Heating Rate Effect on Superplastic Behaviors of an As-cold-rolled 5083 Al-Mg-Mn Alloy

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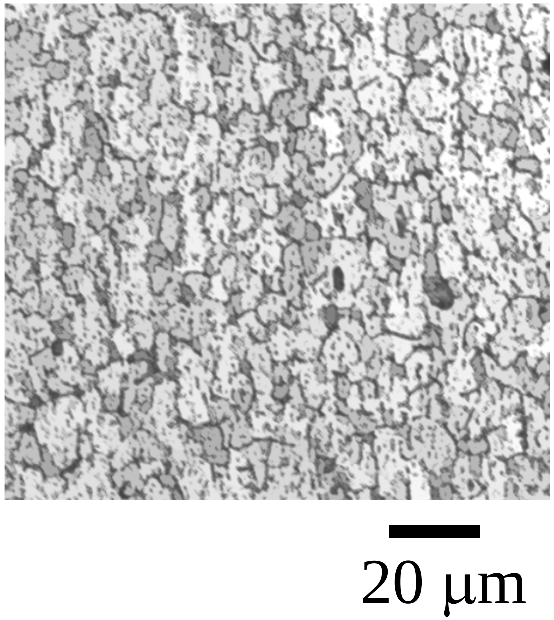
Outline

- Superplasticity
- Superplastic forming: advantages and limitations
- Possible solutions proposed
- Effect of Heating Rate (before Loading)
- Superplastic forming in Taiwan (e.g., High-priced bicycle frame)
- Summary

Microstructure Requirements for superplasticity:

fine grain size



high angle boundary

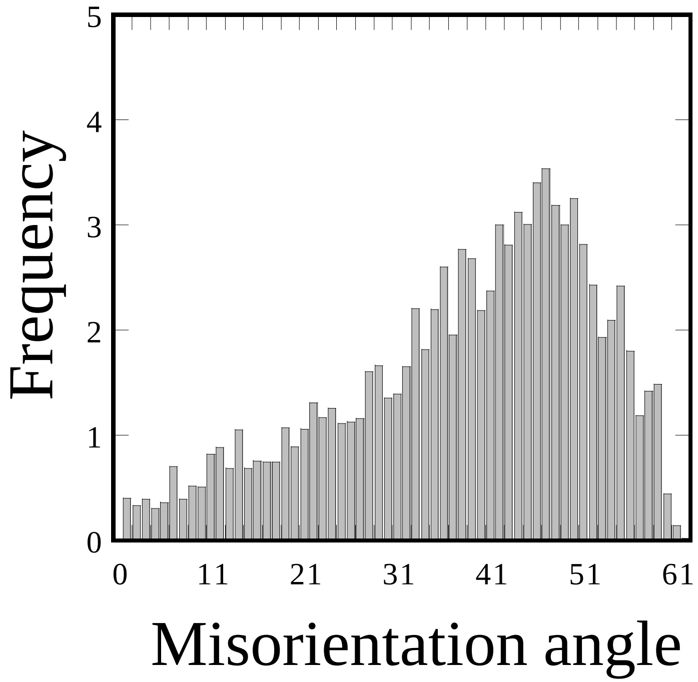


Exhibit superplasticity over a limited strain rate at high temperature

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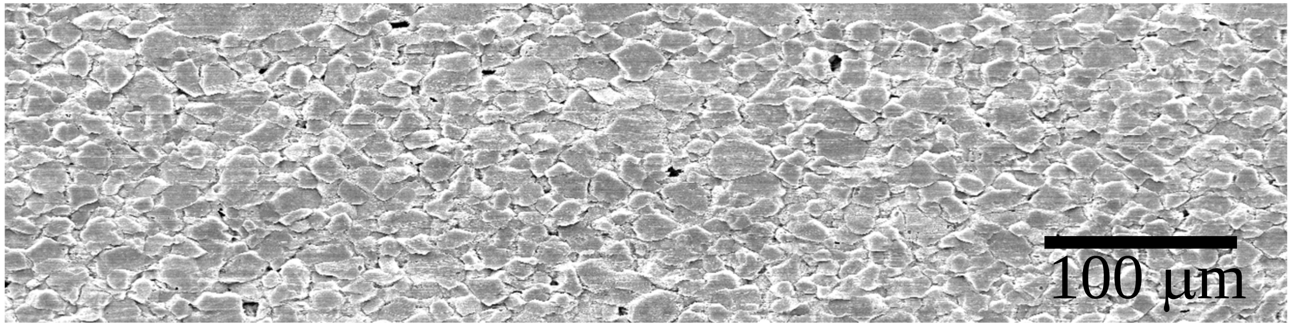
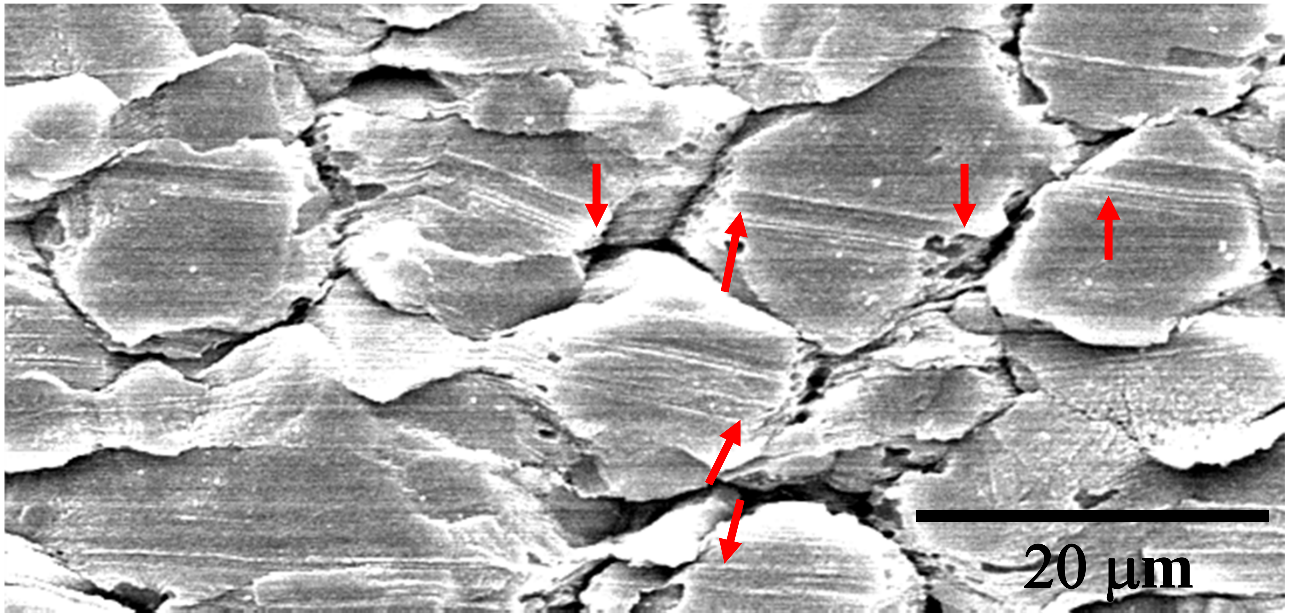
Deformation mechanism: grain boundary sliding





Results of this study

Some materials which shows "superplasticity" are:

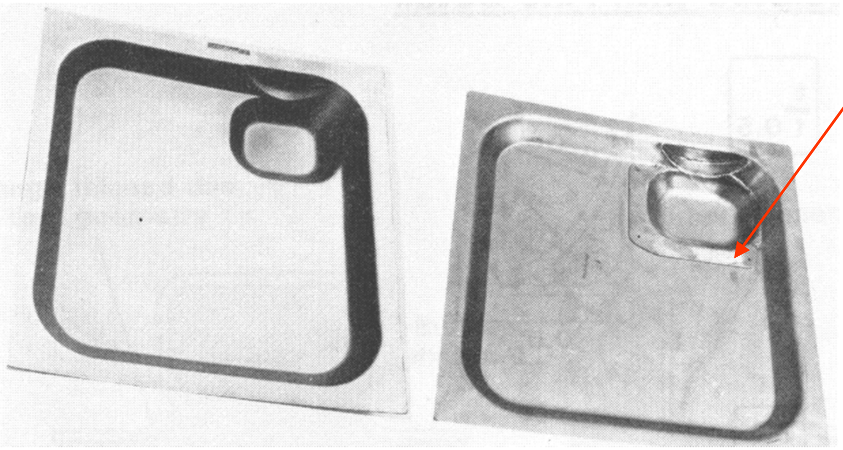
1. Titanium alloys
2. Aluminum alloys
3. Bismuth-tin alloys
4. Zinc-aluminum alloys
5. Stainless steel
6. Aluminum-lithium alloys

Advantages and Limitations

Advantages

- The finished product has excellent precision and a fine surface finish.
- Products can also be made larger to eliminate assemblies or reduce weight, which is critical in aerospace applications.
- Lower strength required and less tooling costs.

Examples:



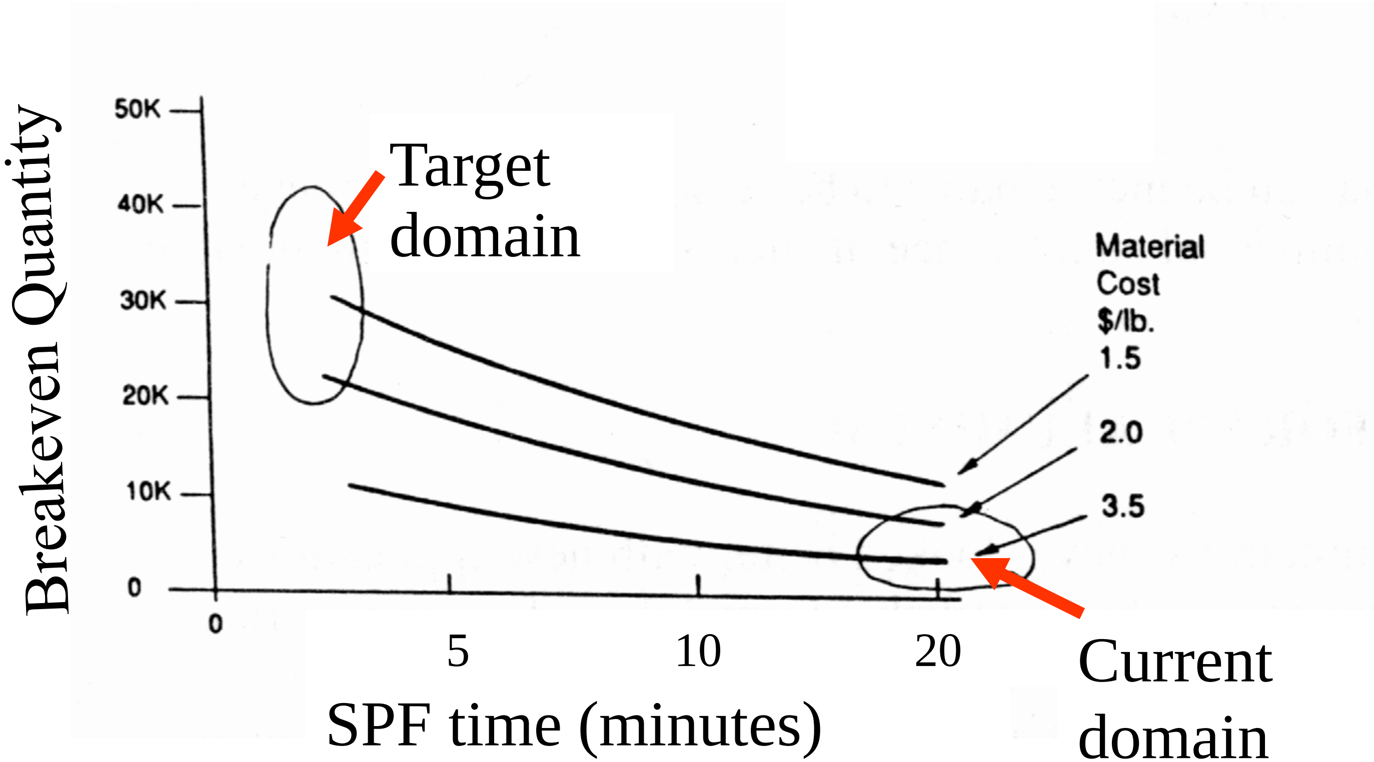
Joints

Airplane Engine Bay Panel (D. Stephen (1987))

Cooperative research program with industry in NCHU, Taiwan

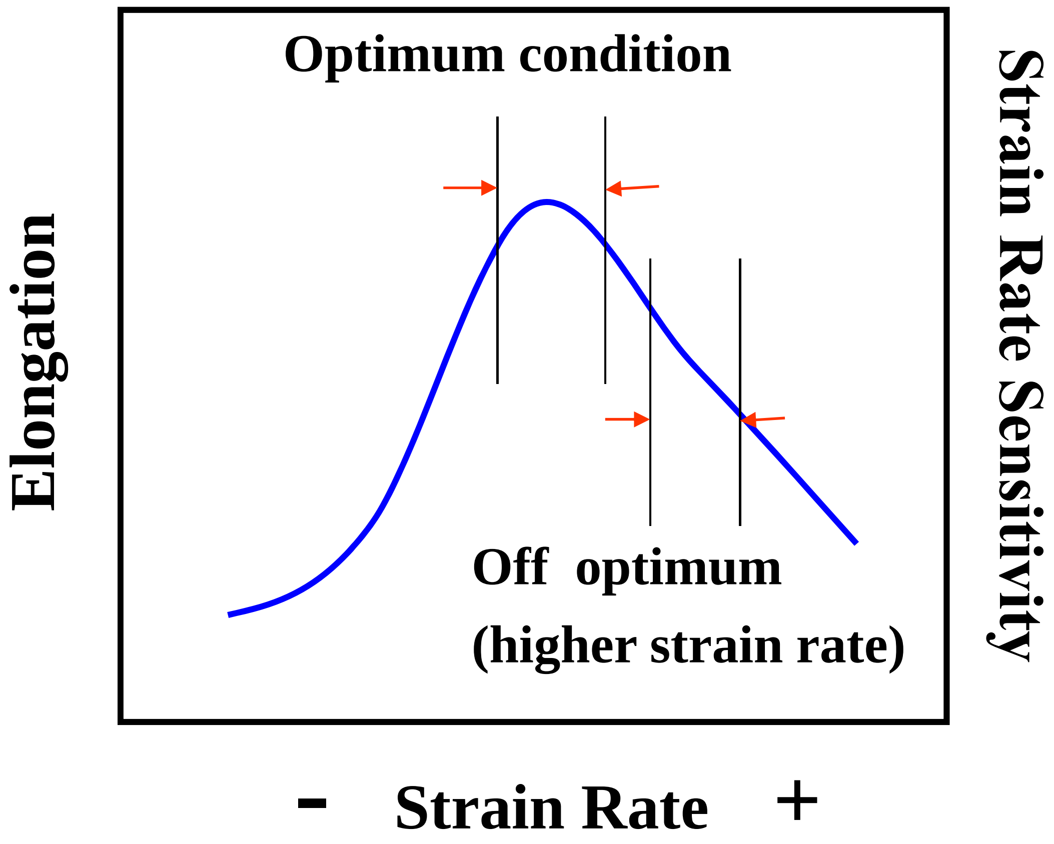
Limitations

Long Cycle Time



A.J. Barnes, Superform, USA
(MRS proceedings, 1999)

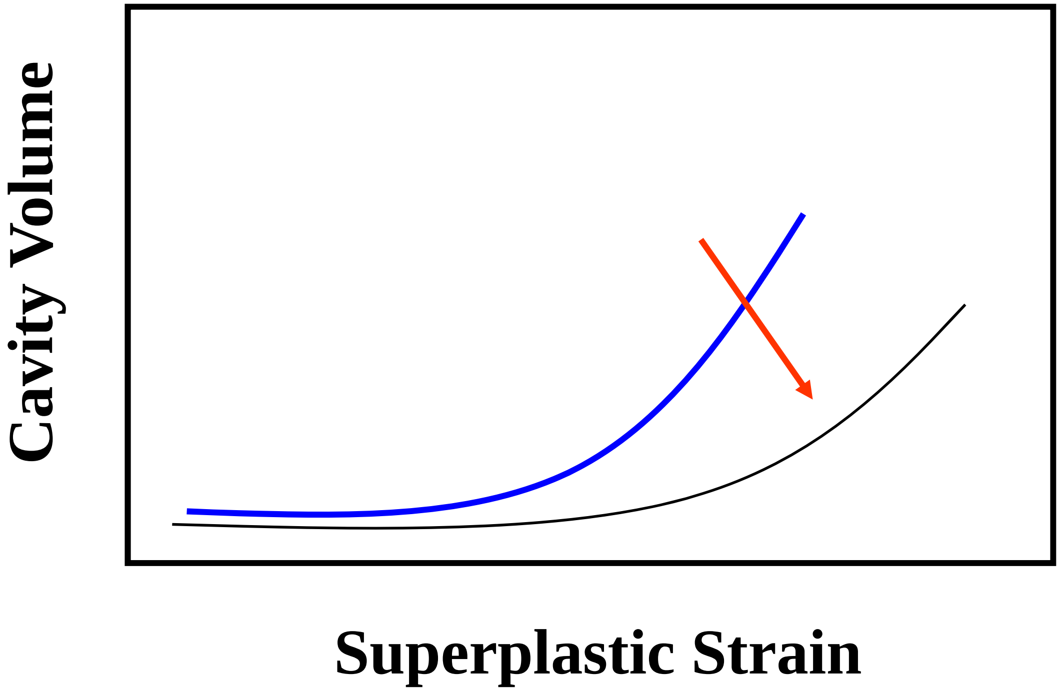
Possible solution

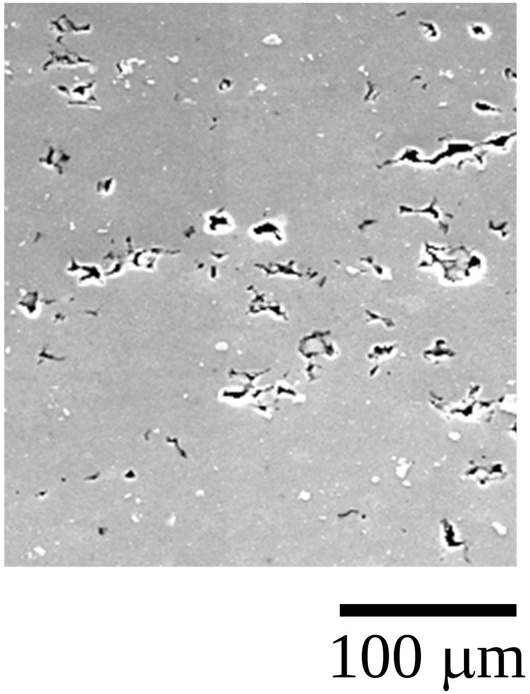


As-cold-rolled 5083 Al-Mg-Mn Alloy

Limitations

Cavitation during superplastic deformation

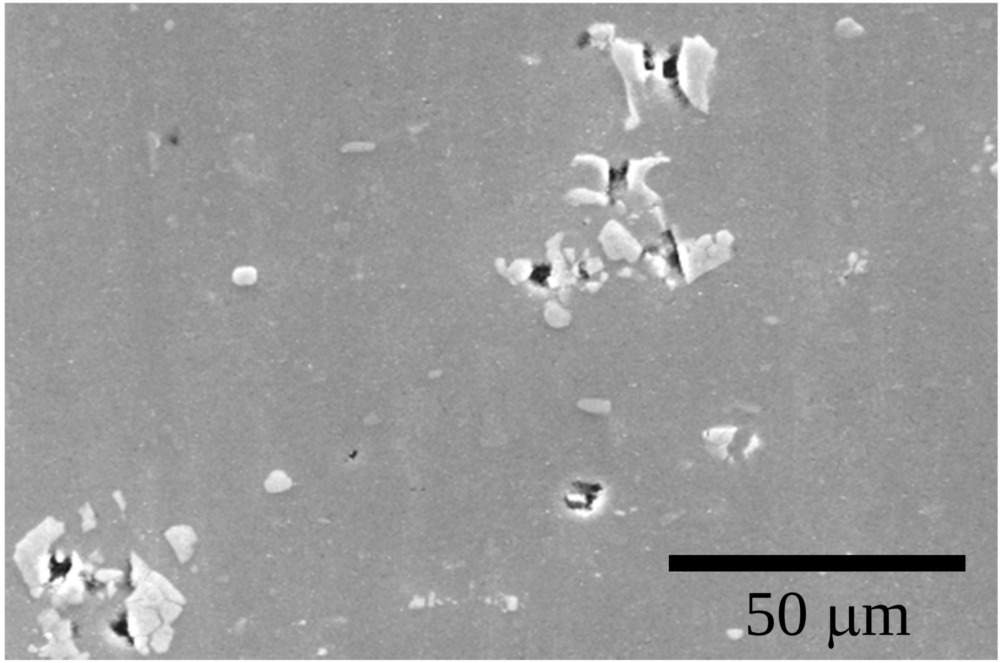




Important research topic: **how to decrease cavitation**

Pre-existing Cavity??

- Large amount of hot and cold rolling, decohesion between particle/matrix
- $Al_6(Mn,Fe)$ or $Al(Mn,Fe)Si$ particle breaking

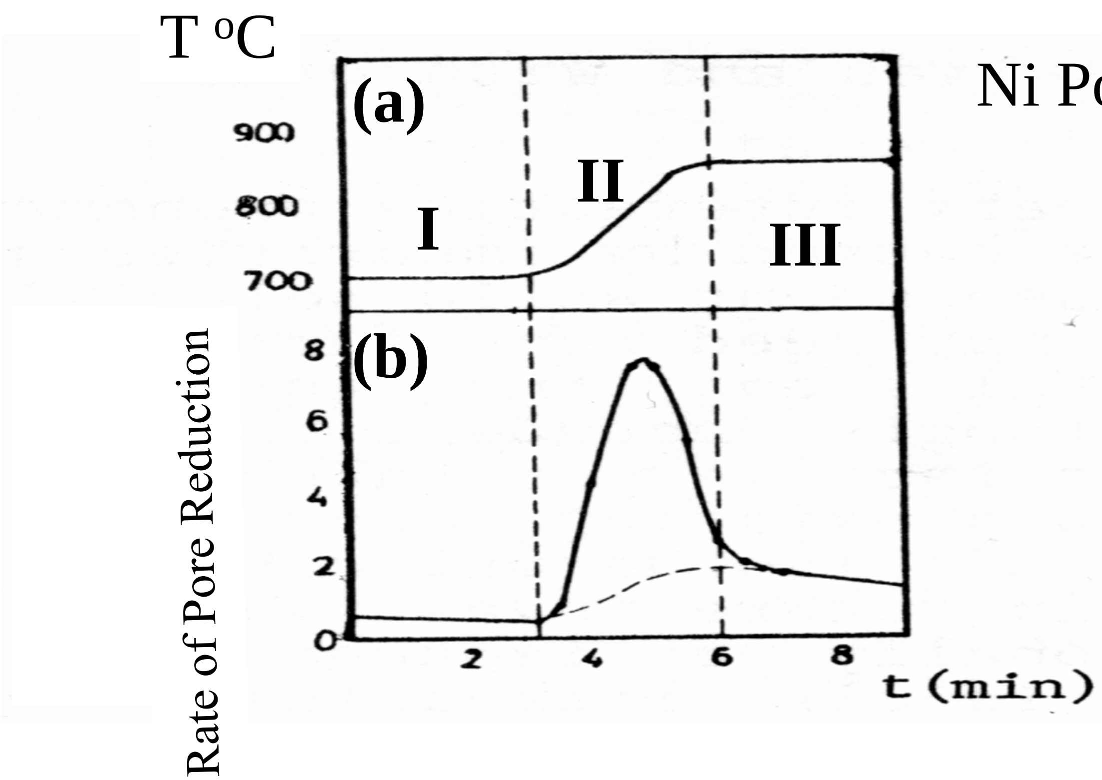


the present study

Possible solution

Heating Rate *vs.* Densification during Sintering

(Researches from D.L. Johnson and V.A. Ivensen)



Ni Powder Compact

V.A. Ivensen, *J. Sci. Sinter*. (1978)

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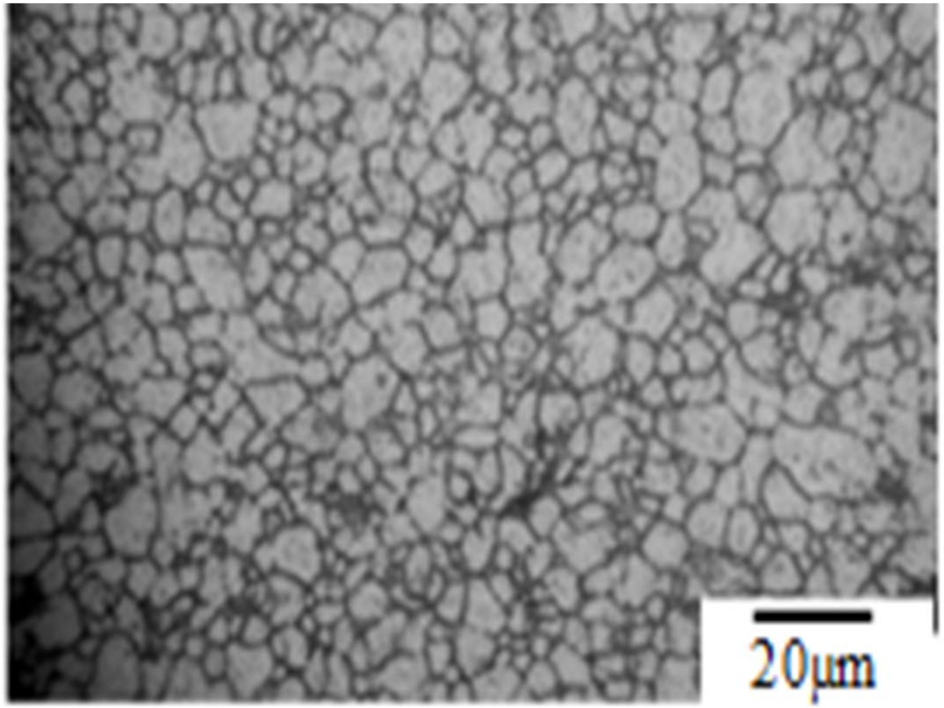
Material

Mg	Mn	Fe	Cr	Si	Zn	Zr	Al
4.34	0.76	0.20	0.09	0.08	0.03	0.01	bal.

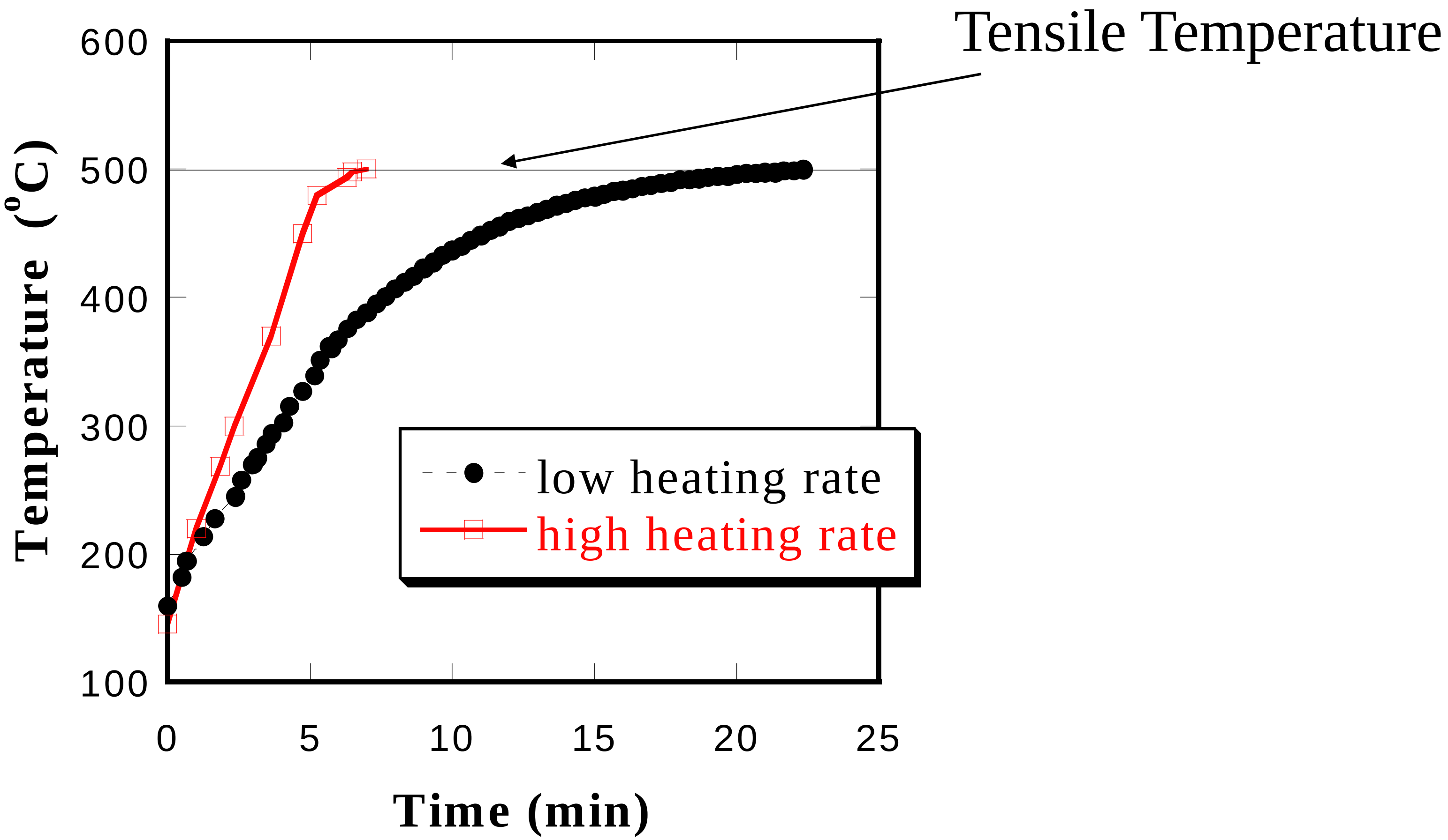
(in wt.%)



$Al_6(Mn,Fe)$;
Al(Mn, Fe)Si

As-cold-rolled 5083 Al-Mg-Mn Alloy

Effect of Heating Rate (before Loading)



infrared heating element

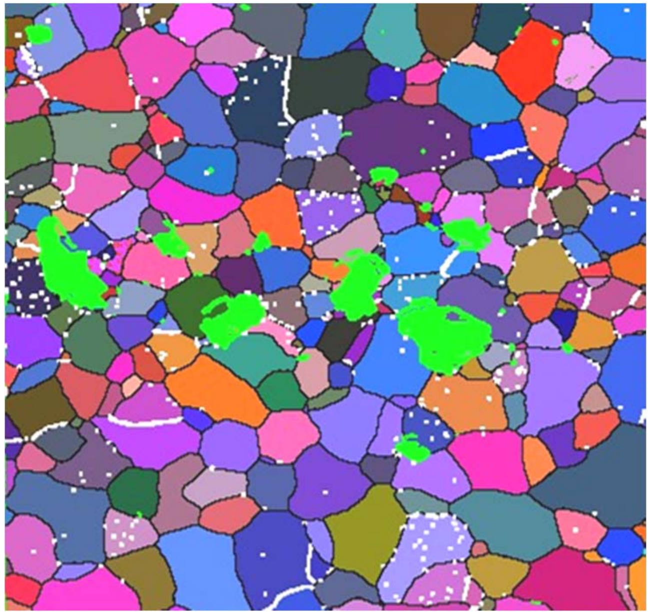
Microstructure difference prior to deformation??

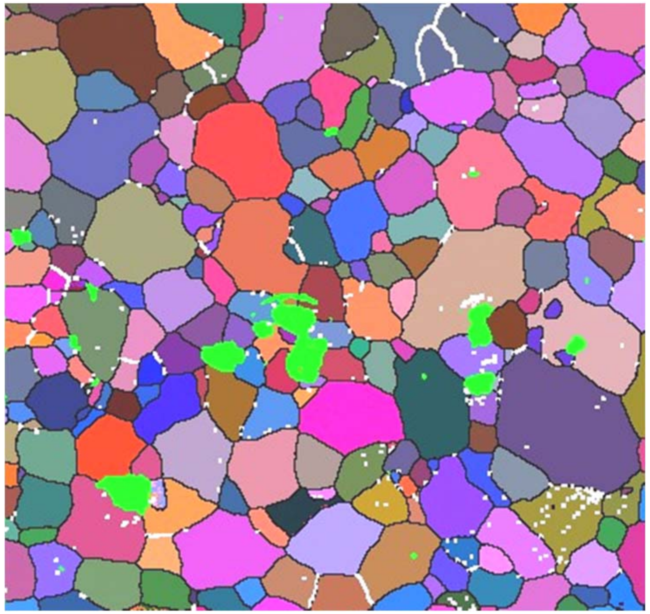
High heating rate **Low heating rate**

Grain size

$$\sqrt[3]{d_L \times d_{ST} \times d_{LT}}$$

10.0 μm **11.1 μm**





25 μm

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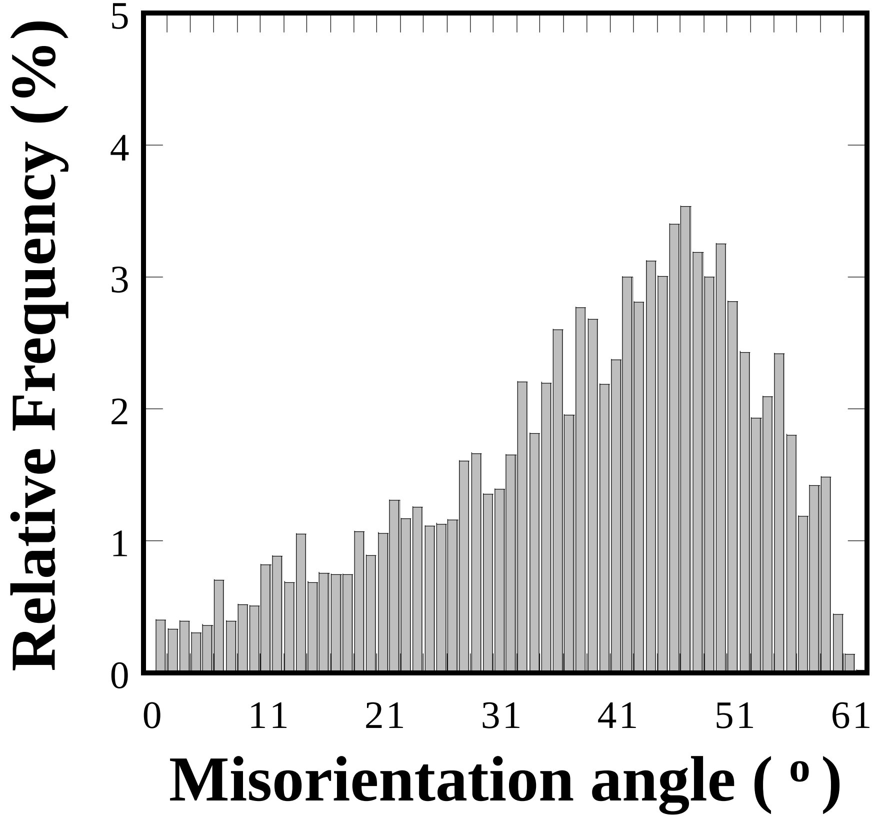
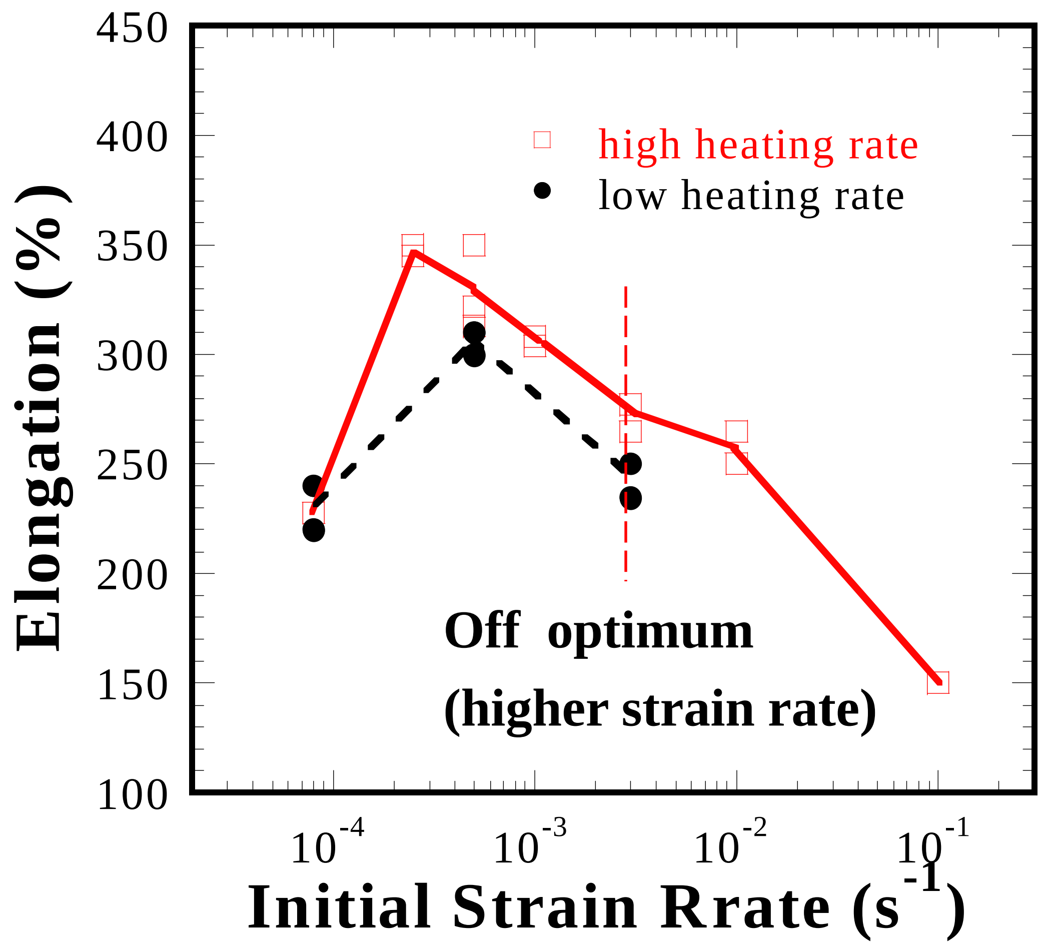
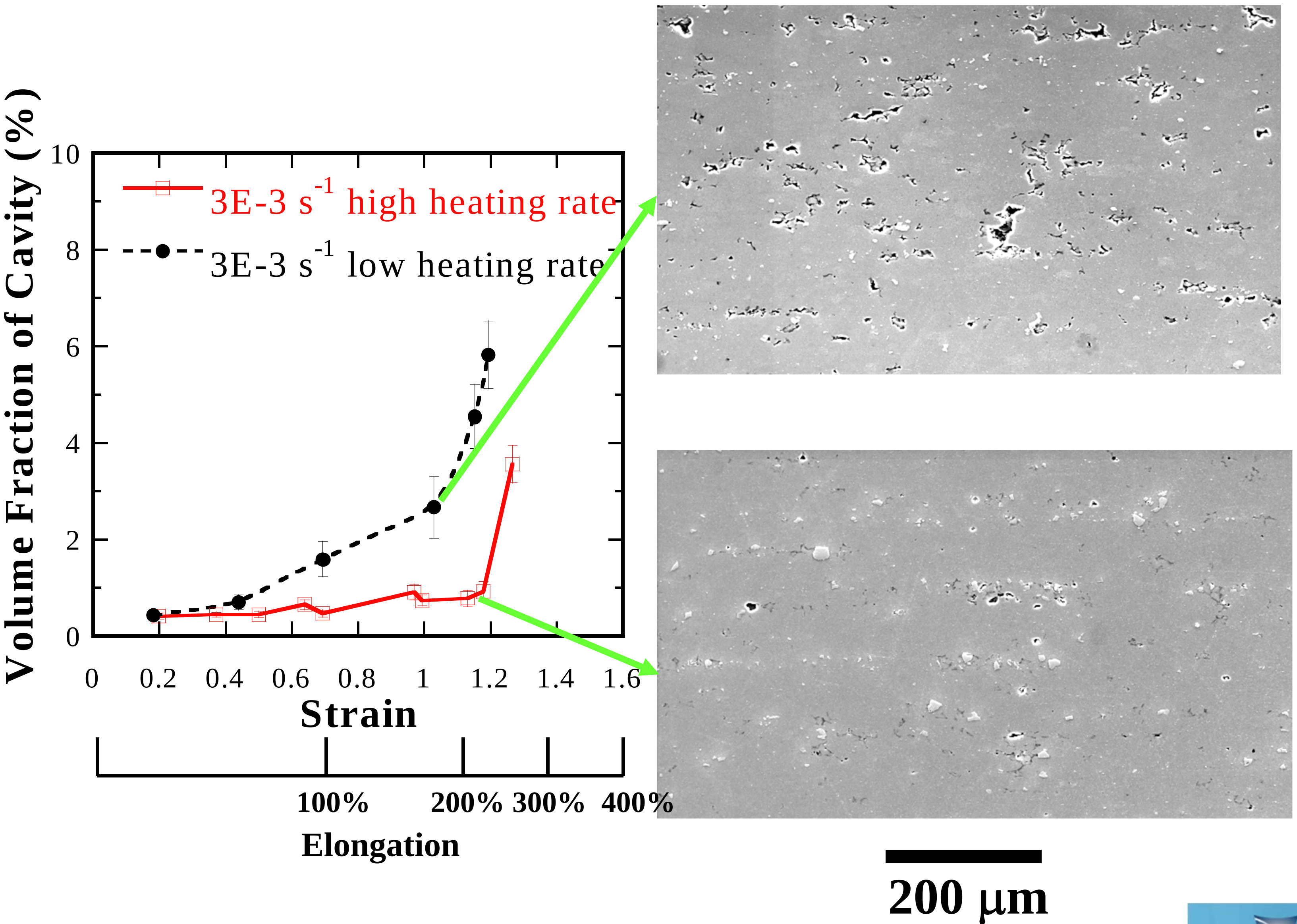
High-angle grain boundary





Specimen gauge length (L_0) = 25.4 mm



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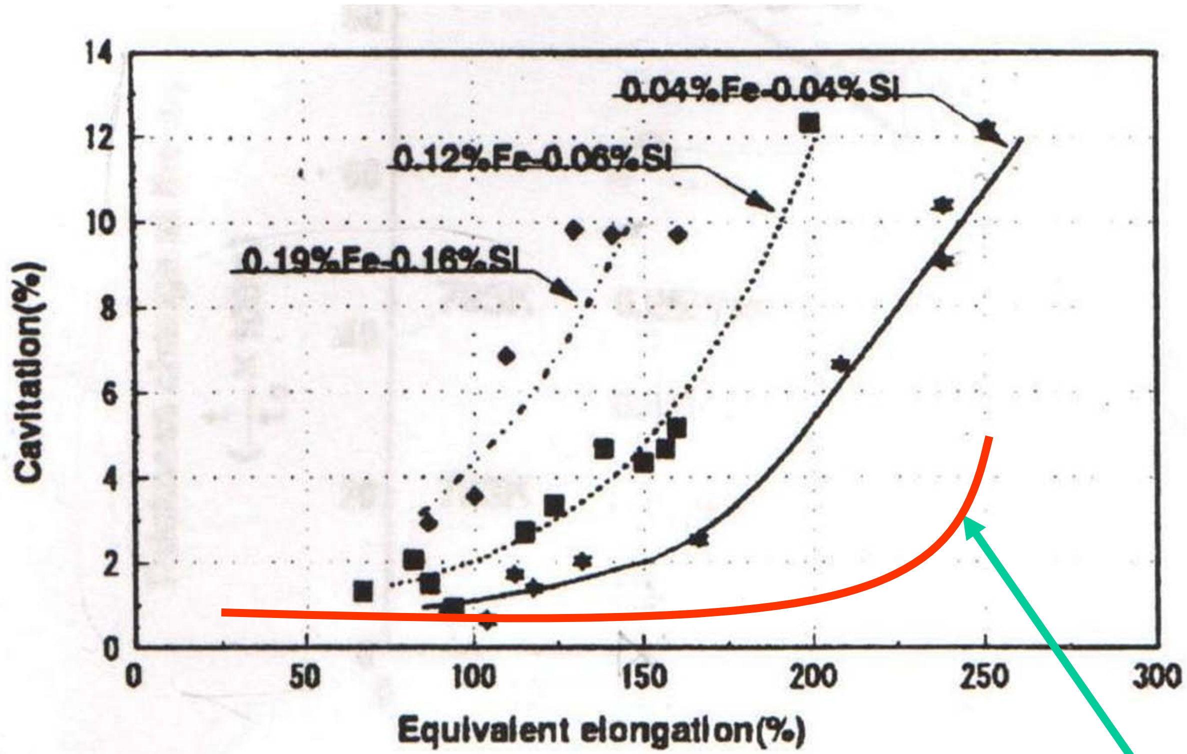


M. Matsuo (1994)
5083 at 500^{o}C

present study,

0.2% Fe and 0.083% Si

Mismatch of thermal expansion coefficient ??

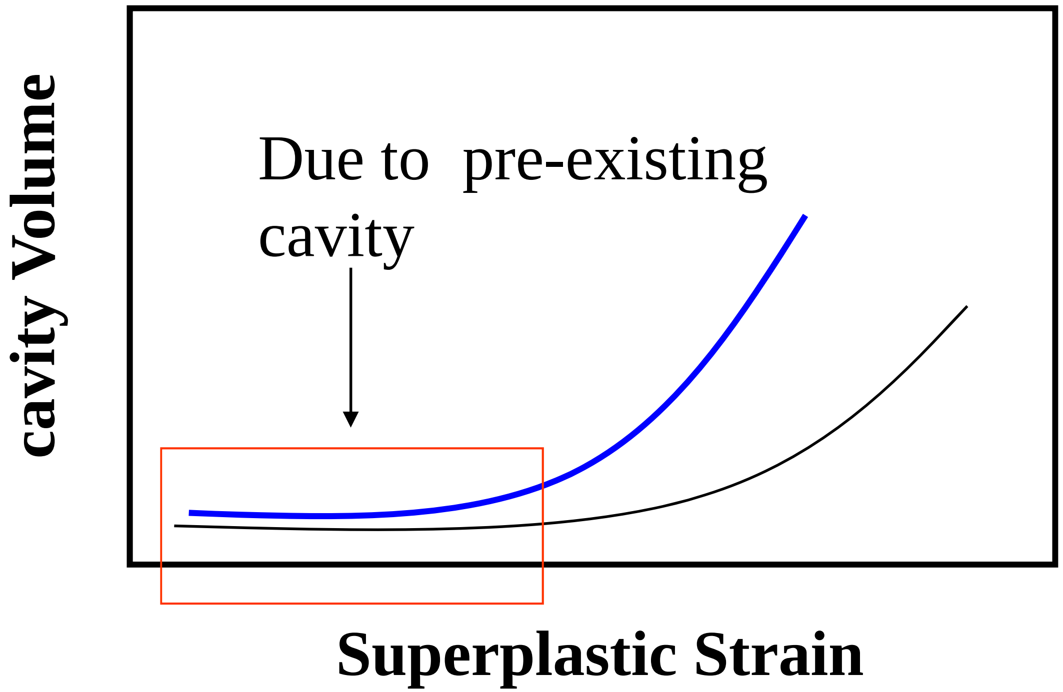
Thermal expansion Coefficient:

Al_6Mn : $14 \times 10^{-6}\ K^{-1}$

$Al_6(Mn,Fe)$: $14.5 \times 10^{-6}\ K^{-1}$

Al - 5% Mg alloy : $\mathbf{22.8} \times 10^{-6}\ K^{-1}$

Tensile force at matrix/particle interface



cavity Volume
Due to pre-existing cavity
Superplastic Strain

Previous efforts to reduce pre-existing cavities:

- High temperature exposure

Chandra and Chen(1999)

Material: 5083

Treatment: **550 ºC, 40 min**

Results: reduce the number and size of pre-existing cavities

Iwasaki et al. (1995)

Material: 5083

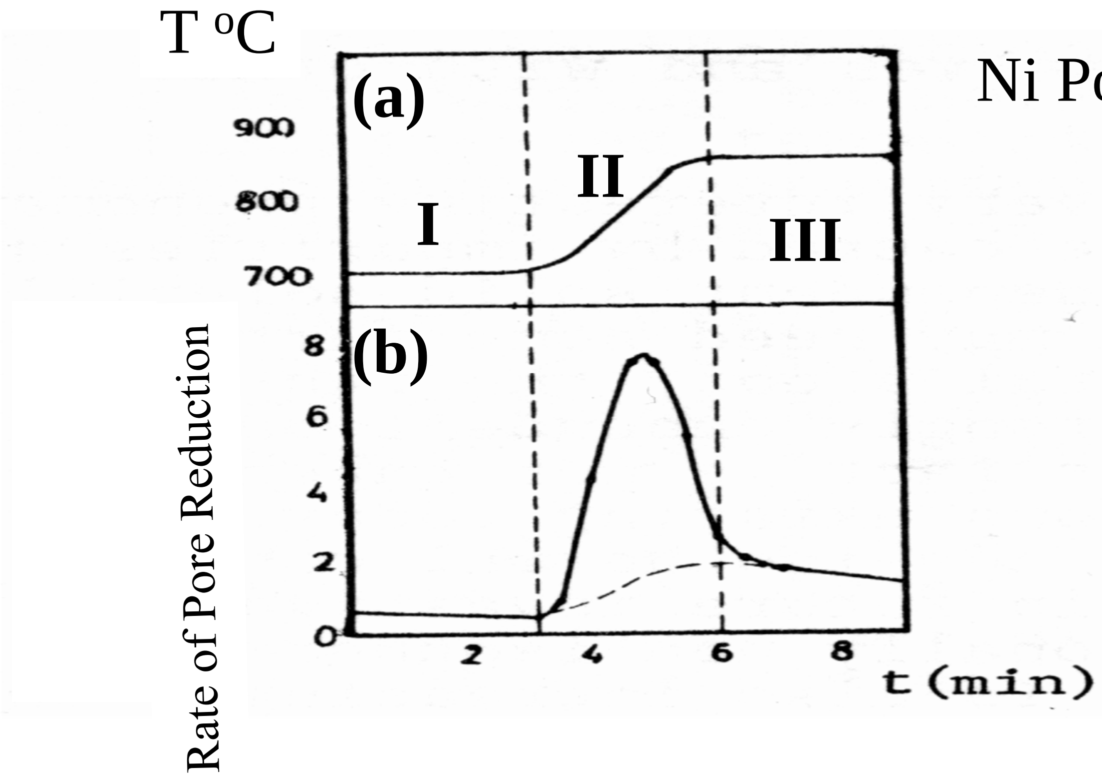
Treatment: **510 ºC 1 hr, then post-annealing at 510 ºC, 4 hr or 560 ºC, 1 hr**

Result: cavity volume fraction 0.43% for 200% elongation

Possible solution

Heating Rate *vs.* Densification during Sintering

(Researches from D.L. Johnson and V.A. Ivensen)



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Summary

<u>High heating rate before loading</u>

- effect of pre-existing cavity on cavitation ↓
- cavitation ↓
- cavitation at higher strain rate deformation ↓
- holding at high temp. (>10 min) help to reduce cavitation, especially heated at higher heating rate