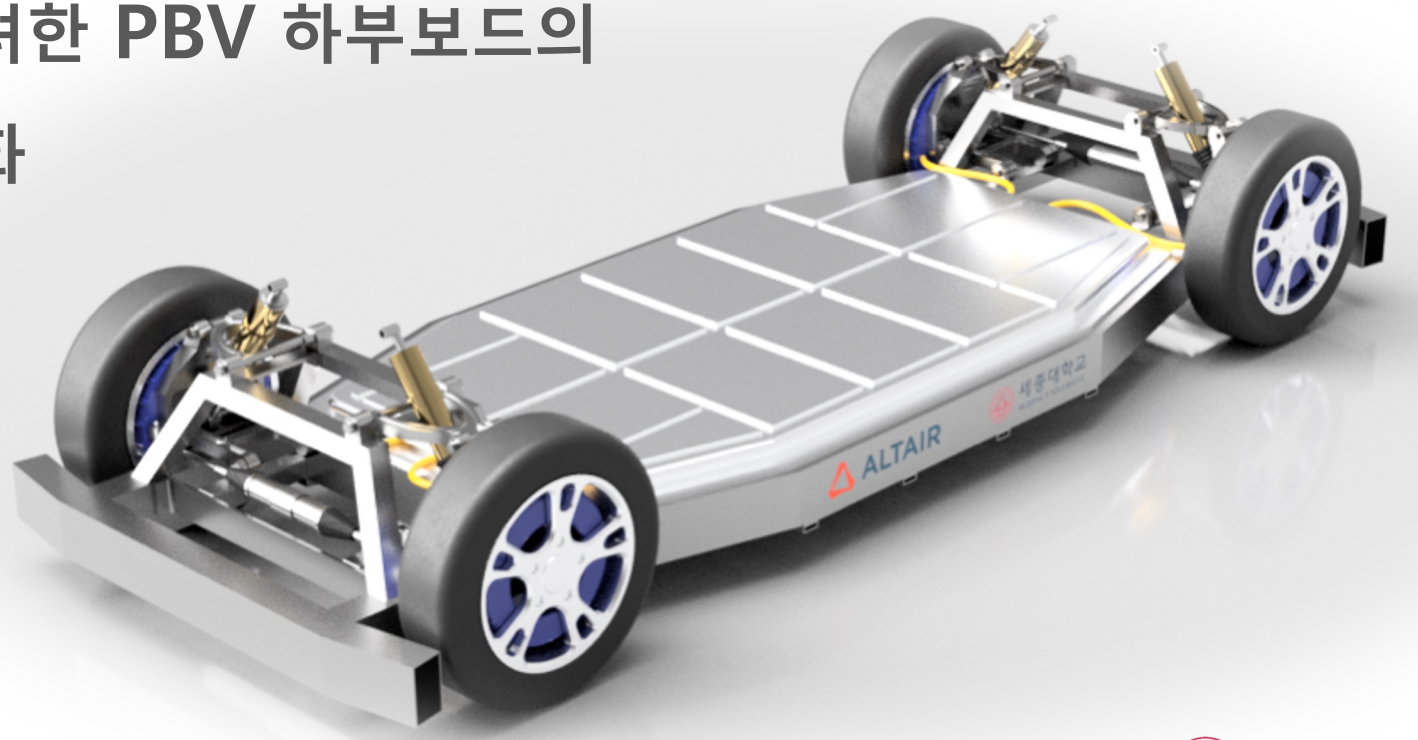
ALTAIR

AOC 2022

Altair Optimization Contest

생산성 및 안전성을 고려한 PBV 하부보드의 모듈화 및 프레임 최적화



팀 명 : Matrix

학 교 : 세종대학교

학 과 : 기계공학과

성 명 : 박희찬, 장민기

지도 교수 : 장강원 교수

세종대학교
SEJONG UNIVERSITY

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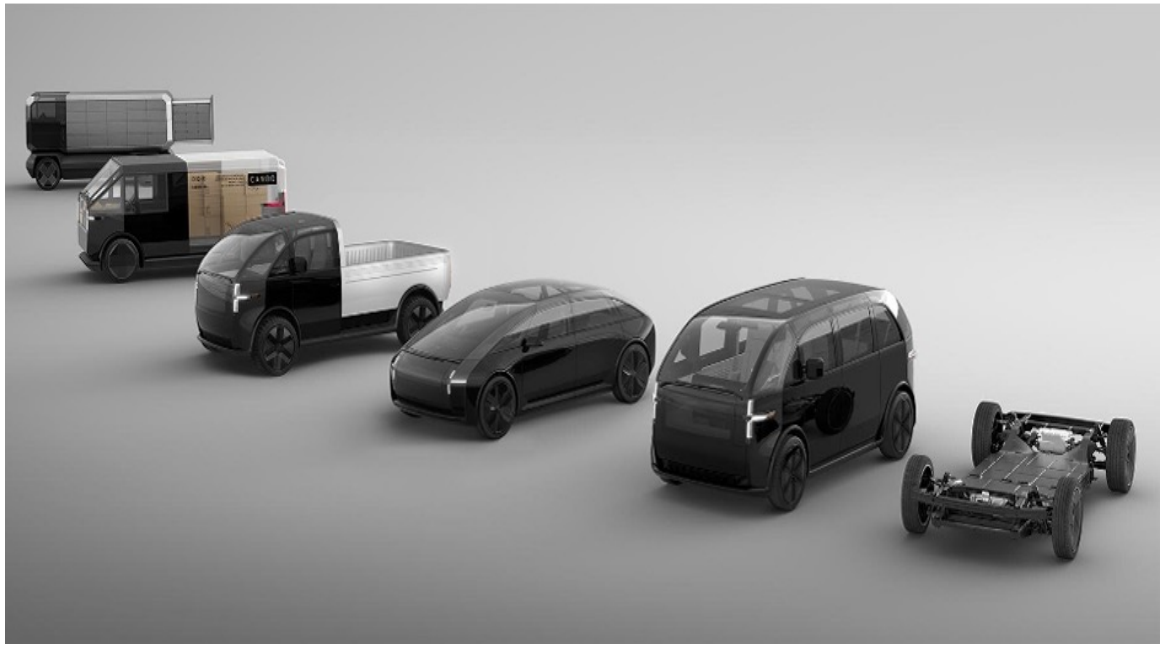
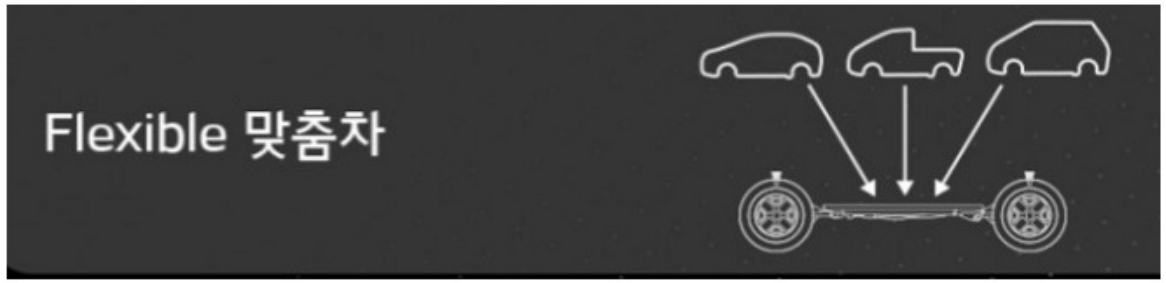
1. 서론

1.1 PBV란?
1.2 연구 배경
1.3 Our idea
1.4 Process

PBV란?





PBV (Purpose Built Vehicle)

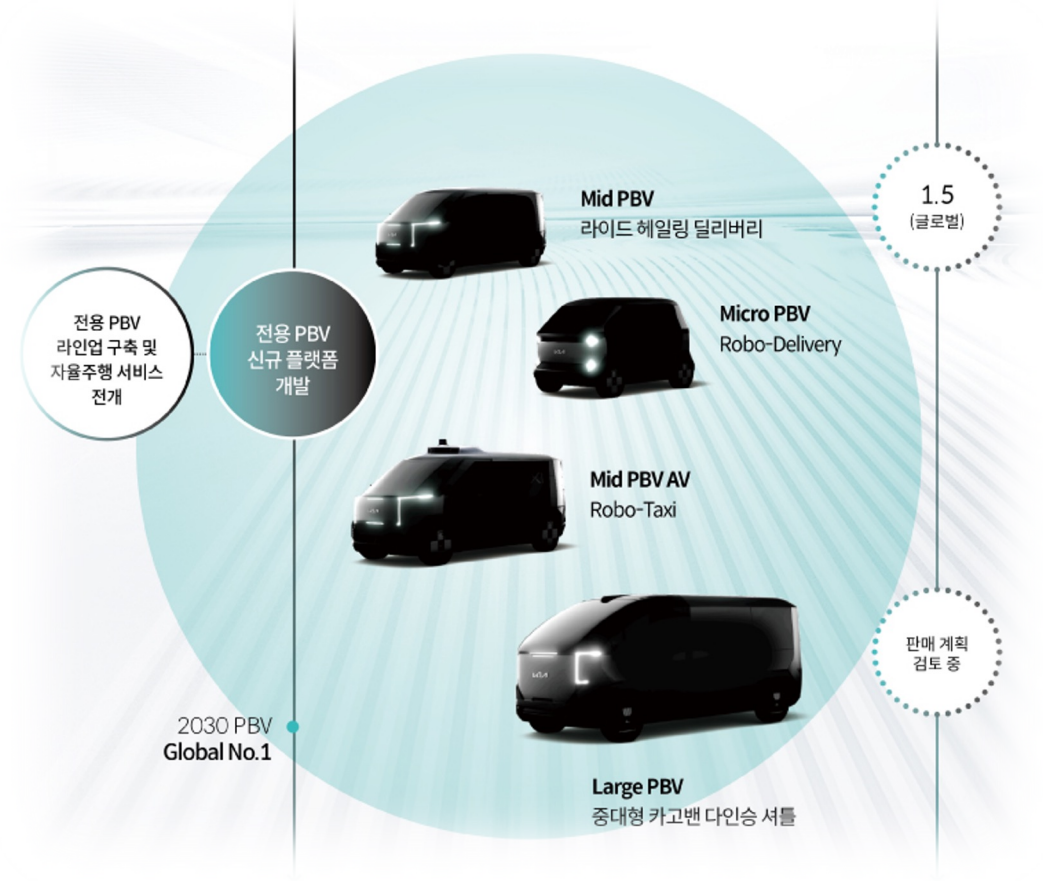
자율주행과 전기자동차를 토대로 고객의 **목적**과 요구에 맞춰 **낮은 비용**으로 제공 가능한 다목적 모빌리티 차량

KEY WORD

- 다목적성
- 단순한 구조(모듈화)
- 낮은 비용
- 확장성(scalability)

PBV 연구 배경

- PBV 연구 전략 및 방향



- 현대 모터 그룹 미래 전략 '플랜S' 2022-04-01 기사

확장성과 생산성을 높여주는 **모듈화** 연구

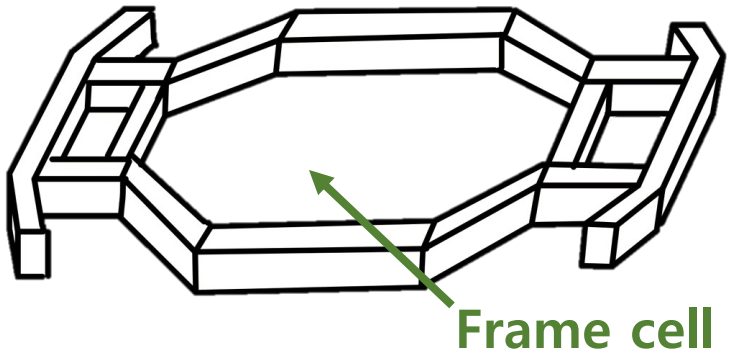
- 경향신문 - '자동차도 레고처럼 조립'... 제조방식 대변혁 예고 (폭스바겐 자동차 제조 전략)

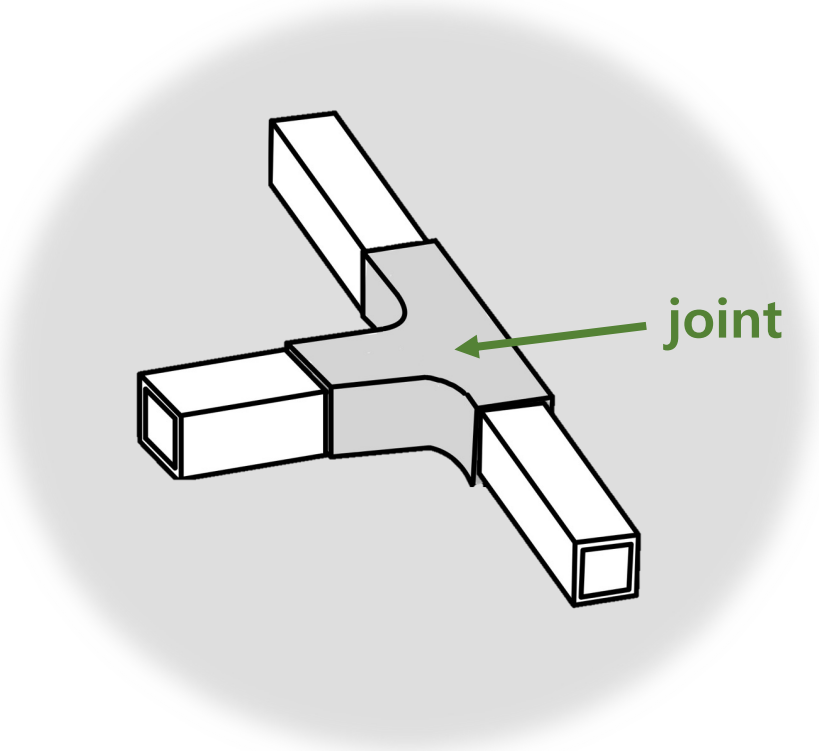
Our Idea

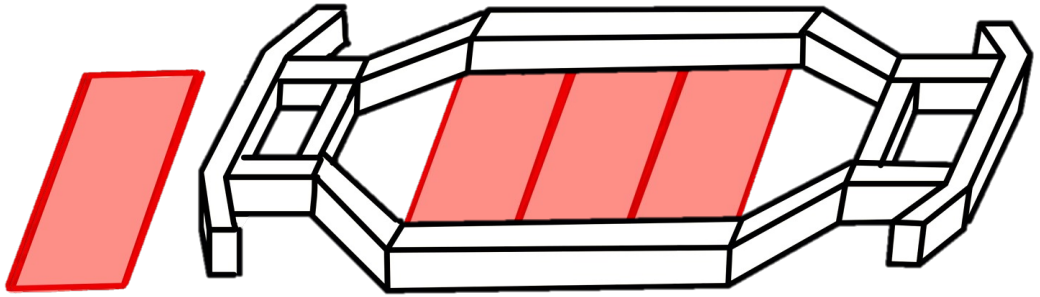
PBV의 다품종 소량생산 방법론 제시

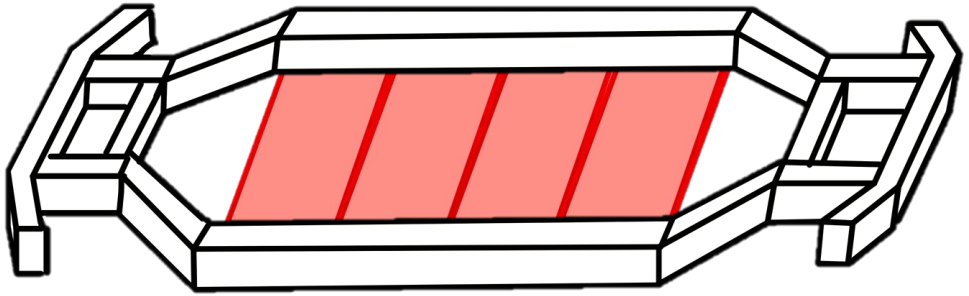
1. **Frame cell 과 Frame**의 **공유**를 고려한 **최적설계**

2. **제작성**과 **생산성**을 높여주며 **공유** 가능한 **조인트** 설계









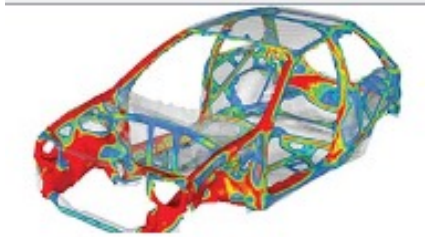
*Frame cell: 반복되는 프레임의 단위

Process

HyperMesh
Latest Version: 2022.1

Setup

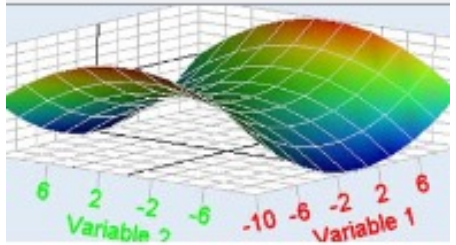
OptiStruct
Latest Version: 2022.1



Topology optimization
(by pattern repetition)

공통적인 Frame cell의 형상 도출

HyperStudy
Latest Version: 2022.1



Parametric & Shape optimization

공통적인 frame 의 두께와 shape 도출

Inspire Cast
Latest Version: 2022.1

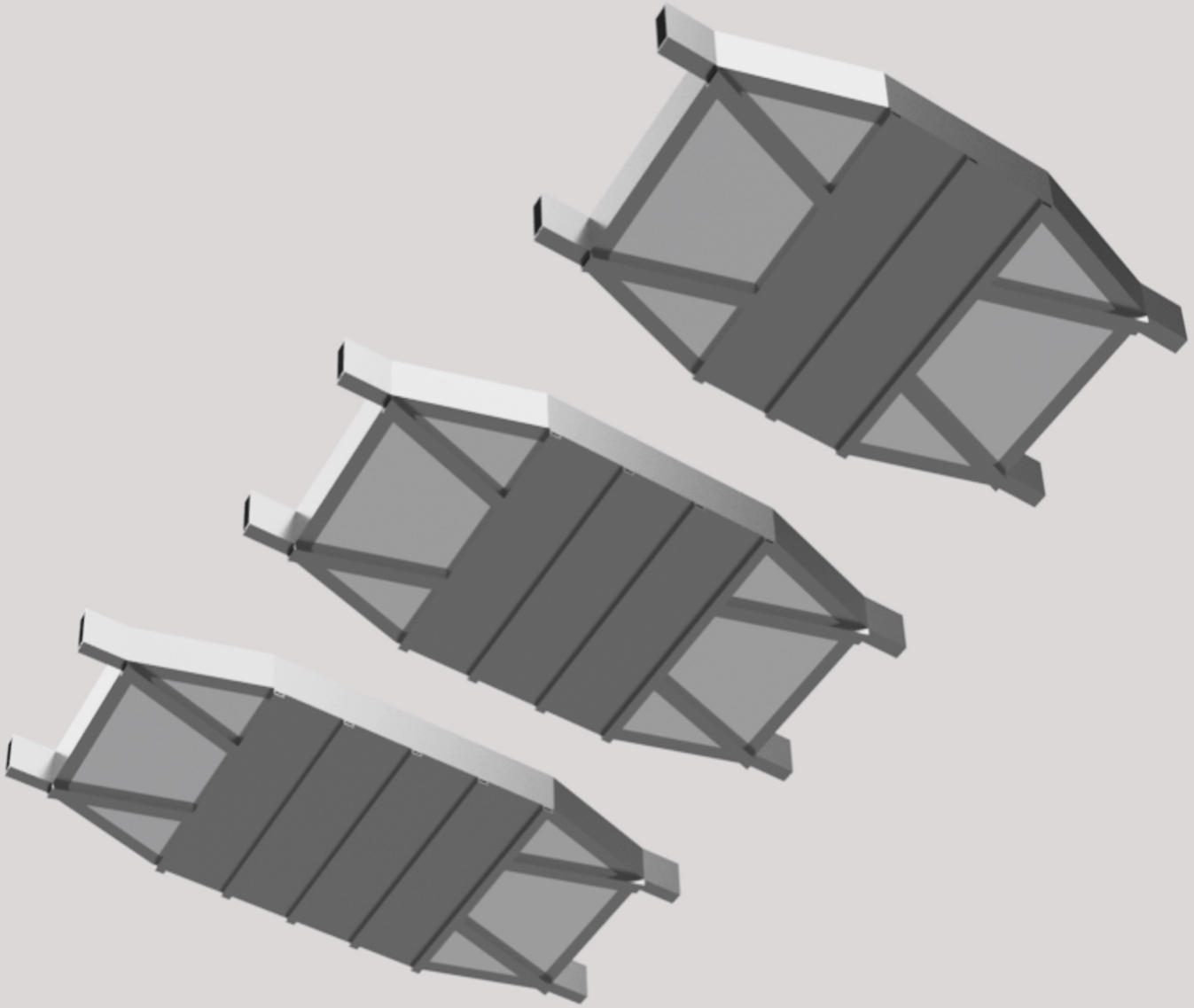
Manufacturing simulation

조인트 설계 및 **주조해석**

2. 모델링

2.1 참고 모델 선정

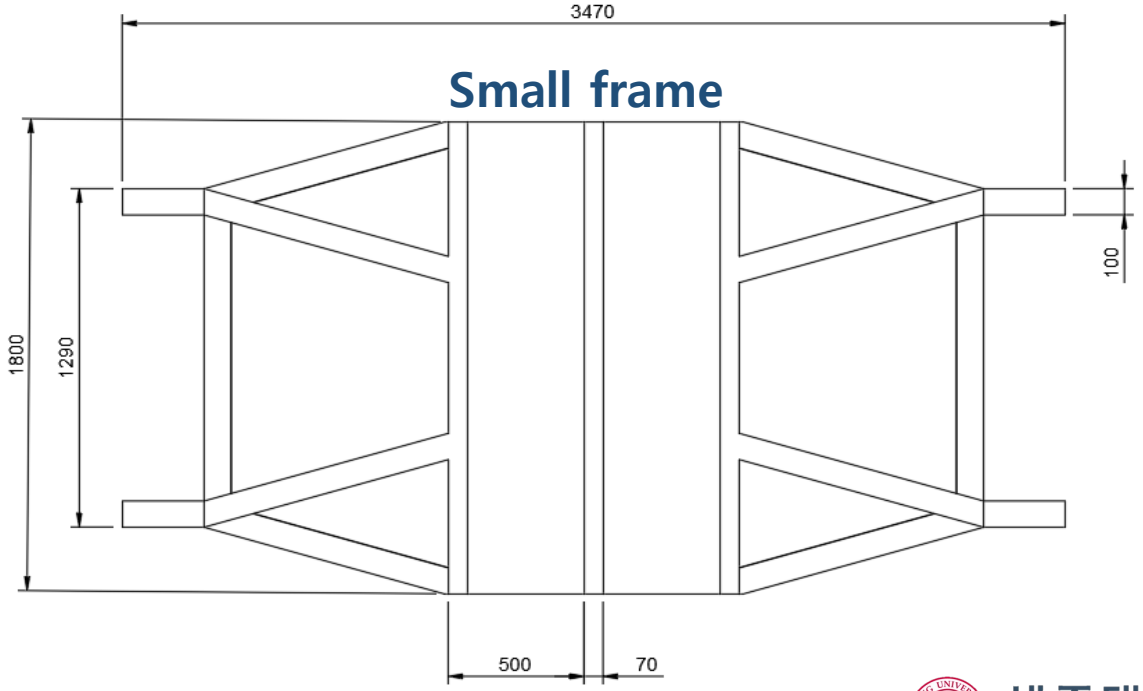
2.2 모델링



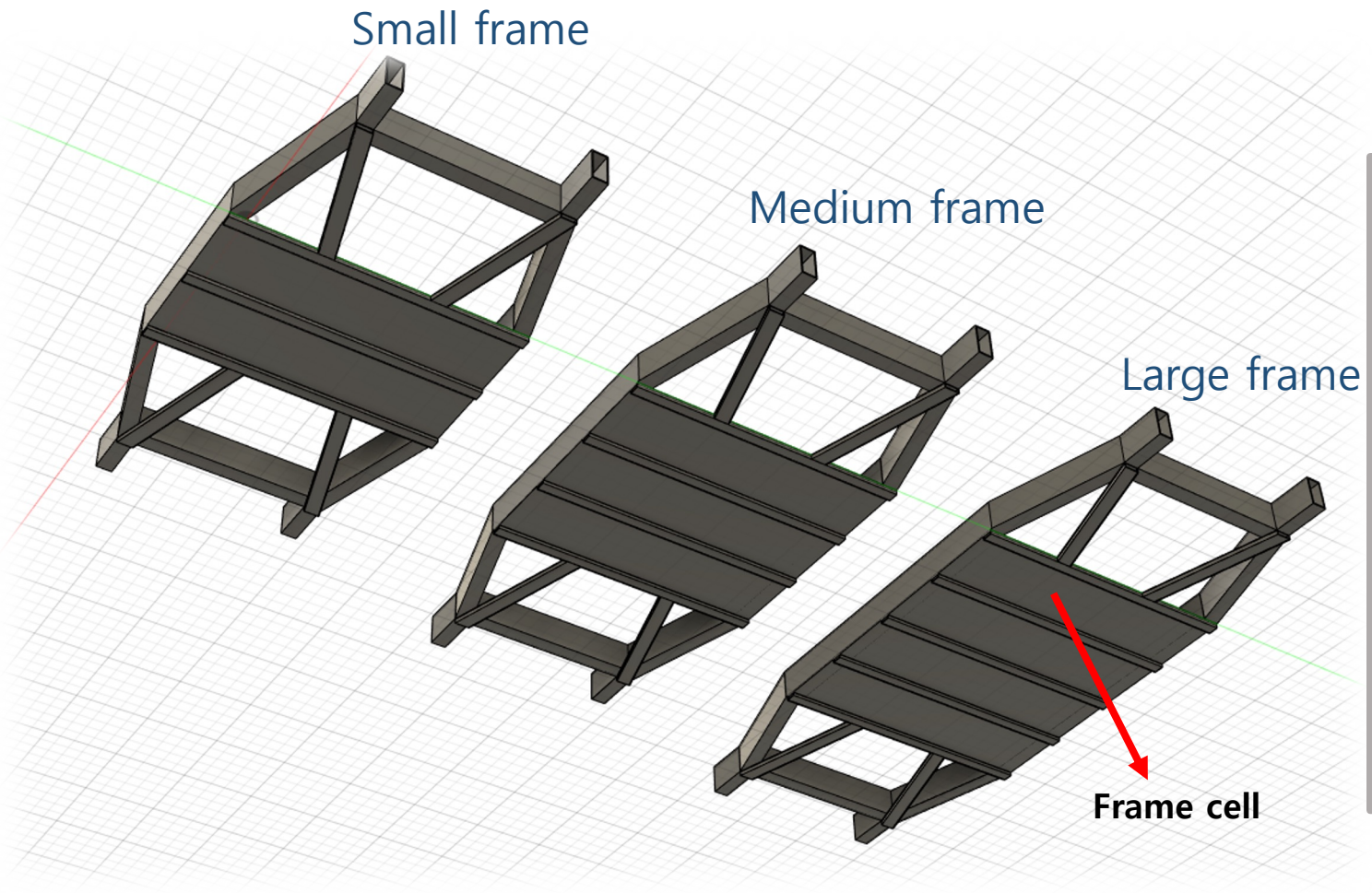
모델링

	아반떼	펠리세이드	스타리아
전장 (mm)	4,650	4,995	5,225
전폭 (mm)	1,825	1,975	1,995
축간 거리(mm)	2,720	2,900	3,275

<참고모델 - 카누 사의 스케이트 플랫폼>



모델링



Frame cell의 **폭을 500mm로 설계**하여 scalable 한 frame 모델링

small frame(2 cells)의 길이 = 3.47m

medium frame(3 cells)의 길이 = 3.97m

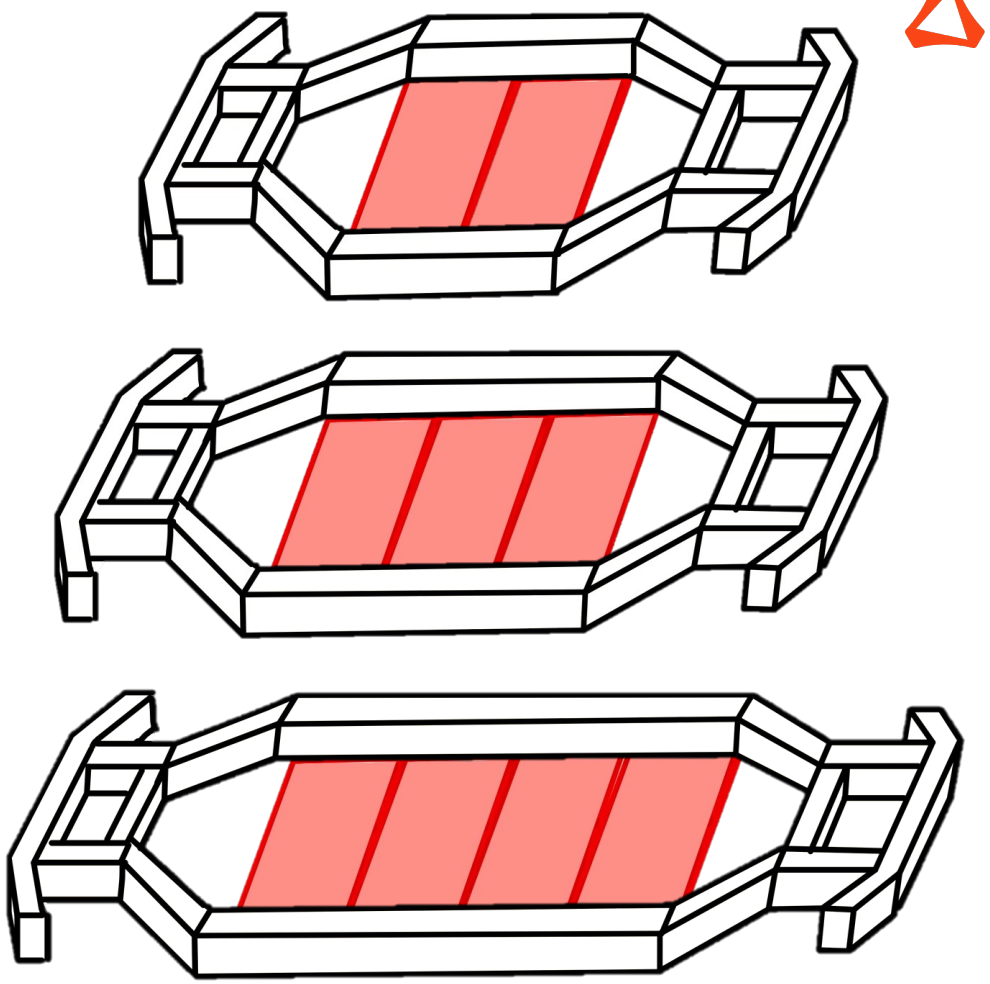
large frame (4 cells) 의 길이 = 4.47m

3. Topology optimization

3.1 하중 및 구속 조건

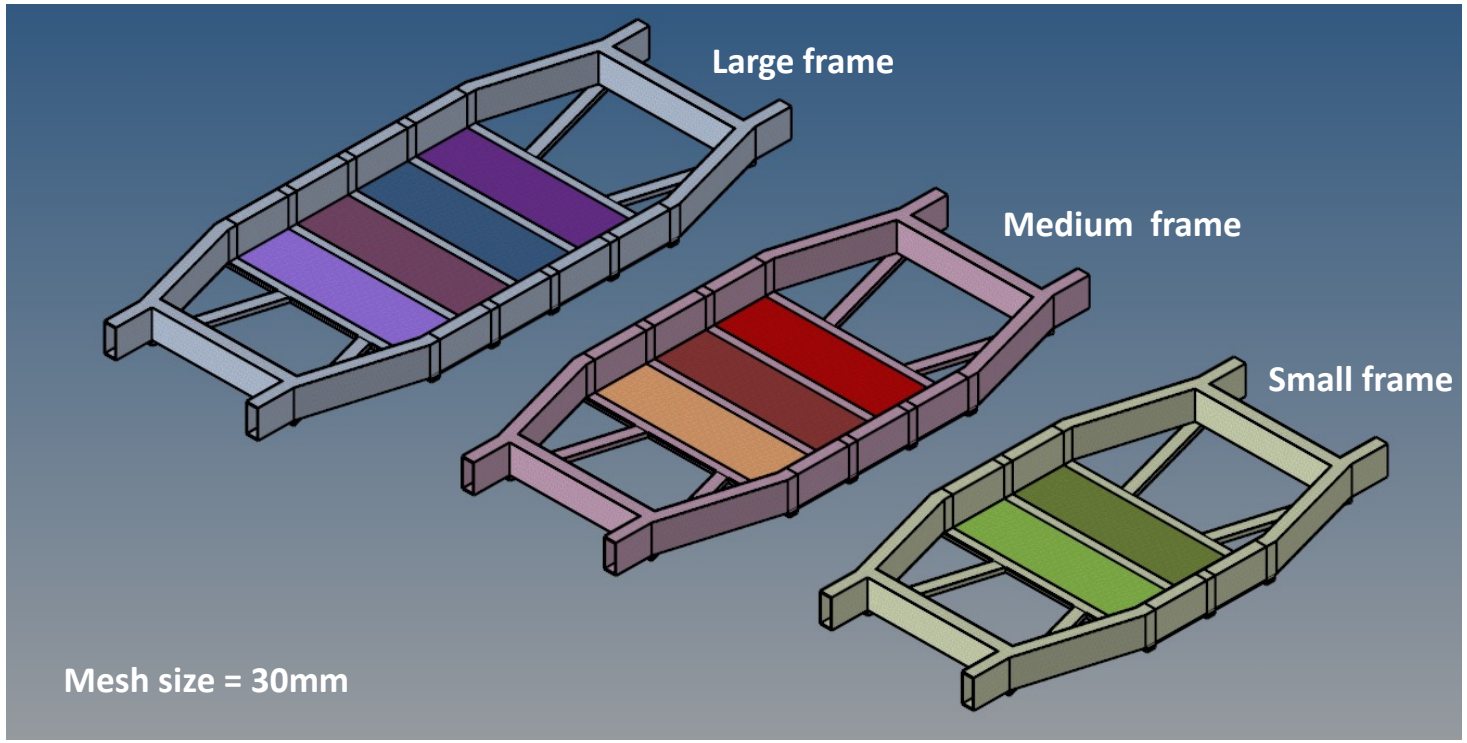
3.2 위상 최적화 조건 설정

3.3 위상 최적화 결과



Issue : Small, Medium, Large 3개의 frame의 성능을 모두 고려한 frame cells의 topology optimization

하중 및 구속 조건



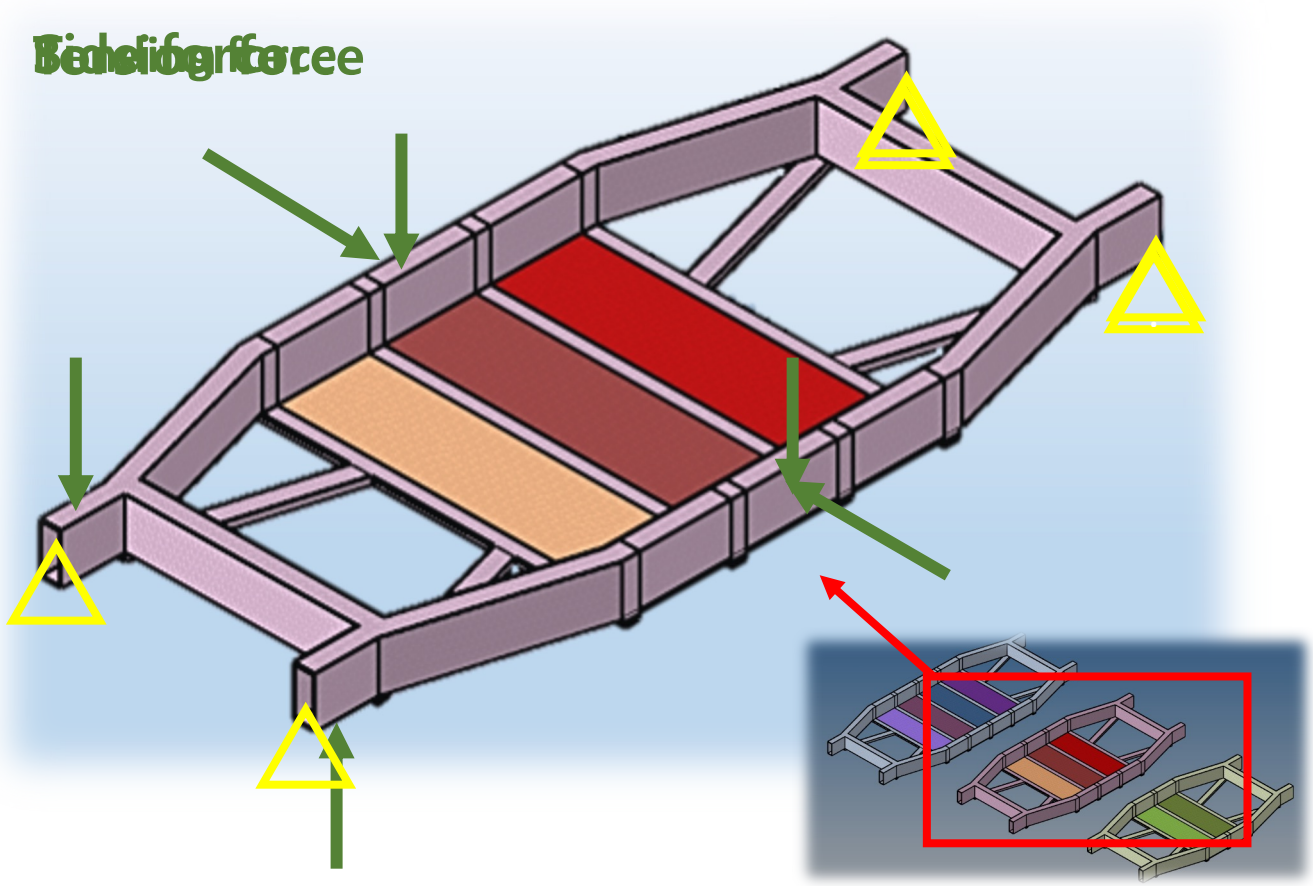
다양한 상황에 대응하기 위하여 **차종의 무게**에 해당하는 **torsion, bending, side force**를 부여한다.

	Steel
Young's modulus(N/mm^2)	210,000
Poisson's ratio	0.3
Mass density(ton/mm^2)	7.85e-09

Frame cells의 Topology optimization 형상을 일치(Pattern repetition)

시키기 위해 **3개의 frame**을 **한 작업공간**에 Import

하중 및 구속 조건



<Medium frame의 경우>

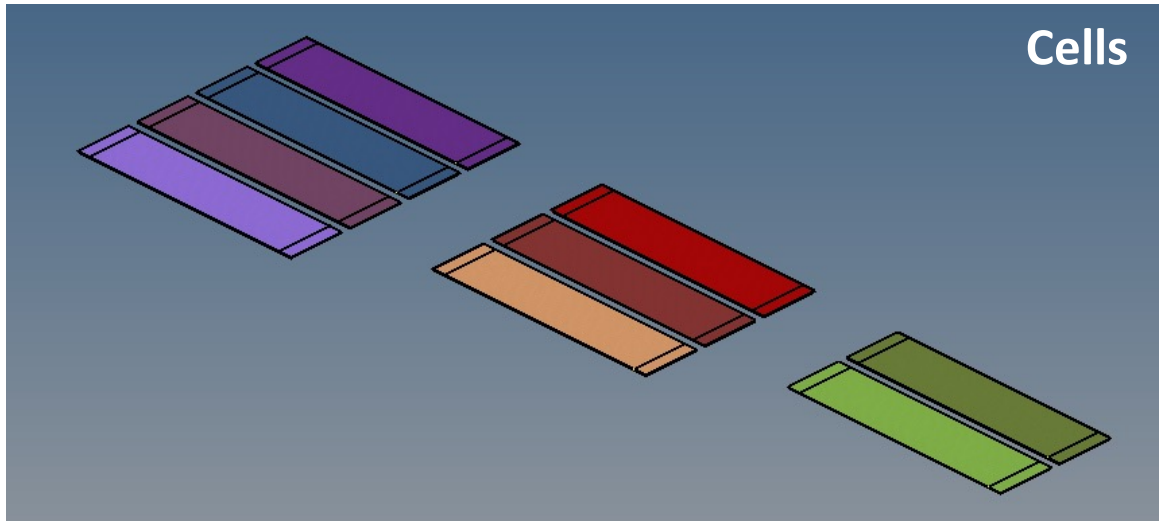
Torsion, Bending, Side force

(차량 무게의 하중을 부여)

	Torsion , Bending force
Small frame	11,770 N (total)
Medium frame	18,640 N (total)
Large frame	23,540 N (total)

	Side force L, R
Small frame	11,770 N (total)
Medium frame	18,640 N (total)
Large frame	23,540 N (total)

위상 최적화 조건 설정



Design variables : **각각의 cells**

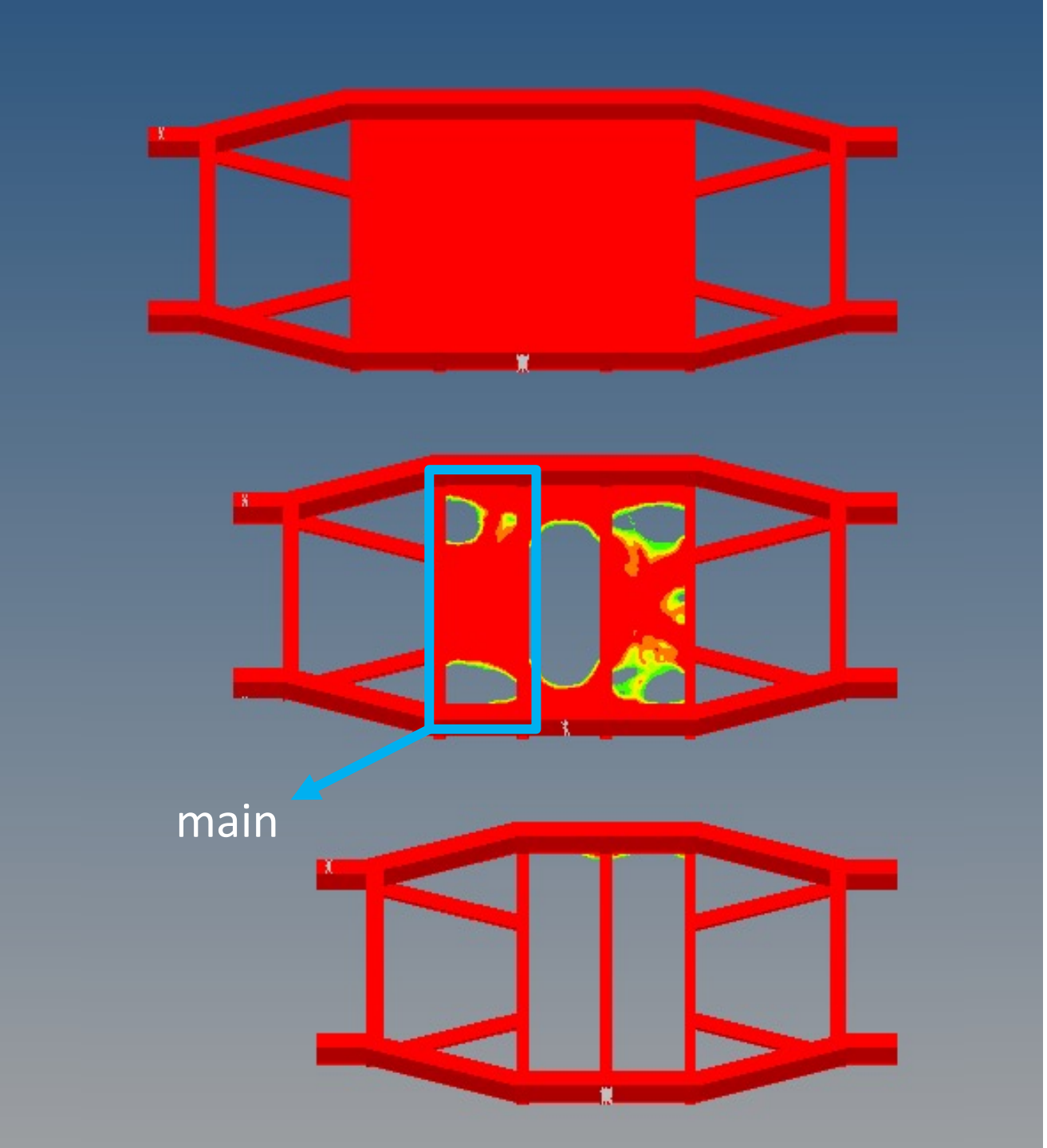
Responses : volume_frac, weighted_compliance

Constraints : volume_frac upper bound = 0.7

Objective : minimize weighted _compliance

Weighted_ compliace		
Frame name	Loadstep	Weight
Small frame	Torsion force	1
	Bending force	1
	Side force_L	0.5
	Side force_R	0.5
Medium frame	Torsion force	1
	Bending force	1
	Side force_L	0.5
	Side force_R	0.5
Large frame	Torsion force	1
	Bending force	1
	Side force_L	0.5
	Side force_R	0.5

* side force에 대한 weight를 0.5씩 부여

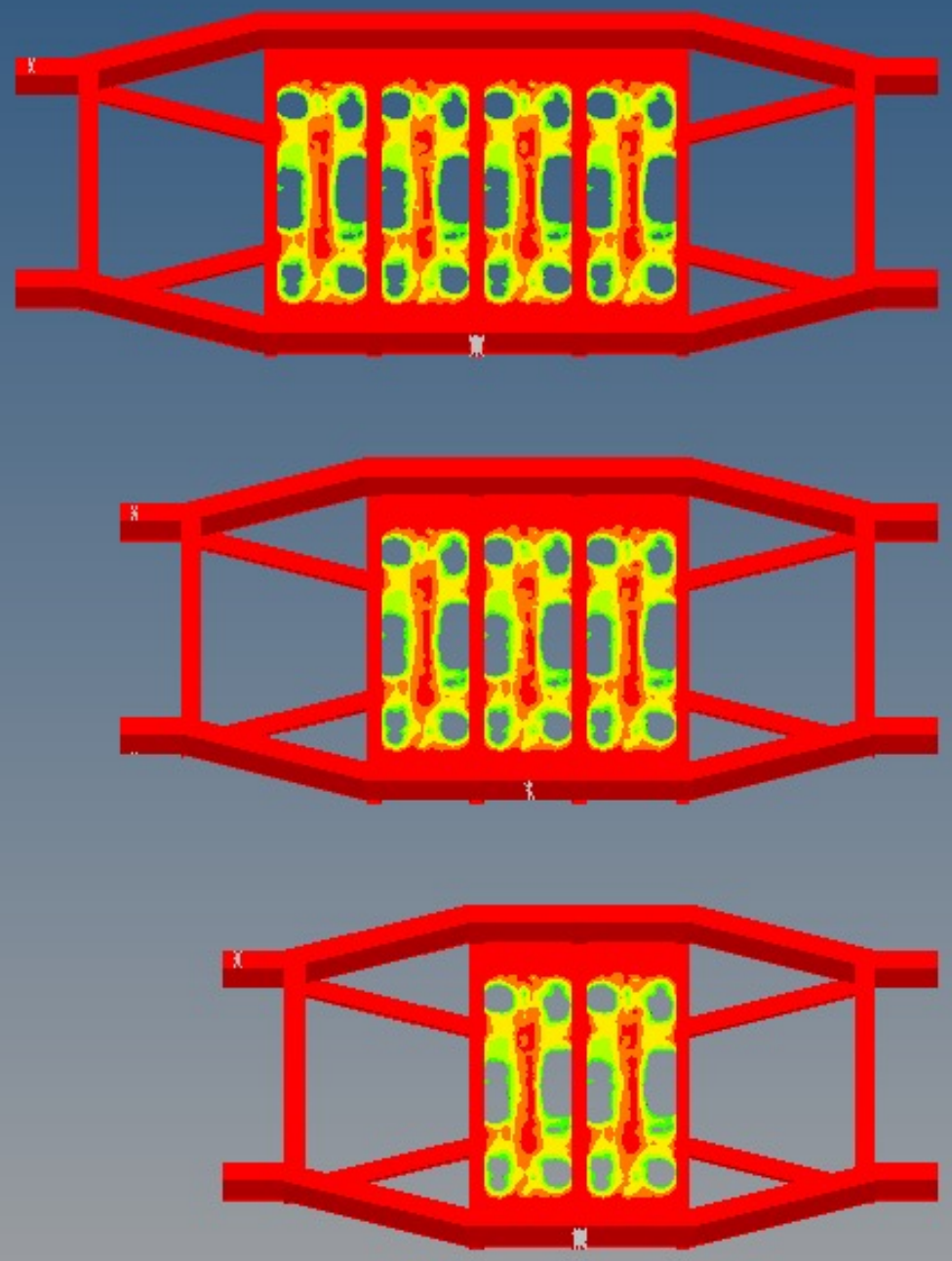


위상 최적화 결과

Before Pattern Repetition

Cell의 공통적인 형상이 나타나지 않아 **생산성이 고려되지 않은 결과**가 나타남

Main과 second를 지정하여 pattern repetition 조건을 설정



위상 최적화 최종 결과

After Pattern Repetition

각각의 Frame의 성능을 동시에 고려한 **공통적인 Cell의 최적화 형상**을 얻게 되었다.

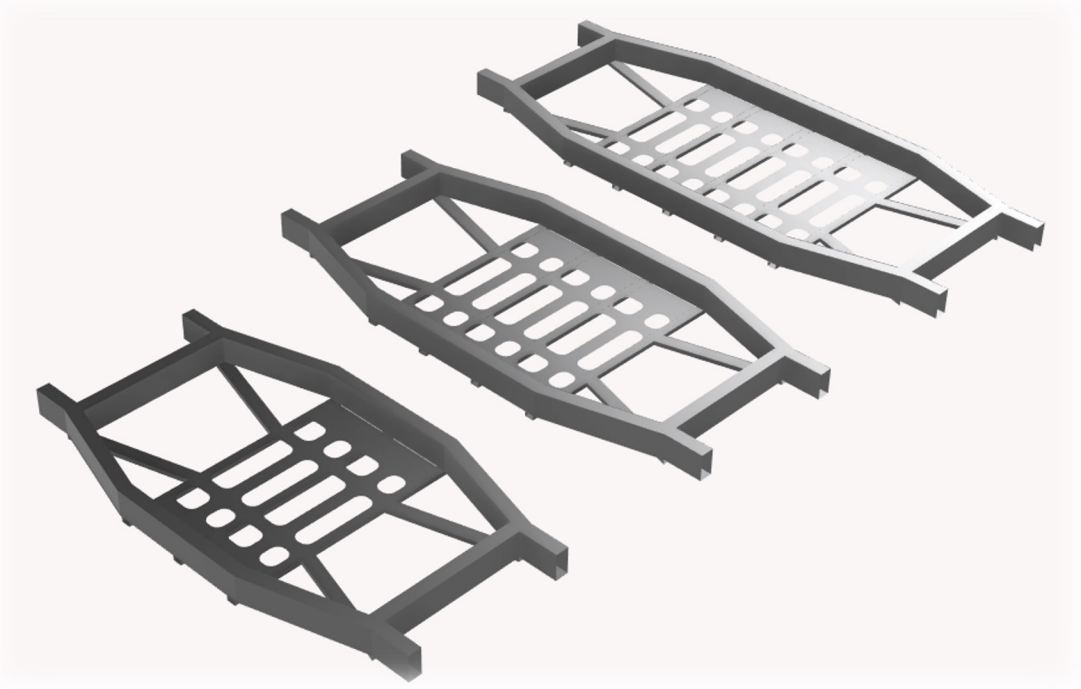
결과적으로, **cell의 개수에 따라 확장가능한** PBV 하부 frame을 제작할 수 있게 되었다.

4. Parametric & shape optimization

4.1 Shell 모델링 및 하중조건

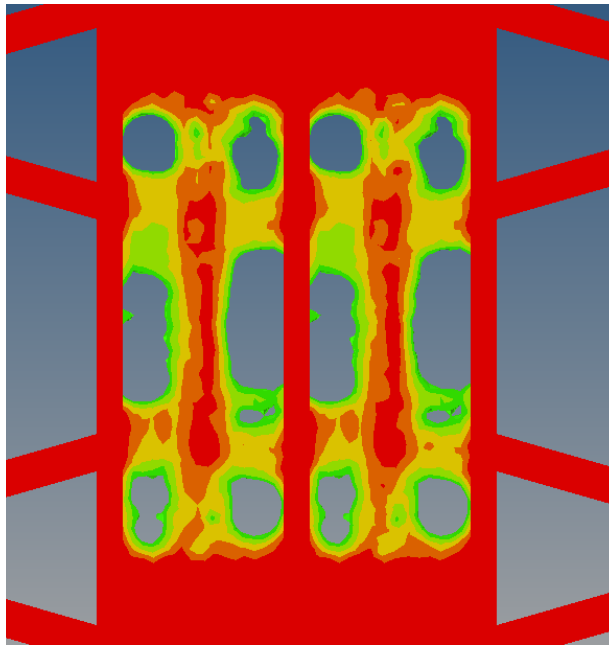
4.2 최적화 조건 설정

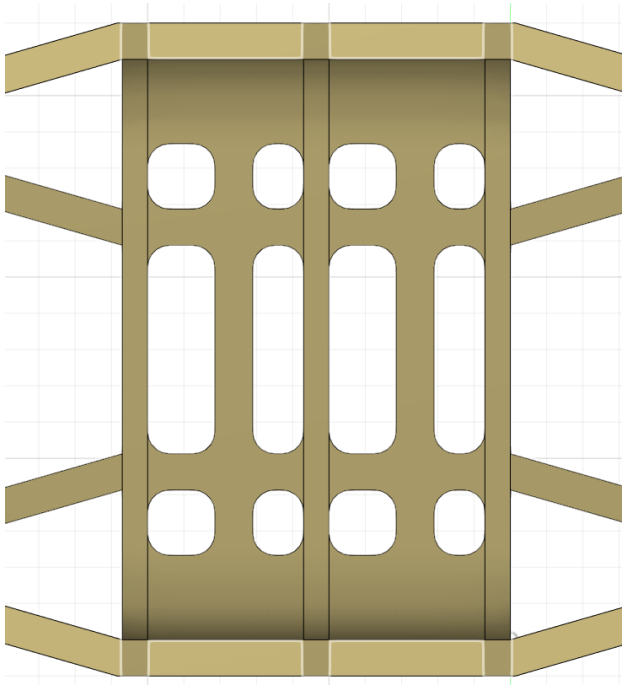
4.3 최적화 결과

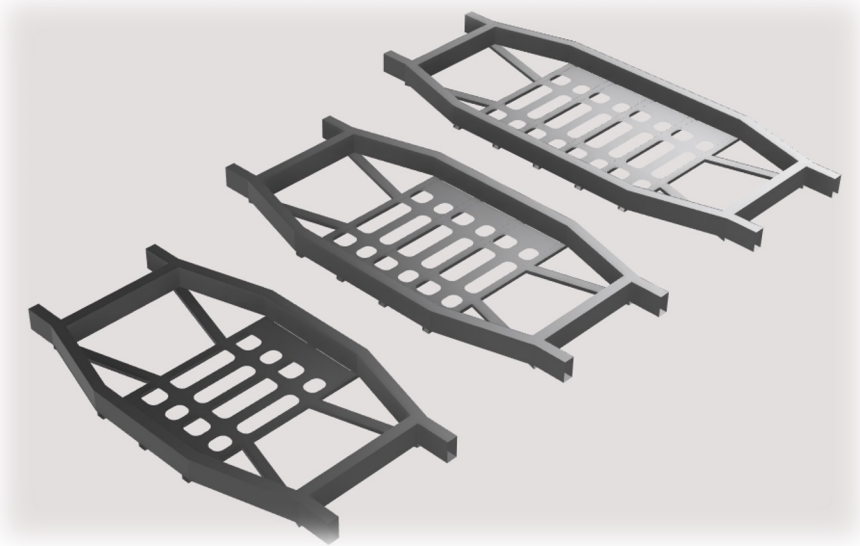


Issue : Small, Medium, Large 3개의 frame의 성능을 모두 고려한 Frame의 Parametric & Shape optimization

Shell 모델링

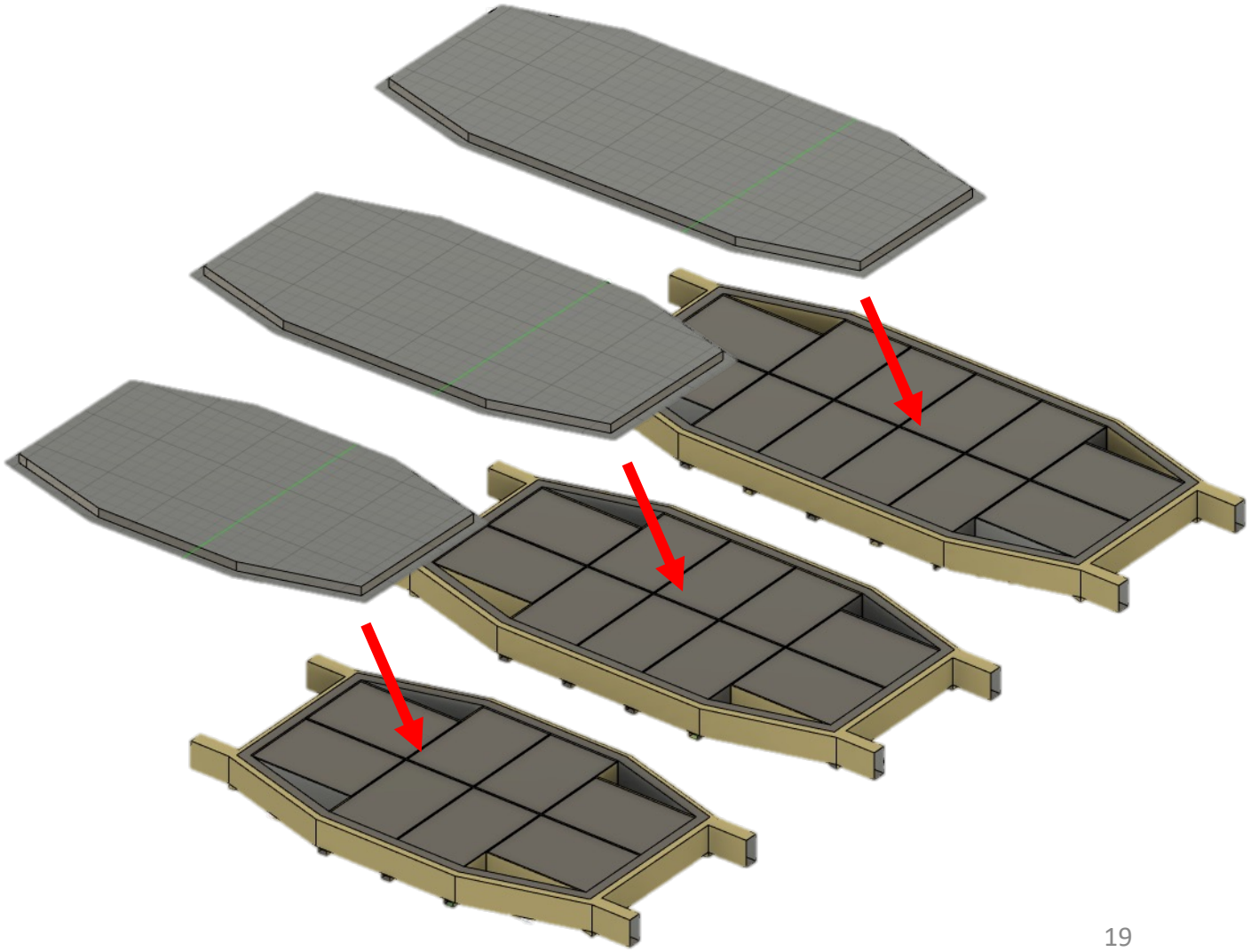






설계변수(빔의 두께, 폭)를 설정하기 위해 **shell model**로 frame을 재설계

모델링 추가사항

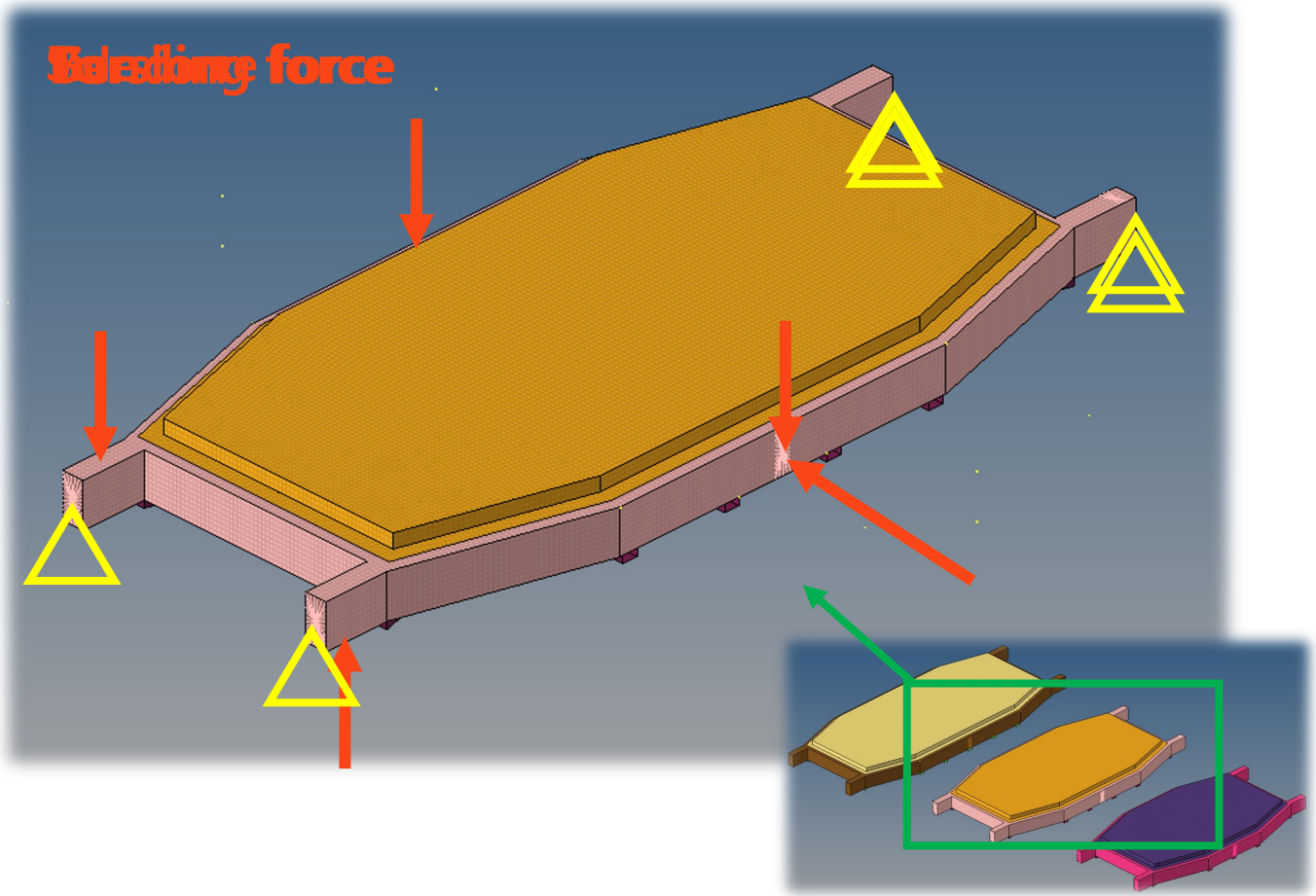


배터리의 stress를 고려하기 위해 배터리 커버, 배터리 모듈 모델에 포함

*배터리 & frame contact type : Tie

	배터리 모듈	배터리 커버
Material	Lithium	Aluminum
Young's modulus(N/mm^2)	674	68,900
Poisson's ratio	0.36	0.33
Mass density(ton/mm^2)	5.34e-10	2.7e-09

하중 조건



<Medium frame의 경우>

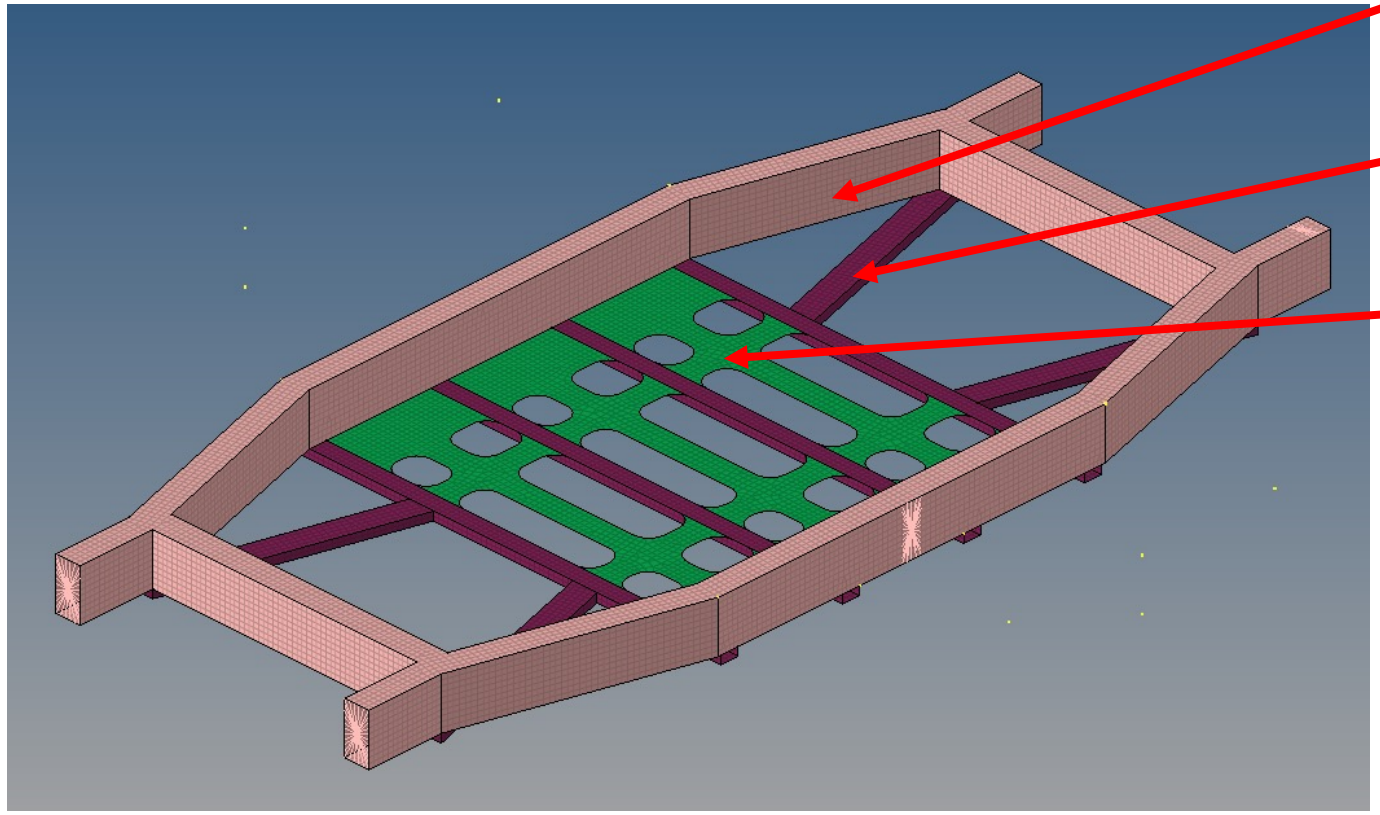
Torsion, Bending, Side force

	Torsion, Bending force
Small frame	23,540 N(total)
Medium frame	37,280 N(total)
Large frame	47,080 N(total)

	Side force
Small frame	23,540 N
Medium frame	37,280 N
Large frame	47,080 N

최적화 조건 설정

Parametric Design variable 설정



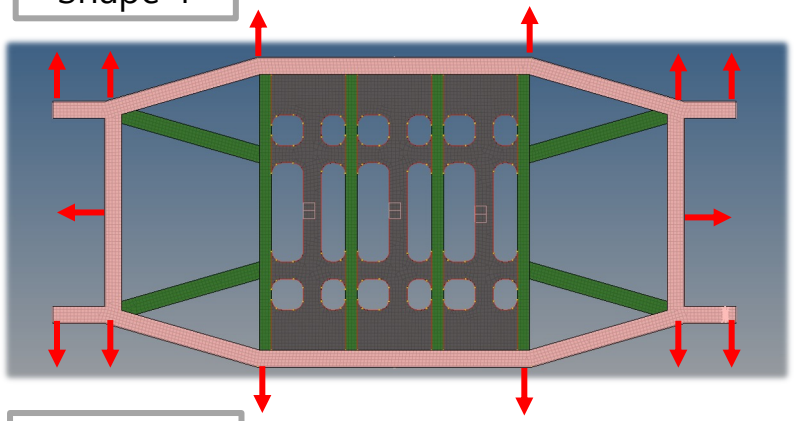
	thickness
Main frame	8 mm
Sub frame	5 mm
Frame cell	8 mm

최적화 조건 설정

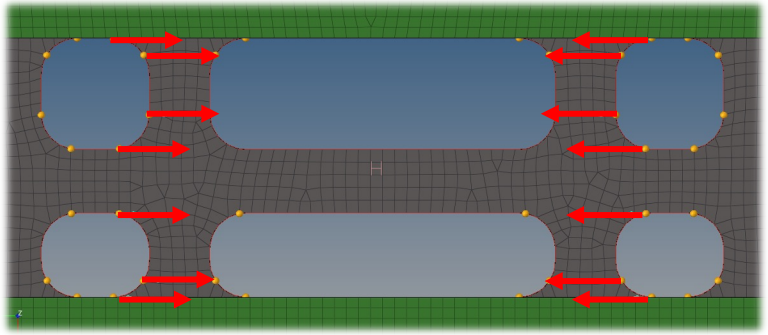
Shape Design variable 설정 (By HyperMorph)

* Shape1 : Main frame의 폭
  Shape2 ~ 6 : frame cell의 형상

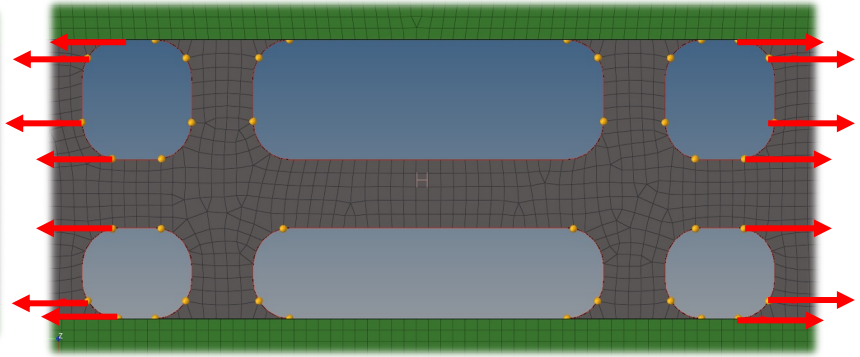
Shape 1



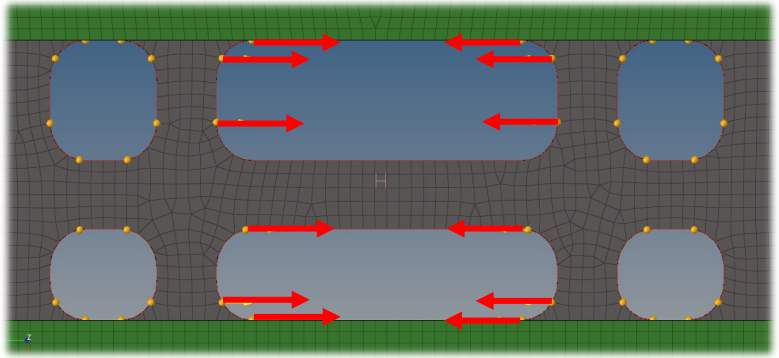
Shape 2



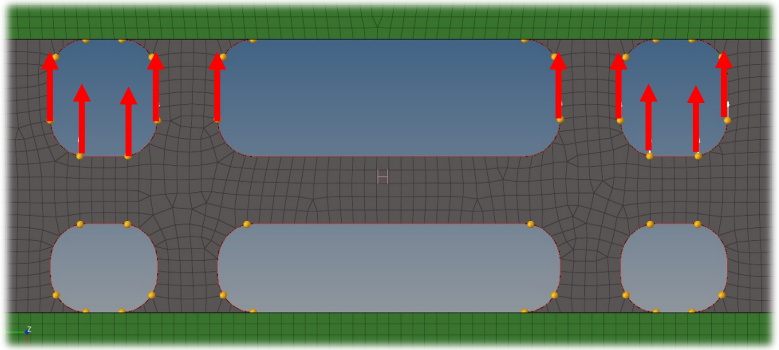
Shape 3



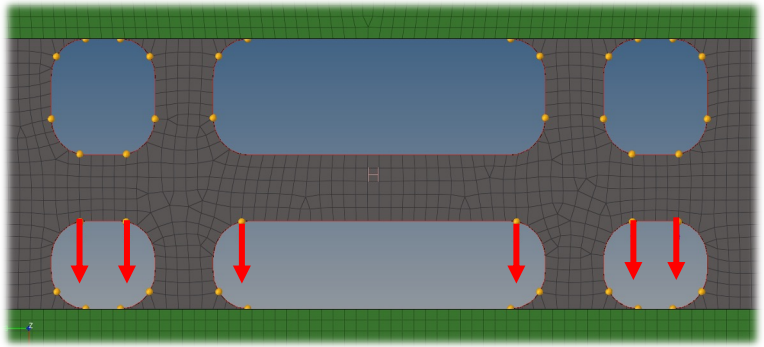
Shape 4



Shape 5

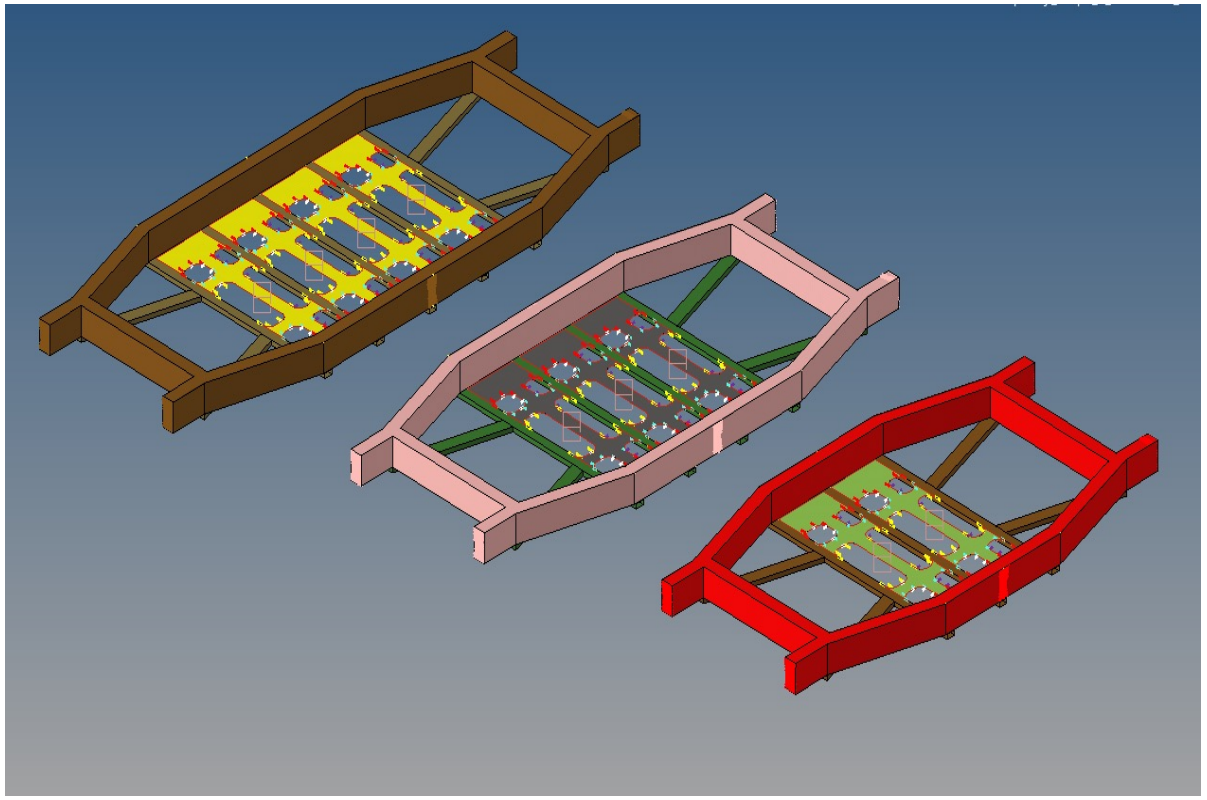


Shape 6



최적화 조건 설정

Design variable 정리 (By Hyperstudy)



	Lower bound	Current value	Upper bound
Main frame	3 mm	8 mm	8 mm
Sub frame	1 mm	5 mm	5 mm
Frame cell	1 mm	8 mm	8 mm
Shape1	-0.5 (-15mm)	0	1.5 (45mm)
Shape2	-1 (-30mm)	0	1 (30mm)
Shape3	-1 (-50mm)	0	1 (50mm)
Shape4	-1 (-50mm)	0	1 (50mm)
Shape5	-1 (-30mm)	0	1 (30mm)
Shape6	-1 (-30mm)	0	1 (30mm)

총 9개의 Design variables를 설정하였으며

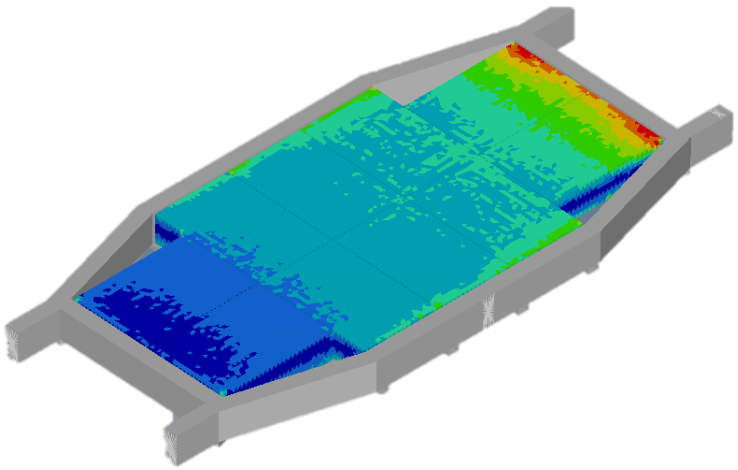
Small, Medium, Large frame에 **동일하게 적용**하였다.

최적화 조건 설정

Constraints & objective설정 (By Hyperstudy)

Frame name	Loadstep	Constraint		objective
Small frame	Torsion force	≤	*0.81Mpa (배터리 모듈이 받는 max stress)	Minimize mass
	Bending force			
	Side force			
Medium frame	Torsion force			
	Bending force			
	Side force			
Large frame	Torsion force			
	Bending force			
	Side force			

*배터리 모듈의 항복응력인 **2.43MPa**
(C. Zhang et al., 『Constitutive behavior and progressive mechanical failure of electrodes in lithium-ion batteries』, Journal of Power Sources, 2017)
을 기준으로 **안전계수 3** 적용



<Medium frame에서 배터리 모듈이 받는 stress>

최적화 알고리즘
Global Response Search Method

최적화 결과

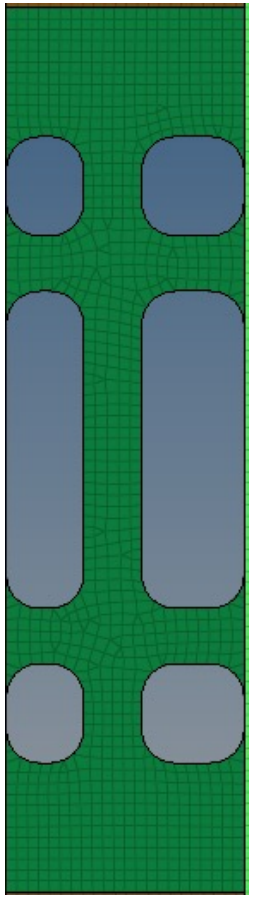
Design variable	Initial value	Optimized value
Main frame	8 mm	**3.87 mm**
Sub frame	5 mm	**1 mm**
Frame cell	8 mm	**1 mm**
Shape1 (translate)	0	**0.689 (20.67mm)**
Shape2 (translate)	0	**-0.556 (-16.68mm)**
Shape3 (translate)	0	**-0.107 (-5.35mm)**
Shape4 (translate)	0	**1 (50mm)**
Shape5 (translate)	0	**-0.531 (-15.93mm)**
Shape6 (translate)	0	**-1 (-30mm)**

Frame	Loadstep	Stress(Mpa)
Small frame	Torsion force	0.125
	Bending force	0.192
	Side force	0.385
Medium frame	Torsion force	0.190
	Bending force	0.230
	Side force	0.438
Large frame	Torsion force	0.260
	Bending force	0.374
	Side force	**0.8104 (Acceptable)**

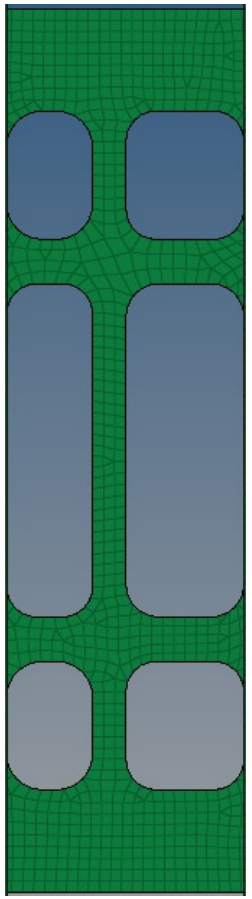
Small frame mass : 0.971 ton → 0.694 ton (**28.5% 감소**)
Medium frame mass : 1.160 ton → 0.833 ton (**28.2% 감소**)
Large frame mass : 1.350 ton → 0.970 ton (**28.1% 감소**)

최적화 결과

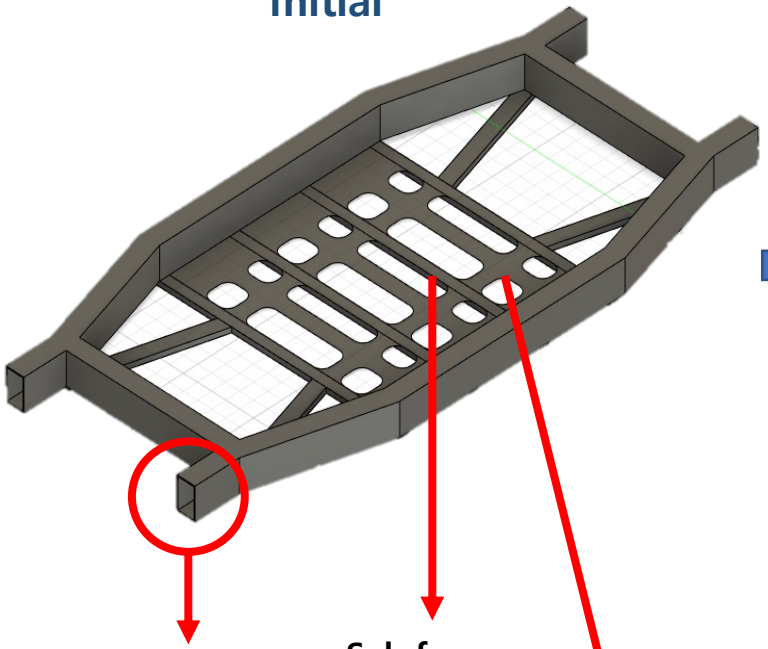
Initial

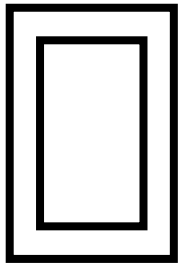


Optimized



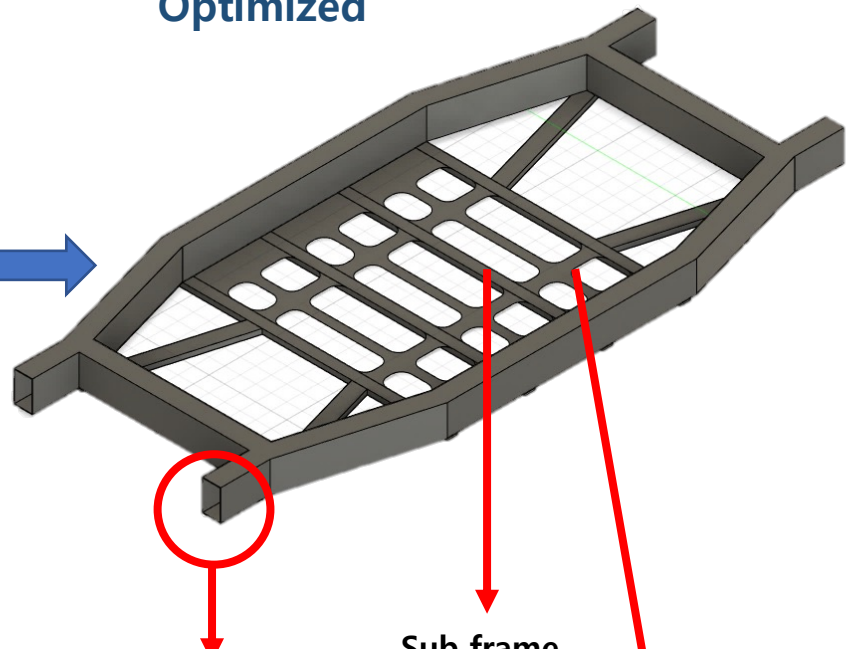
Initial

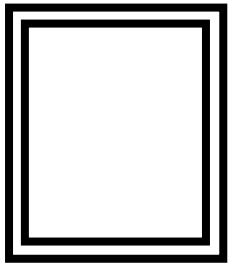




100mm*200mm
T=8mm

Optimized





120.67mm*200mm
T=3.87mm

5. 주조해석

5.1 주조 모델 선정 배경 및 모델링

5.2 주조 모델 해석

5.3 주조 모델 개선 작업

5.4 최종 주조 해석 결과

Altair Inspire™

Cast

2022

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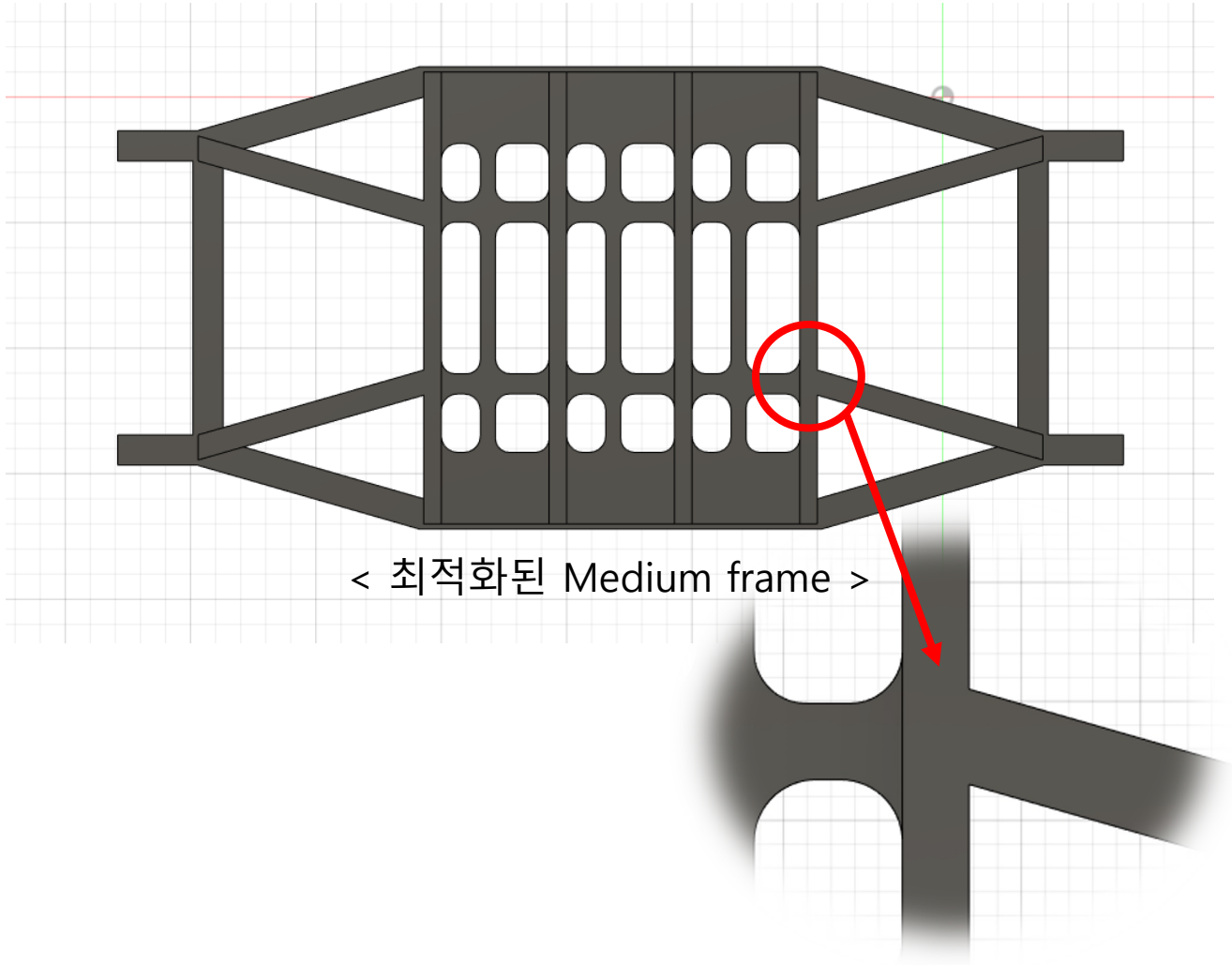
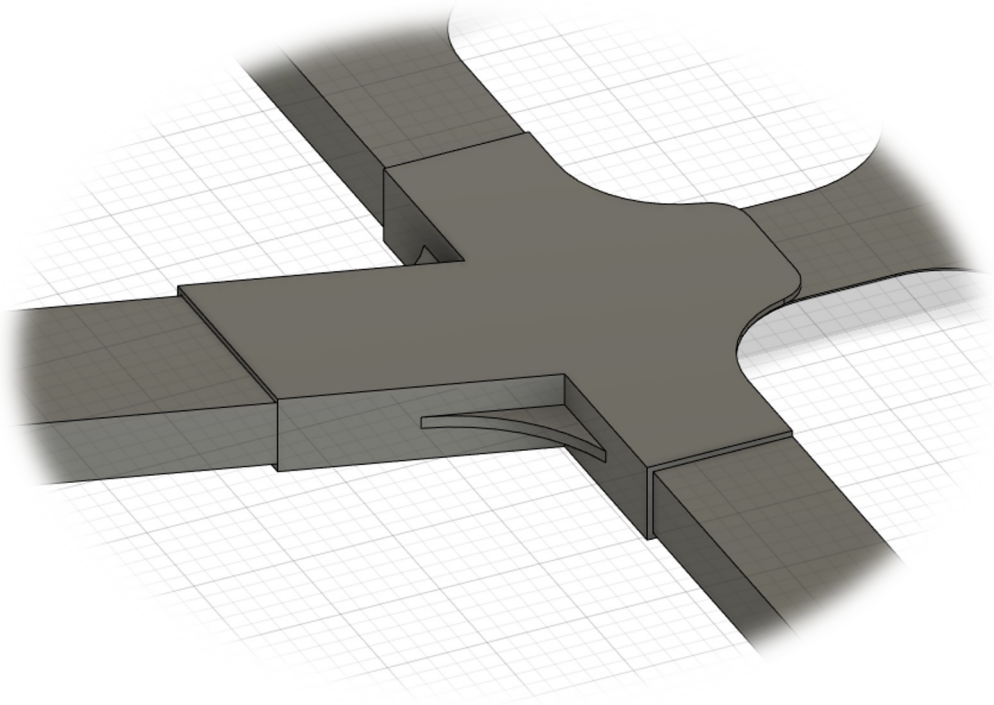
주조 모델 선정 배경



< 최적화된 Medium frame >

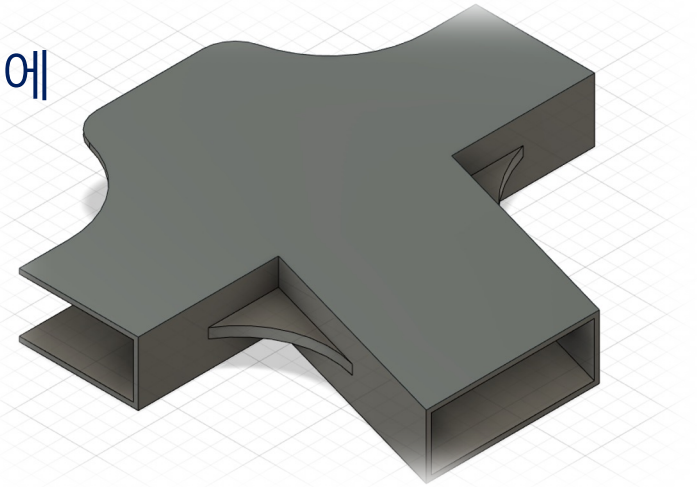


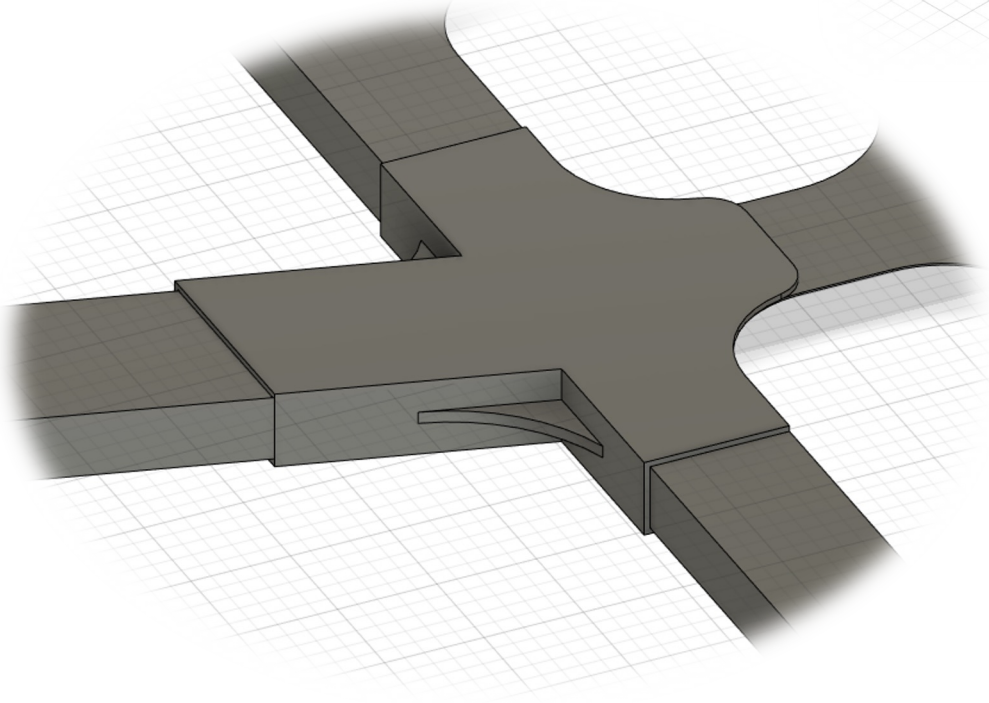
PBV의 **생산성, 제작성** 및 **강성**을 높이기 위해 프레임의 **조인트 결합방식**이 효과적!

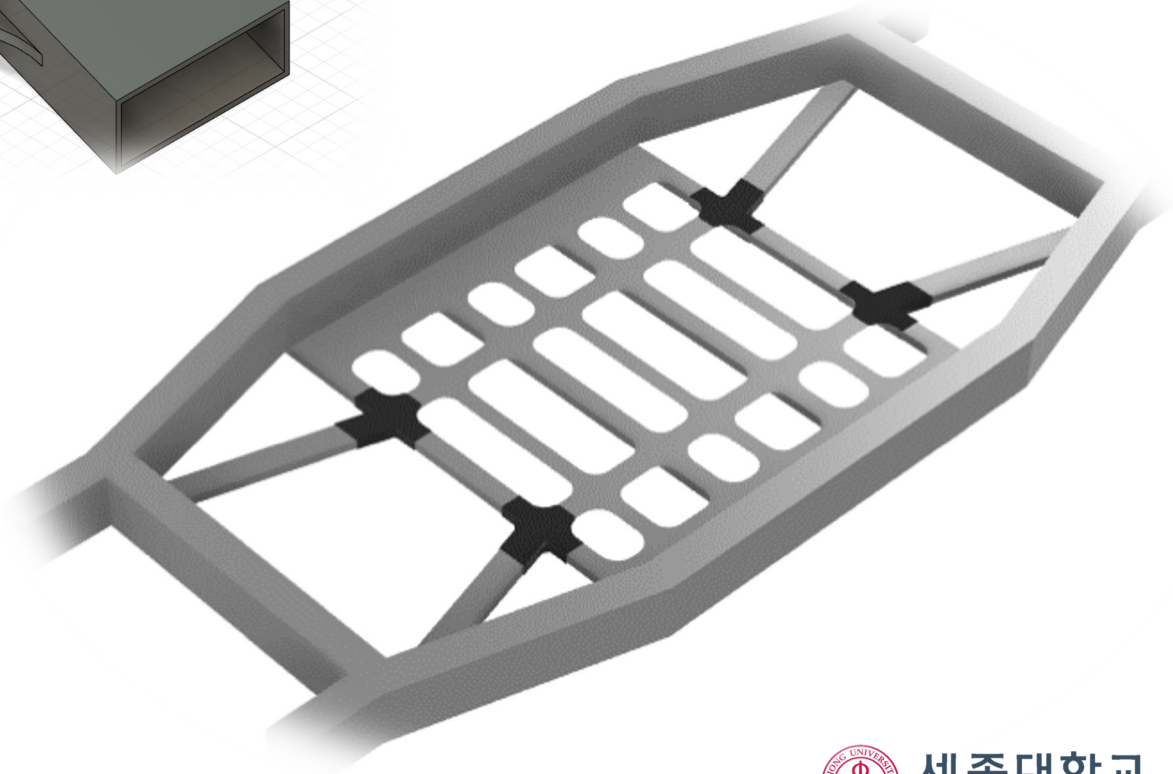
주조 모델 모델링

조인트를 small, medium, large frame에

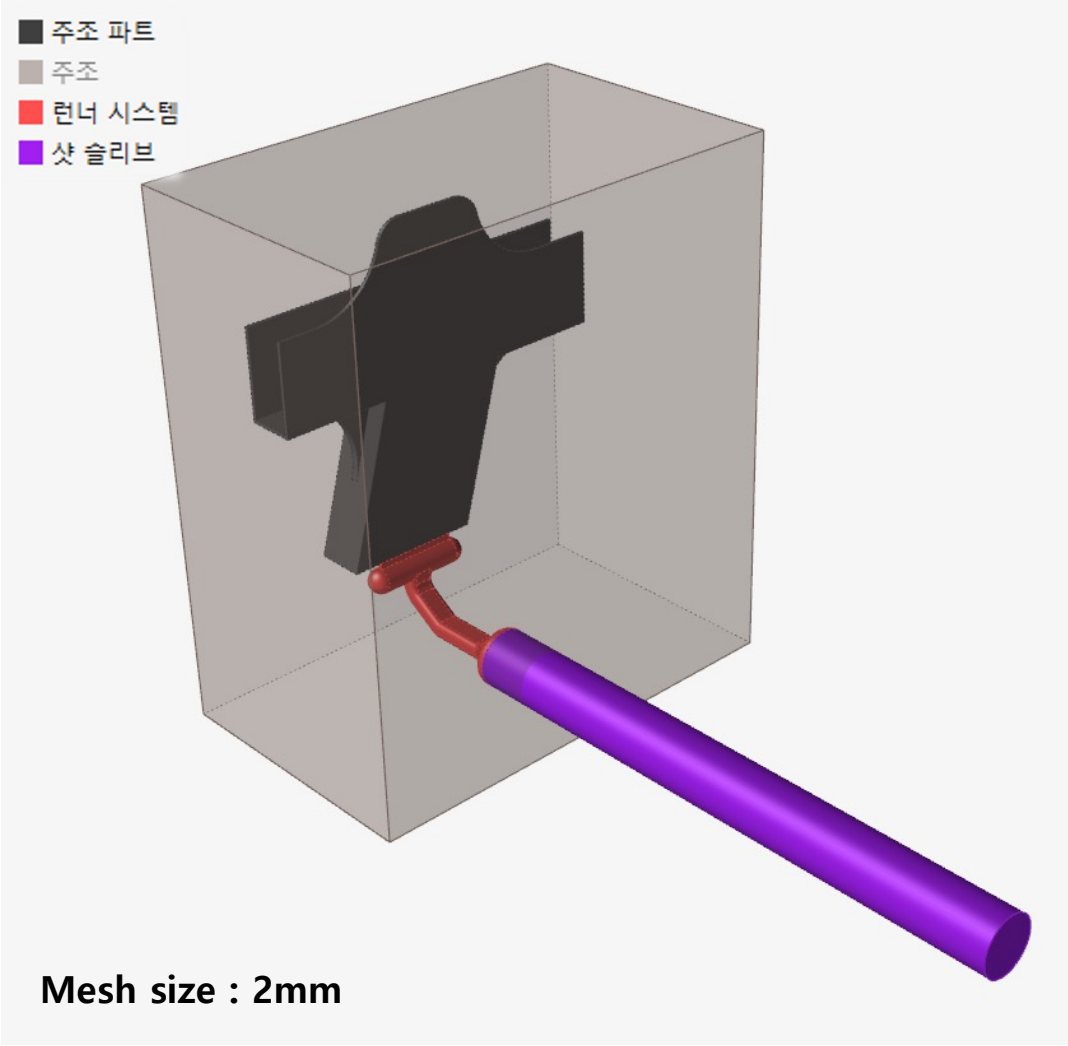
공통적으로 적용 가능



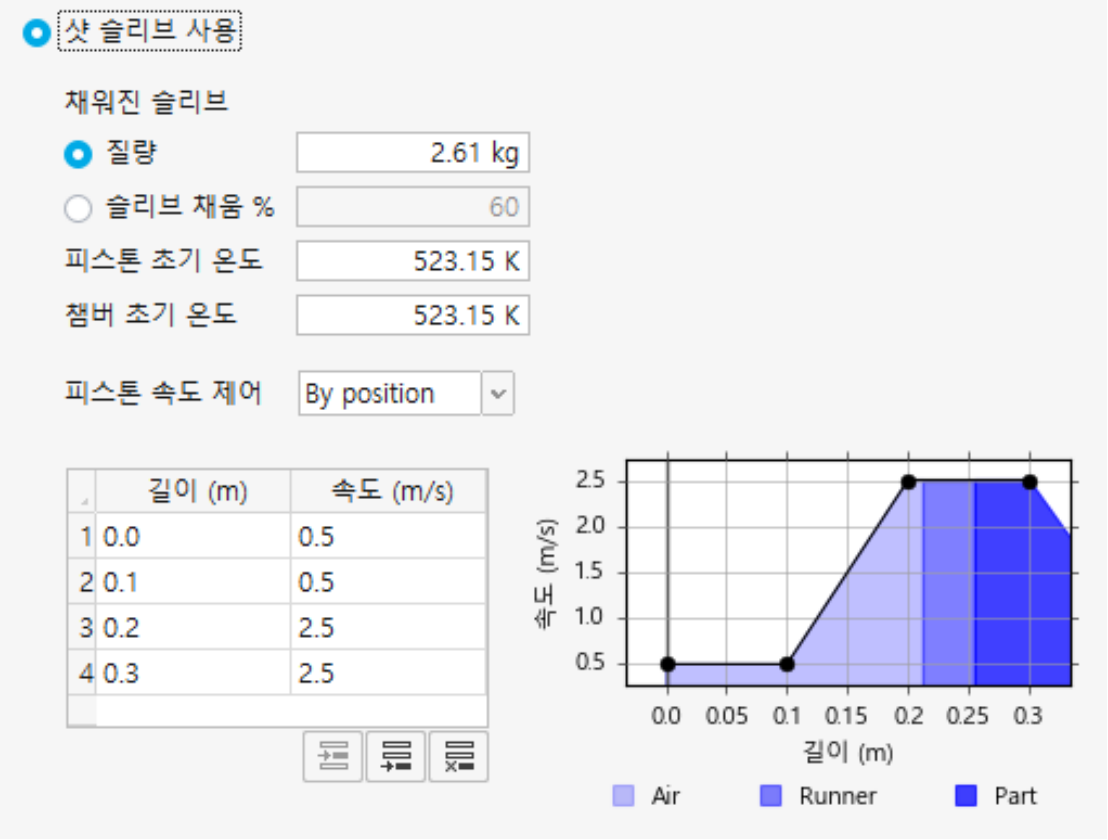




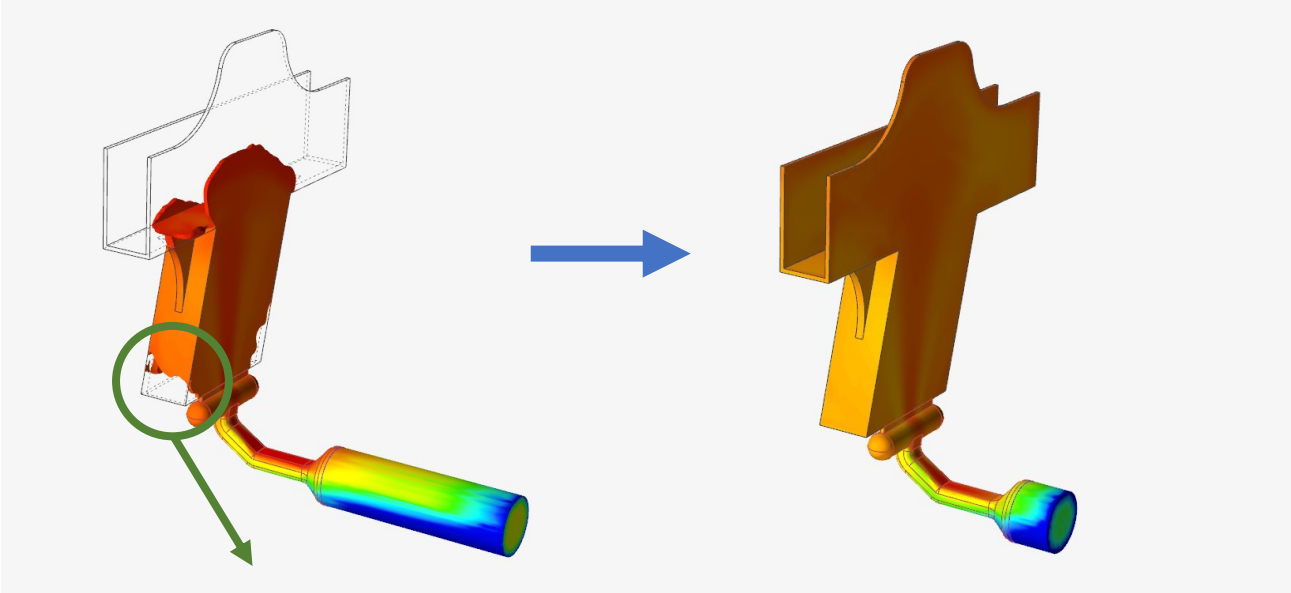
주조 모델 해석

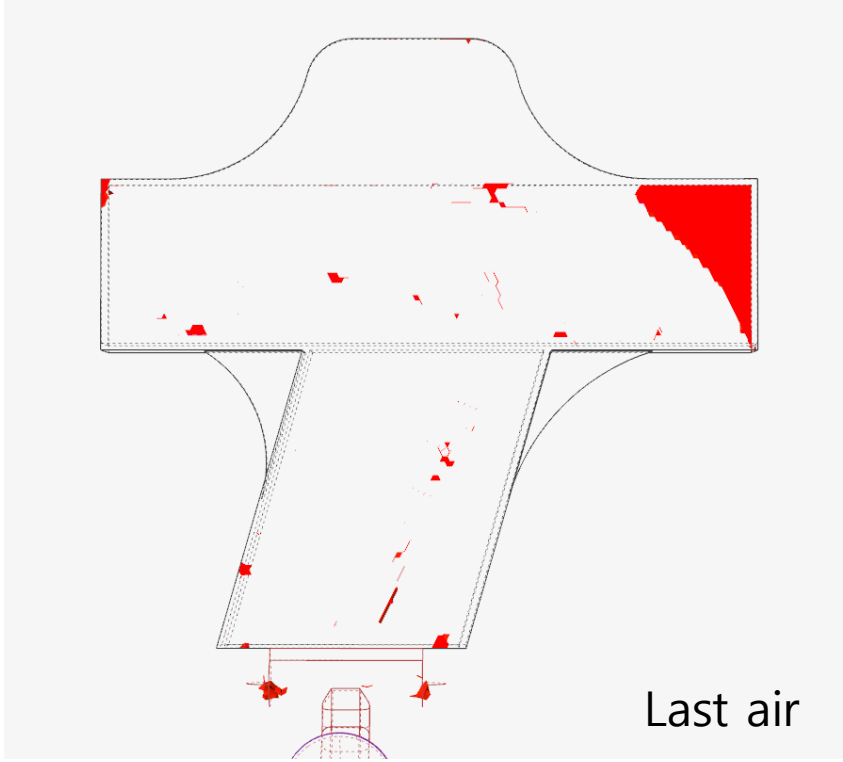


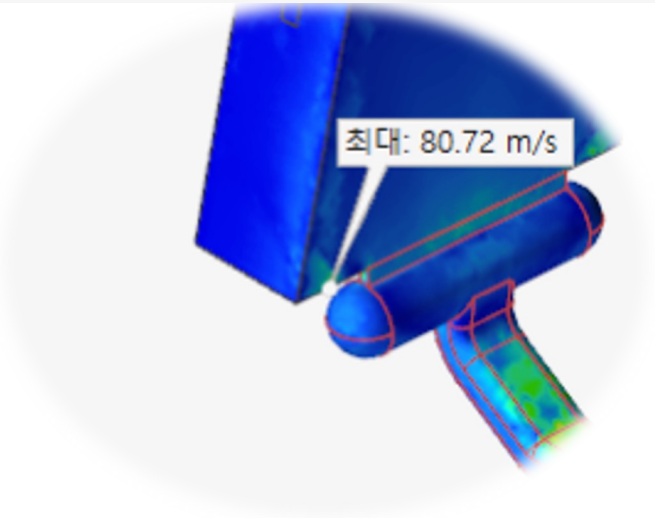
	주조파트	주조
Material	Steel	Green-sand
초기온도 (K)	1874.15	293.15



주조 모델 해석

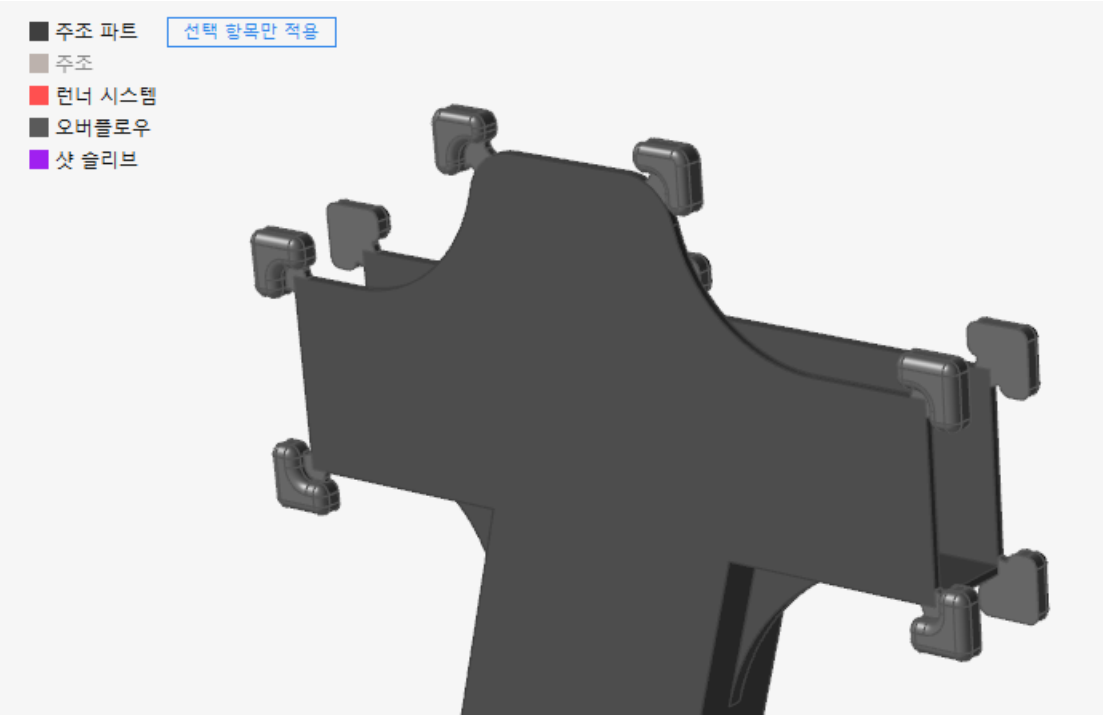




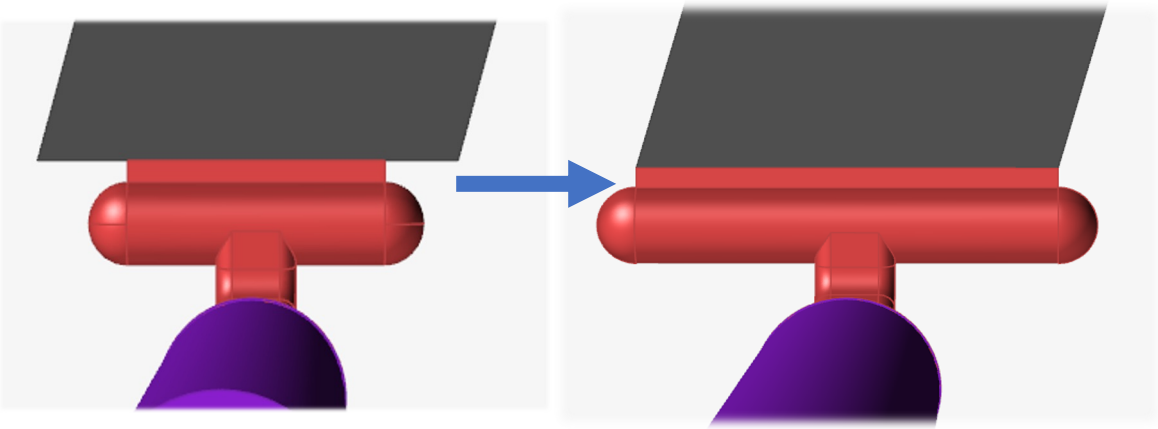


1. 주입구 부분 **높은 유동속도**로 주형침식 우려
2. **Last air** 과다 발생

주조 모델 개선 작업



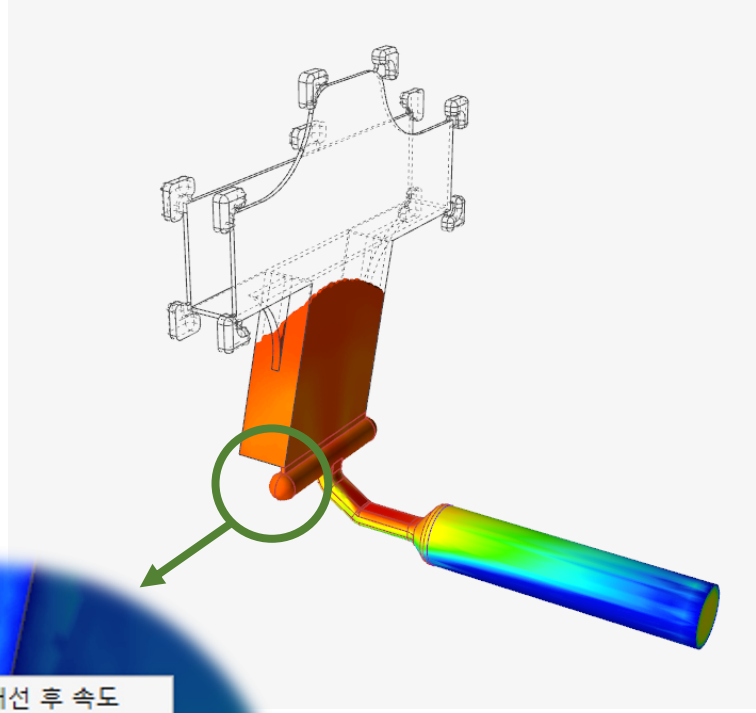
< 오버 플로우 부착된 모습>

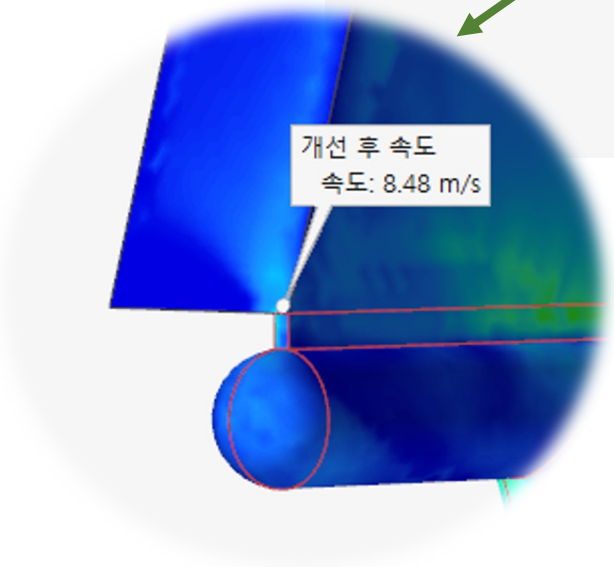


문제점 개선안

- Last Air 제거하기 위한 **오버플로우** 설치
- 주입구 유동속도 감소를 위한 **런너게이트** 수정

개선 후 주조해석 결과



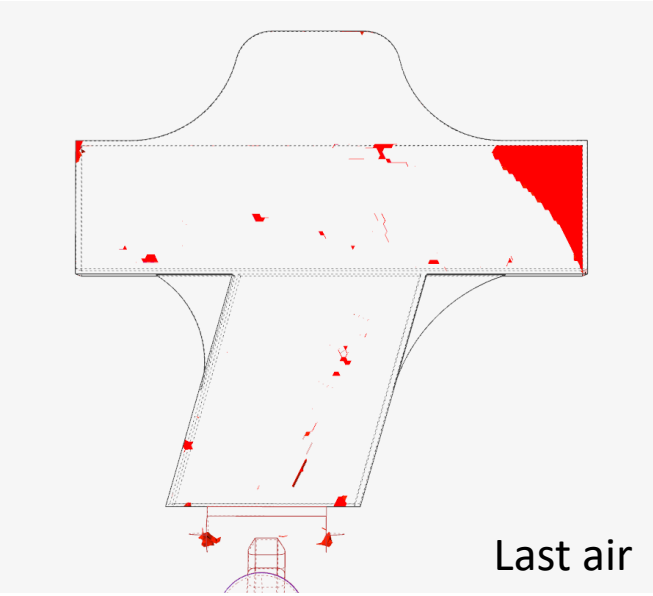


개선 전 속도 : 80.72 m/s

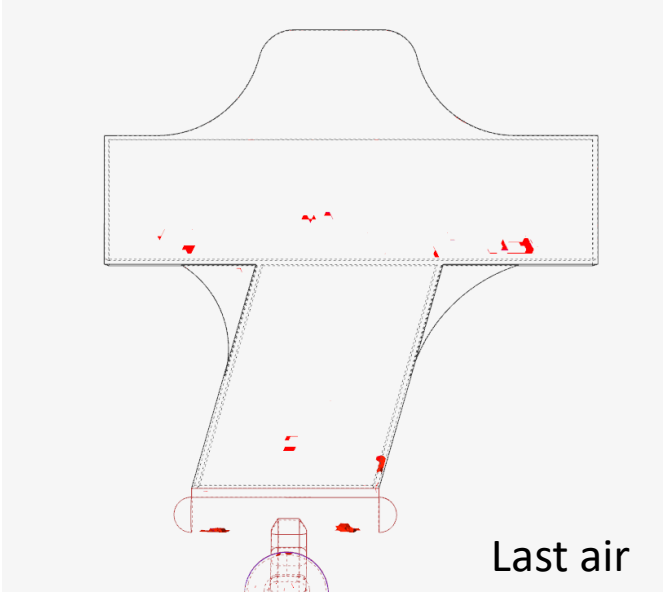
개선 후 속도 : **8.48 m/s**

주형 침식 발생 가능성이 낮아짐

Before

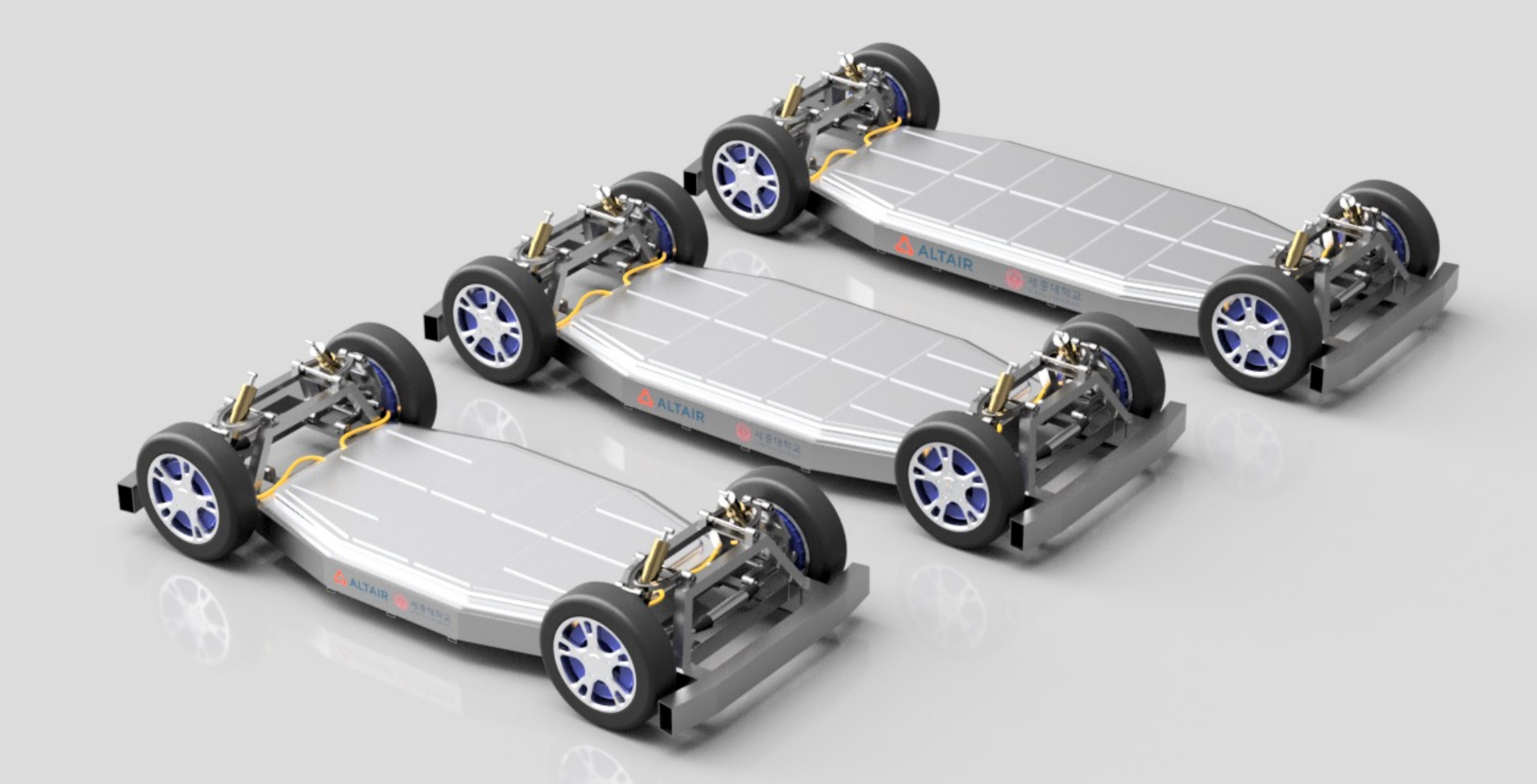


After

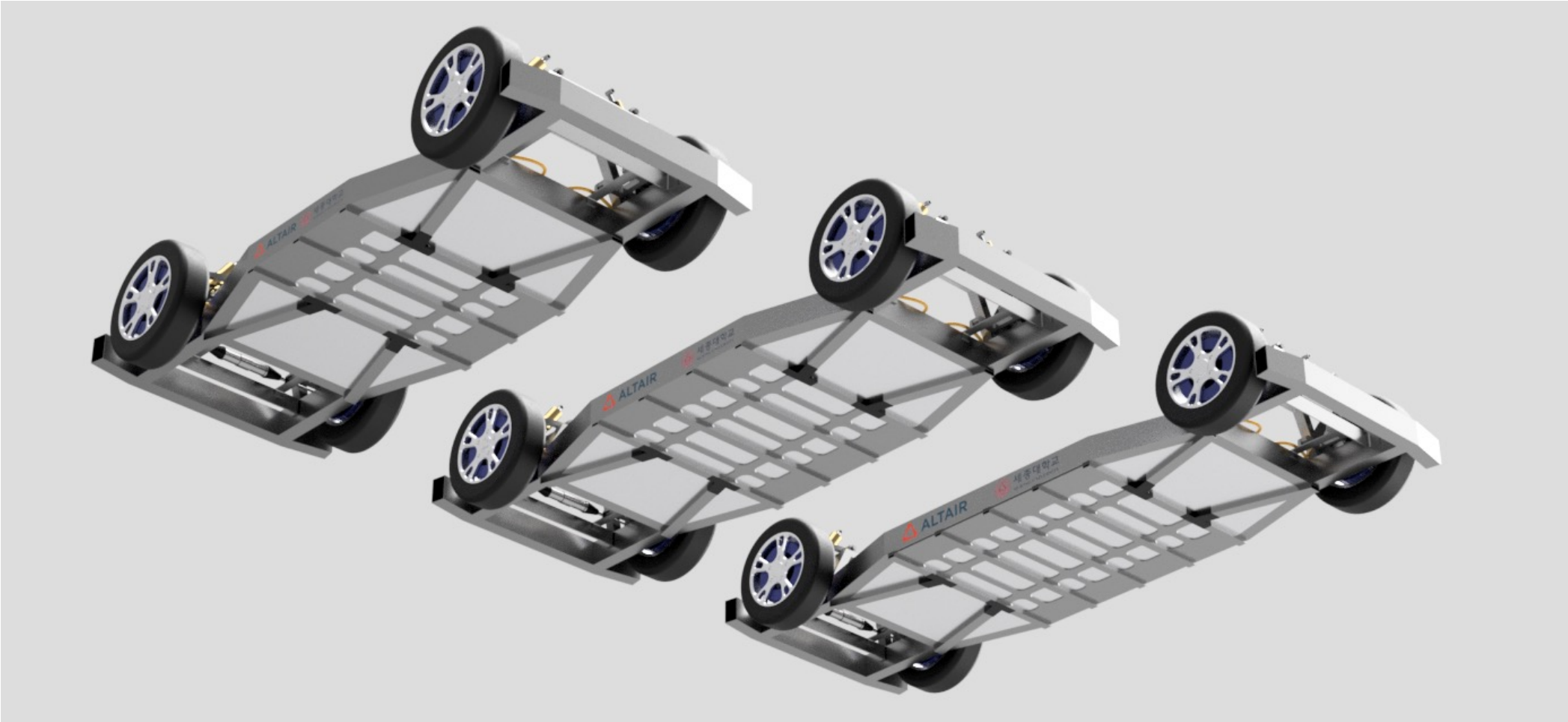


개선 후 **최종 공기가 감소**

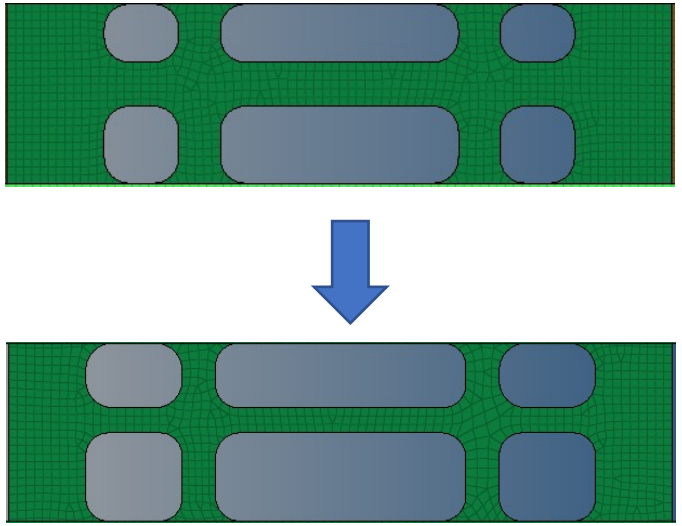
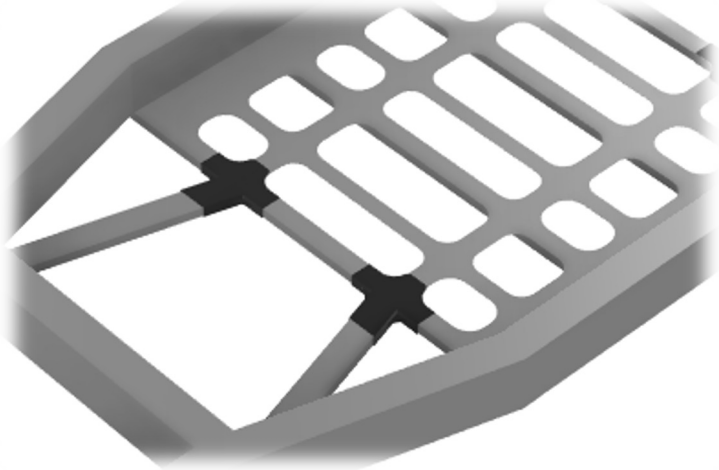
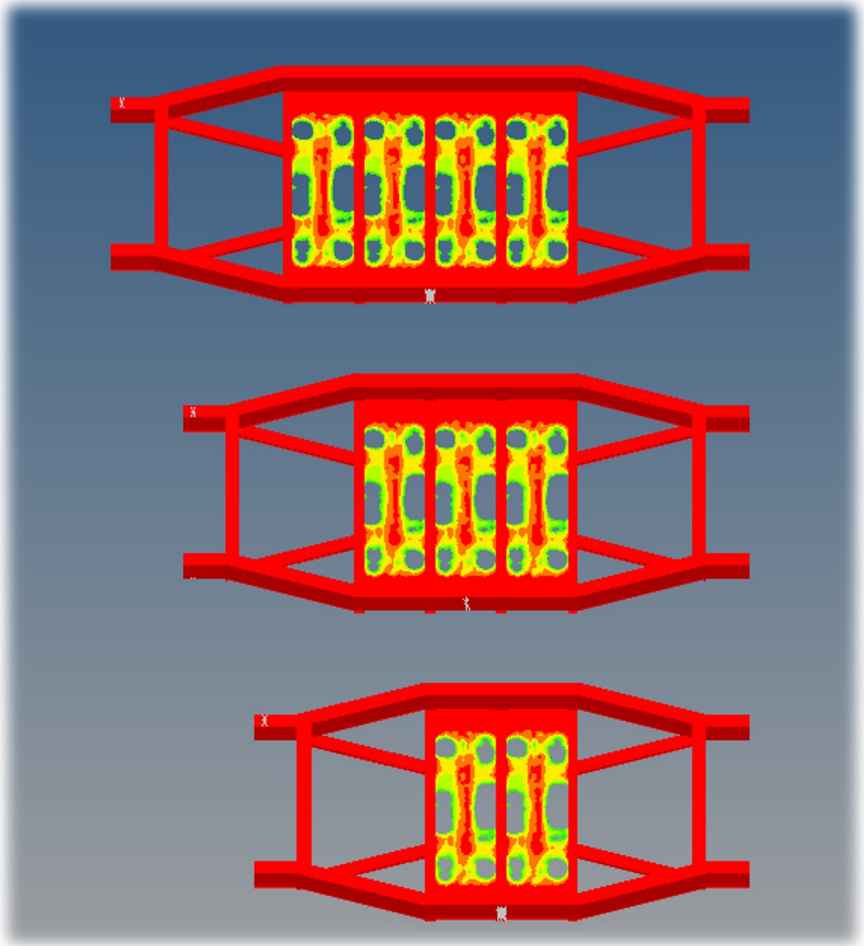
6. Final design



6. Final design



6. 정리

PBV의 다품종 소량생산의 방법론을 제시하여 PBV의 목적인 **높은 생산성, 제작성과 확장성**에 도달하게 되었다.

다양한 크기의 프레임에 적용 가능한 조인트를 **주조해석**을 통해 **제작 가능성을 검증**하였다.