E 바퀴

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Contents

주제 선정 배경

1

주제 선정 배경

Wheel Mass / Inertia 감소 => Effective

E ffective + 바퀴 (Wheel)

설계 과정

2

설계 과정 재료 선정

Physical Properties	Metric
Density	2.7 g/cc
Mechanical Properties	
Hardness, Rockwell B	60
Hardness, Vickers	107
Ultimate Tensile Strength	310 MPa
Tensile Yield Strength	276 MPa
Elongation at Break	12 %
Modulus of Elasticity	68.9 GPa
Poisson's Ratio	0.33
Fatigue Strength	96.5 MPa

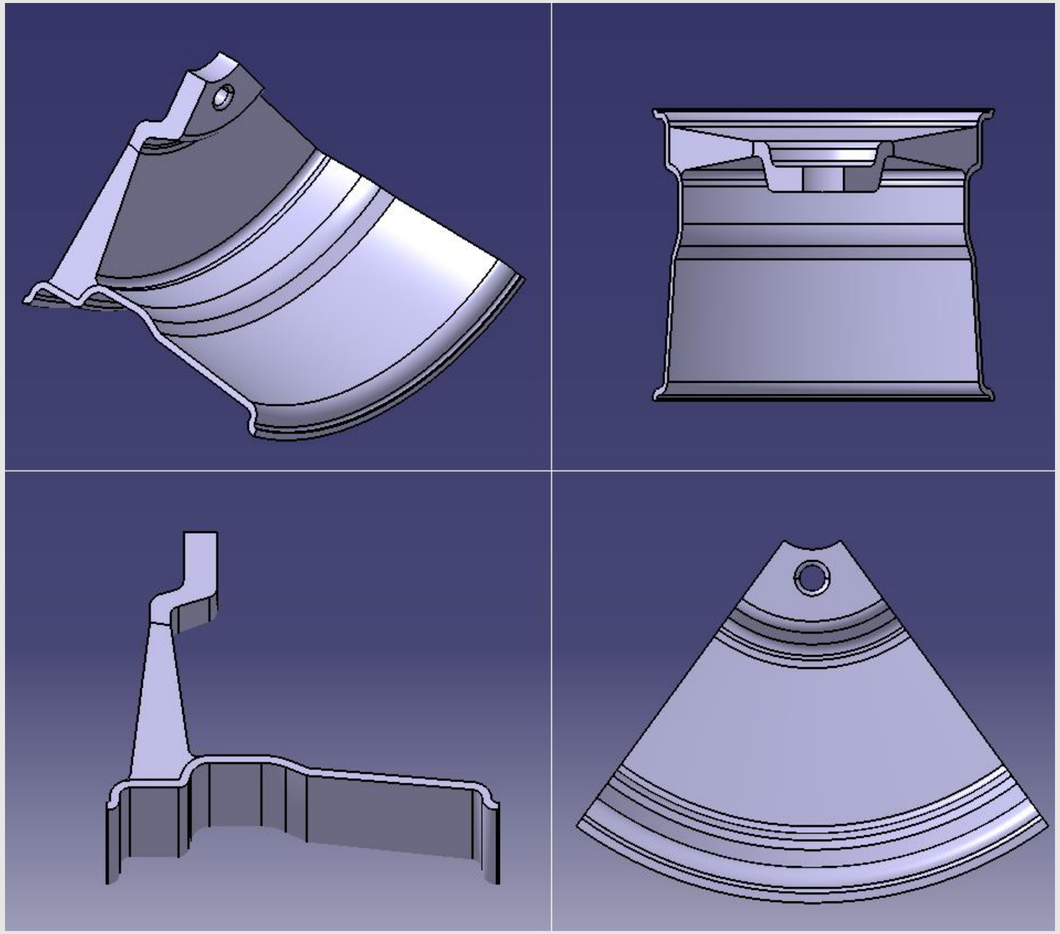
6061 T6 Aluminum Alloy

Yielding Strength : 276 MPa

Fatigue Strength : 96.5 MPa

2

설계 과정 기반 모델 설계



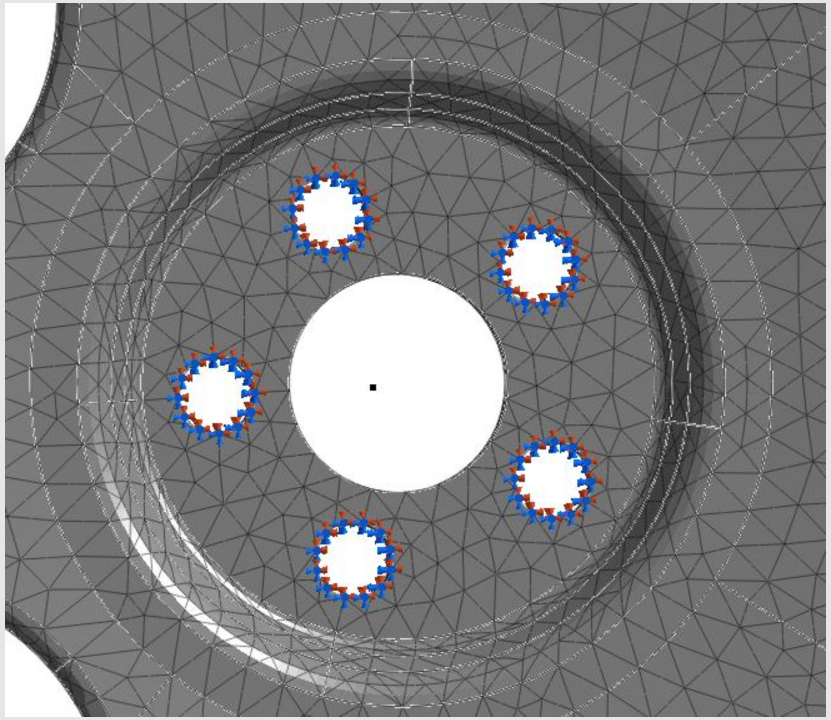
- 휠 1/5 모델 (대칭 조건)

  림 스포크의 개수를 5개

  지면의 하중을 모두 지지

2

설계 과정 하중/구속 조건



2 설계 과정 하중/구속 조건

Table 3.2 Load case – defined load cases

Load case	Forces
Vertical impact	$F_{W,Z} = 9785.48\ N$
Cornering outside wheel	$F_{W,Z} = 6523.65\ N$ $F_{W,Y} = 6523.65\ N$
Cornering inside wheel	$F_{W,Y} = -3261.83\ N$ $F_{W,Z} = 3261.83\ N$
Braking front wheel	$F_{W,Z,f} = 6523.65\ N$ $F_{W,X,b,f} = 4892.74\ N$
Braking rear wheel	$F_{W,Z,r} = 3261.83\ N$ $F_{W,X,b,r} = 2609.46\ N$
Acceleration rear wheel	$F_{W,Z,r} = 5871.29\ N$ $F_{W,X,a} = 4892.74\ N$

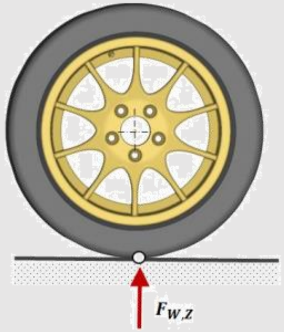


Fig. 3.4 Load case - "Vertical impact"

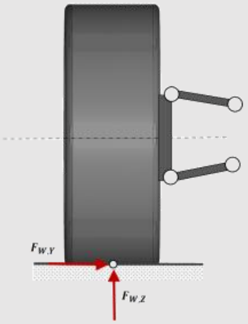


Fig. 3.5 Load case - "Cornering"

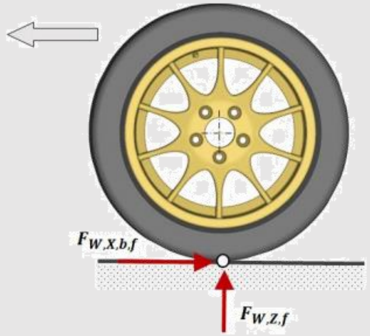
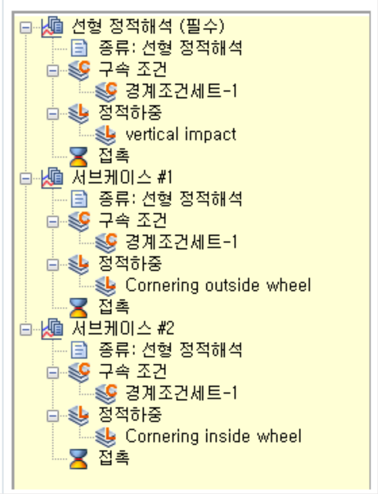
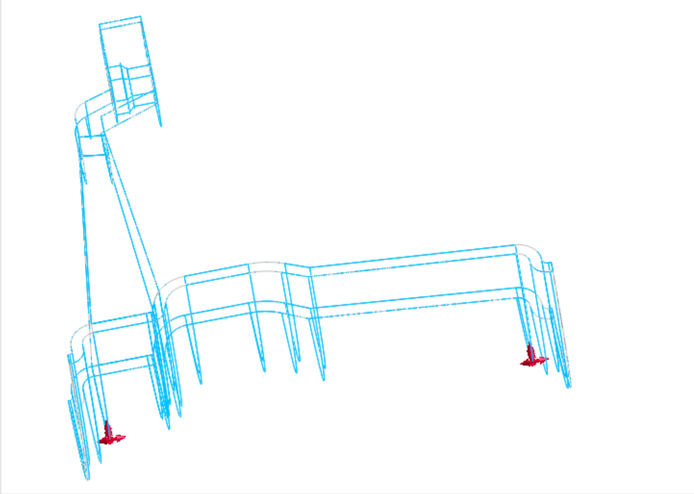


Fig. 3.6 Load case - "Braking"

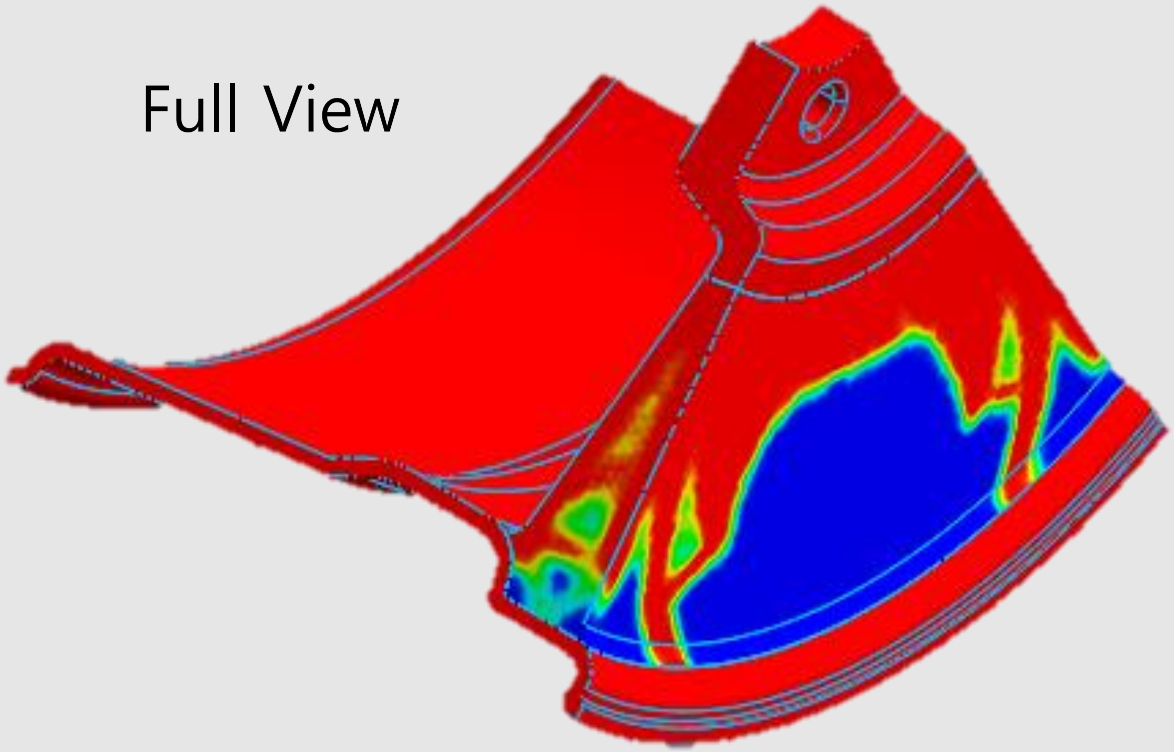


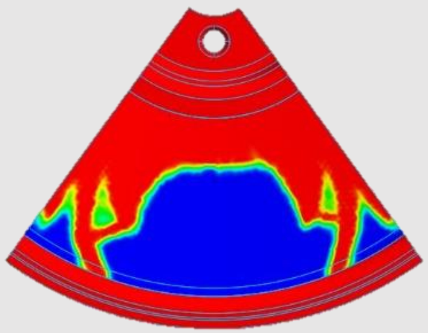


2

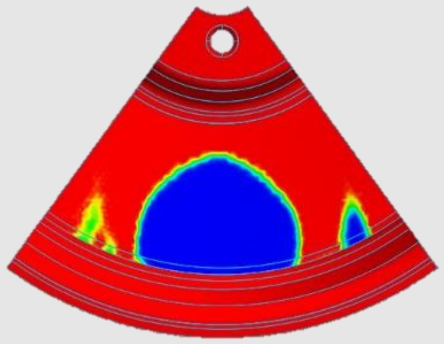
설계 과정 위상 최적화

Full View

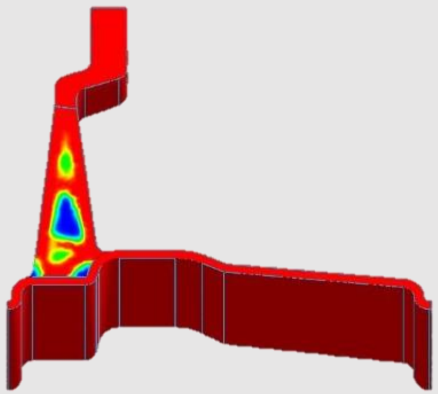




Front

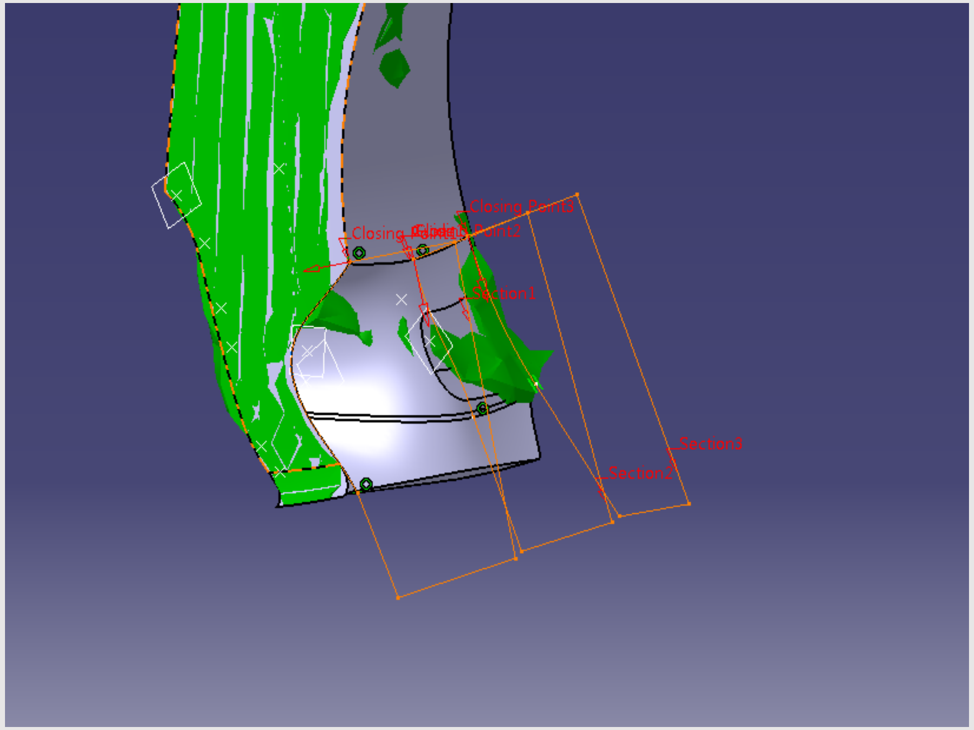


Back

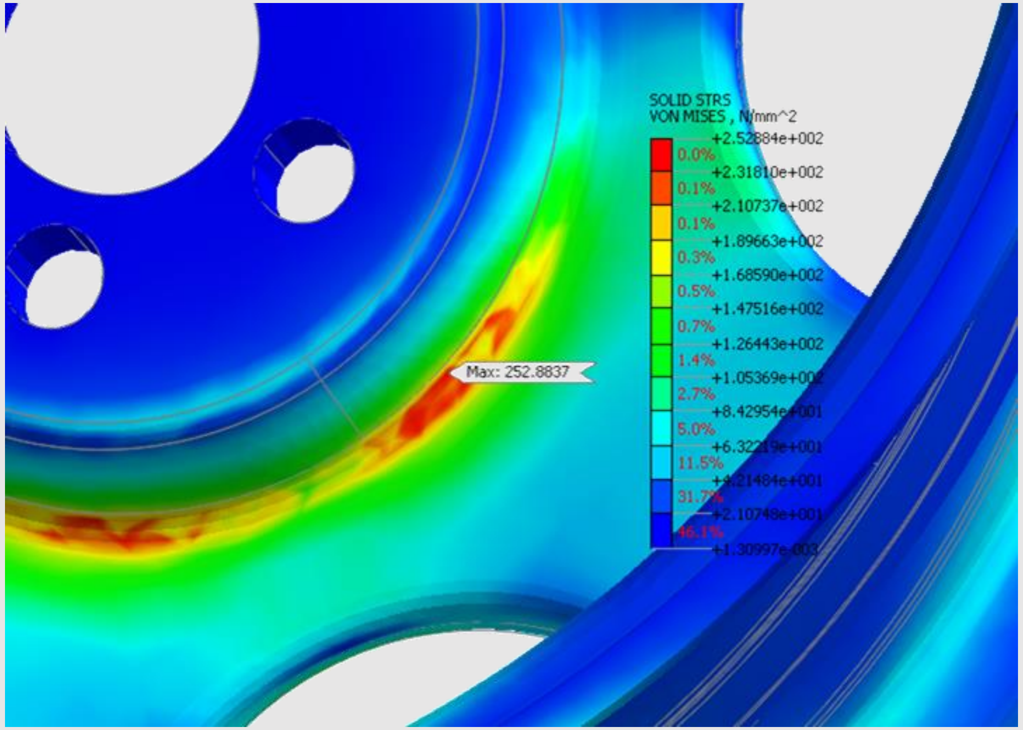


Side

2 설계 과정 결과 기반 형상 설계



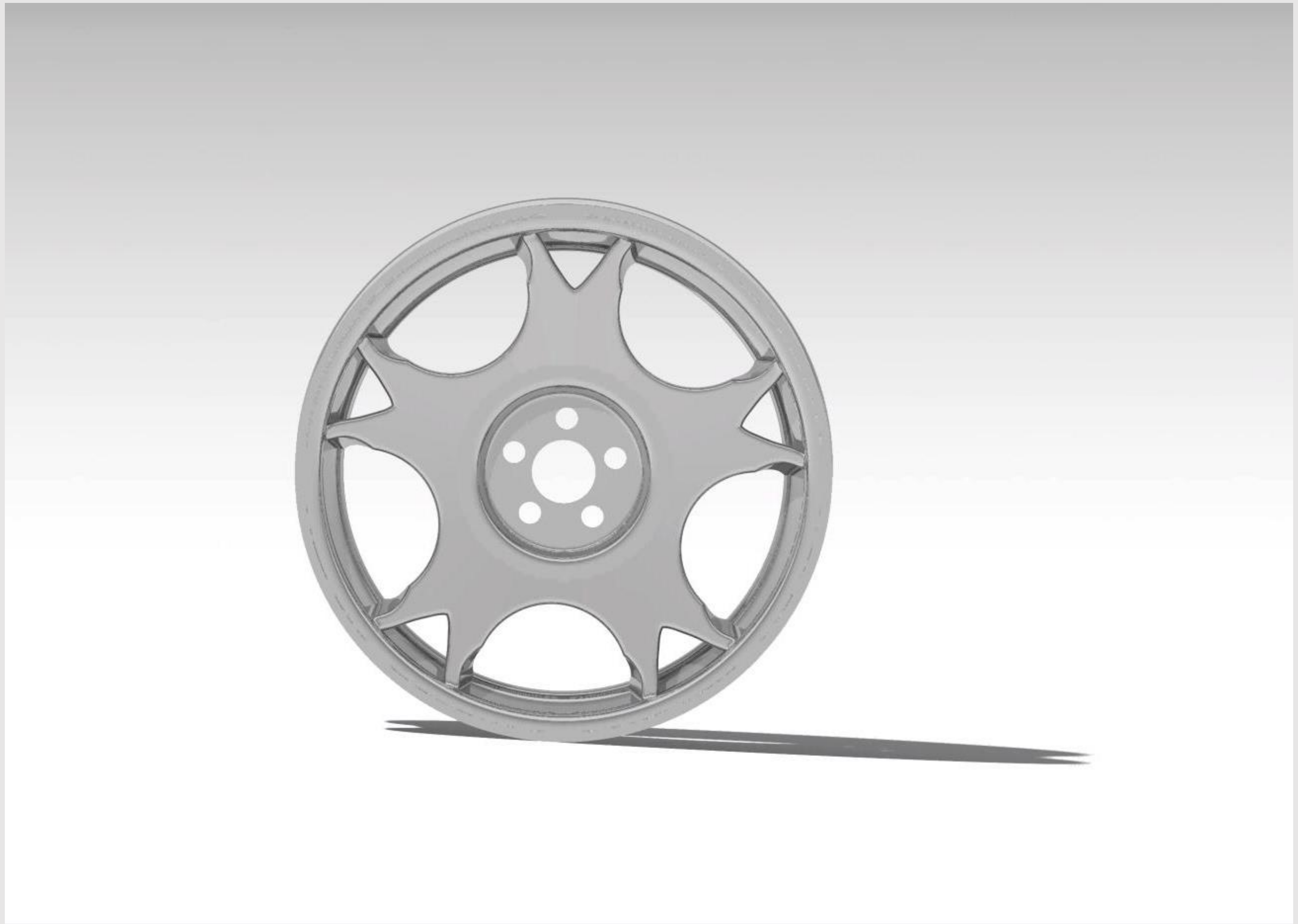
Multi Section 형상 모델링

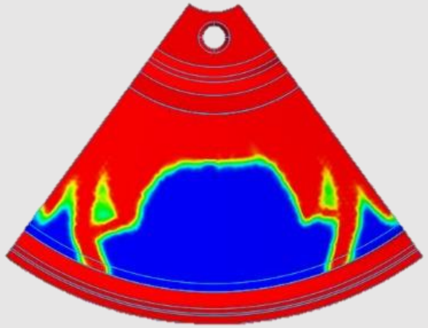


해석을 통한 취약 부위 보강

2

설계 과정 결과 기반 형상 설계





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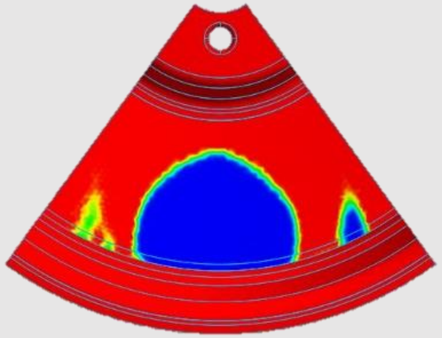
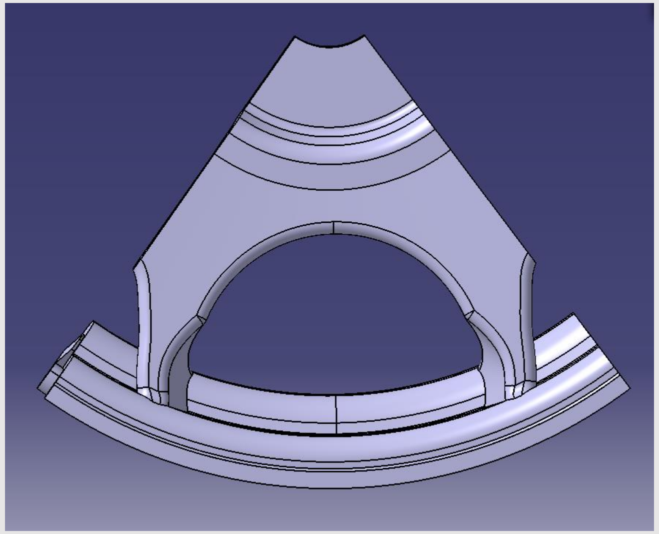


Back

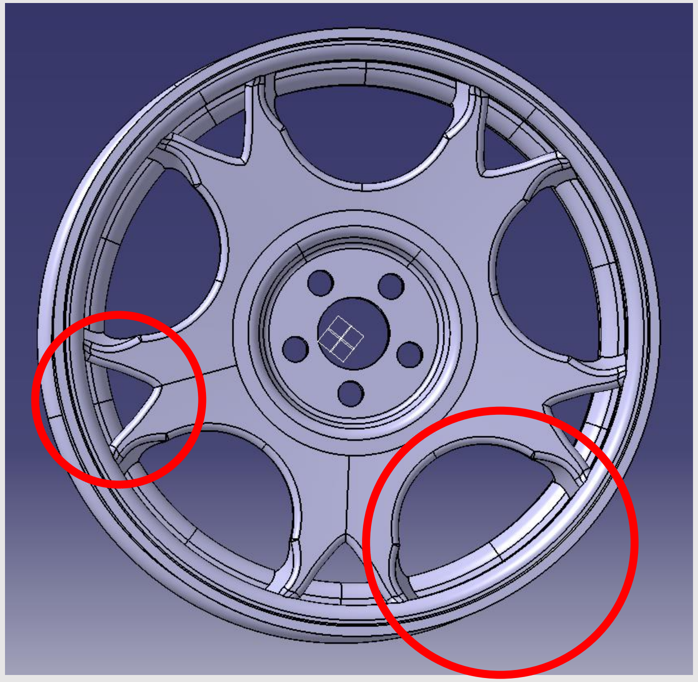
결과 분석

3

결과 분석 설계 특징

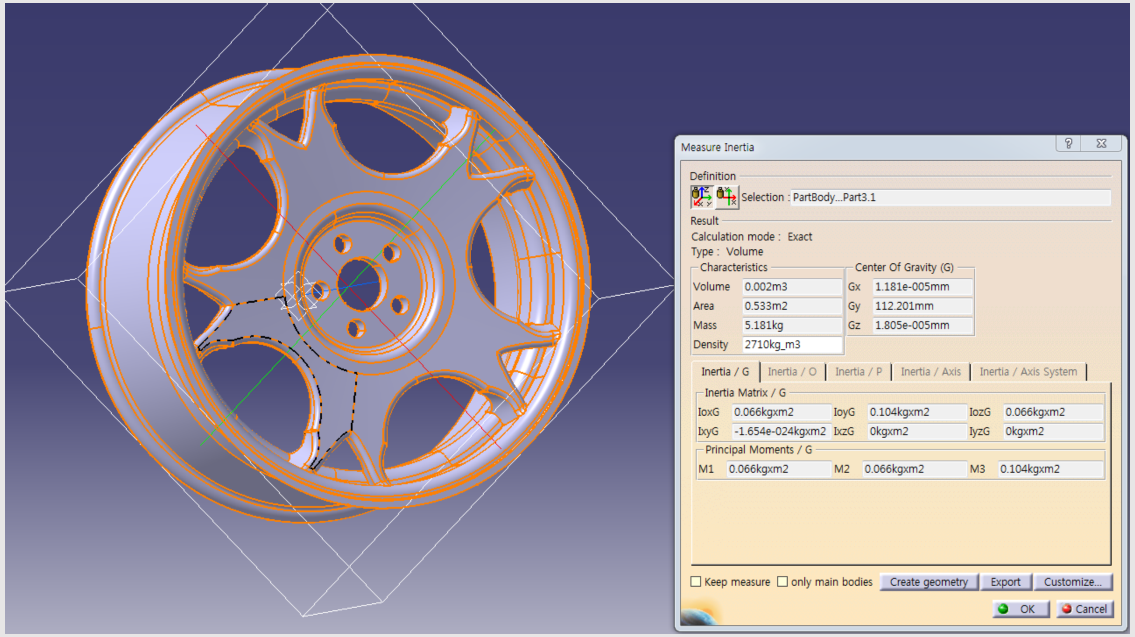


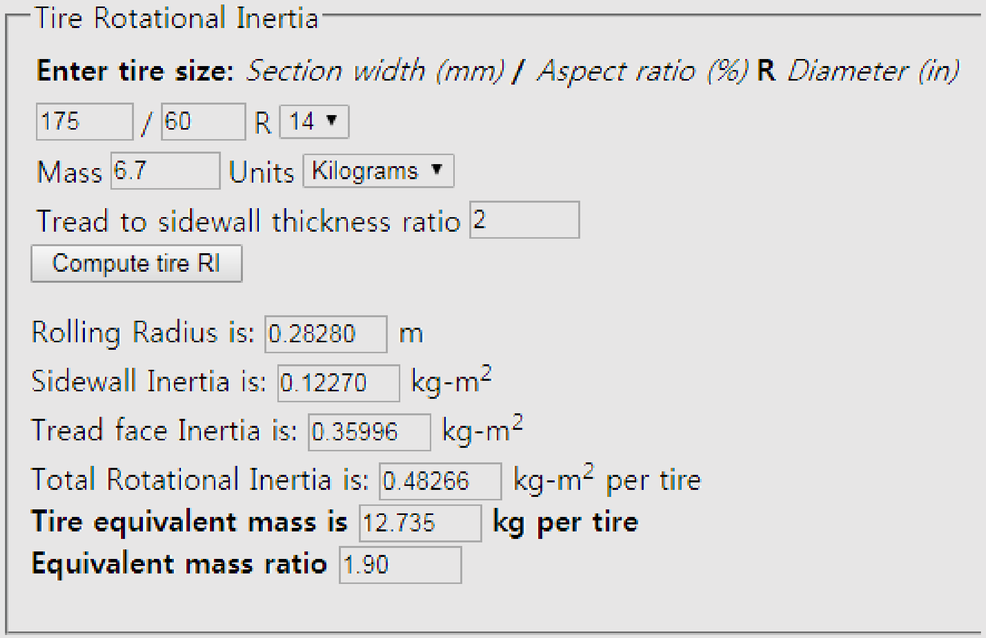
내외측 비대칭 설계



자유로운 형상
두개의 아치 구
조

3 결과 분석 Inertia / Mass 측정





Wheel & Tire inertia : 0.8 -> 0.104 + 0.48 = 0.6 kgm2

mass : 6.7 -> 5.181kg

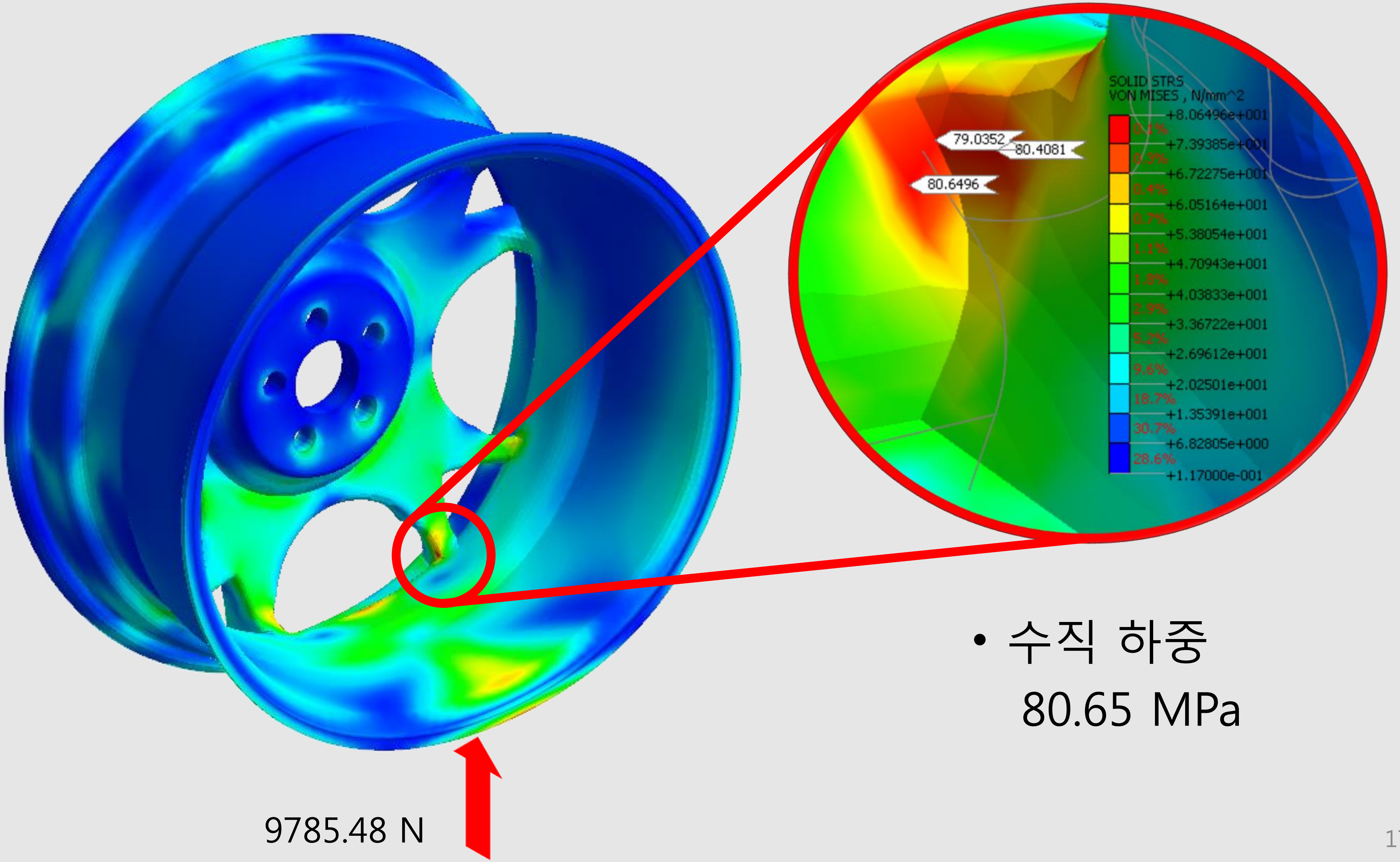
3

결과 분석 안정성 분석 기준

- 최대 von mises 응력 < 276 Mpa
- 96.5MPa 이상일 때 5e8 cycle의 무한수명 확보
- Modal 1^{st} frequency >350 Hz

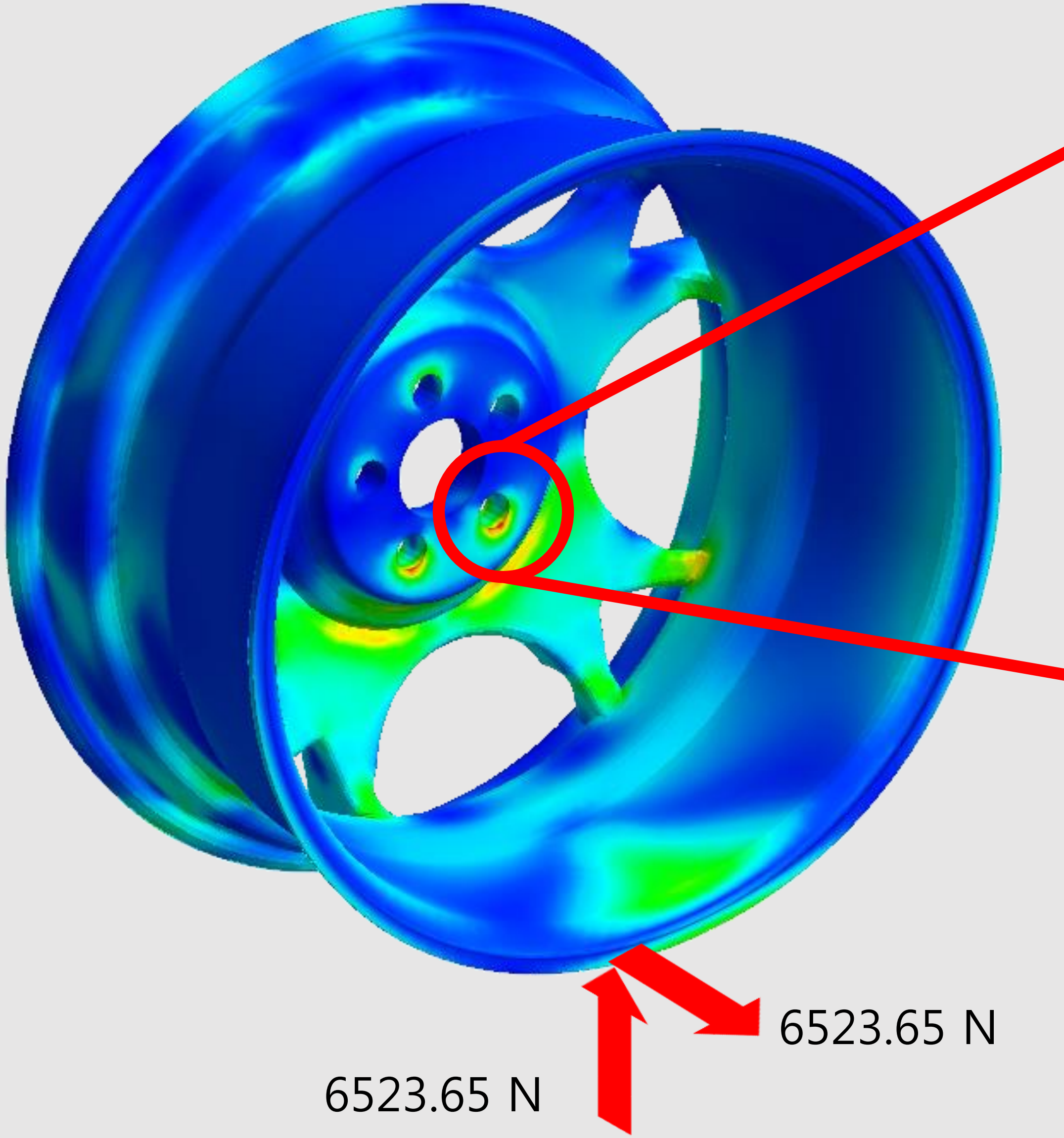
Physical Properties	Metric
Density	2.7 g/cc
Mechanical Properties	
Hardness, Rockwell B	60
Hardness, Vickers	107
Ultimate Tensile Strength	310 MPa
Tensile Yield Strength	276 MPa
Elongation at Break	12 %
Modulus of Elasticity	68.9 GPa
Poisson's Ratio	0.33
Fatigue Strength	96.5 MPa

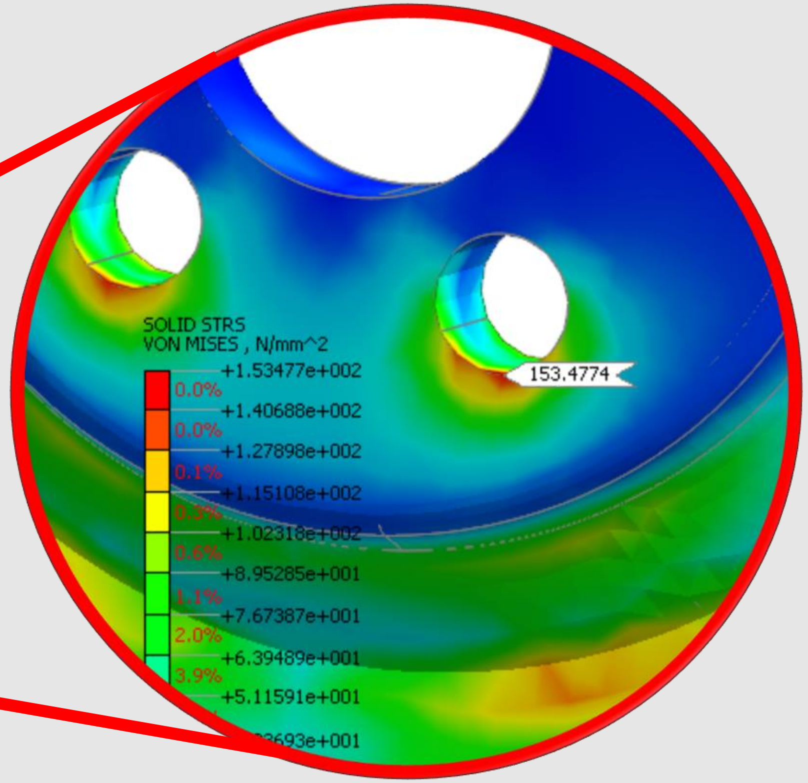
결과 분석 응력 분석



- 수직 하중
  80.65 MPa

결과 분석 응력 분석

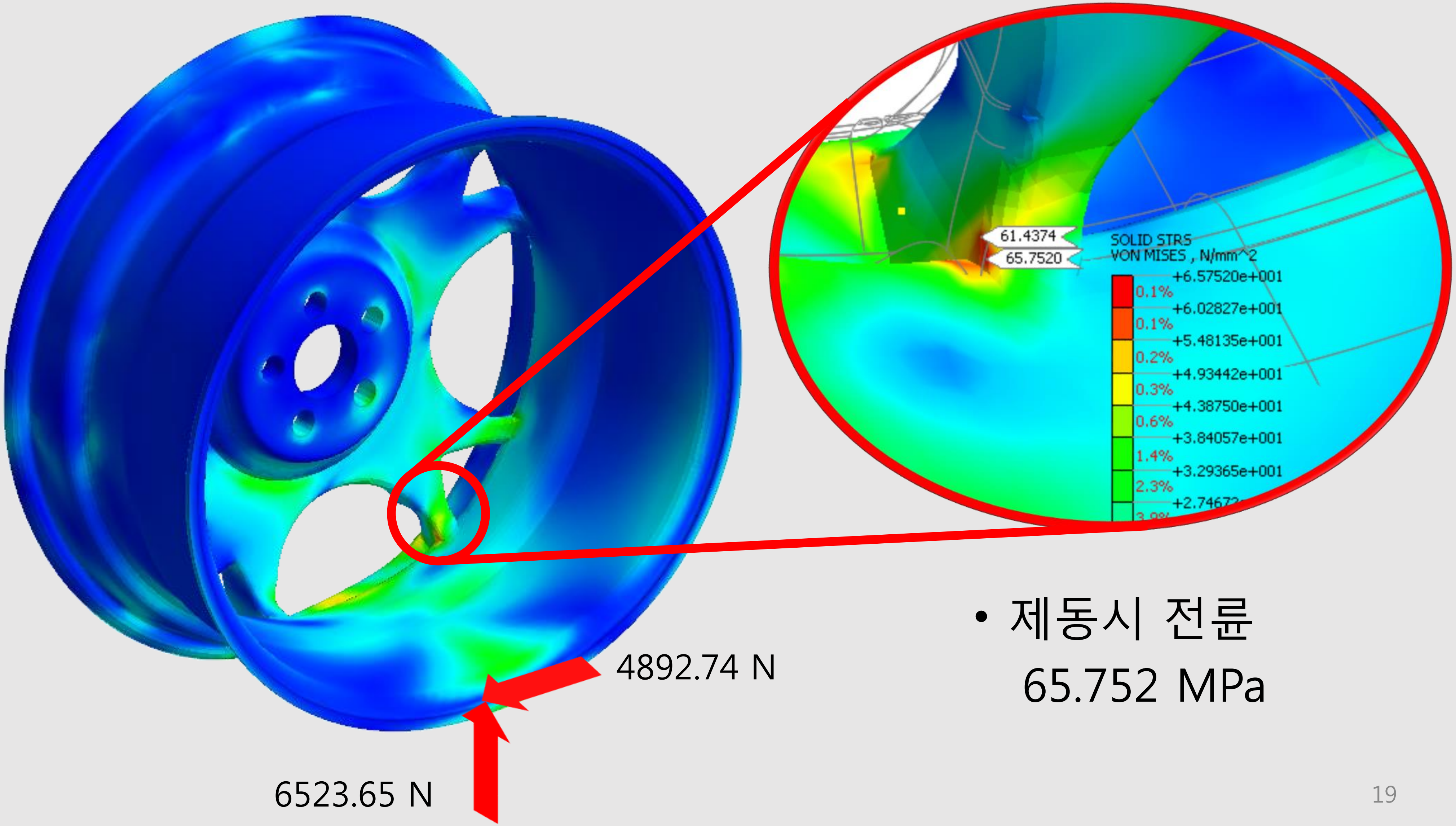




- 코너링 외측 바퀴
  153.477 MPa

3

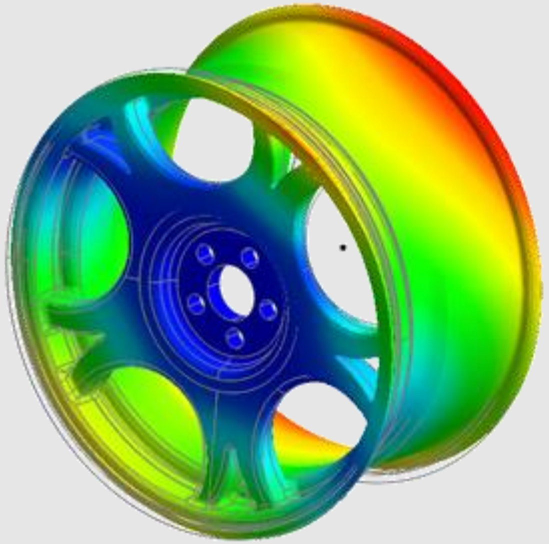
결과 분석 응력 분석

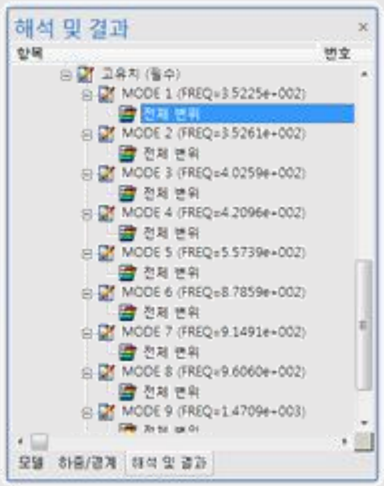


- 제동시 전륜
  65.752 MPa

결과 분석 모드 분석

목표 : 350 Hz





No. Natural frequency	B type		C type		D type	
	Natural frequency [Hz]	Damping ratio [%]	Natural frequency [Hz]	Damping ratio [%]	Natural frequency [Hz]	Damping ratio [%]
1st	372	0.213	326	0.268	311	0.186

설계 Wheel 1st frequency

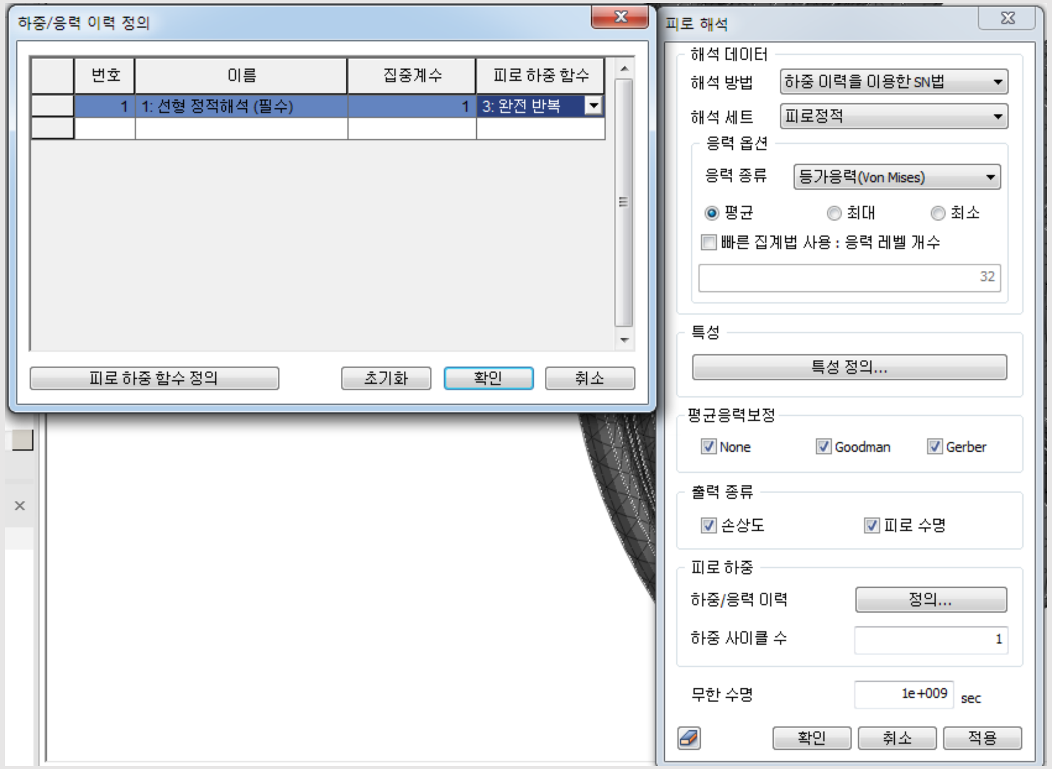
352.25 Hz

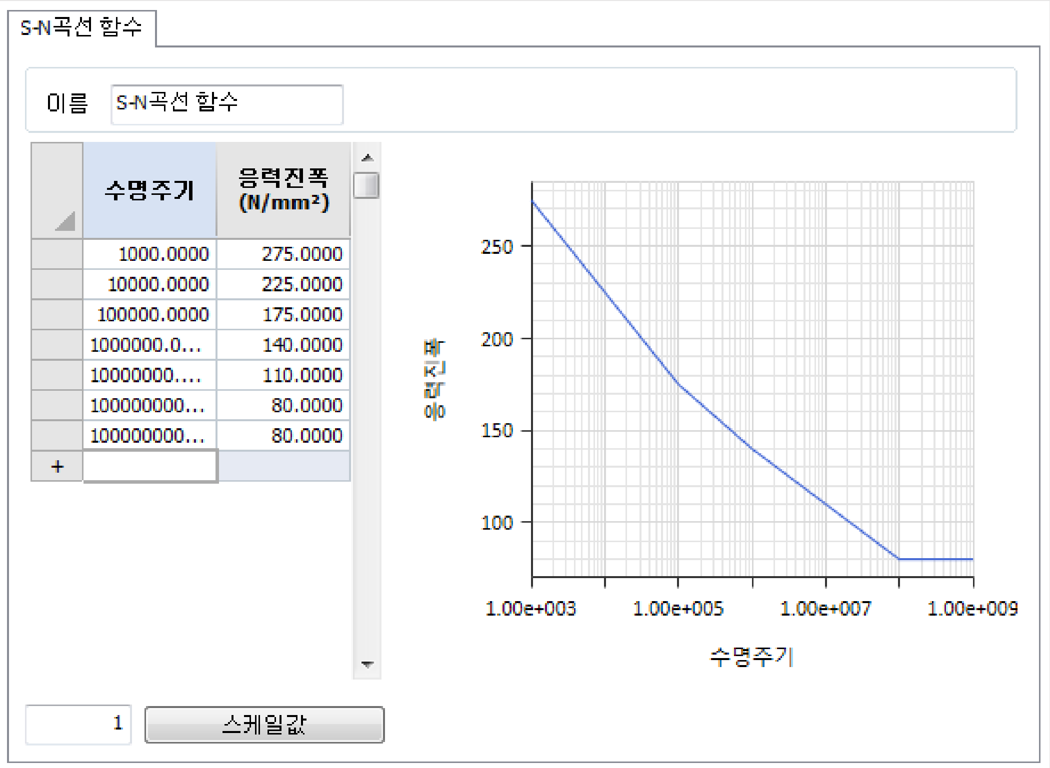
국내 휠의 1st frequency

311 – 372 Hz

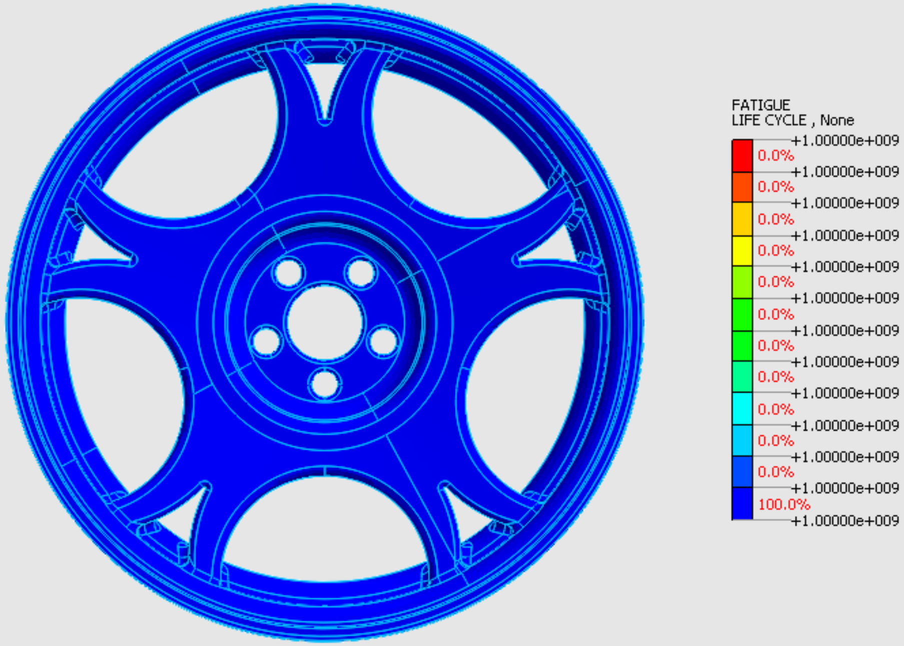
3

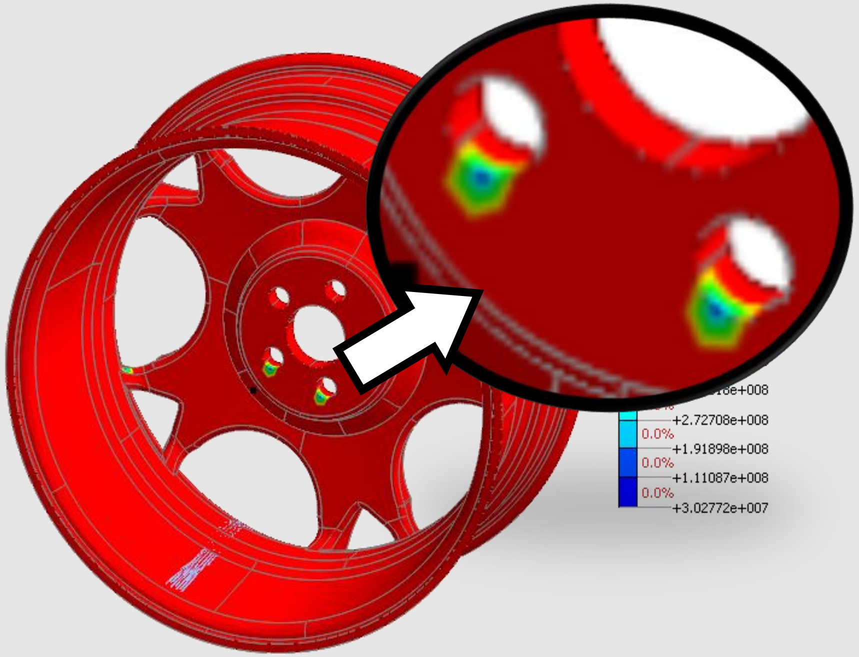
결과 분석 피로 분석


하중/응력 이력 정의
번호
이름
집중계수
피로 하중 함수
1
1: 선형 정적해석 (필수)
1
3: 완전 반복
피로 하중 함수 정의
초기화
확인
취소
피로 해석
해석 데이터
해석 방법
하중 이력을 이용한 SN법
해석 세트
피로정적
응력 옵션
응력 종류
등가응력(Von Mises)
평균
최대
최소
빠른 집계법 사용 : 응력 레벨 개수
32
특성
특성 정의...
평균응력보정
None
Goodman
Gerber
출력 종류
손상도
피로 수명
피로 하중
하중/응력 이력
정의...
하중 사이클 수
1
무한 수명
1e+009
sec
확인
취소
적용


S-N곡선 함수
이름
S-N곡선 함수
수명주기
응력진폭 (N/mm²)
1000.0000
275.0000
10000.0000
225.0000
100000.0000
175.0000
1000000.0...
140.0000
10000000....
110.0000
100000000...
80.0000
100000000...
80.0000
250
200
150
100
1.00e+003
1.00e+005
1.00e+007
1.00e+009
수명주기
1
스케일값

결과 분석 피로 분석



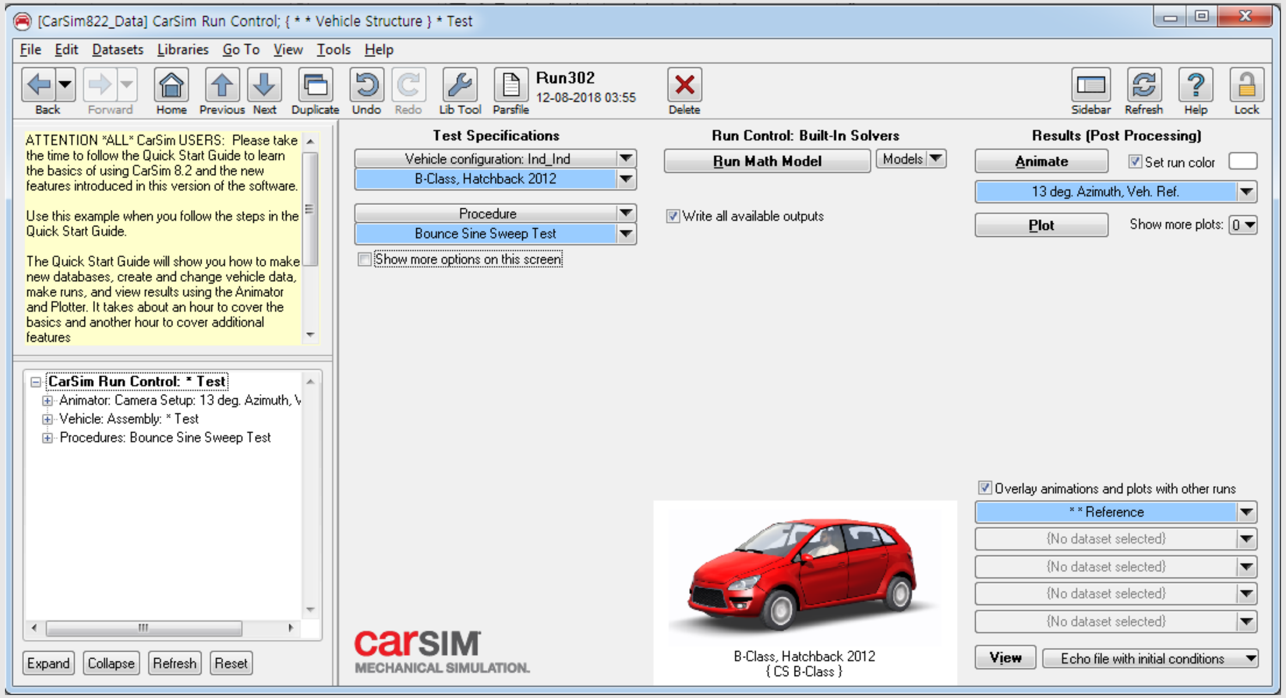


수직 충격
1e9 cycle (무한수명)

코너링 외측 바퀴
3e7 cycle

결과 분석 Performance 분석

- CarSim을 통한 Bounce Test

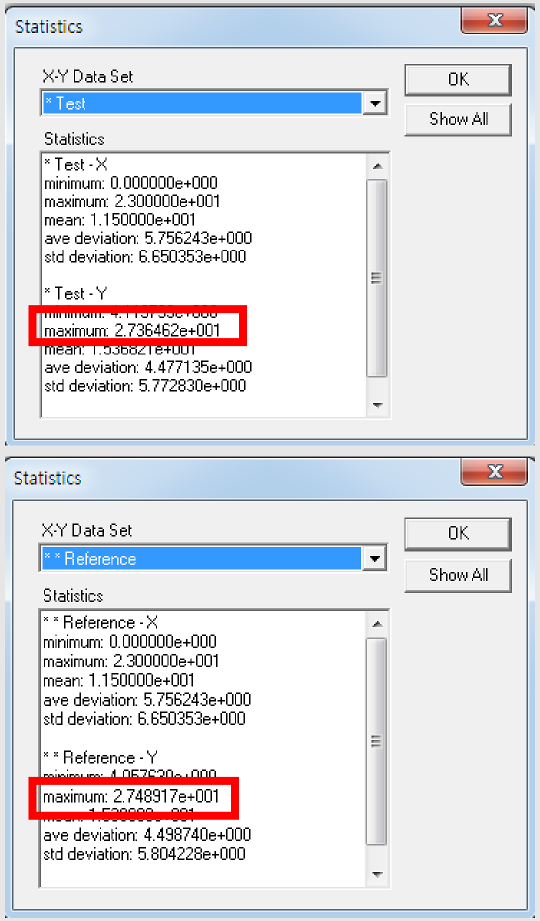


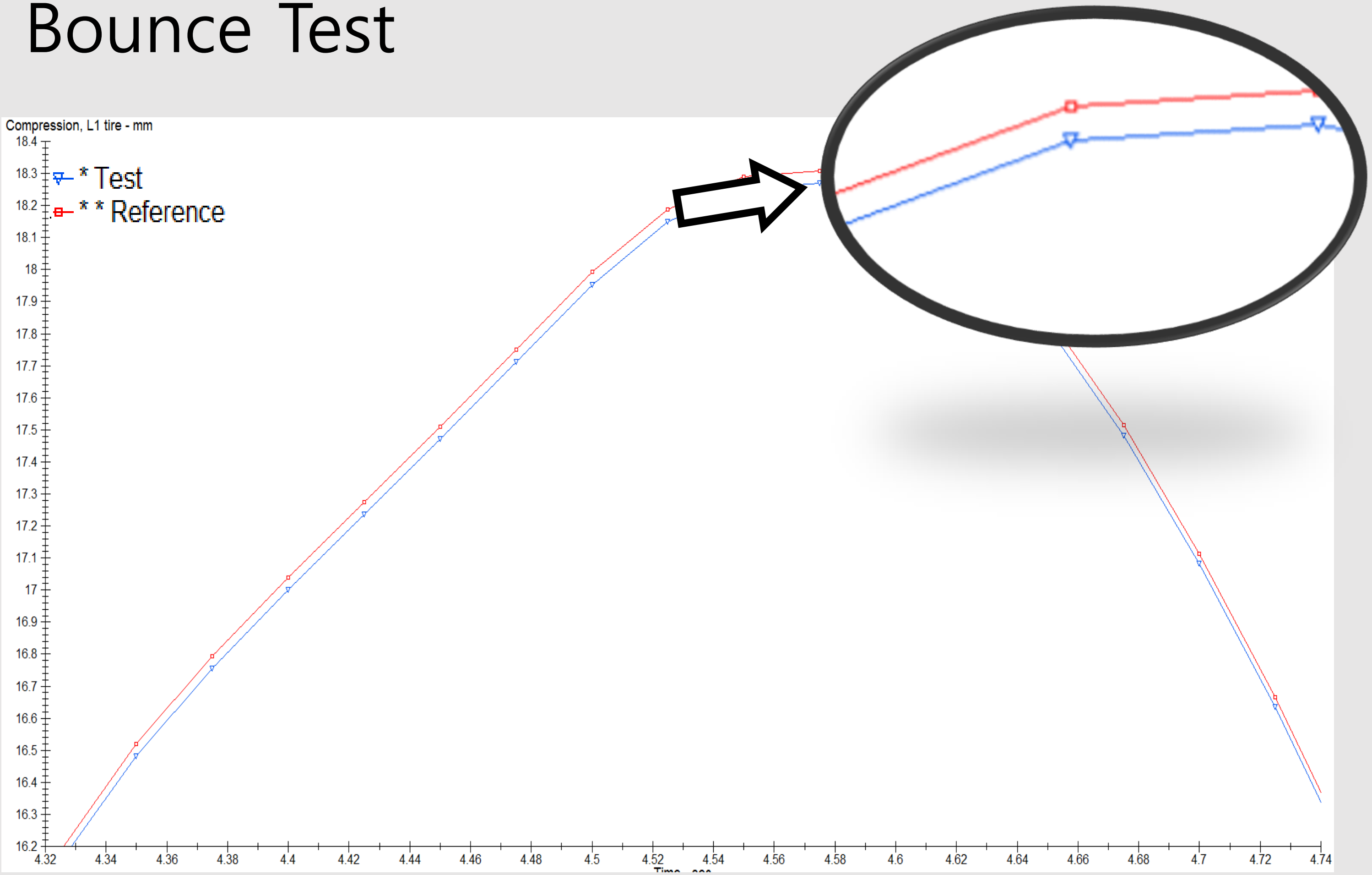
Reference Model
Tire inertia 0.8kgm2
Unsprung mass 60kg

Optimized Model
Tire inertia 0.6kgm2
Unsprung mass 58.5kg

결과 분석 Performance 분석

- CarSim을 통한 Bounce Test

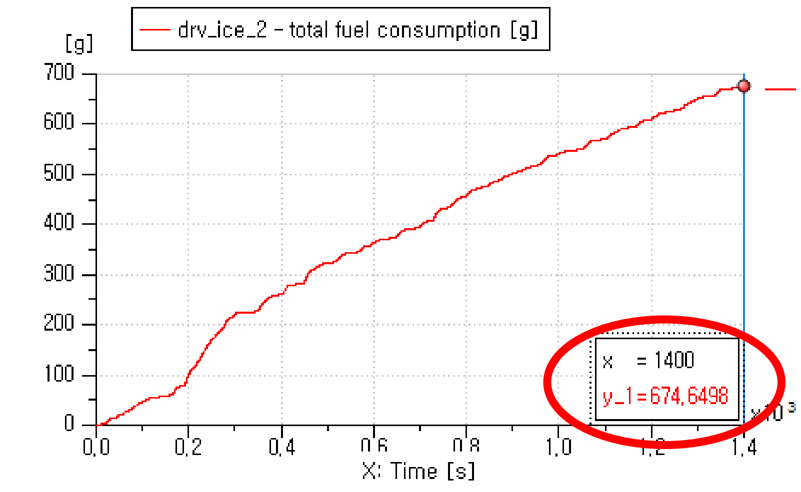


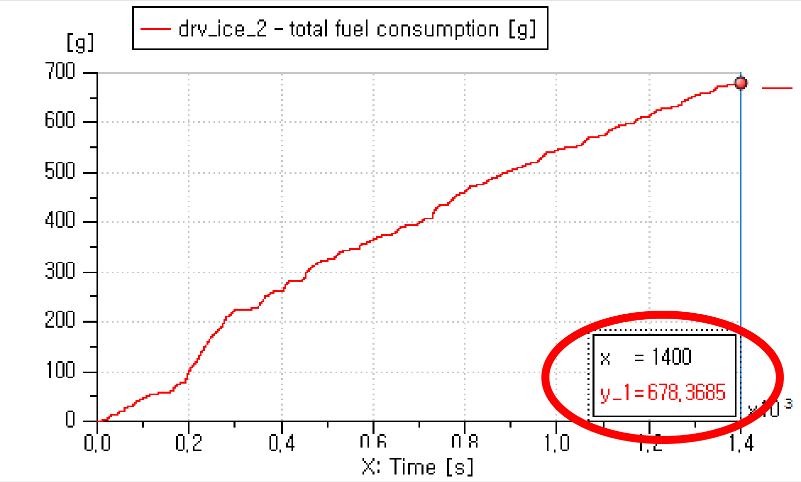


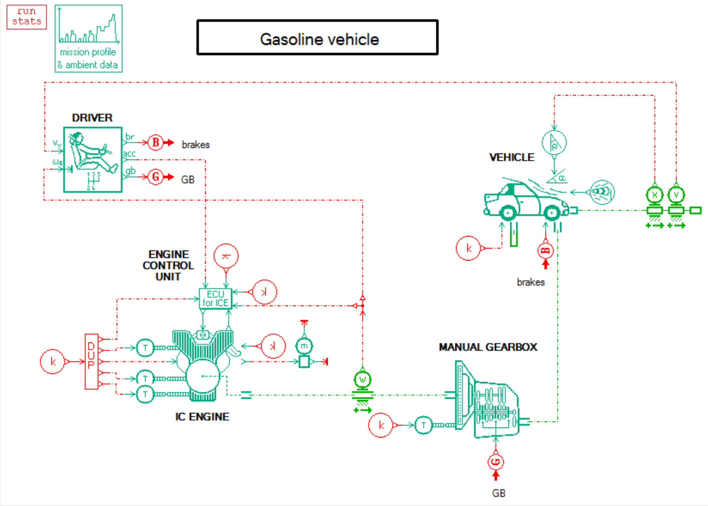
약 0.12mm Tire deflection 감소 : 접지 능력 향상

3 결과 분석 연비 분석

- AMESim Vehicle Model







Reference Model (Inertia 0.8kgm2)
678.3685 [g]

Optimized Wheel Model (Inertia 0.6kgm2)
674.6498 [g]

결론

4

결론

- 위상최적화를 통해 Wheel의 Mass 및 Inertia 감소
- 피로파괴 및 Yielding 안정성 , Mode 안정성 검증
- Mass 및 Inertia의 감소에 따른 차량 성능 및 연비 향상

4

Reference

- Tire의 inertia 계산
  - http://hpwizard.com/rotational-inertia.html
- 하중조건 및 위상최적화 Reference
  - Design of Automotive Road Racing Rim with Aid of Topology Optimization Laurent MARINI Slawomir KEDZIORA Faculty of Science, Technology and Communication University of Luxembourg, Campus Kirchberg, 6 rue Coudenhove-Kalergi
- 6061-T6 Aluminium Alloy S-N Curve
  - https://openi.nlm.nih.gov/detailedresult.php?img=PMC4003947_sensors-14-04364f8&req=4
- Wheel Modal Analysis
  - A LIGHT COMMERCIAL VEHICLE WHEEL DESIGN OPTIMIZATION for WEIGHT, NVH and DURABILITY CONSIDERATIONS 1M. YAMAN* , 1B.YEGIN 1 Ford Otosan, Turkey