

Project 51: Origins of Time-Dependent Aluminum Springback

Fall Meeting

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Project 31-L: Accumulative Roll Bonding of Al and Ti Sheets Toward Low Temperature Superplasticity



- Student: Dawson Tong (Mines)
- Advisor(s): Kester Clarke (Mines)

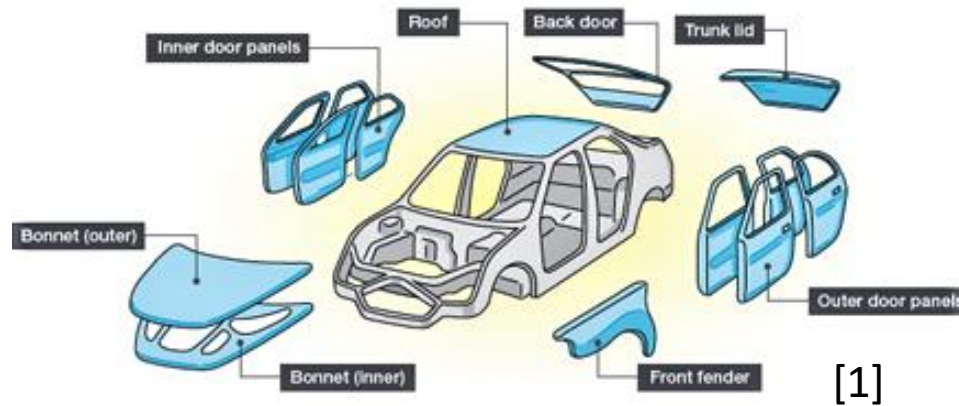
Project Duration
May 2020-May 2021 (REU & MURF)

- **Problem:** Aluminum sheets experience time-dependent springback after forming, resulting in unpredictable final dimensions.
- **Objective:** Measure time-dependent springback after stretch bending, and better understand underlying causes.
- **Benefit:** Deeper understanding will help generate new ways to limit the amount of springback that occurs.

- Recent Progress**
- Literature review of the current understanding of time-dependent springback
 - Evaluating experimental procedures for draw bending tests and tensile tests
 - Set up draw bend test frame

Metrics		
Description	% Complete	Status
1. Literature review	80%	●
2. Acquisition of materials	30%	●
3. Tensile testing for anelasticity	0%	●
4. Draw bend testing for time-dependent springback	30%	●
5. Microstructural characterization	0%	●

Industrial Relevance



- Benefits

- Better dimensional control
- Less wasted material and time
- Higher quality parts
- Increase use of aluminum in automobiles
- Creating different forming techniques to minimize springback
- Utilize with other metals

Creep and anelasticity in the springback of aluminum [2]

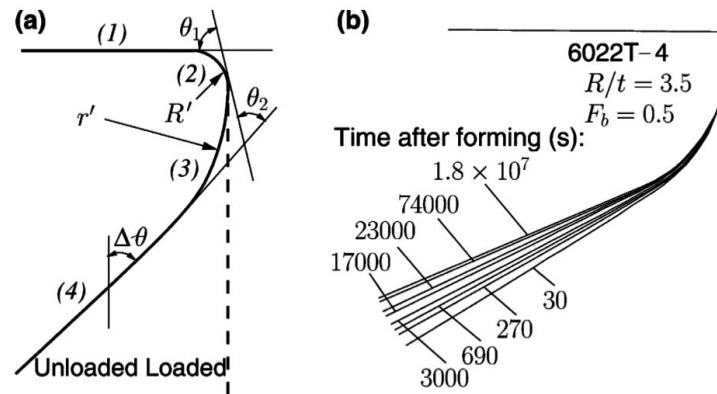


Fig. 3. Draw-bend specimens: (a) schematic geometry before and after springback, (b) tracings for various times following forming and unloading for 6022-T4 aluminum.

- 2008-T4, 5182-O, 6022-T4, and 6111-T4 were draw bend tested
- Springback occurred up to 7 years later, but largely occurred in the first 20 days at room temperature
- They concluded that the springback is residual stress driven creep over long periods while anelasticity contributes to the initial response (1-2 hours) after unloading

The investigation of time-dependent springback for AC170PX aluminum alloy at room temperature [3]



- Tensile and anelastcity testing was conducted on a 1mm thick AC170PX
- Anisotropy seems to play a role in the recovery behavior
- As strain increased, more mobile dislocations became engaged
- Microscopically the driving force may be dislocation movement and atomic diffusion
- With X-ray diffraction they were able to determine a slight displacement in the diffraction peaks after the material had been strained

Time-dependent springback of various sheet metals [4]



- Aluminum (A5052), Magnesium (AZ31B), and Commercially Pure Titanium (CP-Ti) alloy sheet metals were all stress relaxation and creep tested
 - The results from the stress relaxation seemed to show anelastic behavior for the sheet metals
 - The creep test showed varying results based upon a pre-strained sheet versus an unstrained sheet

Time-dependent springback of a commercially pure titanium sheet [5]



- JIS grade 2 CP-Ti was draw bend tested
- The rolling direction and transverse direction were investigated with respect to hold time, strain rate, and elapsed time on the springback angle
- They suggest that twinning activities contribute to the time dependent springback

On the underlying micromechanisms in time-dependent anelasticity in Al-(1 wt%) Cu thin films [6]



- An aluminum thin film was solution heat treated and aged
- It was then mechanically characterized using a micro beam bending method
- The suggested mechanism for is back stress driven diffusion limited dislocation glide or climb

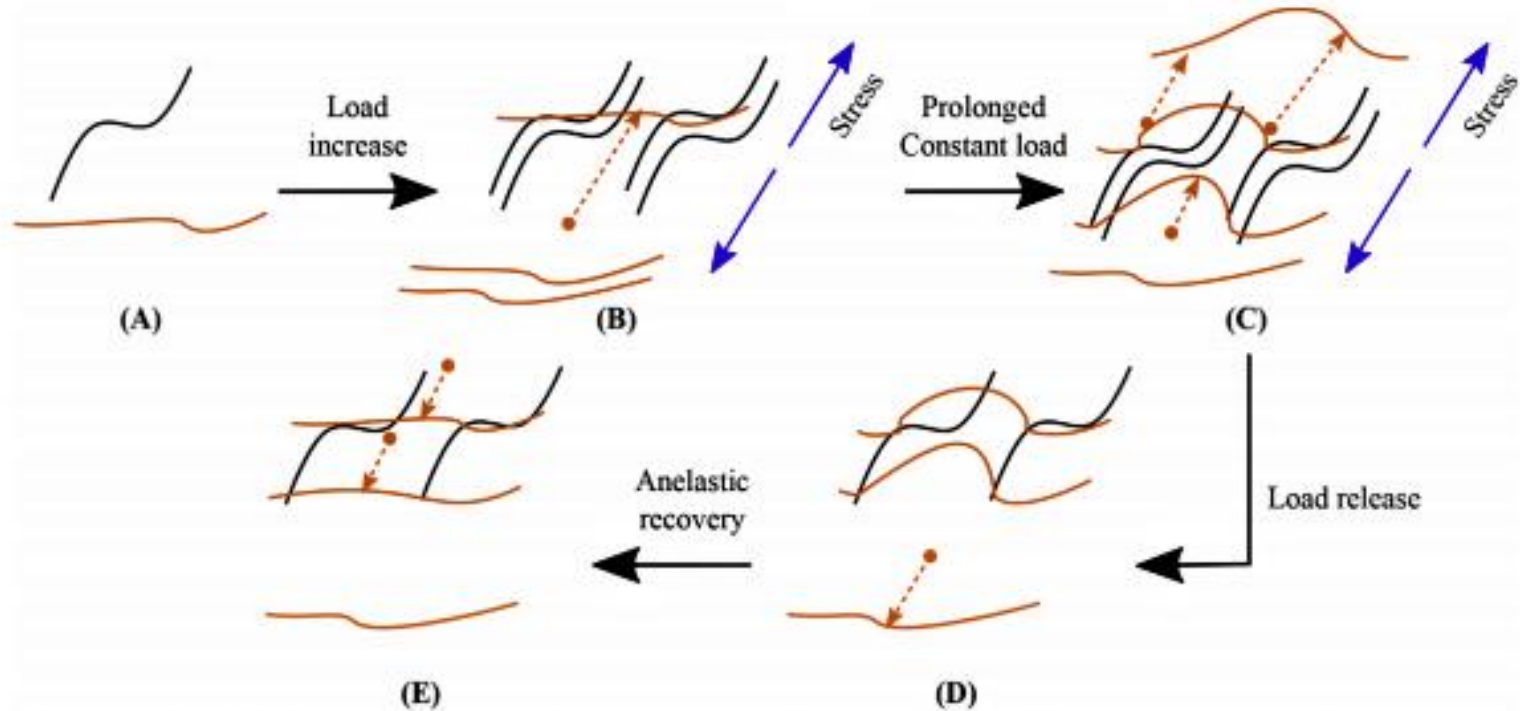


Fig. 11. Sketch illustration proposing a hypothesis of back-stress driven, diffusion-limited dislocation mechanism for observed time-dependent anelasticity in Al/Al-alloy thin films. Orange lines represent dislocation segments residing in one slipplane. The black lines are dislocation segments in other planes which intersect the planes of the orange lines. Orange arrows highlight dislocation motion to the final position in each state. a) The initial state containing few dislocations. b) These are mobilized and multiplied under loading where they may also be pinned by each other. c) The load is maintained causing dislocation loop extension through diffusion-limited climb or glide. Some dislocations might escape the pinned situation. d) Upon load removal, back-stresses reverse the motion of the unpinned dislocations. e) The extended dislocation loops slowly shrink under the influence of the remaining back-stresses and the reverse diffusion-limited glide or climb, resulting in anelastic recovery. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Current Progress



- Draw bend test frame configuration
- Multipurpose 6061 Aluminum sheets
- Cut initial samples to 45mm x 2.5 mm along rolling direction
- Thicknesses of 0.8, 1.0, 1.6, 1.3 mm

Challenges & Opportunities



- Starting lab testing as soon as possible (COVID dependent)
 - Given the amount of time for the springback to occur draw bend tests should hopefully be started within the next two months
 - Discussion of characterizing the springback mechanism

Thank you!

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References



- [1] Aluminum Alloy Sheets for Automobile Panels : UACJ Corporation. (n.d.). Retrieved from <https://www.uacj.co.jp/english/products/sheeting/aas-panel.htm>
- [2] Wang, J.F. et al., Creep and anelasticity in the springback of aluminum, *Int. J. Plasticity* 20 (2004) 2209 – 2232
- [3] Sun, S. and Daxin, E., The investigation of time-dependent springback for AC170PX aluminum alloy at room temperature, *Materials and Design* 93 (2016) 118 – 127
- [4] Hama, T., Suzuki, T., Nakatsuji, Y., Sakai, T., & Takuda, H. (2020). Time-Dependent Springback of Various Sheet Metals: An Experimental Study. *Materials Transactions*, 61(5), 941–947. doi: 10.2320/matertrans.mt-m2019283
- [5] Hama, T., Sakai, T., Fujisaki, Y., Fujimoto, H., & Takuda, H. (2017). Time-dependent springback of a commercially pure titanium sheet. *Procedia Engineering*, 207, 263–268. doi: 10.1016/j.proeng.2017.10.772
- [6] Bergers, L., Hoefnagels, J., & Geers, M. (2017). On the underlying micromechanisms in time-dependent anelasticity in Al-(1 wt%)Cu thin films. *Acta Materialia*, 124, 47–58. doi: 10.1016/j.actamat.2016.10.058