Vehicle Structure Project

Topology optimization of overhead crane for volume optimization considering standards of Korean industrial standard

2021.12.13

Taeyoon Lim

Background

CDL Computational Design Lab

➢ **Used in many places**

small overhead crane (0.5t)

Small to large factory overhead cranes

Overhead Container crane

➢ **Safety, production standards**

크레인제작기준·안전기준및검사기준

[시행 2002. 1. 1.] [노동부고시 제57호, 2001. 10. 10., 일부개정]

1. Securing the fundamental safety of cranes
2. Use of steel or equivalent or higher material specified in the Korean Industrial Standards
3. Allowable tensile, compressive, shear, bearing stresses must not be exceeded
4. Has many type of loads
5. Wall buckling of significant deformation must not occur, so stiffness must be maintained
6. Maximum Deflection limit must not be exceeded

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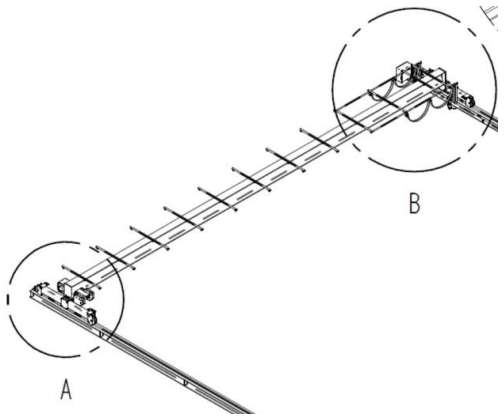
➢ **Objective** (안전성, 경제성)

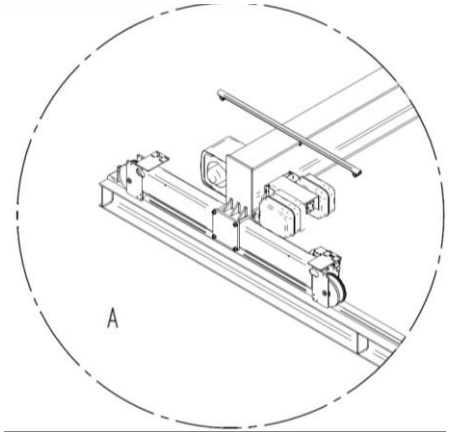
✓ Keep the standards of Korean Industrial standards

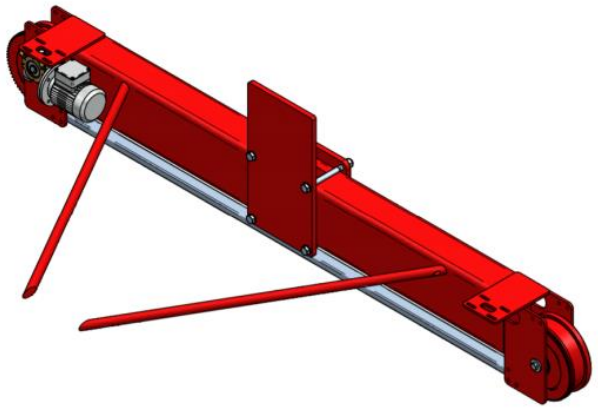
✓ Volume optimization

Model 선정

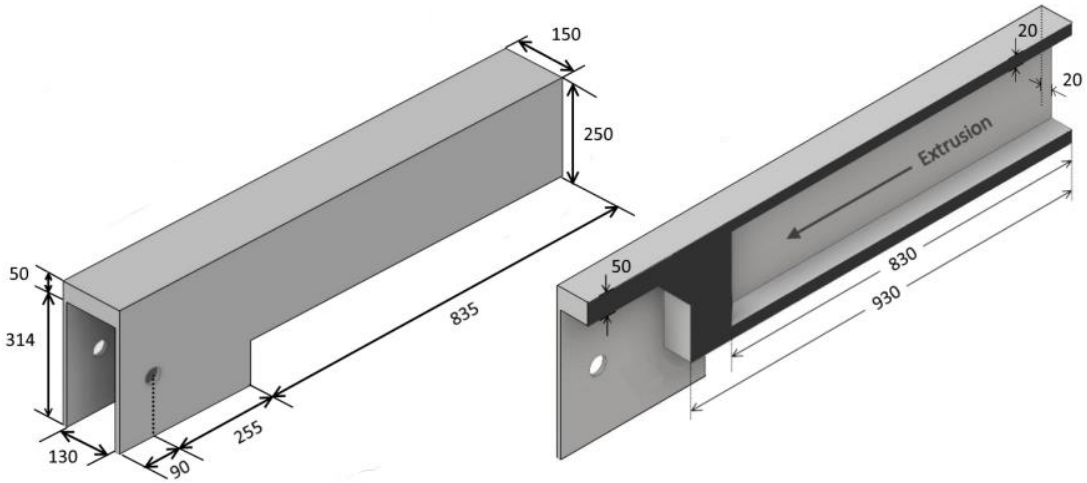
➢ 비교 모델 선정







➢ End truck assembly (10 ton)



[PDF] Topology optimization of crane component
E Hartveit-Schee - 2018 - uis.brage.unit.no

Reference

➢ 천장크레인 설계기준 [크레인제작기준, 안전기준및검사기준 – 고용노동부]

크레인제작기준·안전기준및검사기준

[시행 2002. 1. 1.] [노동부고시 제57호, 2001. 10. 10., 일부개정]

KS 고시

표준·표준화 활동 > KS 고시

고시번호	2016-0487
고시명	KSBISO20332 등 18종 개정 고시
고시일	2016-12-13
시행일	2016-12-13
담당부처	국가기술표준원
담당과	기계소재표준과
담당자	김학영
담당자연락처	043-870-5371

구분	표준번호	표준명
개정	KSBISO20332	크레인 — 강구조물의 적합성 검증
개정	KSBISO4301-4	크레인 — 분류 — 제4부: 지브 크레인
개정	KSBISO9927-3	크레인 — 검사 — 제3부: 타워크레인
개정	KSBISO16881-1	크레인 — 레일바퀴 및 트롤리 트랙 지지구조물 설계 계산 — 제1부: 일반
개정	KSBISO8686-4	크레인 — 하중 및 조합 하중에 관한 설계원리 — 제4부: 지브 크레인
개정	KSBISO4301-1	크레인 — 분류 — 제1부: 일반
개정	KSBISO4301-2	크레인 — 분류 — 제2부: 이동식 크레인
개정	KSBISO4301-5	크레인 — 분류 — 제5부: 천장크레인 및 겐트리 크레인
개정	KSBISO4301-3	크레인 — 분류 — 제3부: 타워크레인
개정	KSBISO4302	크레인 — 풍하중 평가
개정	KSBISO10245-3	크레인 — 제한장치 및 지시장치 — 제3부: 타워크레인
개정	KSBISO10245-1	크레인 — 제한장치 및 지시장치 — 제1부: 일반
개정	KSBISO23814	크레인 — 검사자 자격 요건
개정	KSBISO4304	이동식 및 부앙 크레인 이외의 크레인 — 안정성을 위한 일반 요건
개정	KSBISO4306-5	크레인 — 용어 — 제5부: 브릿지 및 겐트리 크레인
개정	KSBISO4310	크레인 — 시험 기준 및 절차
개정	KSBISO8686-2	크레인 — 하중 및 조합 하중에 관한 설계원리 — 제2부: 이동식 크레인
개정	KSBISO11660-1	크레인 — 접근 통로, 난간 및 방책 — 제1부: 일반

➢ 크레인강 구조 부분의 계산 기준 KS A1627 (JIS B8821) 규격

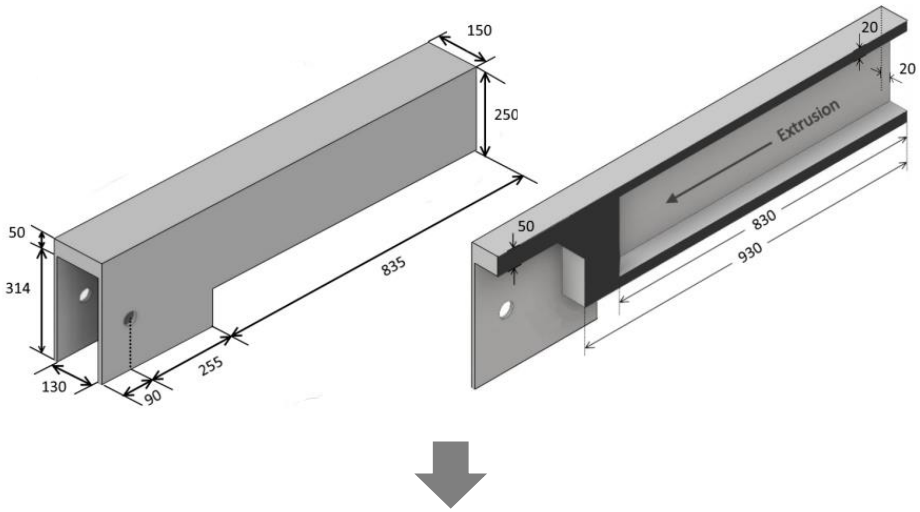
➢ 제약조건 ➔ 매 반복회의 Von-Mises 응력 < 허용응력

Table 1 Mechanical properties of SS400, Rail 37A

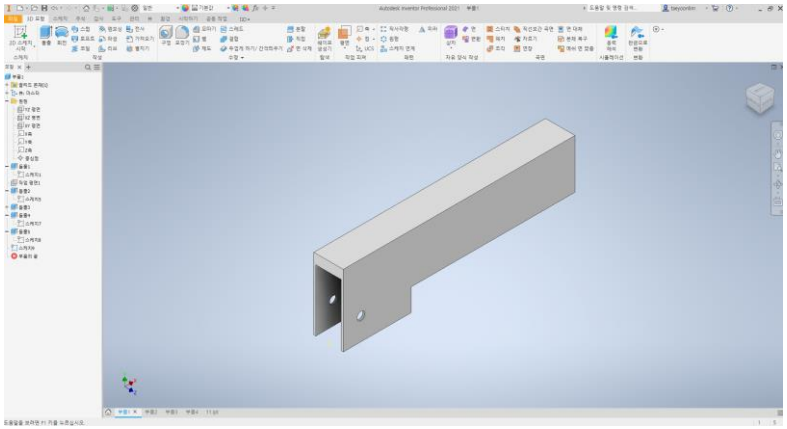
Item list \ Material	SS400	Rail 37A (37 kg/m)
Yield Strength(MPa)	245(t≤16)	760 ~ 790
Density(kg/m^3)	7,959	8,010
Elastic Modulus(GPa)	204.08	210.2
Poisson's Ratio	0.3	0.3

Modeling

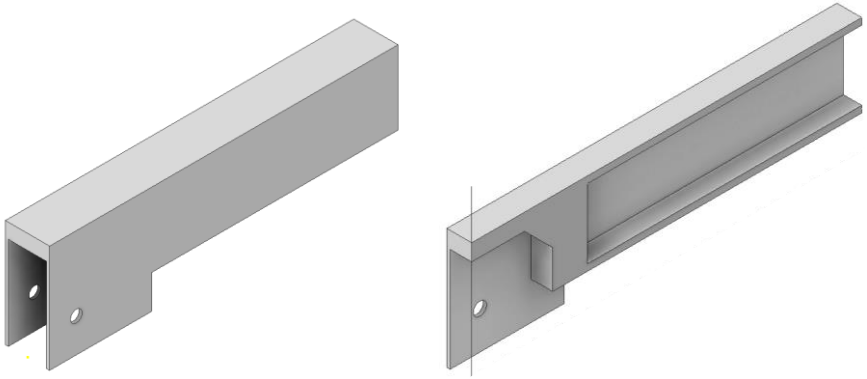
➢ Modeling

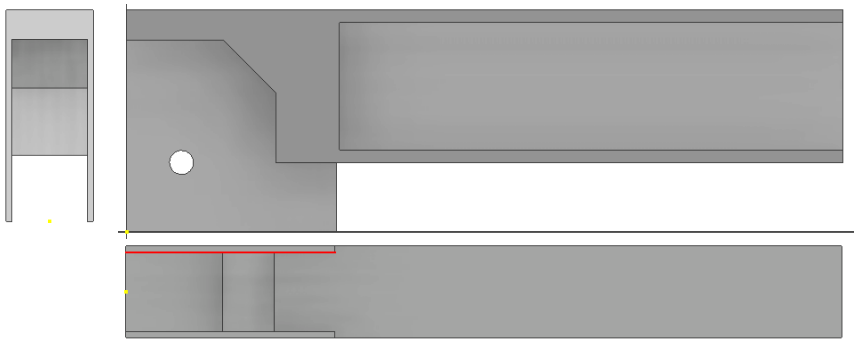


➢ Using Inventor (Autodesk 3d cad program)



➢ Design domain





Linear static analysis

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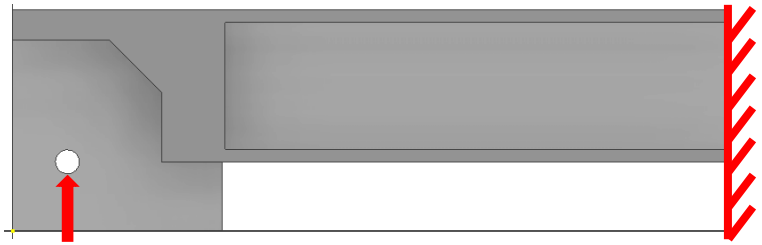
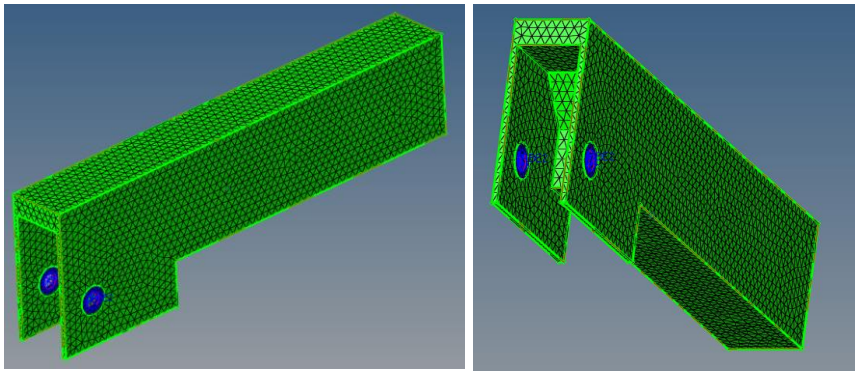
➢ boundary conditions



➢ Meshing

Mesh size	Mesh type
20	3D tetras



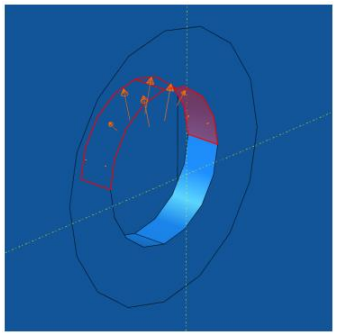
➢ Loading conditions

Name	P [N]	P' [N]	w [N/mm]	q [N/mm^2]
$R_{max}Dyn$	64 000	32 000	3200	80
K_r	1500	750	75	1,88
$F_{b,1}$	18 800	9400	940	23,5

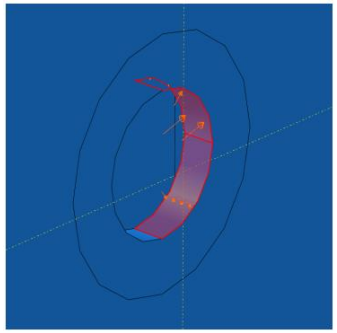
According to DIN 4132, DIN 15018

For vertical loads: $$f(z) = \cos\left(\pi \frac{(z_0 - |z|}{d}\right)$$

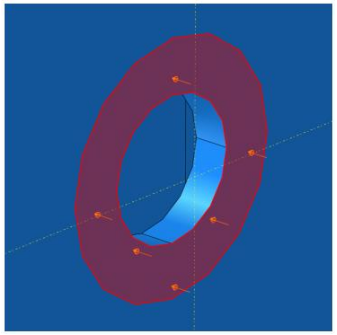
For horizontal loads: $$f(y) = \cos\left(\pi \frac{(y_0 - |y|}{d}\right)$$



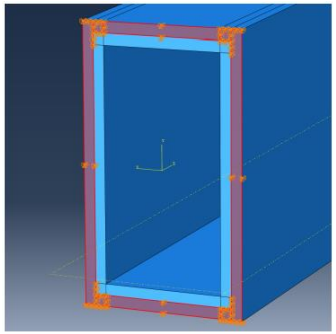
Vertical load



Horizontal load



Lateral load



Boundary condition

Linear static analysis

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Poisson's Ratio	0.3	0.3

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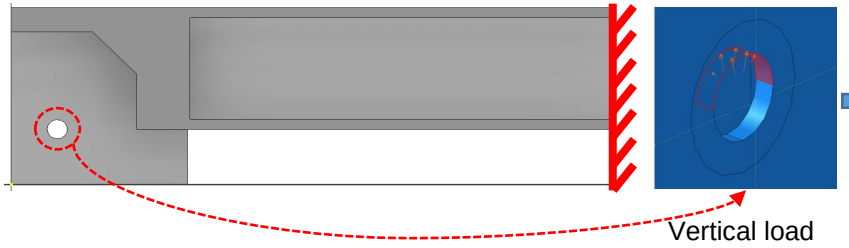
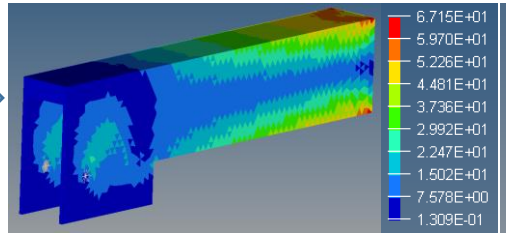
Table 7 Allowable condition

Allowable condition	Value
Allowable Stress($\sigma_{al} \leq \sigma_y / S_s$)	163.3 MPa

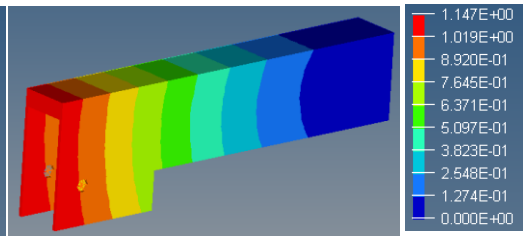
안전율 S = 1.5

➢ Vertical load



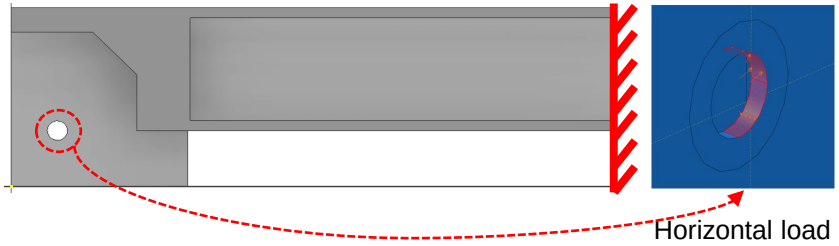


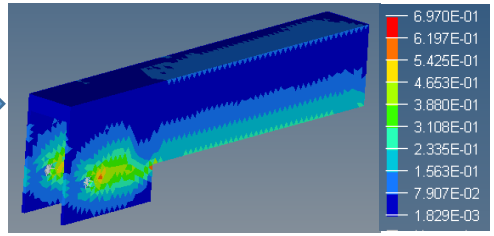
Max Von-mises stress : **67.15Mpa < 163.30Mpa**



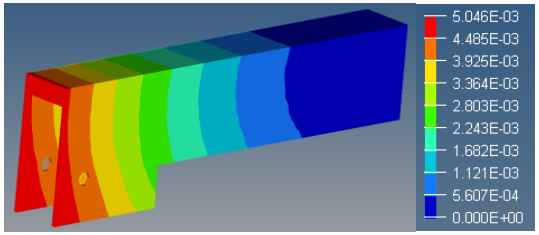
Max displacement : **1.147mm < 2.950mm**

➢ Horizontal load



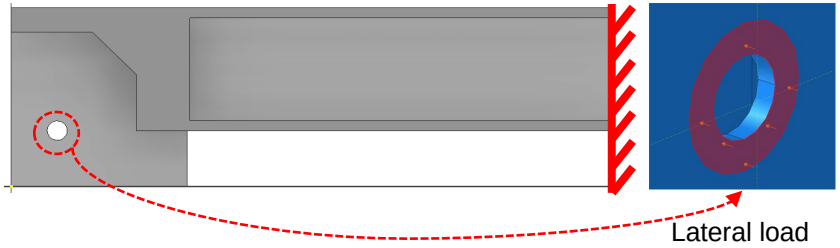


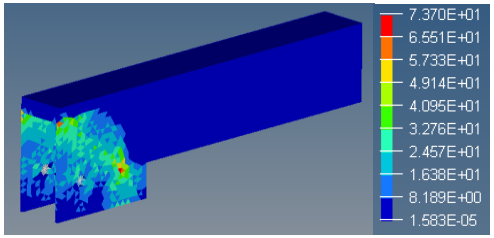
Max Von-mises stress : **0.69Mpa < 163.30Mpa**



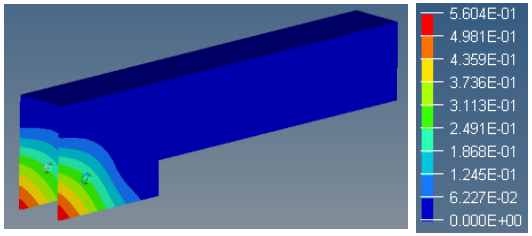
Max displacement : **0.005mm < 2.95mm**

➢ Lateral load





Max Von-mises stress : **73.70Mpa < 163.30Mpa**



Max displacement : **0.56mm < 2.95mm**

Topology optimization

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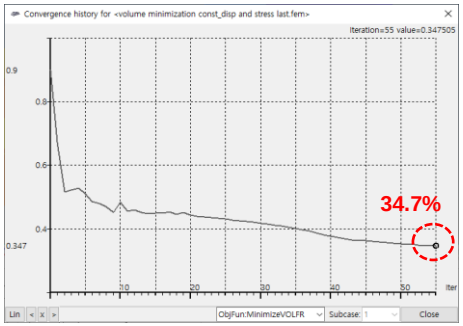
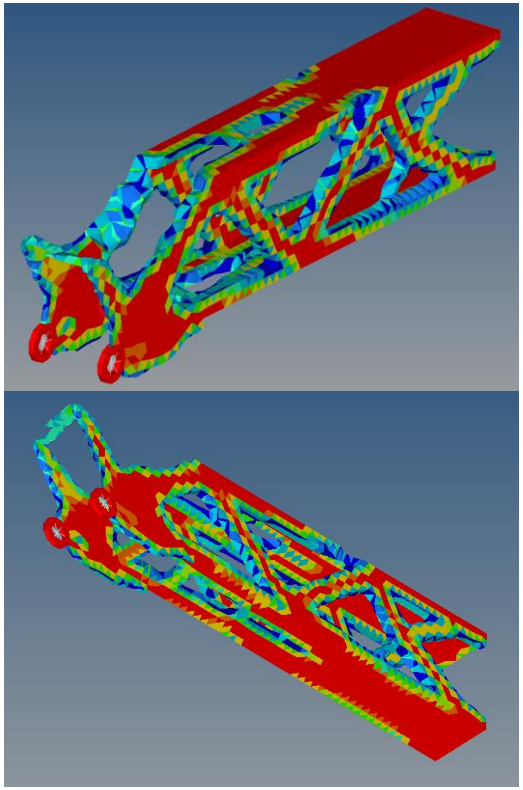
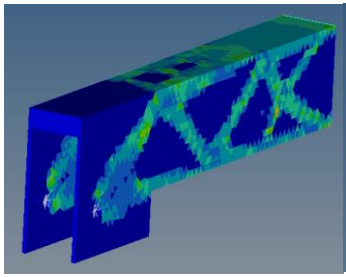
➢ Volume minimization

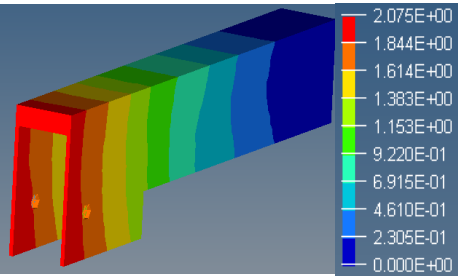
- 목적 함수: 부피 최소화
- 설계 변수: 요소 형상 밀도
- 구속 조건: 응력 < 163.3Mpa
  변위 < 길이의 1/800





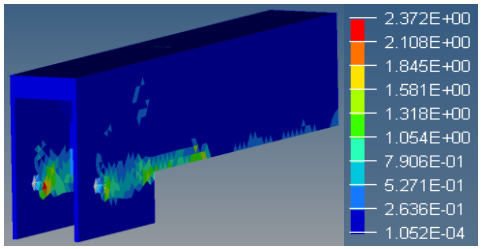
➢ Vertical load

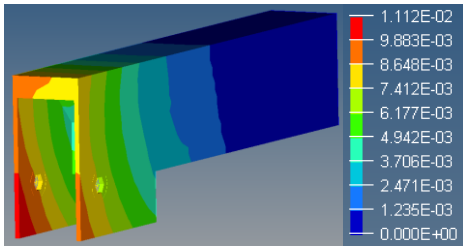




Max Von-mises stress : **129.80Mpa < 163.30Mpa** Max displacement : **2.075mm < 2.950mm**

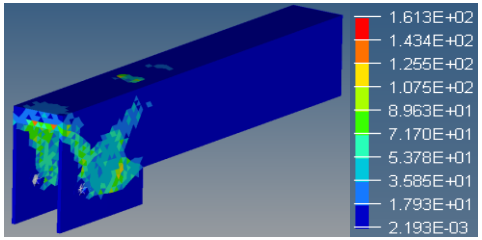
➢ Horizontal load

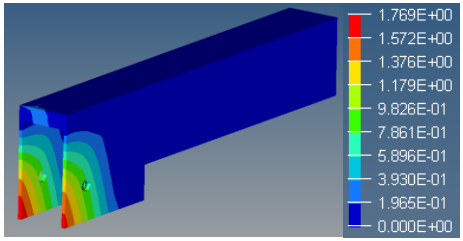




Max Von-mises stress : **0.697Mpa < 163.30Mpa** Max displacement : **0.011mm < 2.950mm**

➢ Lateral load





Max Von-mises stress : **161.30Mpa < 163.30Mpa** Max displacement : **1.769mm < 2.950mm**

Bending Analysis

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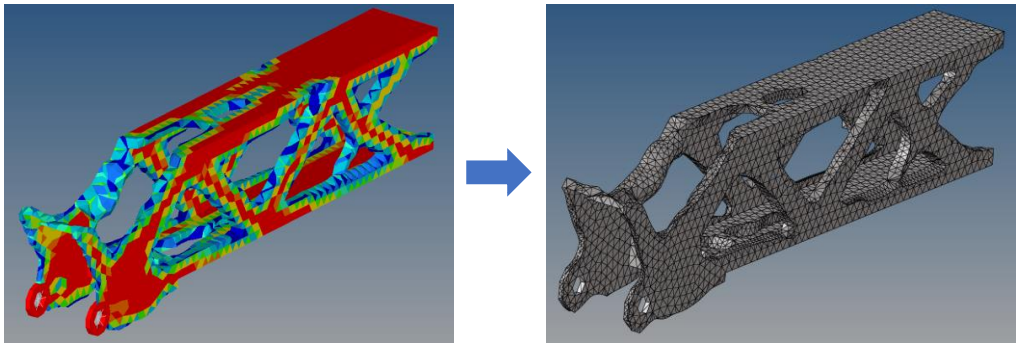
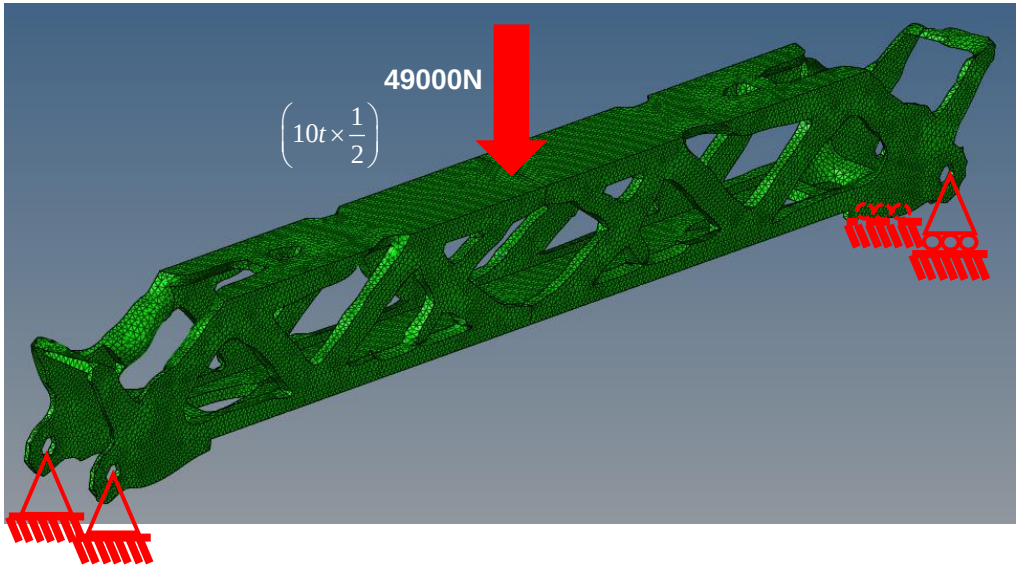
➢ 부피최적화 결과를 CAD 파일로 추출하기 : OSSmooth



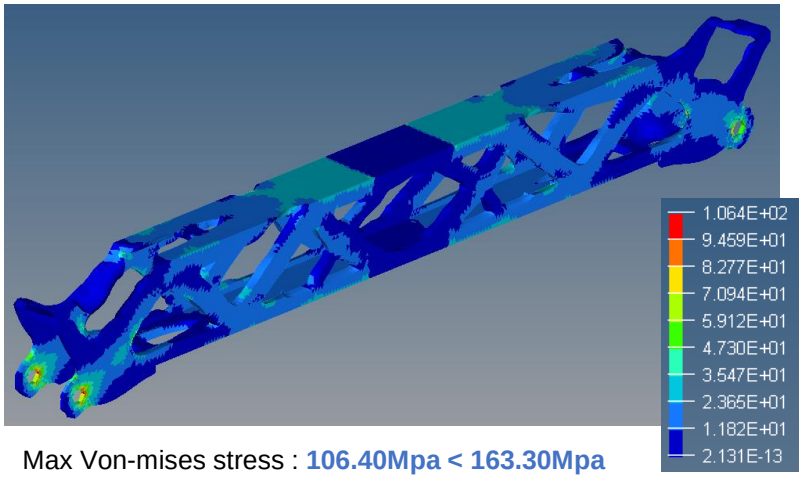
매쉬 대칭

Mesh size	Mesh type
10	3D tetras

➢ 구속 및 하중조건

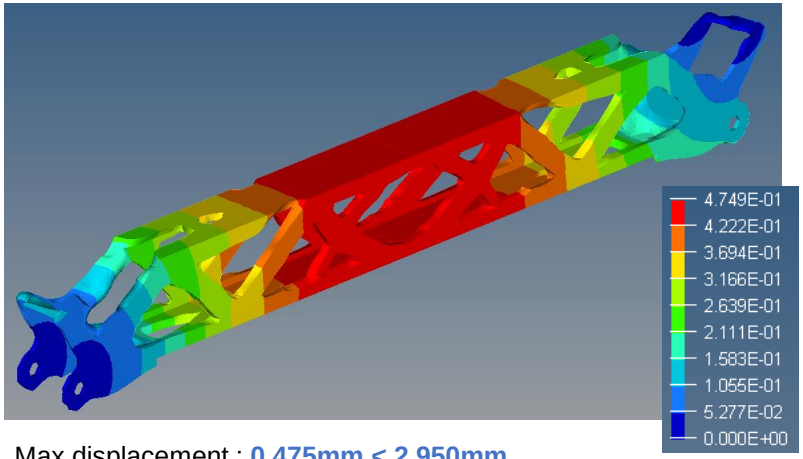


➢ Contour Plot of Element Stresses (vonMises)



Max Von-mises stress : **106.40Mpa < 163.30Mpa**

➢ Contour Plot of Displacement



Max displacement : **0.475mm < 2.950mm**

Frequency Response Analysis

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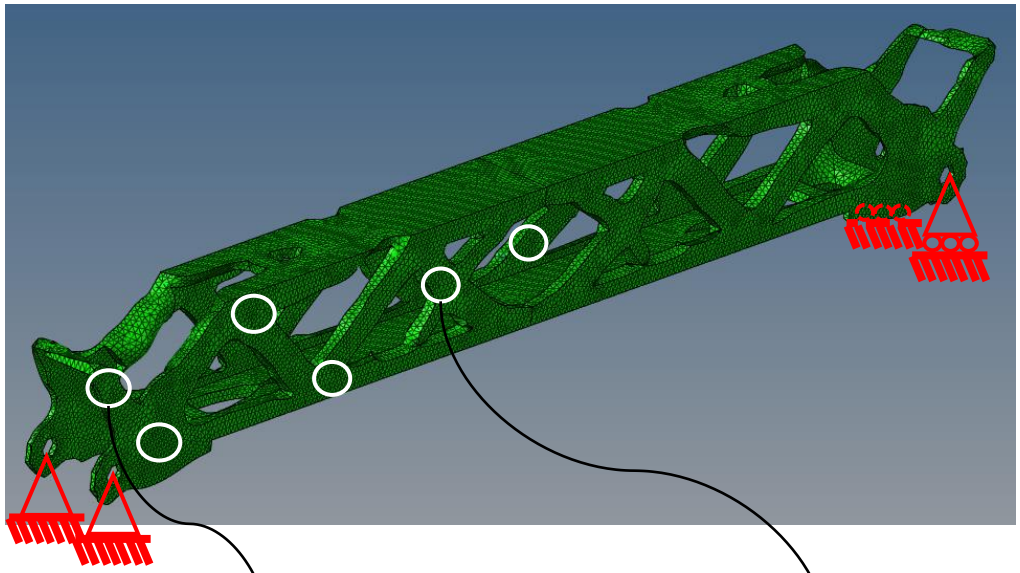
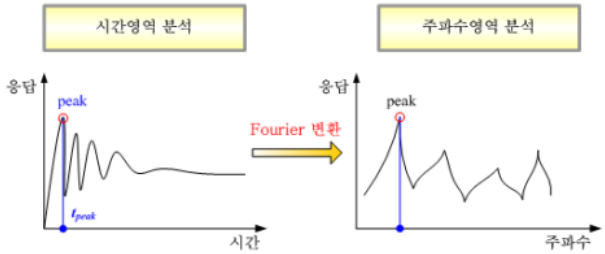
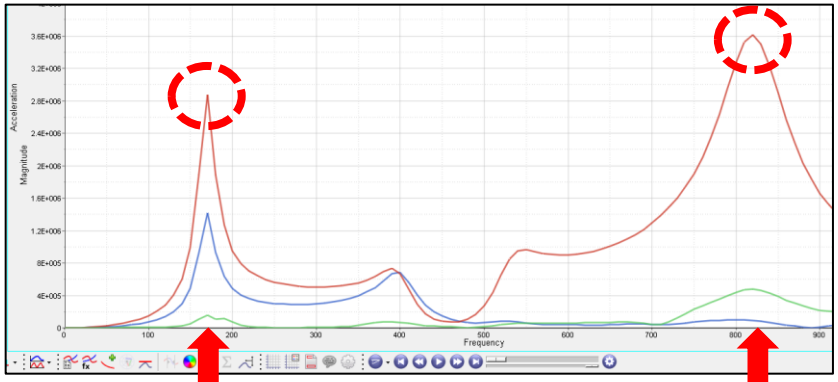
➢ 주파수 응답해석 수행



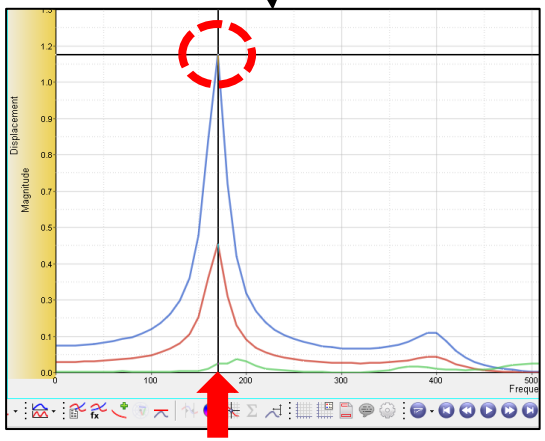


➢ Acceleration



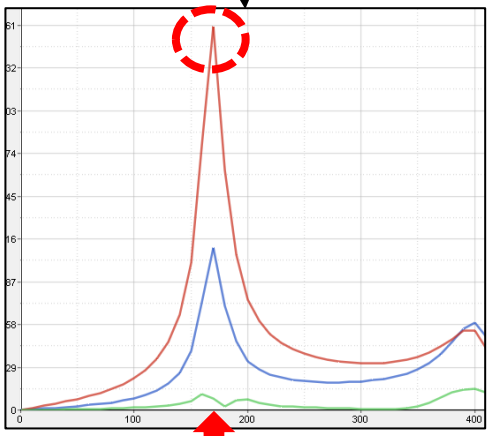
170Hz 820Hz

➢ Displacement



170Hz

➢ Velocity



170Hz

➢ Overhead crane의 모터

한국 모터

상용주파수(Hz)

60Hz

50Hz (외국)

Comparison with Reference

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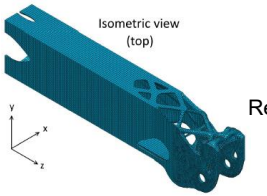
➢ **참고논문과 비교** (참고논문과 최대한 비슷하게 조건을 부여하였을때 결과값 비교하려함)

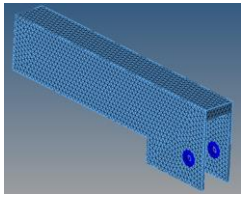
항목	변경 전	변경 후(논문조건)
설계변수	요소 형상 밀도	요소 형상 밀도
목적함수	Volume 최소화	Compliance 최소화
구속조건	응력 / 변위	응력
Boundary & Loading	6Page 동일	6Page 동일
재료물성	SS400	S355

Matrerial Property	SS400	S355
Yield Stress	245Mpa	355Mpa
Young's modulus	204.08Gpa	200Gpa
Poisson's ratio	0.3	0.3
Density	7959(kg/m^3)	7850(kg/m^3)

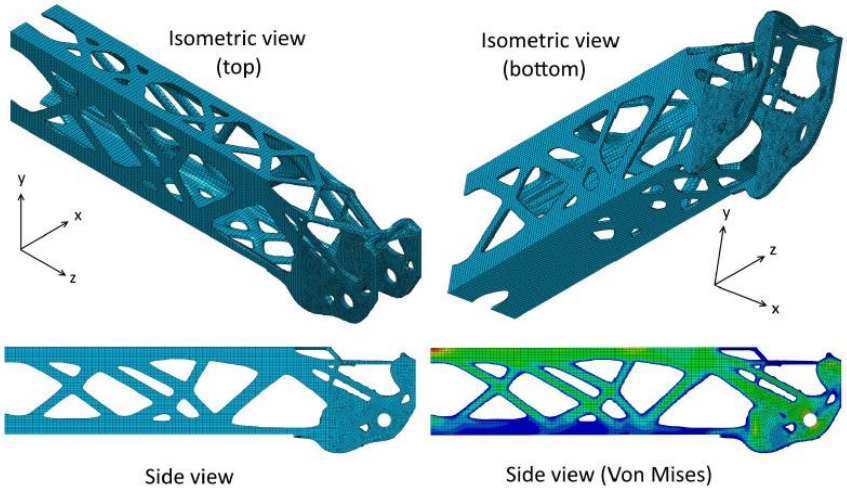
➢ **참고논문**

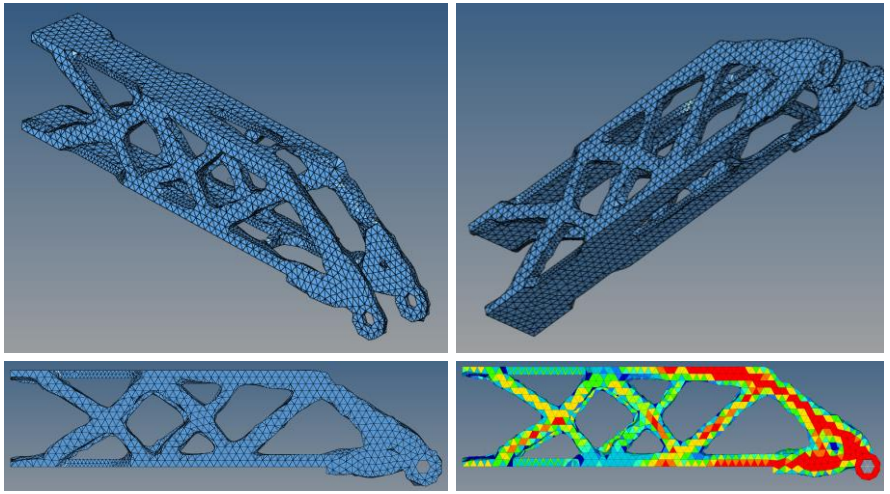


Reference's initial shape



My project's initial shape





Max Von-mises stress : **332.54Mpa < 335Mpa**

Max Von-mises stress : **333.90Mpa < 335Mpa**

형상의 크기와, 하중조건만을 참고하고자 했기에 제가 수행한 프로젝트와 참고논문을 비교하기엔 어려움이 있었습니다.
하여 논문에서 제시해 준 조건을 부여하였을 때 결과값이 차이가 어떻게 되는지를 비교해보았습니다.

Conclusion

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➢ 참고문헌

Universitetet i Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

MASTER'S THESIS

Study programme/specialisation: Engineering Structures and Materials Specialisation: Structural engineering	Spring semester, 2018 Confidential
Author: Eirik Hartveit-Schee	(signature of author)
Faculty supervisor: Assoc. Prof. Ove K. Mikkelsen External supervisor: Atle Sjølyst-Kverneland, T. Kverneland & Sønner AS	
Title of master's thesis: Topology optimization of crane component	

참고문헌	My Project
• 목적 함수 : compliance 최소화 • 설계 변수 : 요소 형상 밀도 • 구속 조건 : 응력 S355 (Yield stress 355Mpa, EN)	• 목적 함수 : 부피 최소화 • 설계 변수 : 요소 형상 밀도 • 구속 조건 : 응력 / 변위 SS400 (Yield stress 245Mpa, KR)
목적 1. 전통 제조용 개념 디자인 목적 2. 적층 제조용 개념 디자인	목적 1. 위상최적화 결과의 타당성 목적 2. 주파수 응답 해석 ➔ 모터고려

[PDF] Topology optimization of crane component
E Hartveit-Schee - 2018 - uis.brage.unit.no

Thank you

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