

Thickness Minimization of Polyurethane Foam for Automobile Seat Product

Polyman

팀장: 최현준(화공) / 팀원: 심준섭(화공), 이영민(화공), 김기찬(화공)
지도교수: 김정현(화공) / 산업체멘토: 최권용(현대 자동차)

1. 연구목표

연구 배경



Polyurethane foam Seat

정적특성 (비주행시 성능)	- 착좌감	Sag factor Hysteresis Loss 영구압축률 반복압축변화율
동적특성 (주행시 성능)	- 안락감	진동전달률 응력완화

산업체 애로사항

경량화
↓
물성 저하



물성 향상
↓
밀도 증가

산업체 요구물성

(시편 규격: 70kg/m³, 50 × 50 × 25 mm³)

Hysteresis loss	15%이하
Sag factor	3.3이상
응력완화	20%이하
반복압축변화율	5%이하
영구압축줄임율	10%이하

산업체 애로사항 해결방안



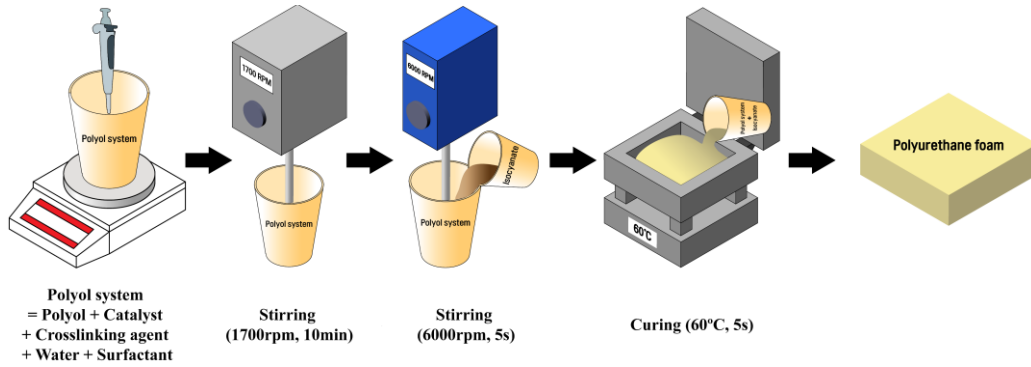
Comport property 향상

+

원료 배합 기술 가이드 확보
셀크기 제어 처방 확립

2. 연구내용

폴리우레탄 폼 제작 과정

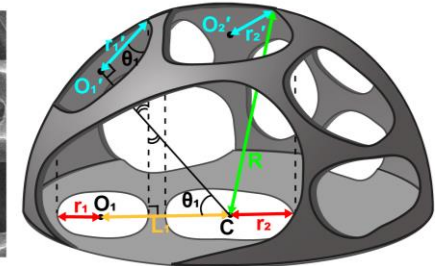
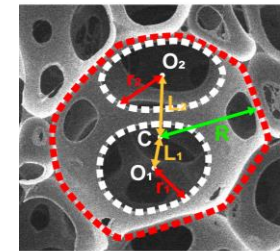
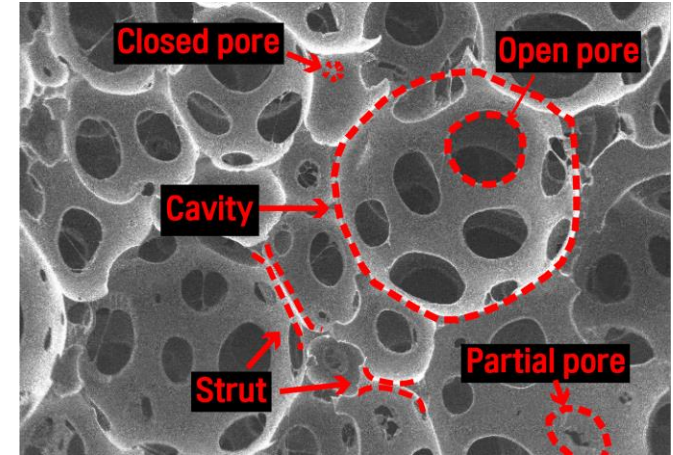


팀원의 아이디어를 바탕으로
첨가제의 효율을 증가시키는 공정 적용

기본적인 폴리우레탄 폼 제조

High disperse 공정을
통한 폴리우레탄 폼 제조

폴리우레탄 형태학 분석



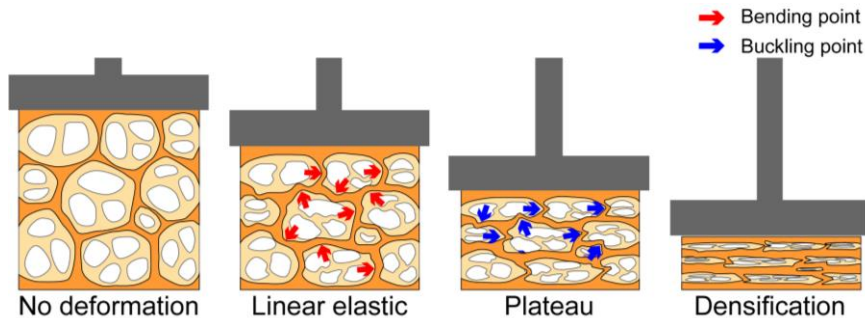
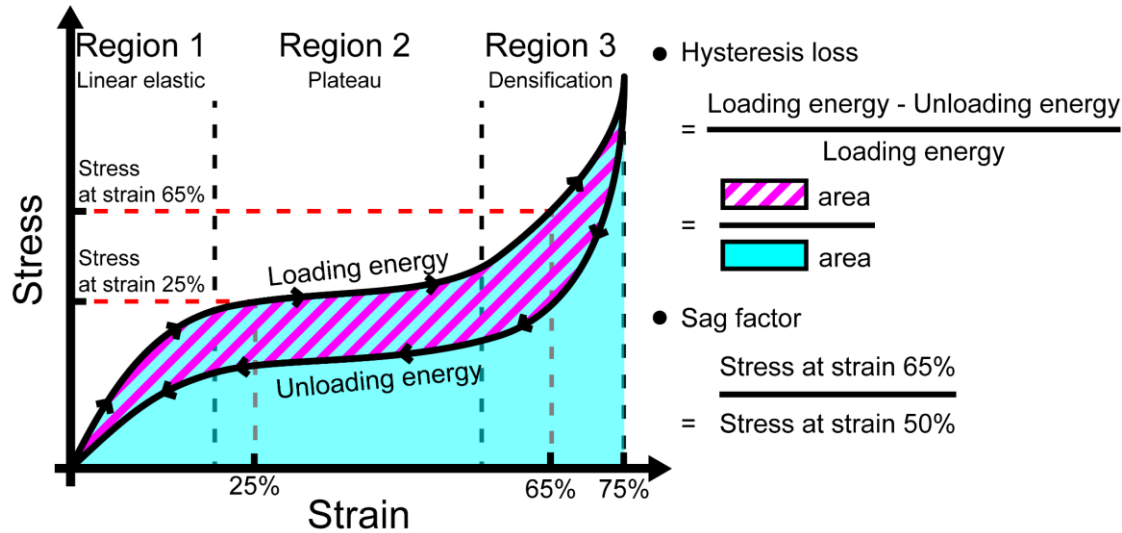
$$(1) r_1' = \frac{K - \sqrt{K^2 - 4r_1^2 R^2}}{2} \quad (K = r_1^2 + R^2 - L_1^2)$$

$$(2) \text{Pore area} = 2\pi R \left(R - \sqrt{R^2 - r_1'^2} \right)$$

$$(3) \text{Cell wall area ratio} = 1 - \frac{\sum \text{Pore area}}{\text{Half surface}} = 1 - \frac{\sum 2\pi R \left(R - \sqrt{R^2 - r_1'^2} \right)}{2\pi R^2}$$

2. 연구내용

히스테리시스 곡선과 압축 메커니즘



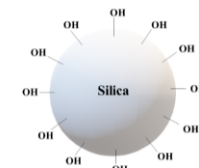
충진재 표면 특성에 따른 물성 향상

입자의 표면 특성에 따른 결과 응용



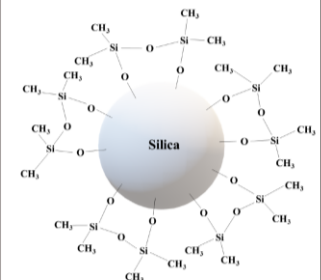
나노 입자를 통해 충진재의 단점 해소

Aerosil-300



Hydrophilic

Aerosil-R972



Hydrophobic

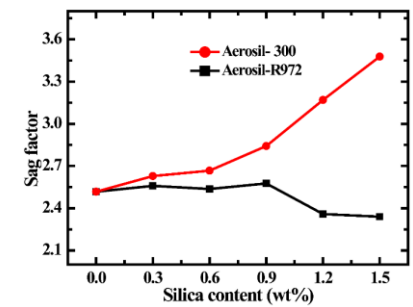
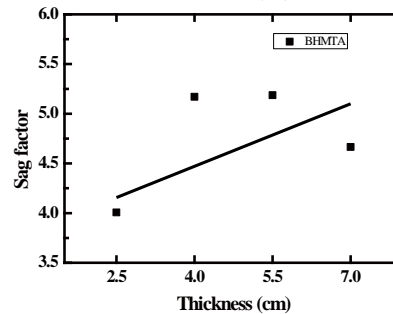
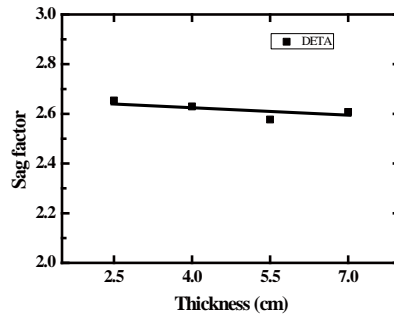
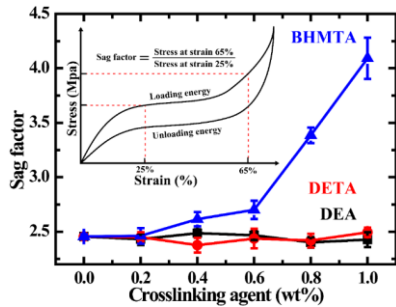
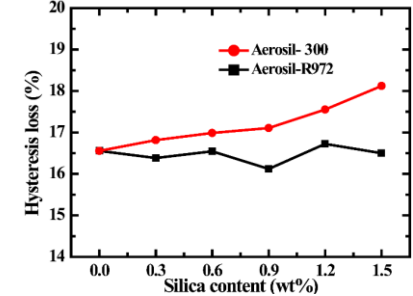
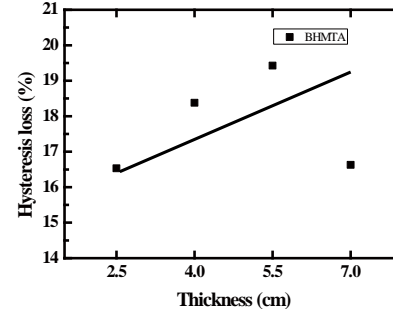
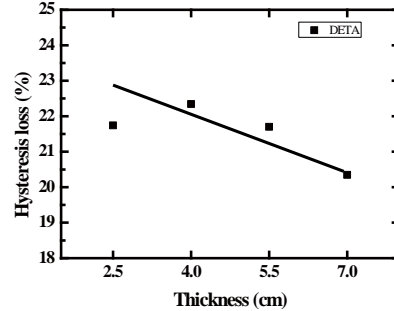
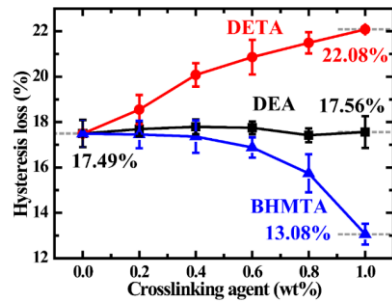
3. 연구성과

연구 데이터

Goal : Hysteresis loss 15% 이하, Sag factor 3.3 이상

- Crosslinker(Diethanolamine, Diethylenetriamine, Bis(hexamethylene)triamine) & sample thickness

- Silica nanoparticle:
Hydrophilic (Aerosil 300)
Hydrophobic(Aerosil R972)

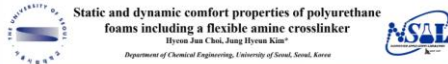


산업체 피드백

- 가교제 물성향상 결과는 우수했지만 두께에 따른 경향을 분석하기엔 어렵다고 판단하여, 밀도 유지 물성향상에 대한 조언을 받음.

3. 연구성과

학회 발표



Abstract
Flexible polyurethane (PU) foams are widely used in various automobile products for seat cushioning, sound absorbing, and heat insulating purposes. The PU foams were fabricated by applying hydroxyl and amine types of crosslinking agents in order to examine the comfort properties. The bisoxazoline/urethane (BIMTA) crosslinker produced the largest cell and pore sizes due to the highest charge flow rate, but the diethylurethane (DEA) crosslinker led to the smallest sizes due to the increased reactivity and hydrogen bonding. The cell wall area ratio resulted in the highest with the DETA and the lowest with the BIMTA, and this cell wall area had a strong relation with the hysteresis loss (low with BIMTA vs. high with DETA). The sag factor was the highest with the BIMTA due to the lowest stress value at 25% strain. The vibration transmissibility was the lowest with the BIMTA crosslinker due to the lowest cell wall area ratio. Therefore, it is critical to choose a proper crosslinking agent in fabrications of the flexible PU foams for superior static and dynamic comfort properties.

Experimental
Table 1. Formulation details for fabrications of PU foams with various crosslinking agents.

Material	Formulation 50
PU prepolymer	100
Casting Catalyst	0.12
Blowing Catalyst	0.08
Crosslinker	0.04
Blowing agent	1.00
Surfactant	1.12
Inoculant	0.04

Table 1. Formulation details for fabrications of PU foams with various crosslinking agents.

Fig. 1. Molecular structures of three different types of the crosslinking agents (DEA, DEFA, and BIMTA).

Results & Discussion

Figure 2. FTIR absorbance spectra from the PU foams without crosslinking agents during initial polymerizations (a) with 1 wt% crosslinking agents at foam reaction time (b).

Figure 3. SEM images for the PU foams without crosslinking agent (a) and including 1 wt% of crosslinking agents: DEA (b), DEFA (c), and BIMTA (d).

Figure 4. Cell wall area ratio of the PU foams including three different types of crosslinking agents.

Figure 5. Hysteresis loss of the PU foams including three different types of crosslinking agents.

Figure 6. Sag factor of the PU foams including three different types of crosslinking agents.

Reference
1) J. H. Choi, S. K. Kim, *Journal of Polymer Science*, 23, 1 (2009).
2) M. Norder, *Synthetic Handbook of Polyurethanes*, Second Edition, Taylor & Francis, 2012.



Abstract
Polyurethane composite foams are widely used in various applications for automotive products (seat pad and sound absorber). In this work, two types of nano-silica particles are applied in fabrications of flexible polyurethane composite foams to investigate the static (sag factor, hysteresis, and compression strength) comfort properties. Nano-silica particles affect the formation mechanism of cellular morphology (cavity and pore) of polyurethane composite foams by increasing phase separation of the polyurethane composite foams. Comfort properties of urethane foams are strongly dependent on the foam morphology. Scanning electron microscopy (SEM), universal testing machine (UTM), impedance tube are used to study on the physical properties of the foams.

Experimental
Table 1. Formulation details for fabrications of PU foams with various silica nano-particles.

Material	Formulation 50
PU prepolymer	100
Casting Catalyst	0.12
Blowing Catalyst	0.08
Crosslinker	0.04
Blowing agent	1.00
Surfactant	1.12
Inoculant	0.04

Table 1. Formulation details for fabrications of PU foams with various silica nano-particles.

Fig. 1. Molecular structures of two types of the silica nano particles. (R300, R372).

Results & Discussion

Figure 2. SEM images for the PU foams without silica (a) and including 1.5 wt% of R300(b), and R372 (c).

Figure 3. Cavity (a) and pore (b) sizes of the PU foams including two different types of silica particles.

Figure 4. Cell wall area ratio (a) and the number of pore at each cavity of the PU foams including two different types of silica particles.

Figure 5. Compression stress at 50% strain of the PU foams as a function of silica contents.

Figure 6. Sag factor of the PU foams as a function of silica contents.

Figure 7. Hysteresis loss of the PU foams as a function of silica contents.

Reference
1) H. Choi, J. H. Lee and J. H. Kim, *Composites Science and Technology*, 197, (2020).
2) G. Sanyal and S. K. San, *Applied Journal of Chemical Engineering*, 46, 1 (2017).
3) M. Norder, *Synthetic Handbook of Polyurethanes*, Second Edition, Taylor & Francis, 2012.

- 한국 화학공학회 추계발표 2건
- 팀장(최현준) 가교제에 따른 물성향상 연구 발표
- 팀원(심준섭) 실리카 표면 특성에 따른 연구 발표

논문실적

- **최현** , **이재현** , **김정현** . Polyurethane composite foams including CaCO3 fillers for enhanced sound absorption and compression properties, *Composites Science and Technology*, 194, 108153 (2020)
- **최현준**, **김정현**. Static and dynamic comfort properties of polyurethane foams including a flexible amine crosslinker. *Journal of Industrial and Engineering Chemistry* 90, 260 (2020)
- **최현준**, **심준섭**, **김정현**. Comfort property of the polyurethane composite foams including hydrophilic and hydrophobic fumed silica nanoparticles. Submission

SCI(E)급 저널 논문 2편 게재

4. 결론

연구 목표 달성도

물성	목표	측정물성값	달성도
Hysteresis loss	15%이하	13.06%	100%
Sag factor	3.3이상	5.32	100%
응 력 완 화	20%이하	8.91%	100%
반복압축변화율	5%이하	1.46%	100%
연구압축 줄음율	10%이하	5.46%	100%

후속 연구 및 연계 활동



연구팀 자체 평가

① 정량적 평가

- 5개의 물성 지표 중 5개 항목에서 달성(전체 100% 달성)
- SCI(E)급 저널 논문 2편 게재
- 심준섭 학생의 실리카 입자 연구를 바탕으로 SCI(E)급 저널 논문 투고 완료

② 정성적 평가

- 이영민, 김기찬 학생은 특수 폴리올과 물성 간 상관 관계를 분석하기 위해 실험 준비 중임.
- 자동차 시트폼의 주요 항목에서 목표 대비 우수한 결과를 도출함, 후속 연구 추진 필요성이 요구됨