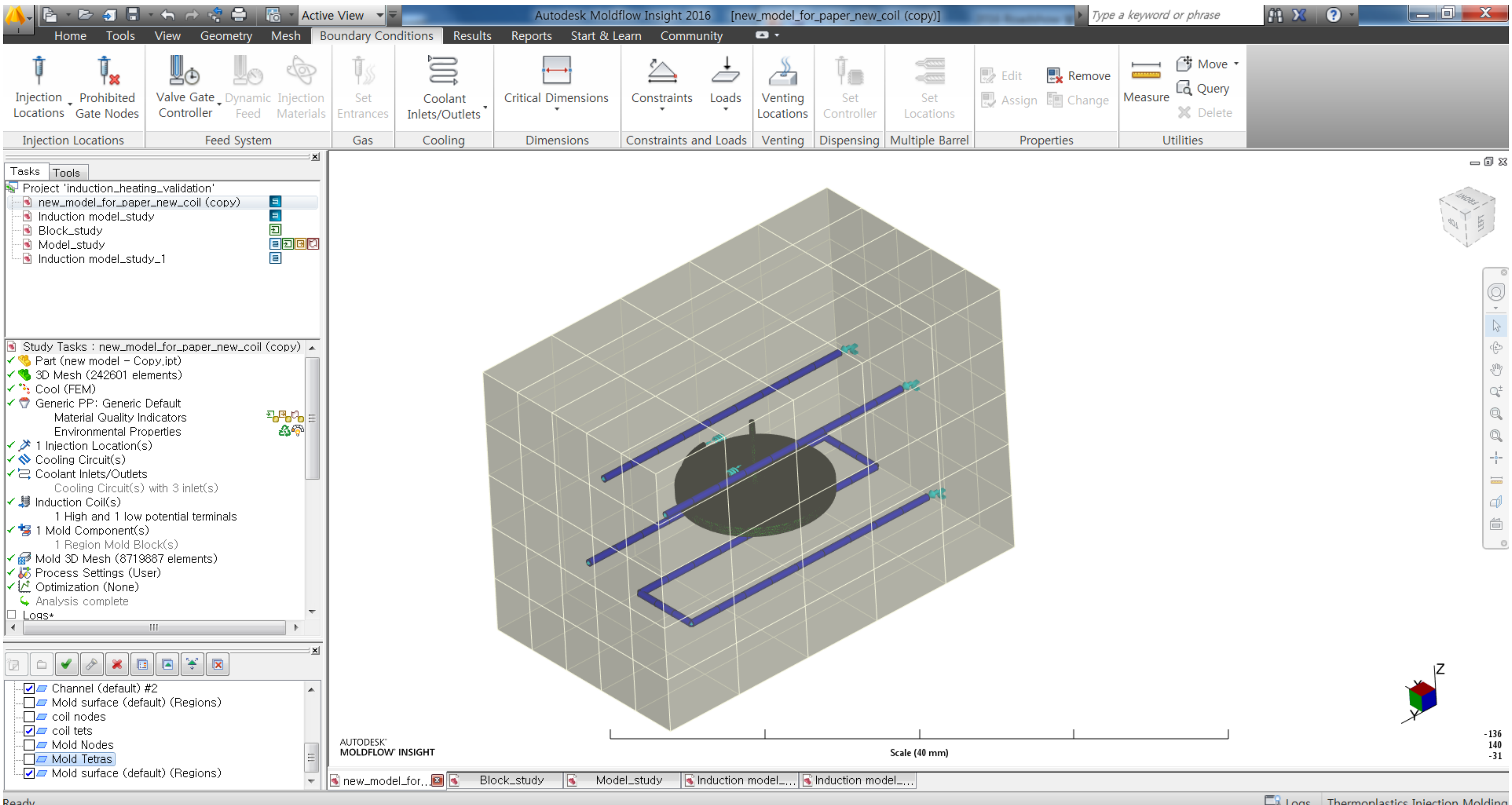
Induction Heating 해석 실습

- Mold Surface 생성



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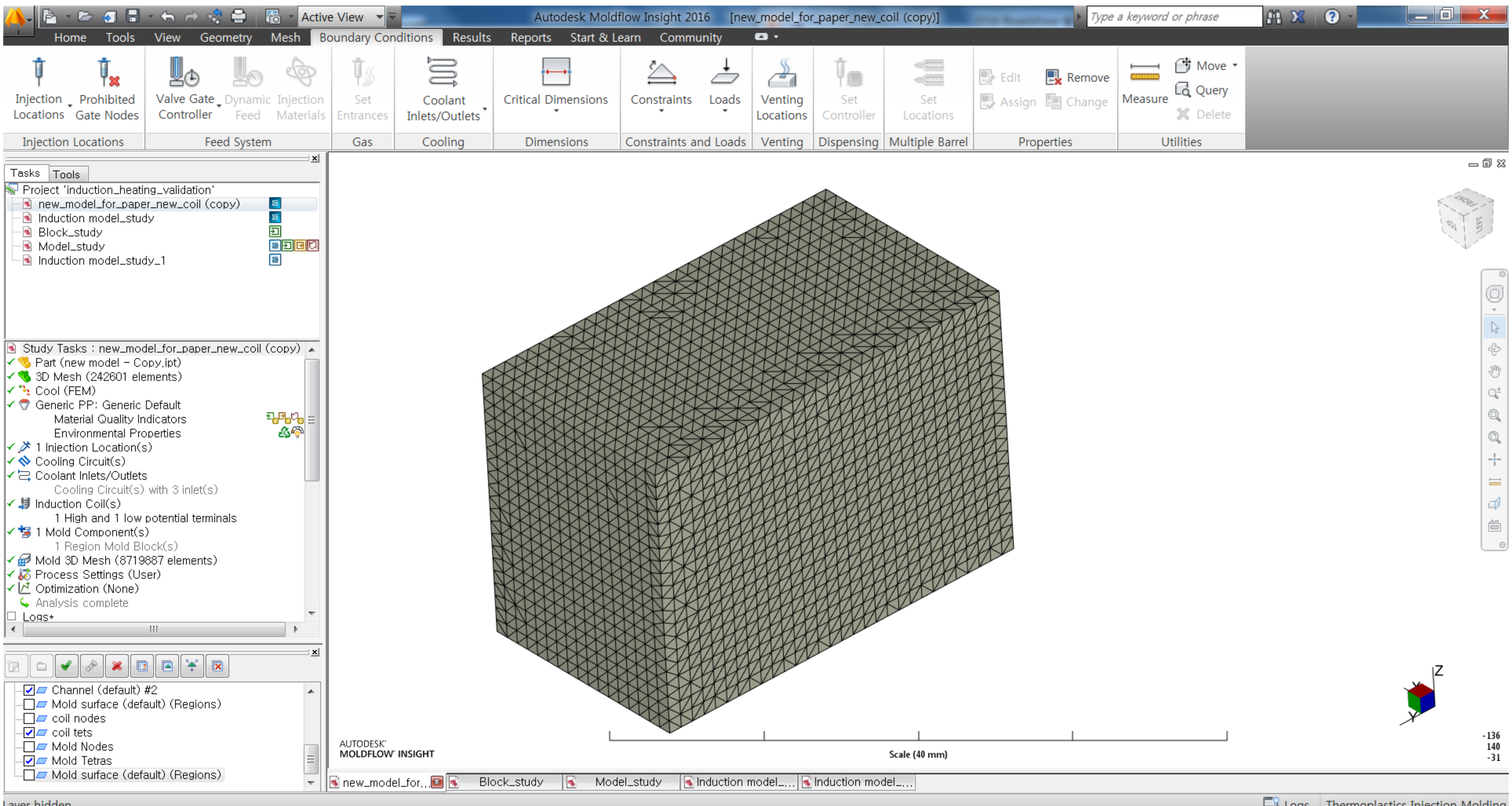
- Mold Surface Mesh 생성



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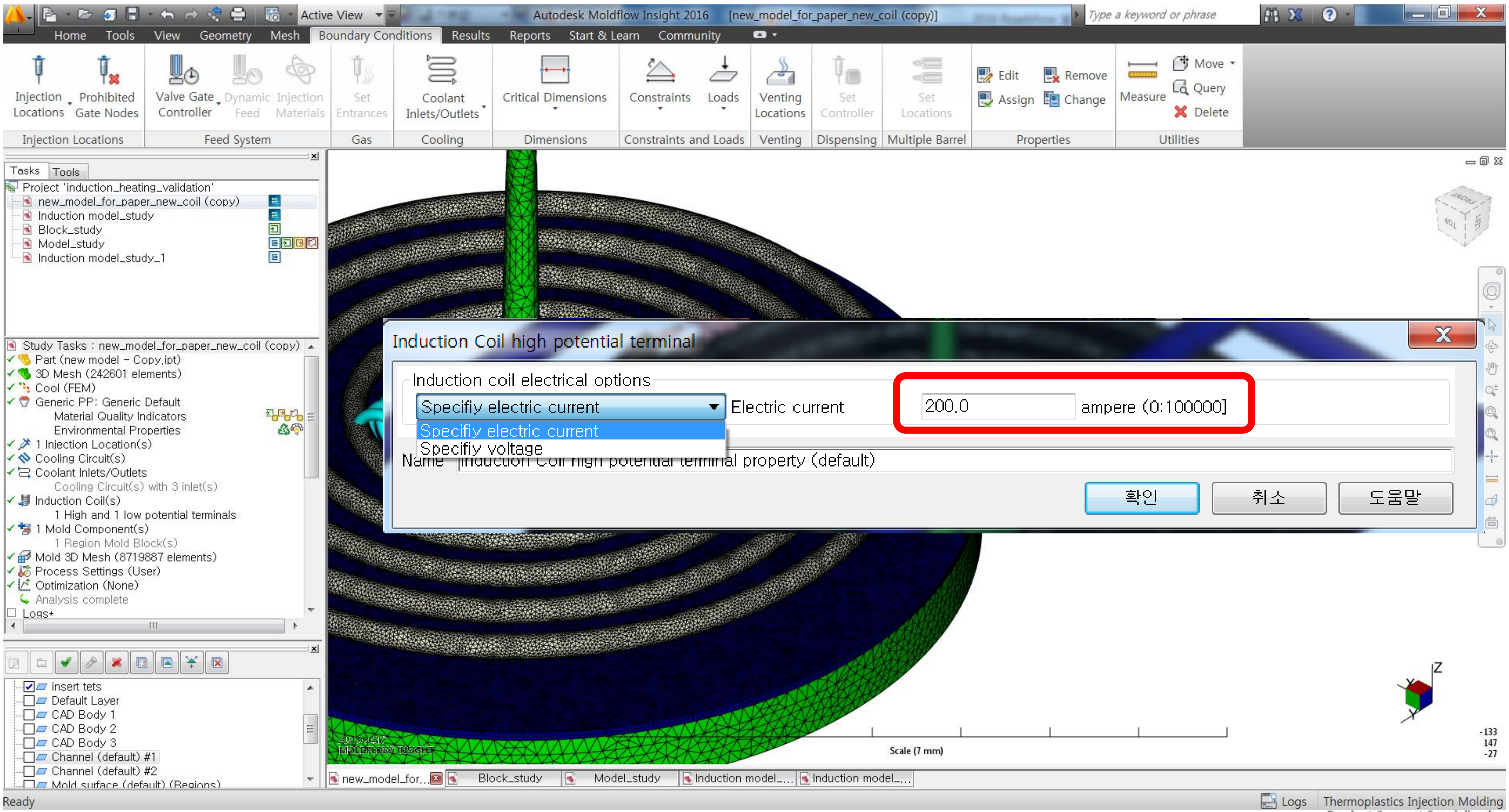
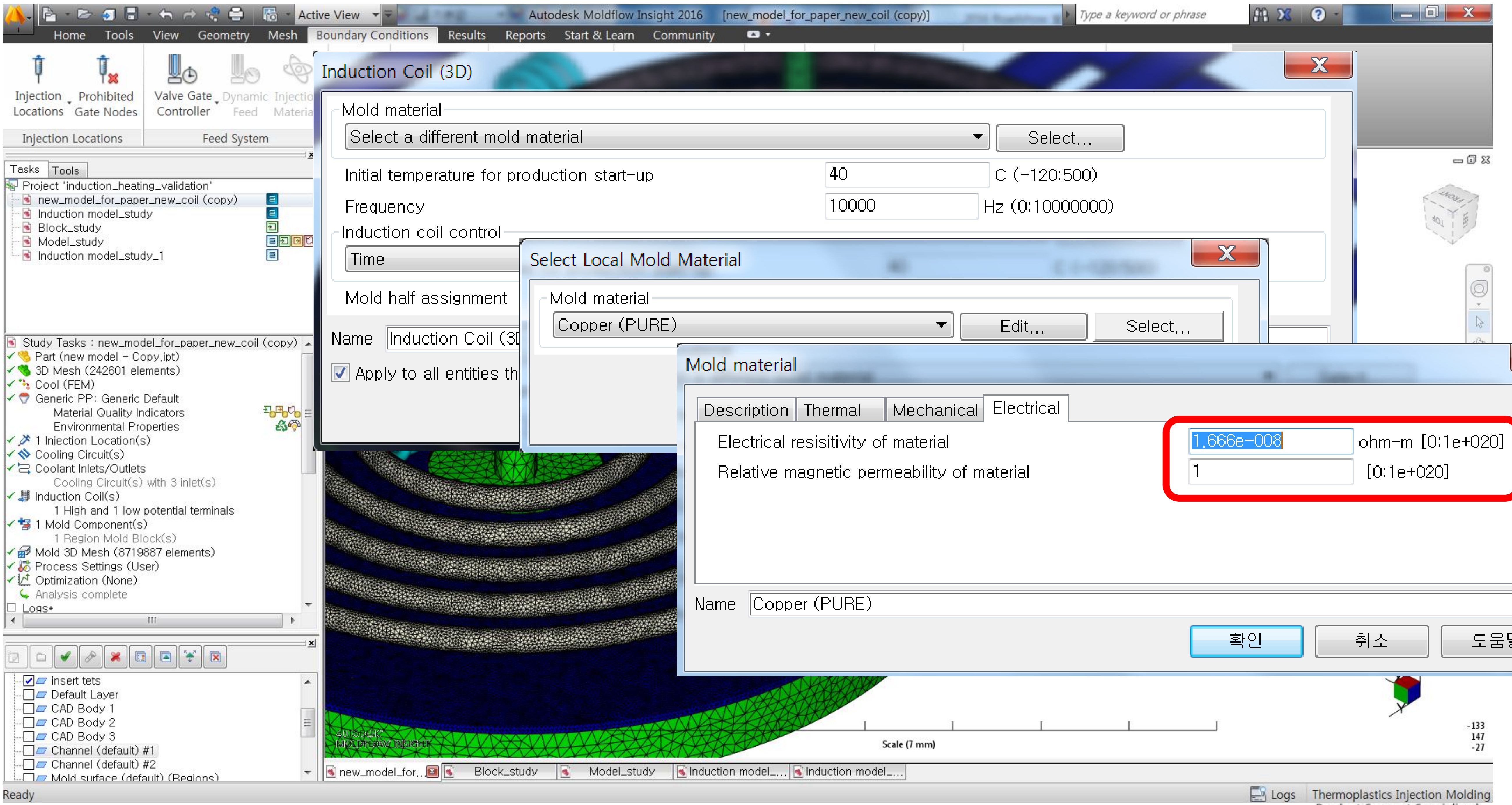
Induction Heating 해석 실습

- Induction Coil high potential terminal에 전류 및 전압 설정



Induction Heating 해석 실습

- Induction Coil 속성 설정(Electrical- 전기저항 및 상대투자율)



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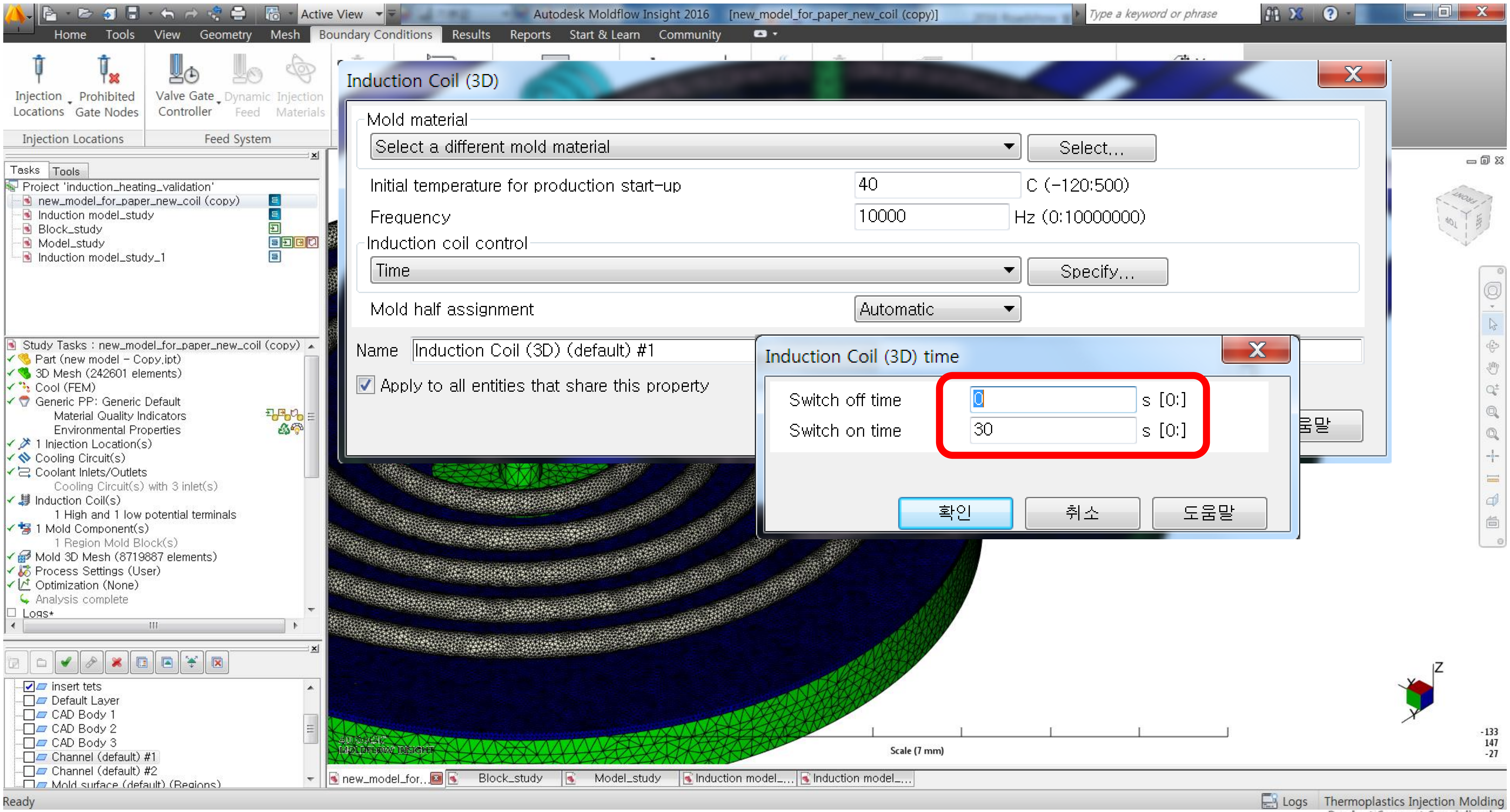
Induction Heating 해석 실습

- Induction Coil 속성 설정 (시간설정)



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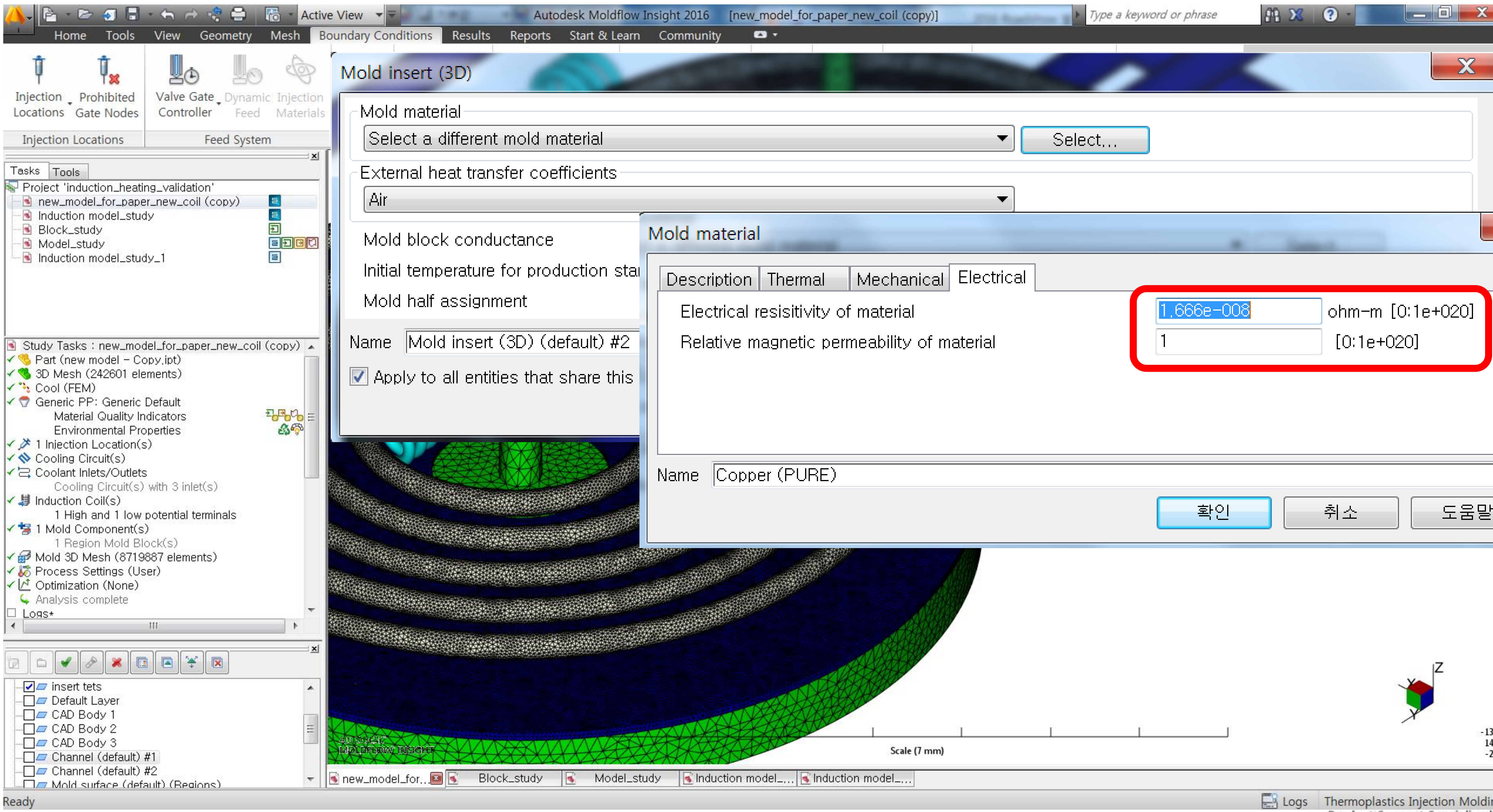
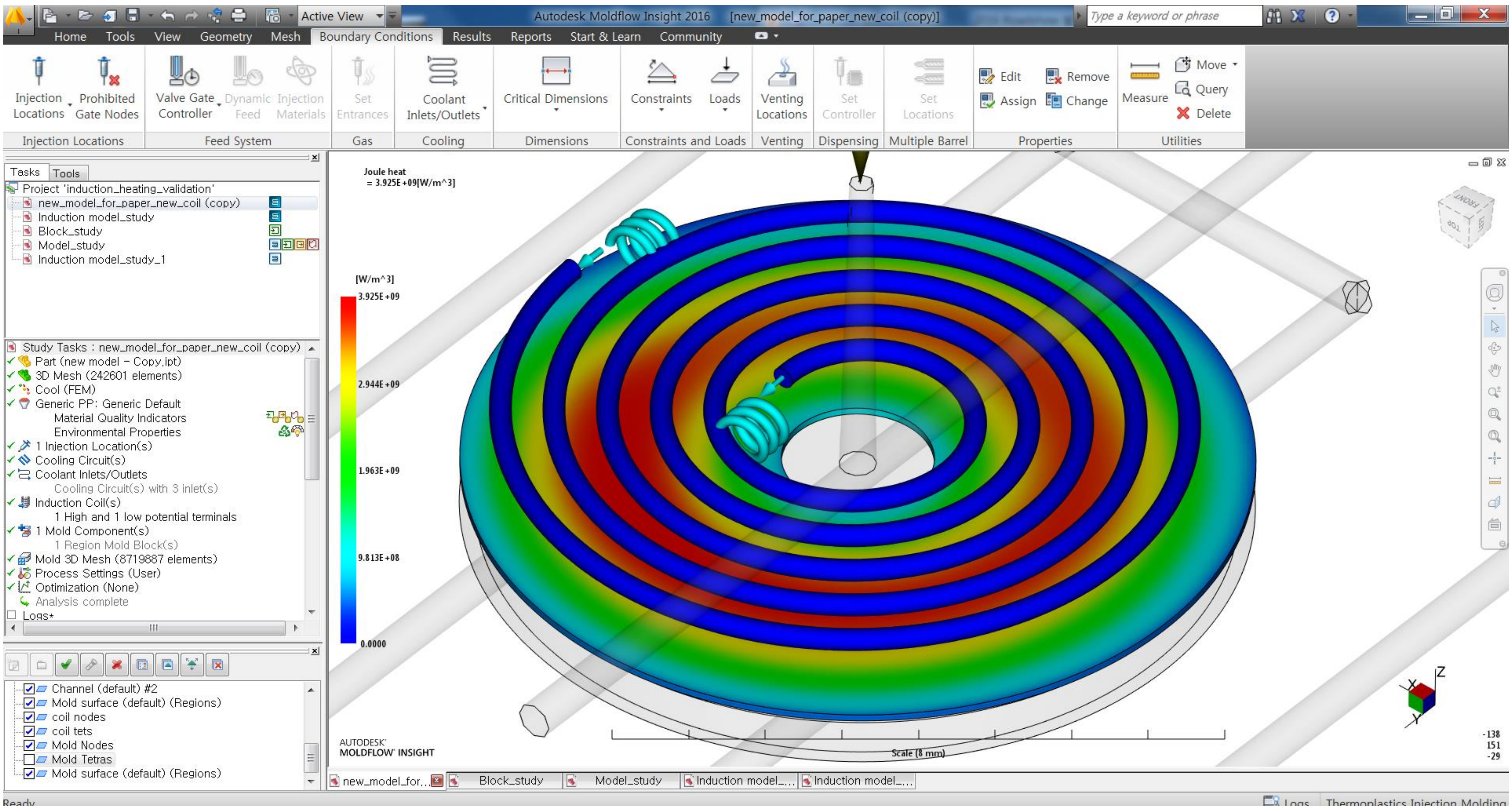
Induction Heating 해석 실습

- Mold Insert 속성 설정(Electrical- 전기저항 및 상대투자율)



Induction Heating 해석 결과

- Joule heating 결과 – 단위 체적당(m^3) 발생하는 전력(W) 1W=1J/s, 1J=1Nm



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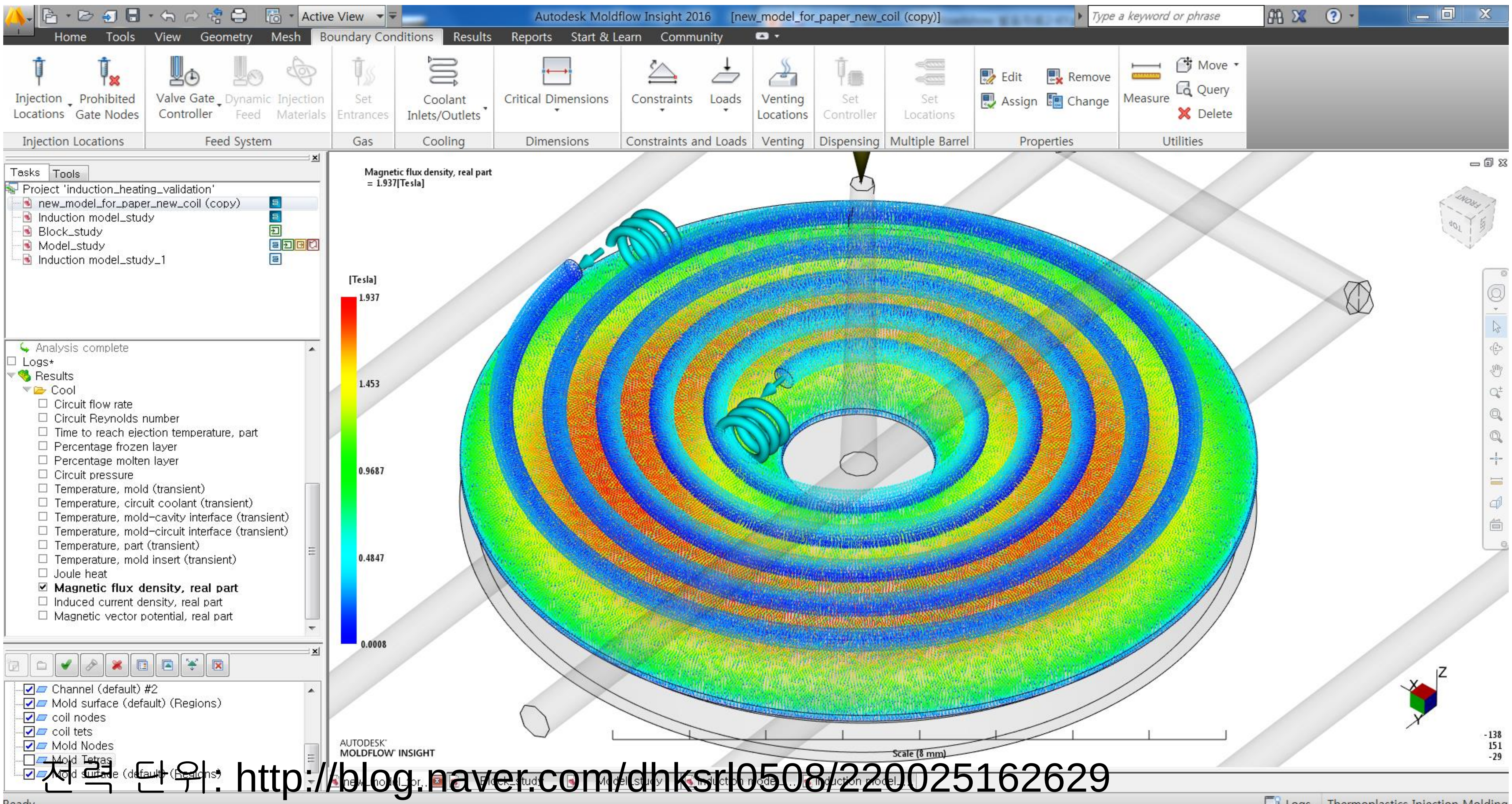
Induction Heating 해석 실습

- Magnetic flux density, real part – 제품에 생성되는 자속 밀도 단위 T



전력 단위: http://blog.naver.com/dhksrl0508/220025162629

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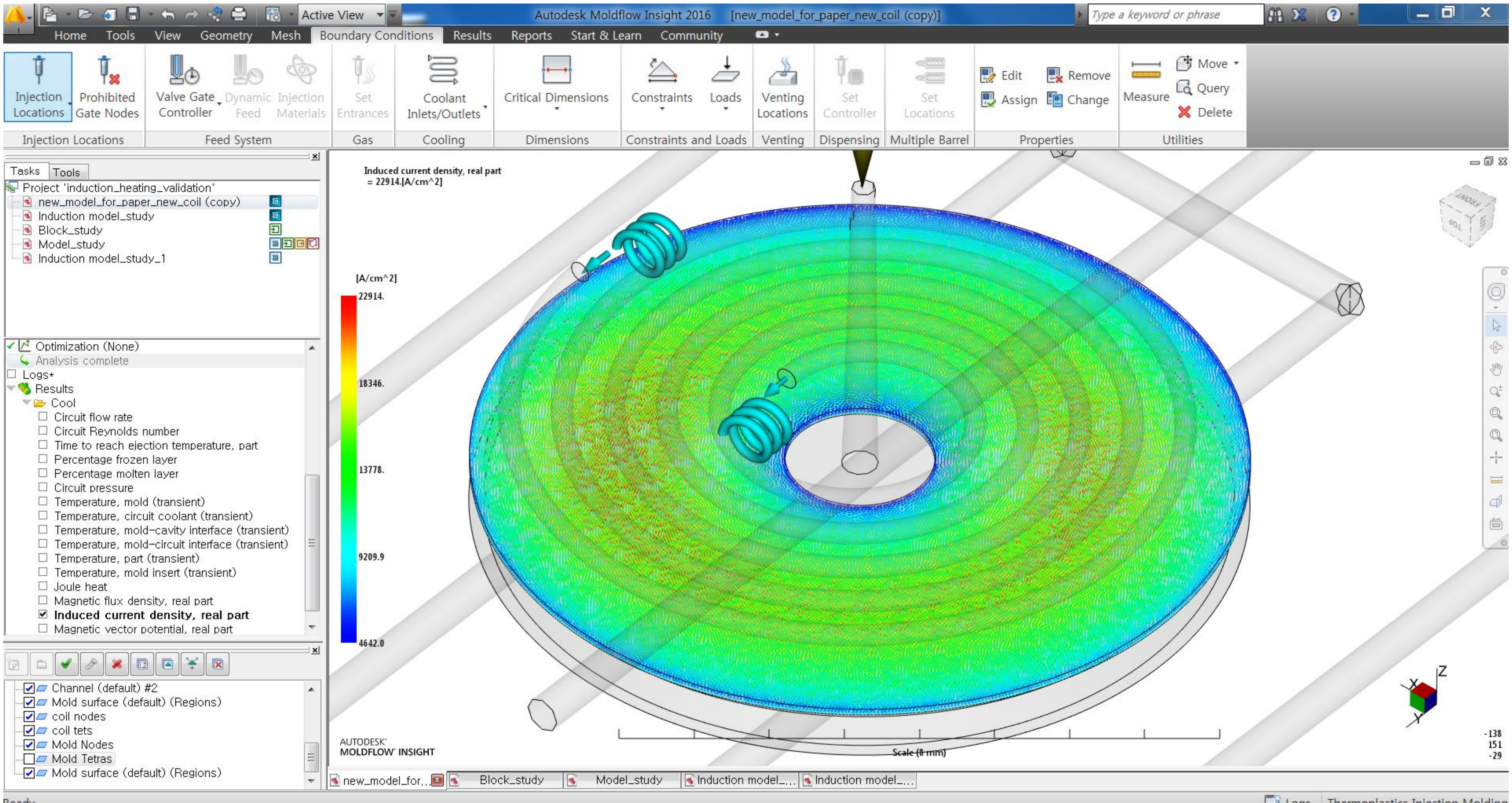
Induction Heating 해석 실습

- Induced current density, real part– 제품에 발생하는 유도전류 밀도 H/m=A/m



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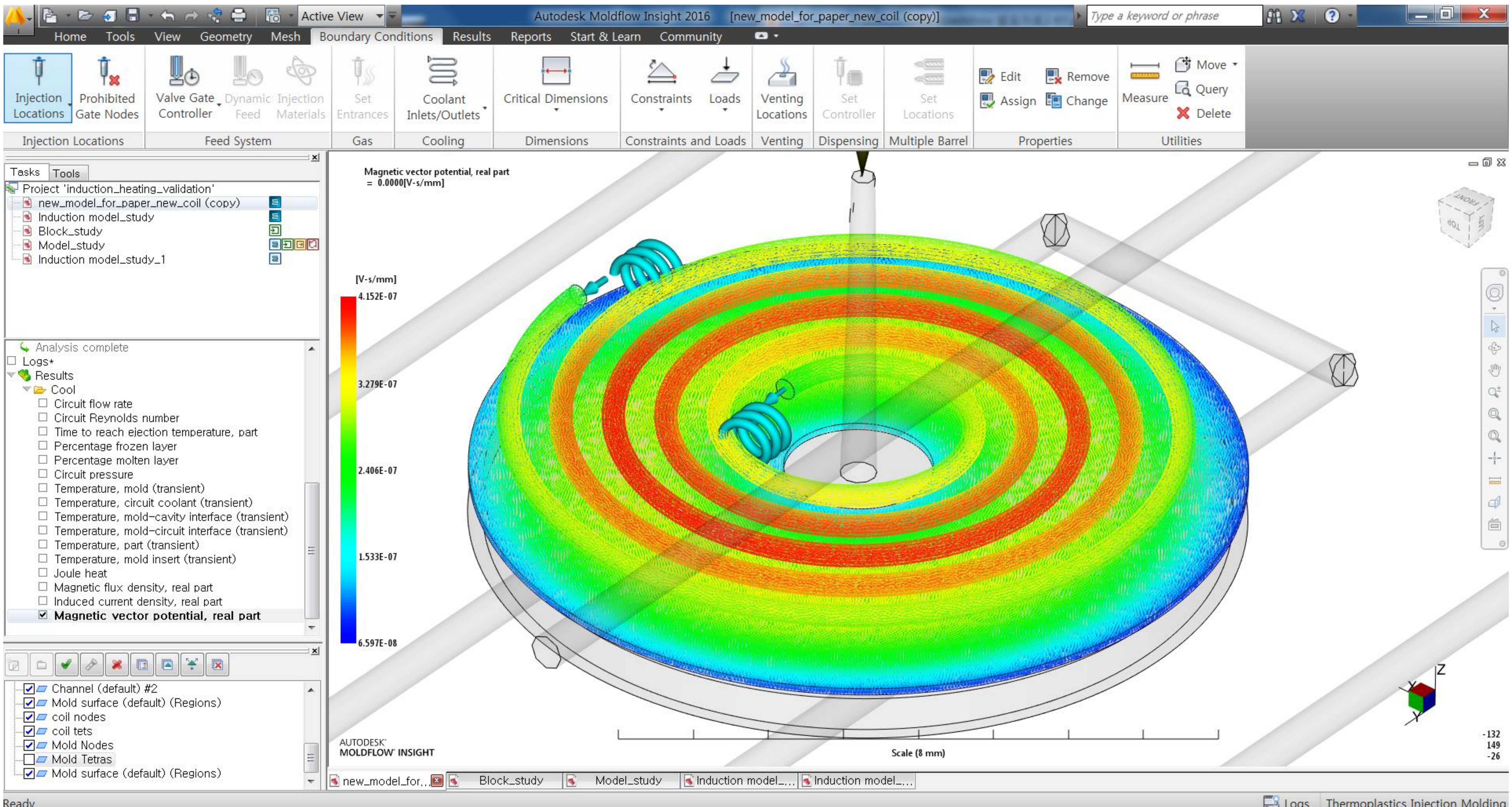
Induction Heating 해석 실습

- Magnetic vector potential, real part – 잠재적인 자기벡터 결과
  - Joule heating 결과를 생성시키기 위한 중간 결과로 자기장의 방향 및 크기를 확인



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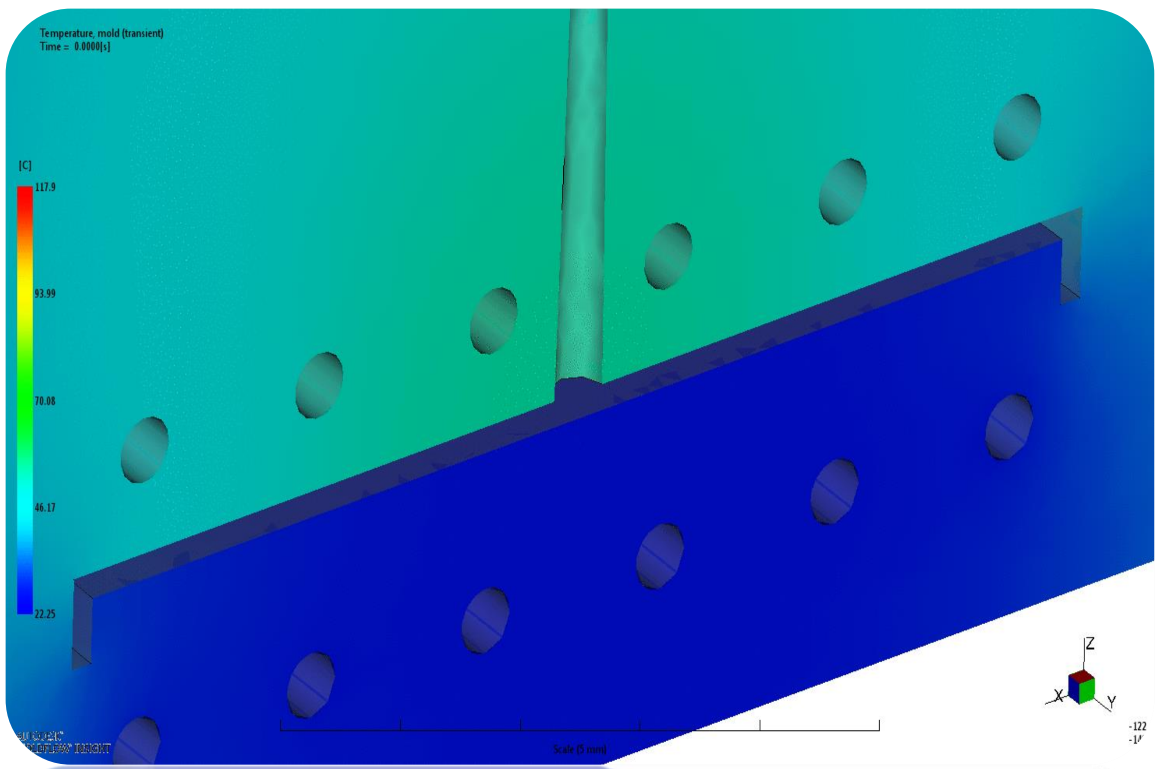
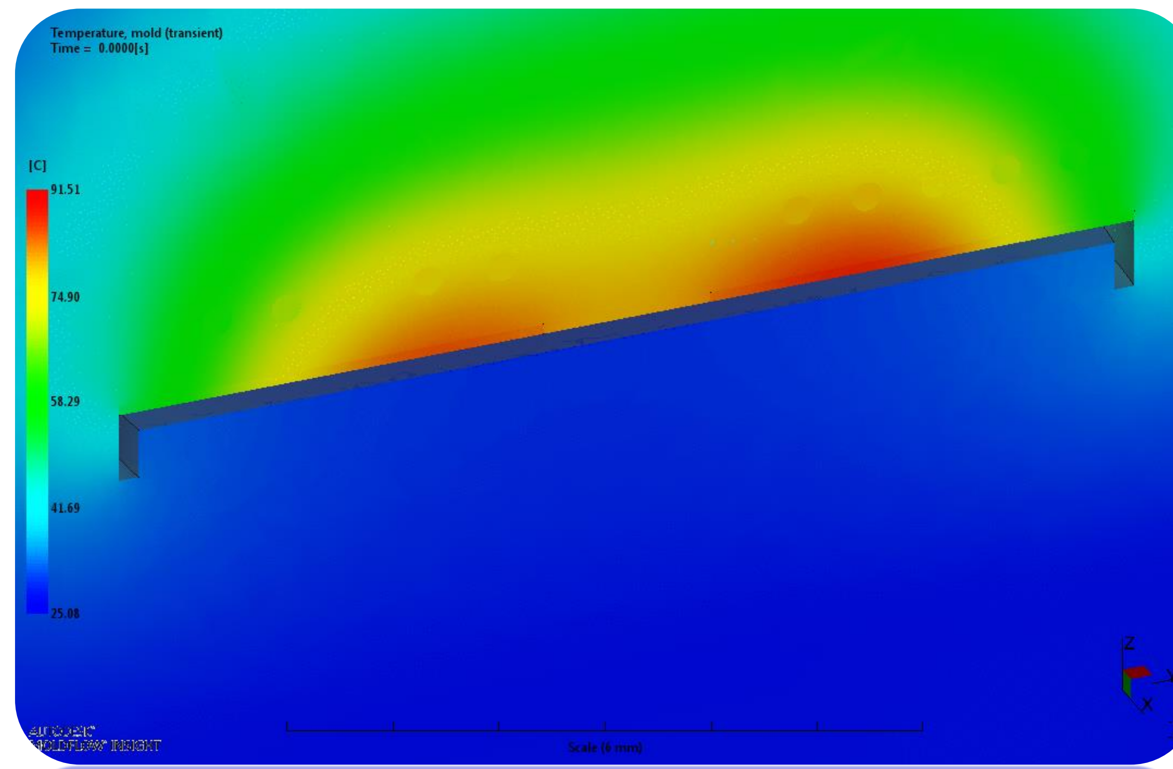
Induction Heating 해석 실습

- Temperature, mold(transient) – 금형온도 결과

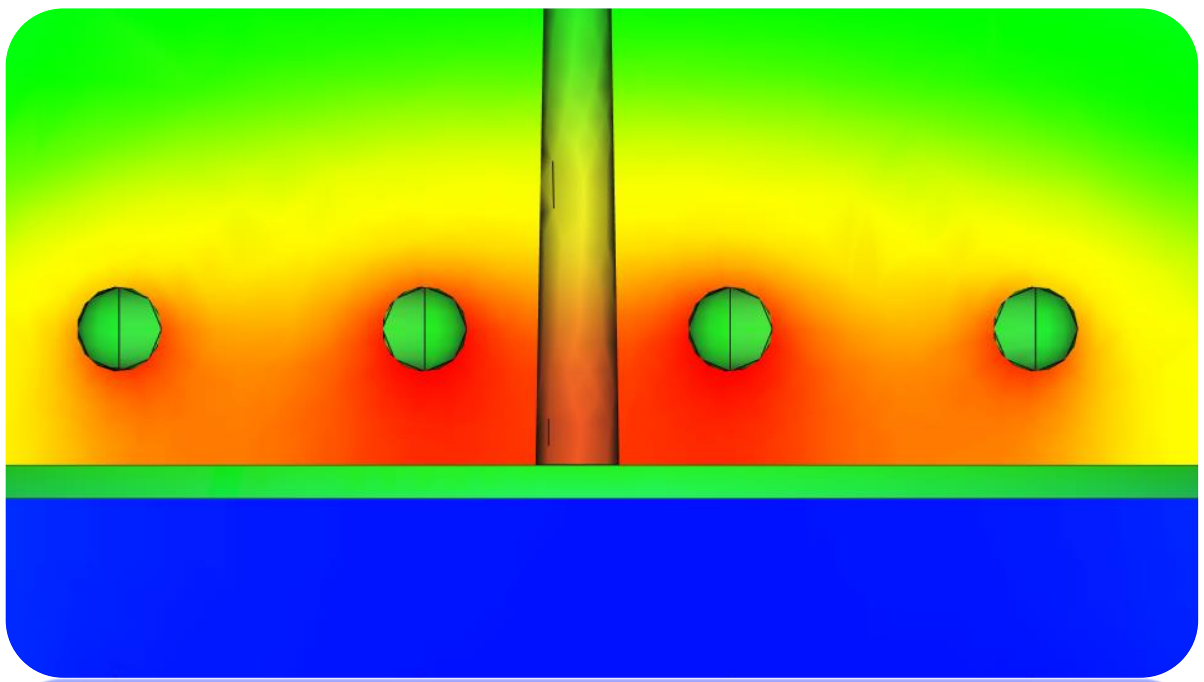
Induction Heating 결과는?



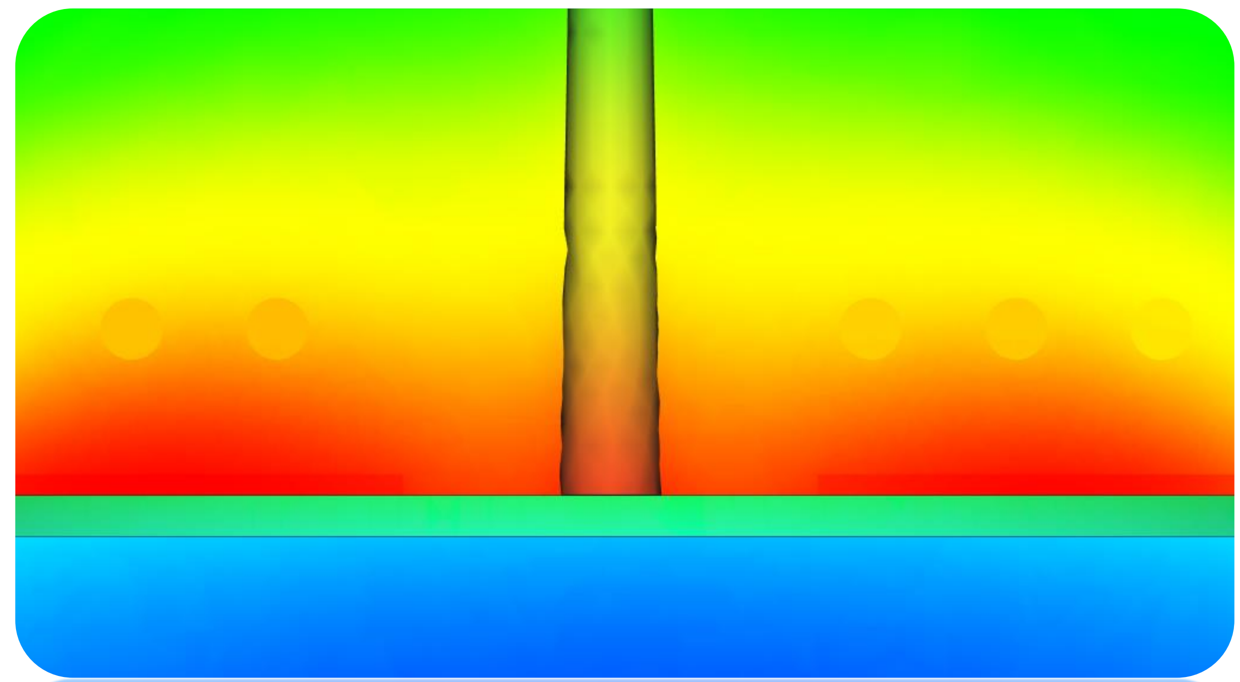


Induction Heating 해석 실습

- 어떤 결과가 Induction Heating 일까요?



Steam 해석



Induction Heating

Conclusions

1. Induction Heating해석을 위해서는...
   재료의 전기저항, 상대투자율, 전류or전압을 정확히 입력해야 함.

2. Mold Insert 의 표면에서 1st Layer의 두께는...
   $$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}}$$
   → **전력 주파수, 재료의 투자율, 재료의 전기 전도율**을 알아야 함.

3. Mold Insert 의 표면 매시 사이즈는...
   $mesh\ size = \frac{\delta}{0.8}$ 로 정해야 한다.

4. Induction Heating의 장점으로...
   복잡한 형상도 균일한 가열이 가능하다.
   급속 가열이 가능하다.
   열전도에 대한 손실이 우수하다.

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