Comparison of the Fatigue Behavior of Copper Alloys

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Introduction

Thrust Chamber

- Develop advanced copper alloys for rocket engine applications
- Desire: high thermal conductivity, good creep strength, adequate fatigue strength.
- Advanced alloy – GRCop-84 Developed at NASA-GRC, commercially available.

Objective

- Characterize fatigue behavior of GRCop-84 in various forms
- Compare fatigue of GRCop-84 to existing high conductivity copper alloys

AMZIRC
Narloy-Z
Glidcop
Cu-1Cr
Cu-1Cr-0.1Zr

Material

GRCop-84 Extruded bar

- Reference data - for Reuseable Launch Vehicle program
- Tested in as-extruded and in simulated braze conditions

GRCop-84 Large Extrusion

- Tested in as-extruded condition
- L, L-T and S-T orientations

GRCop-84 0.04” thick sheet

- Tested after 500 °C/ 30 min heat treatment
- L and L-T orientations

Material

AMZIRC Extruded bar

Tested in as-extruded and in simulated braze conditions

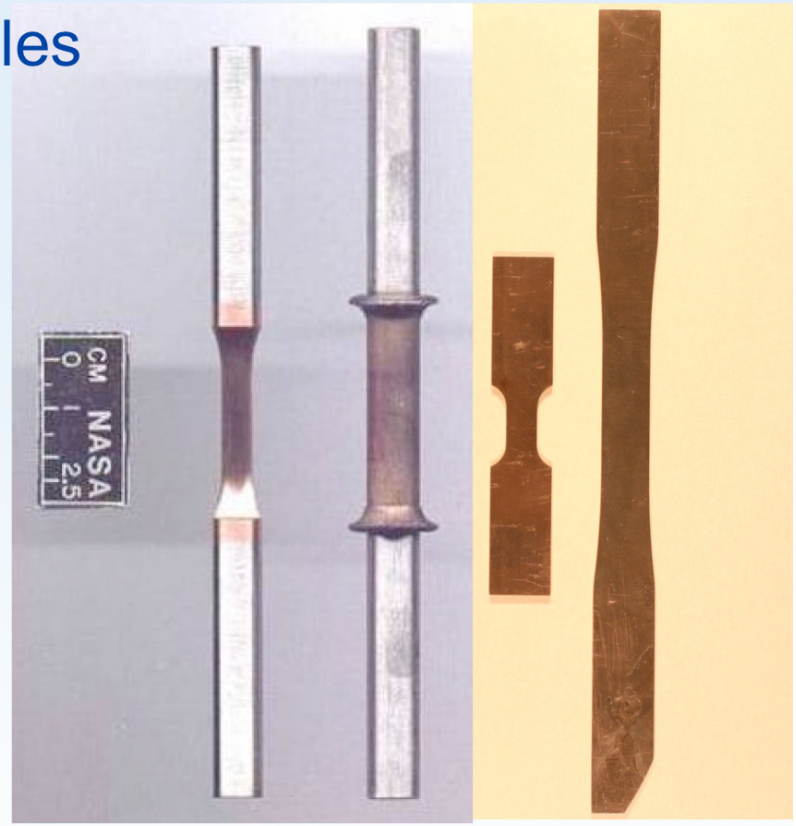
Narloy-Z cast and hot rolled plate 1.5” thick

Tested in heat treated condition:

927 C/2 hrs + 482 C/4 hrs

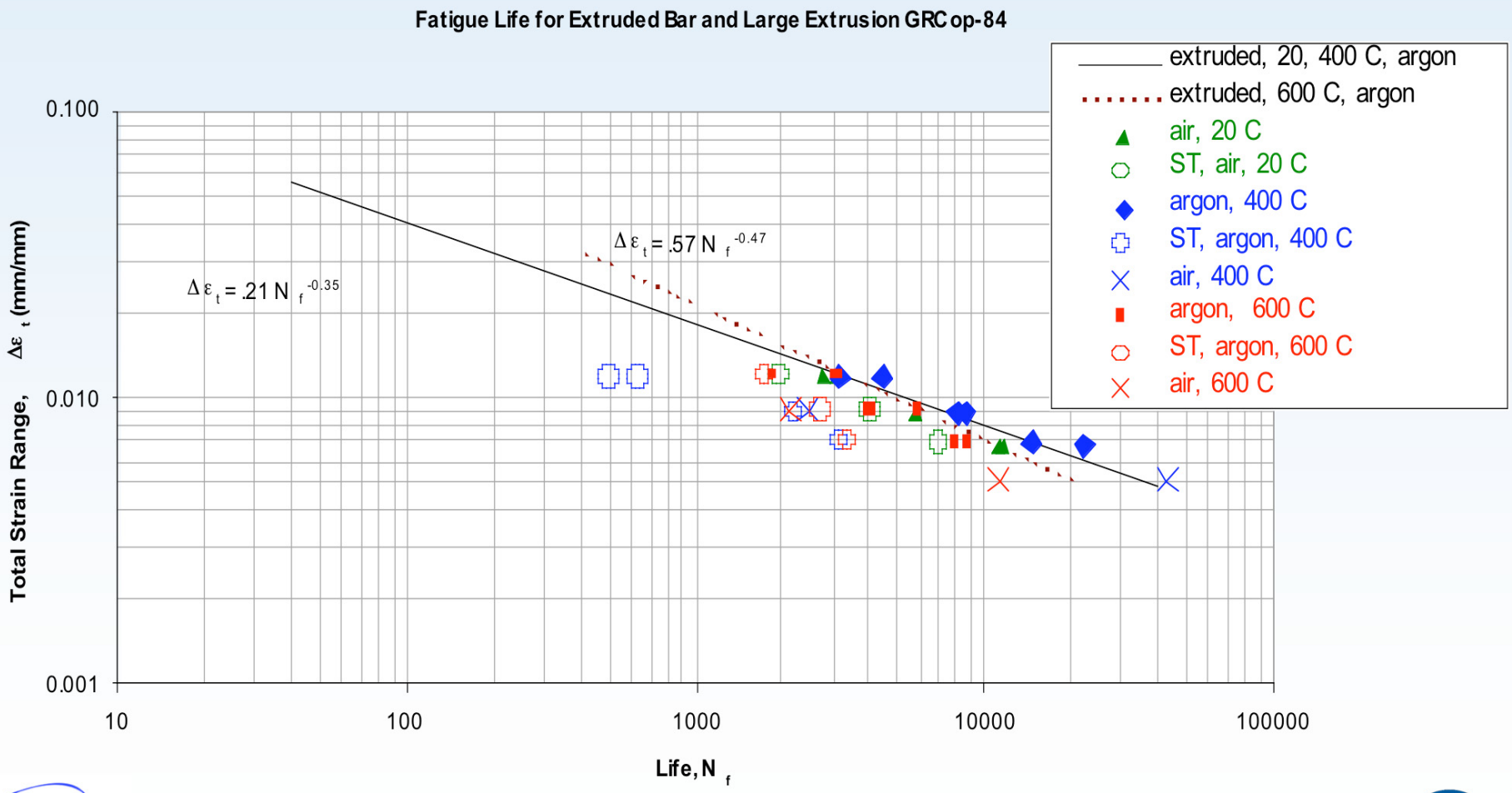
Experimental Details

- 6 inch long, dogbone-shaped samples
- Gage diameter 0.25”
- Specimens cycled in strain control
- Strain ratio = -1
- Strain rate = 0.002/sec.
- Temp. = 20, 400, 600 °C
- Environment: argon, air
- Failure defined as two pieces
- Sheet samples tested with both buckling guides and unconstrained

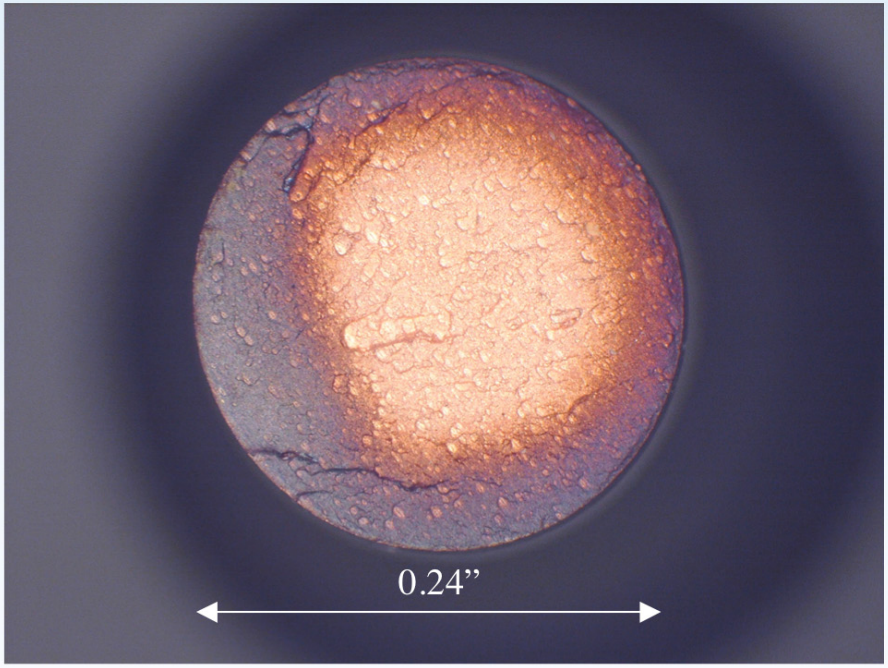


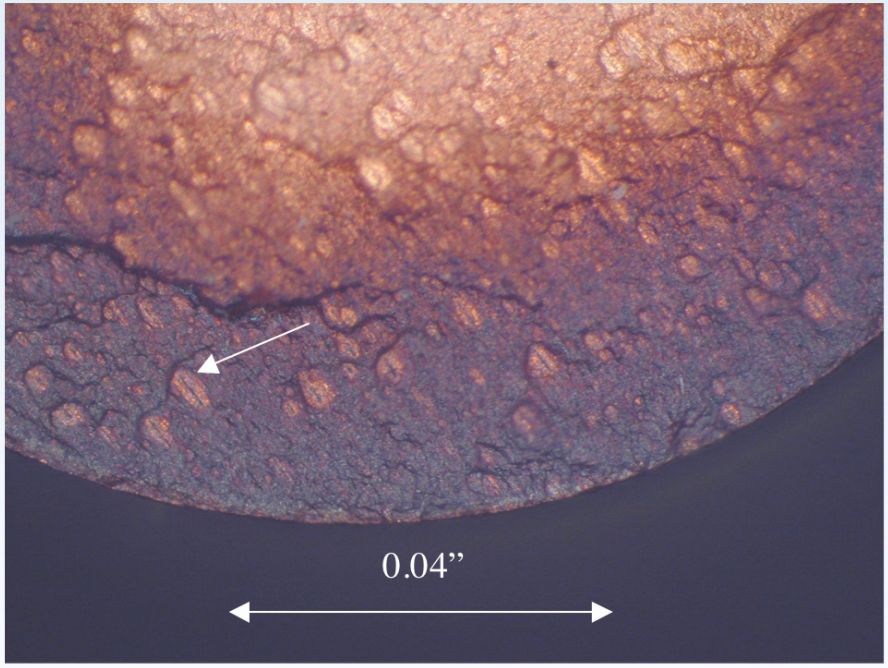
GRCop-84 Large Extrusion

Fatigue lives of both forms are similar



GRCop-84 Large Extrusion, L-T Orientation

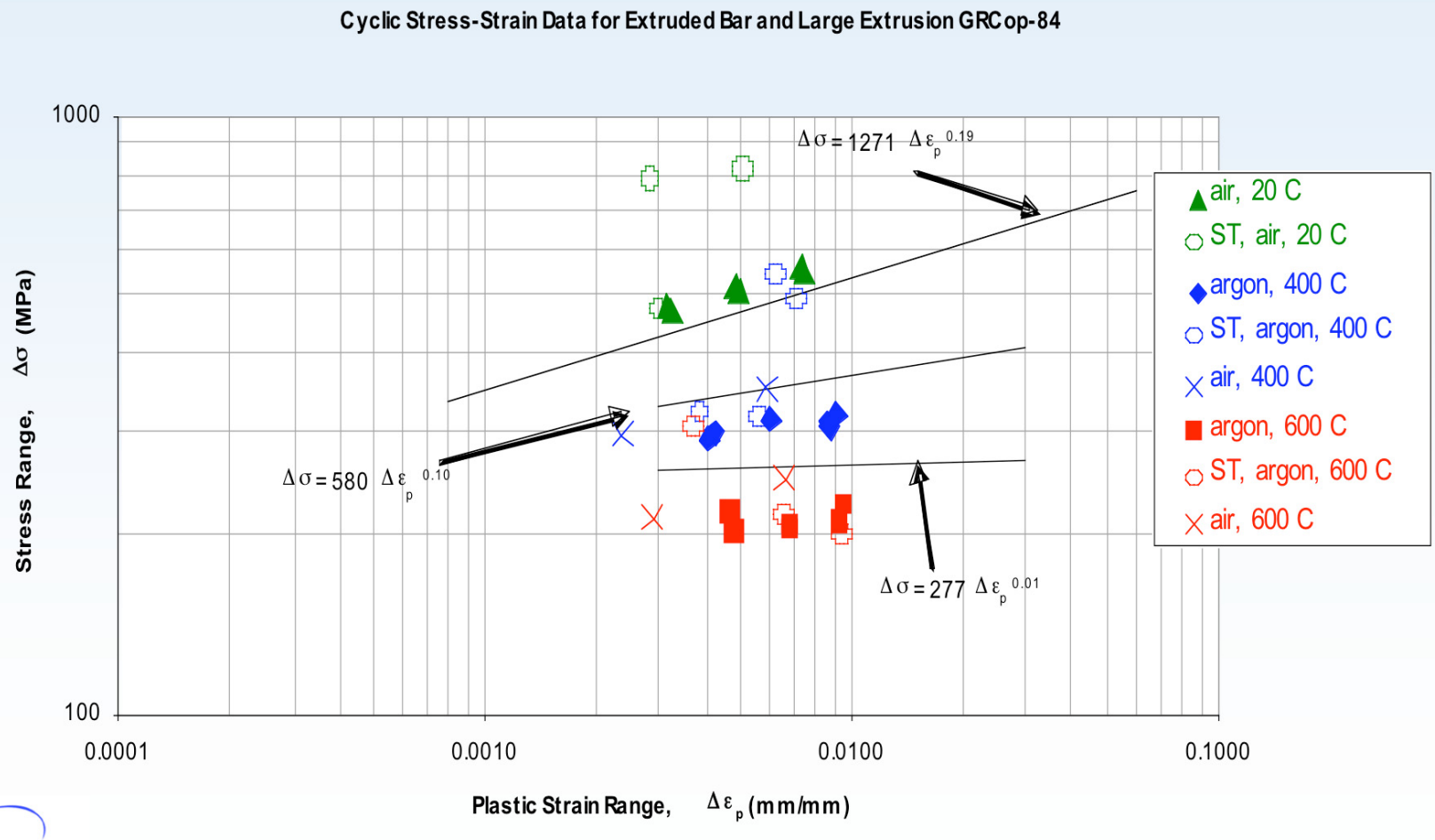




Cr2Nb stringers responsible for low life of S-T samples

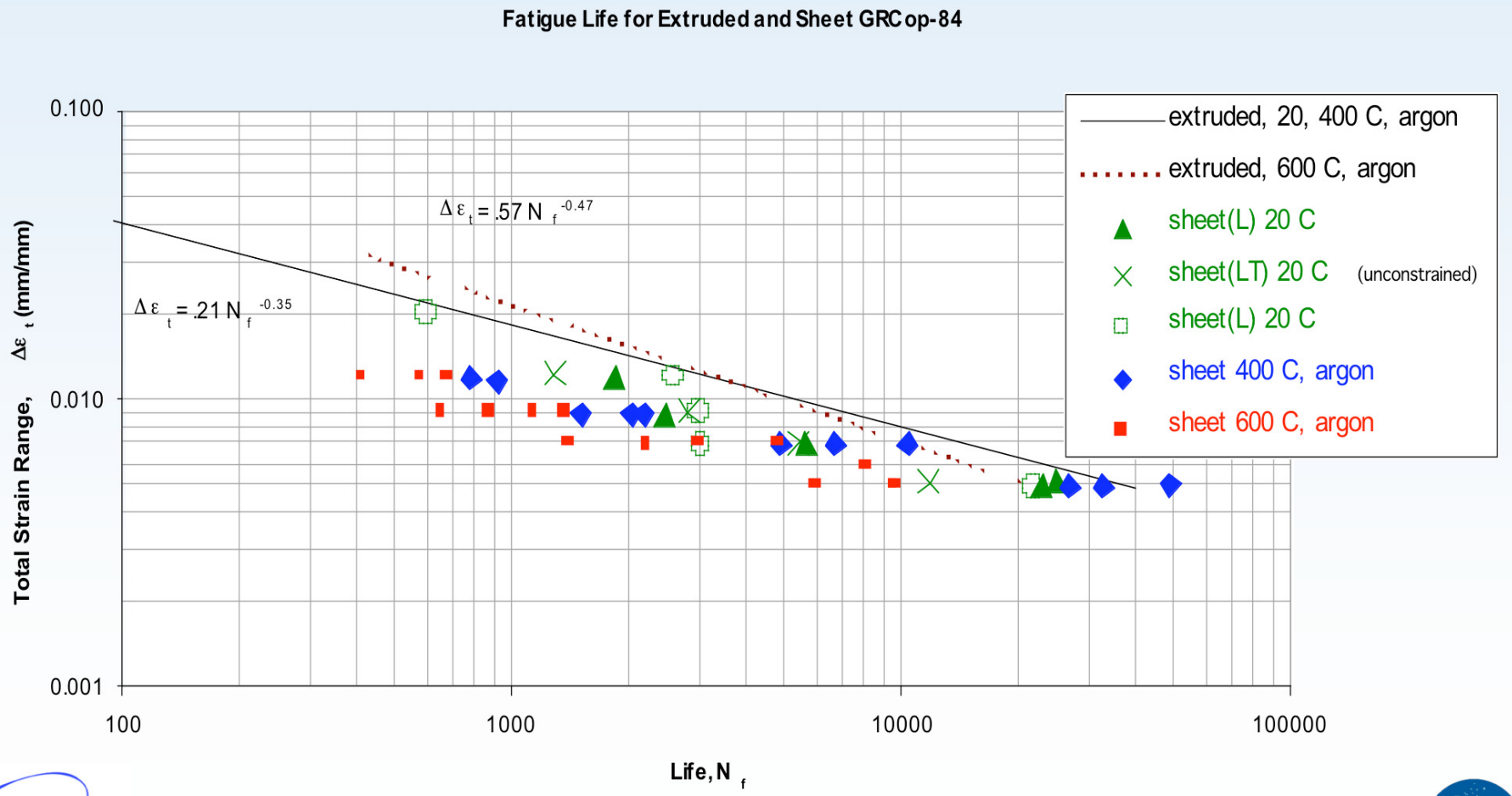
GRCop-84 Large Extrusion

The large extrusion is slightly softer at elevated temperatures



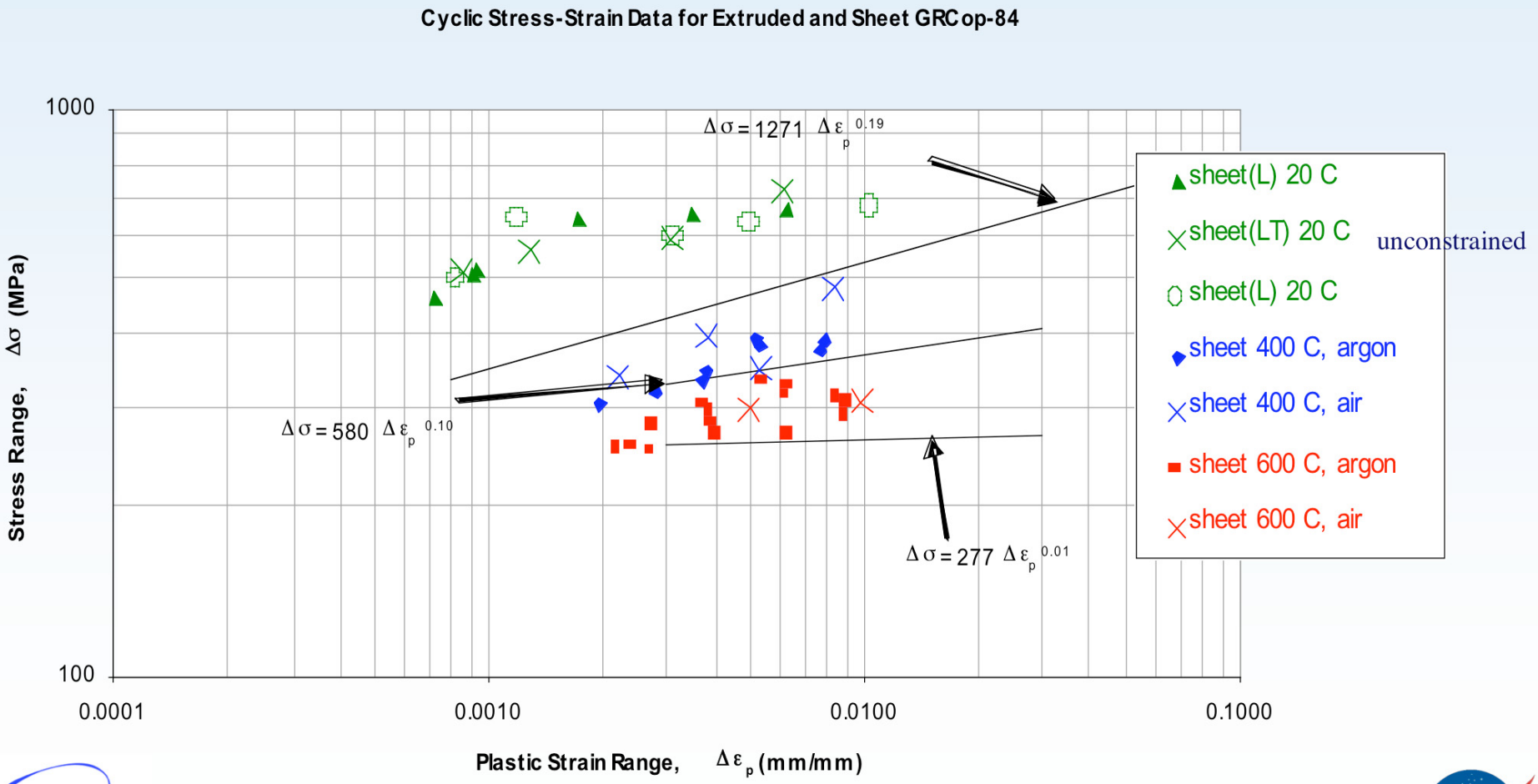
GRCop-84 0.04" Thick Sheet

Sheet material has shorter life than extruded bar



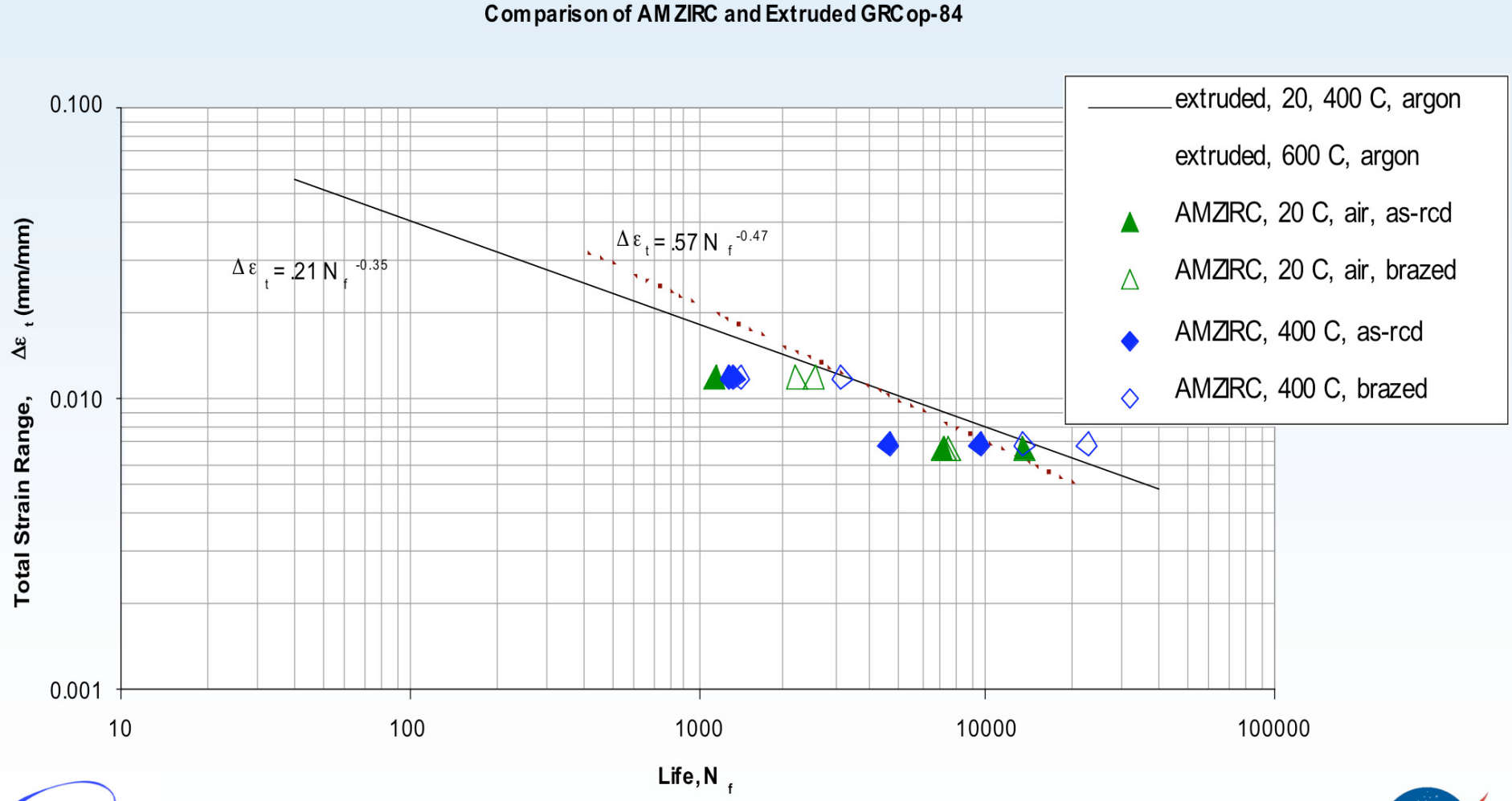
GRCop-84 0.04" Thick Sheet

Sheet material is cyclically stronger than bar form



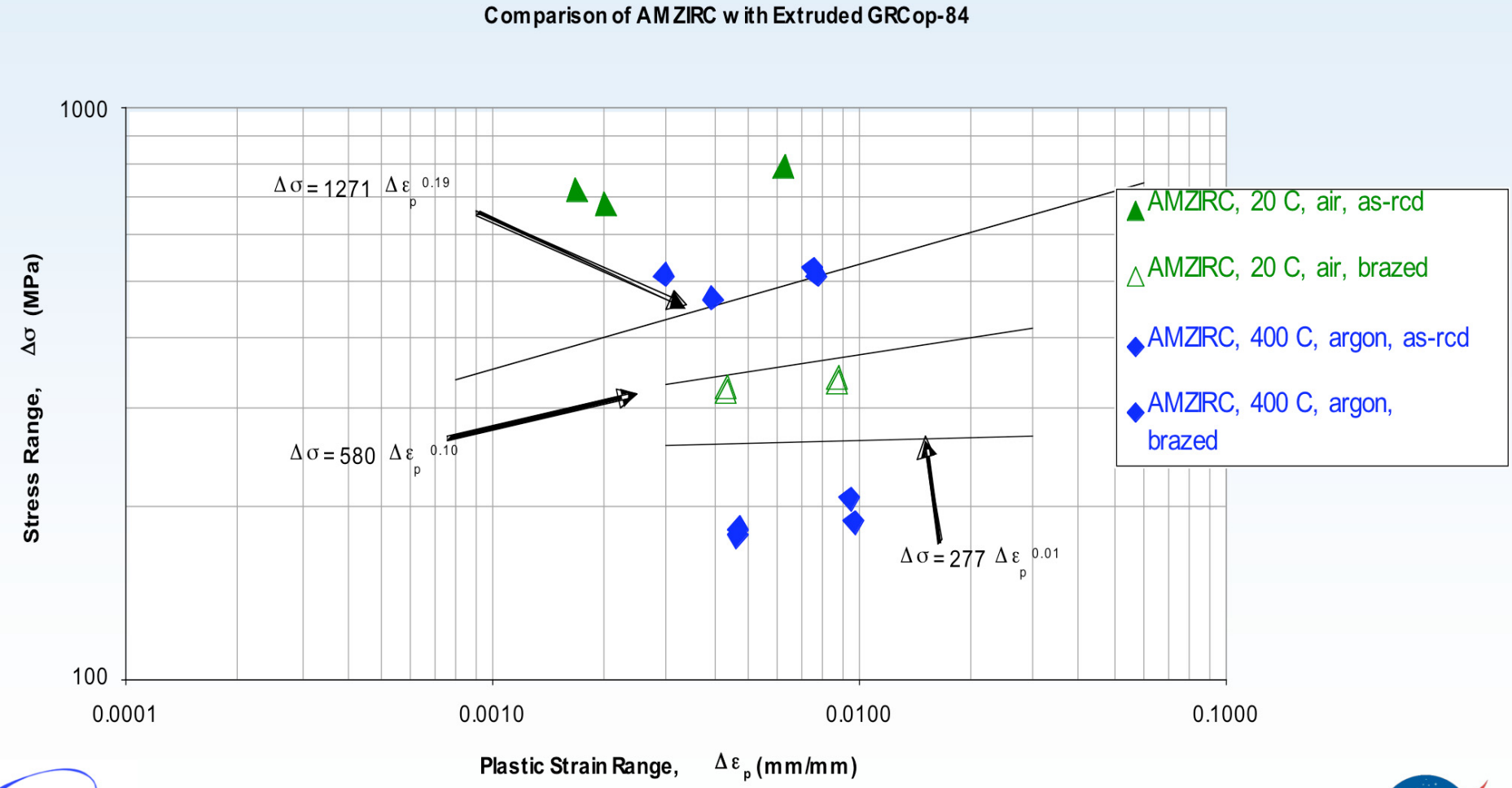
AMZIRC

AMZIRC has a similar life to GRCop-84 at moderate temperatures



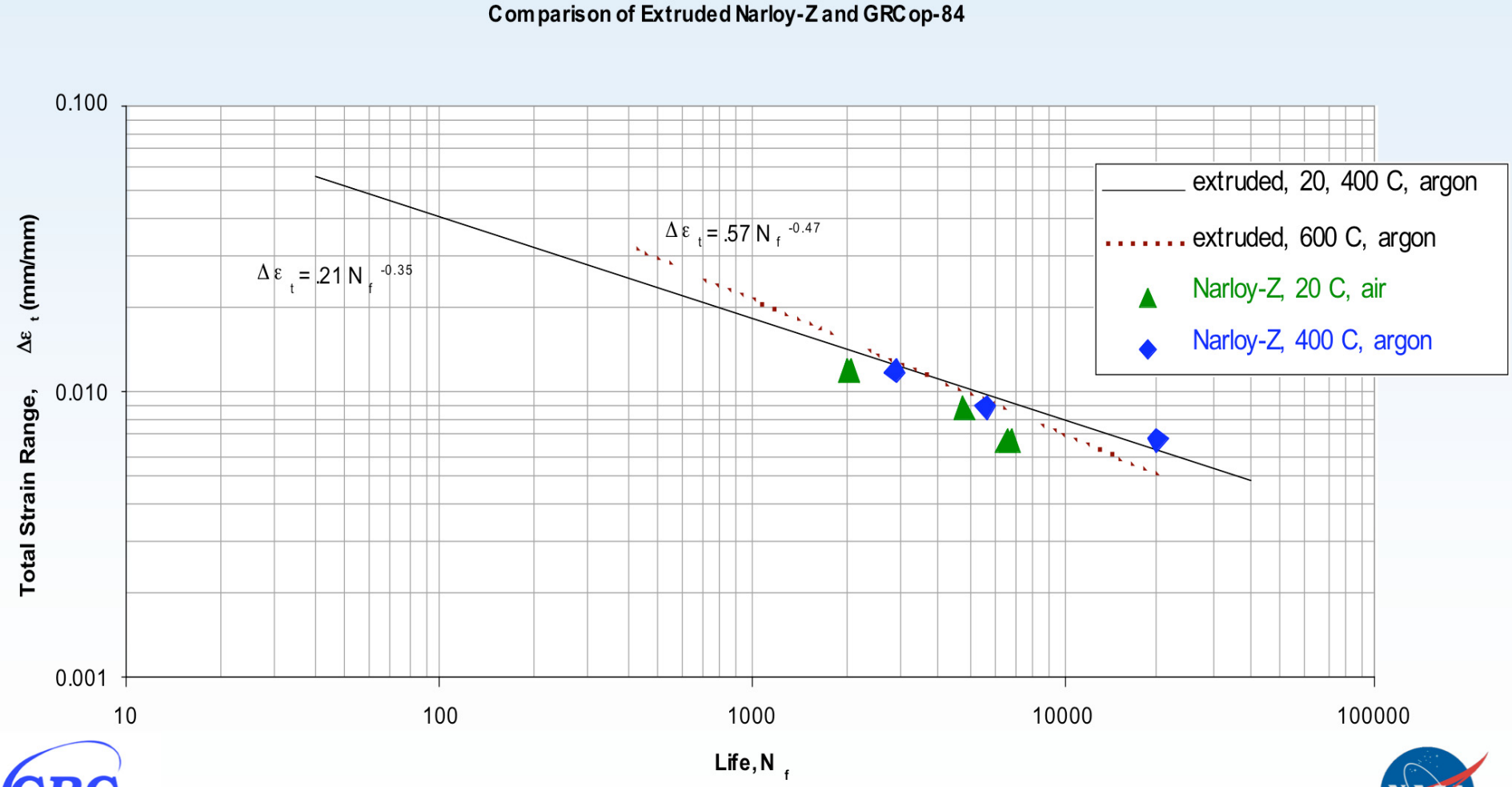
AMZIRC

Contrary to GRCop-84, braze condition affects strength of AMZIRC



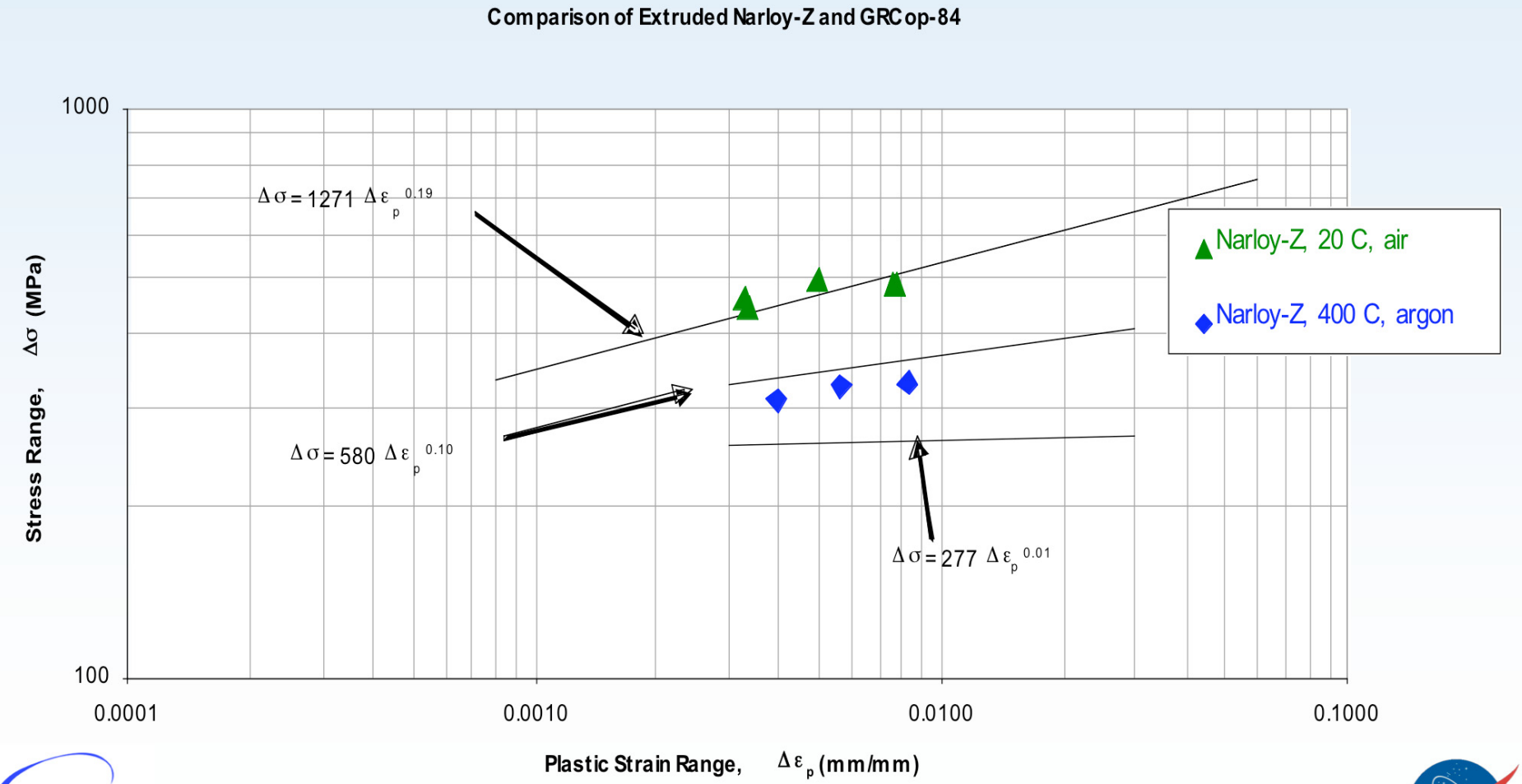
Narloy-Z

Narloy-Z has similar fatigue lives at moderate temperatures



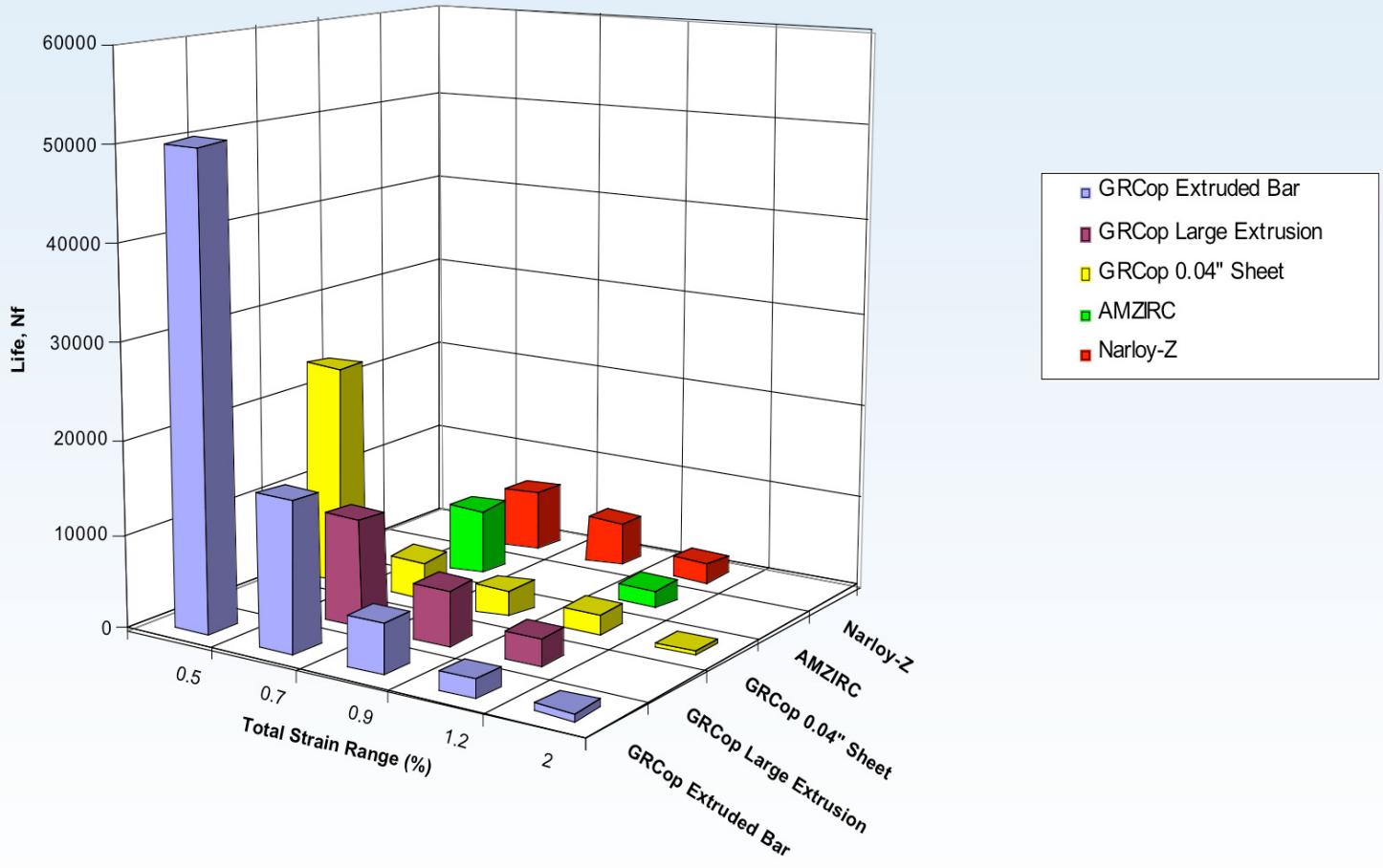
Narloy-Z

Narloy-Z has similar strength to GRCop-84 at moderate temperatures



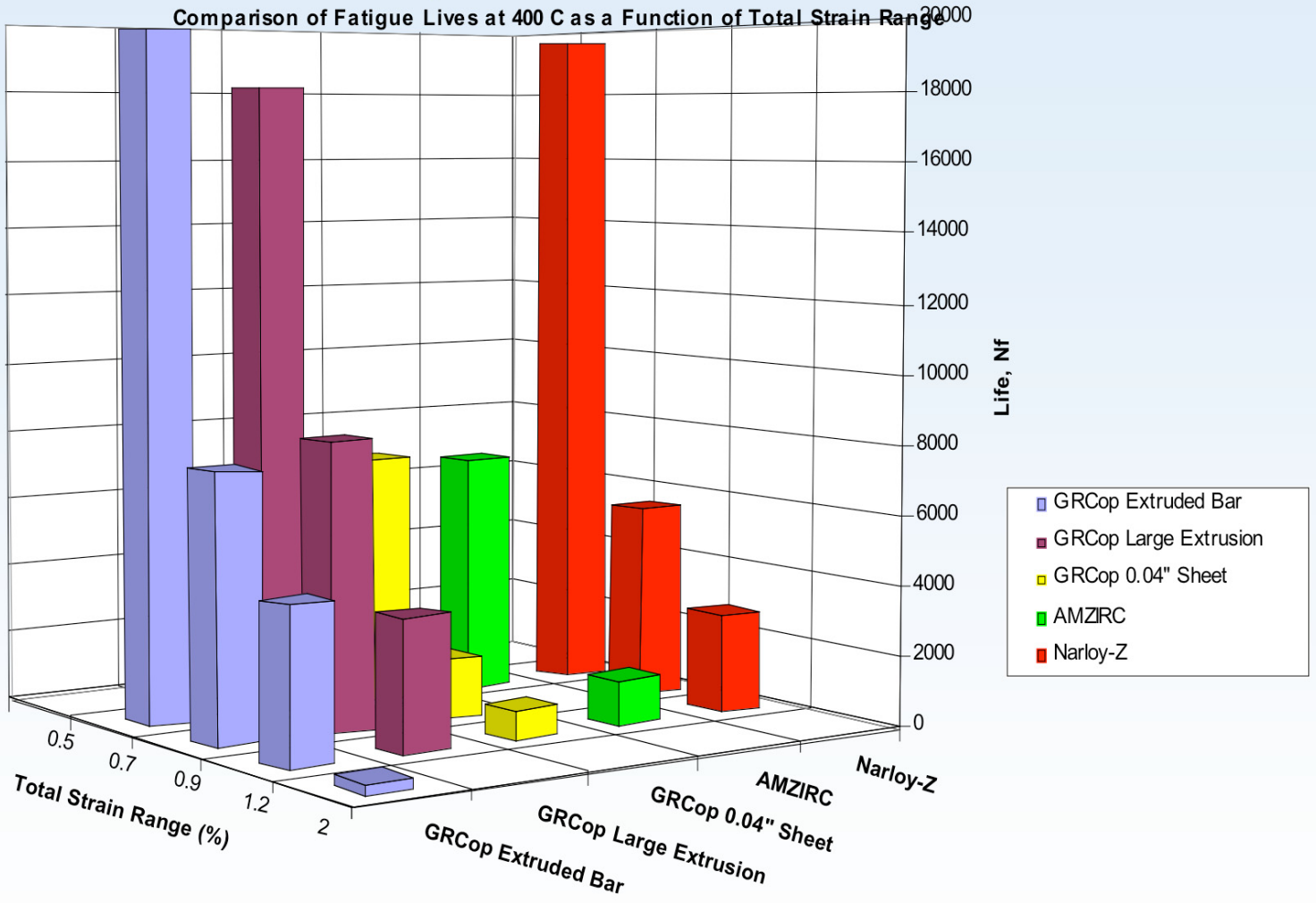
Life Comparison – All Alloys

Comparison of Fatigue Lives at 25 C as a Function of Total Strain Range



GRCop-84 has similar fatigue lives at 25 °C

Life Comparison – All Alloys



GRCop-84 has equivalent or better lives at 400 °C

Summary

- Large Extrusion has similar life to extruded bar
  - S-T orientation has shorter life due to stringers
  - Temperature effects are minimal on life
- Sheet has slightly poorer fatigue life
  - Temperature effect is larger
- AMZIRC has equivalent moderate temperature lives
  - Expect smaller lives at elevated temperatures
- Narloy-Z has equivalent lives at 20 and 400 C

Conclusions

- GRCop-84 has equivalent or better isothermal fatigue lives compared to other commercially available copper alloys
- GRCop-84 can be fabricated in various forms with minimal change in the fatigue lives
- GRCop-84 is equivalent in isothermal, fatigue to AMZIRC at moderate temperatures
- Narloy-Z is equivalent in fatigue capabilities to GRCop-84 at 400C and below