SpringerMaterials

Phase Diagram – use cases

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Outline

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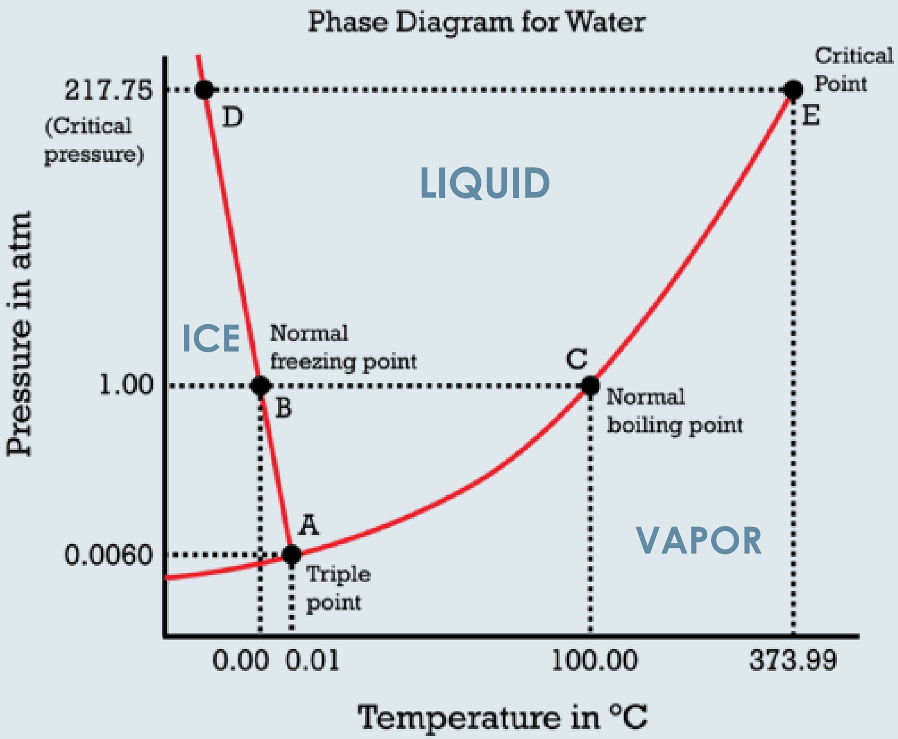
02 **Why** do we use them?

03 Phase diagrams **in real life**

What is a **phase diagram**?

PHASE DIAGRAMS & THEIR IMPORTANCE IN MATERIALS RESEARCH



Phase diagrams help us to understand the physical state of materials under certain conditions.

- They are indispensable for anyone working with alloys and in designing new materials.
- But, phase diagrams are hard to find in published literature.
- Assessing which phase diagrams are the most trustworthy require an expert's evaluation which is not always easily available.

Image: https://courses.lumenlearning.com/cheminter/chapter/phase-diagram-for-water/

Why do we use them?

The use of phase diagrams allows Research & Development, and production to be done **more efficiently** and **cost effectively**

DEVELOPMENT OF NEW ALLOYS

Phase diagrams are used to design alloys for **new or specialized applications** and to develop alternative alloys to replace those containing scarce, expensive, hazardous, or "critical" alloying elements.

FABRICATION INTO USEFUL CONFIGURATIONS

Phase diagrams are invaluable for tailoring existing alloys to **avoid overdesign** in current applications.

DESIGN & CONTROL OF HEAT TREATMENTS

Phase diagrams are particularly useful in controlling heat treatment solutions to **prevent damage** caused by incipient melting, and developing new processing technology.

SOLVING PROBLEMS OF ALLOY PERFORMANCE

Try as we might, we don't always get the manufacturing process right. Phase diagrams can be used to analyze current compositions of alloys to **determine where performance problems lie**.

Source: ASM Handbook, Volume 3: Alloy Phase Diagrams, 1992

Phase diagrams in real life

Designing new materials

Search by Elements: select **Al – Ni,** refine by "phase diagram" under *properties*

THE SCENARIO: we want to create a nickel-based **superalloy** for a gas turbine engine, to use in either **aircraft or utility gas turbines** for electric power.

- Gas turbines experience **high temperatures** and require **high strength** and **creep resistance** properties.
- The **Ni-Al phase diagram** helps a researcher decide the best and most **stable composition**.
- In this case the composition of Ni_3Al Y' region has a structure that is stable up to **1372 °C**.

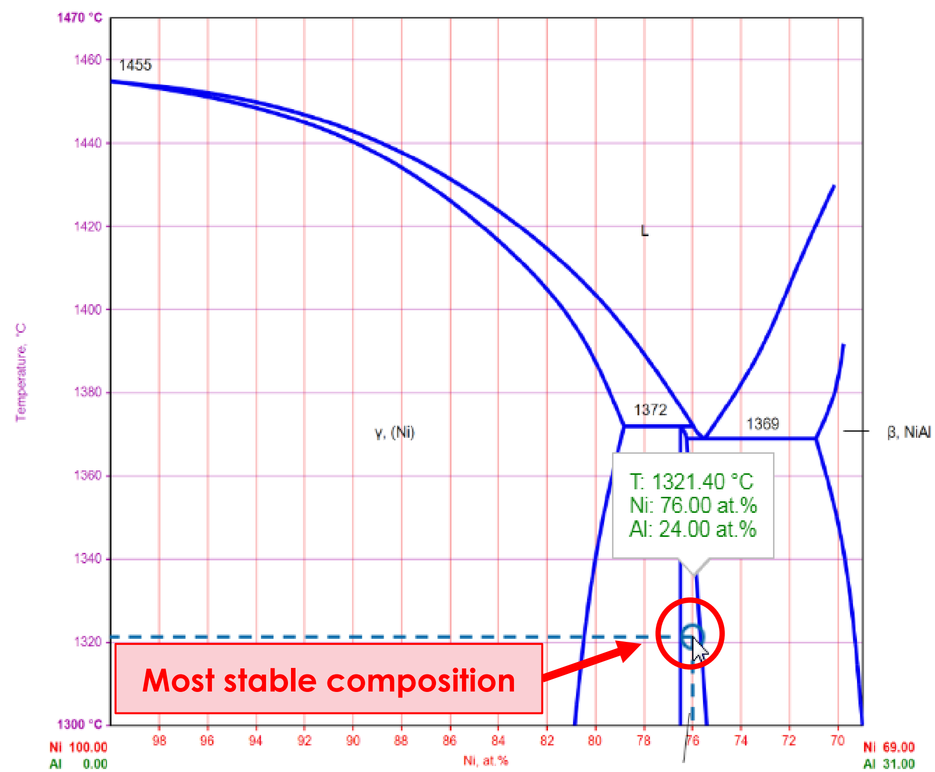


Fig. 2: The binary system Ni-Al (Ni-rich region)

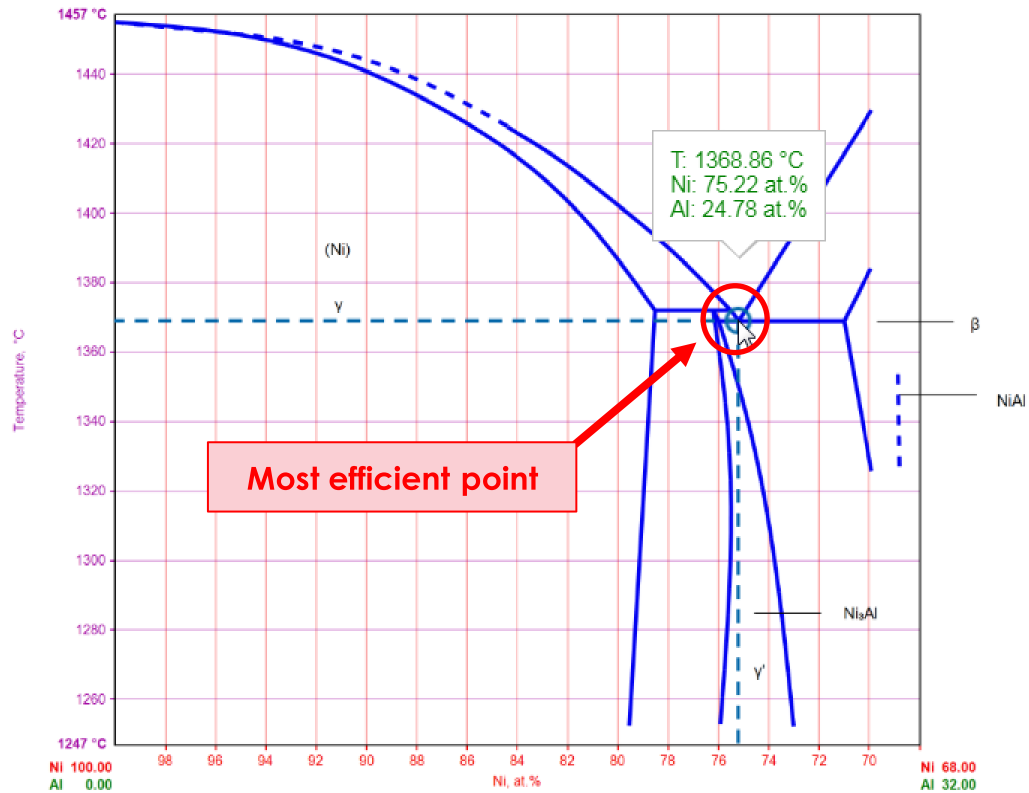
Phase diagrams in real life

Determining the best manufacturing conditions

Search by Elements: select **Ni – Al**, refine by "phase diagram" under *properties*

THE SCENARIO: we want to create **an alloy** with **75% Ni** and **24% Al**, the minimum temperature at which these two will combine to form an alloy is **1368 ° C**

- **Phase diagrams** allow you to determine the **most efficient conditions** for manufacturing alloys – this saves the manufacturer on energy costs
- At this temperature and composition of **Ni and Al**, the materials immediately turn into a **solid** without a long time to cool down so, if it needs to be cast into a die, it can be done around this temperature.



MSI Fig. 1: Part of the boundary binary Ni-Al system [87Hil]

Phase diagrams in real life

Choosing the best materials for your project

Search by Elements: select **Al – Mg – Zn**, refine by "phase diagram" under *properties*

THE SCENARIO: we want to create an **aluminum alloy** to make **seatbelt hinges** and **automobile bumpers.** This alloy should be corrosion resistant, have good weldability, and high strength.

- These properties can be obtained by adding **Zinc** and **Magnesium** to **Aluminum**.
- A good candidate for such a material should also have a combination of **two distinct phases** (α and η) in its structure. The permissible compositions can be found in the phase diagram for **Al-Zn-Mg (yellow region)**
- **A7003 aluminum alloy** has the right combination Al-Zn-Mn and can be used for these applications.

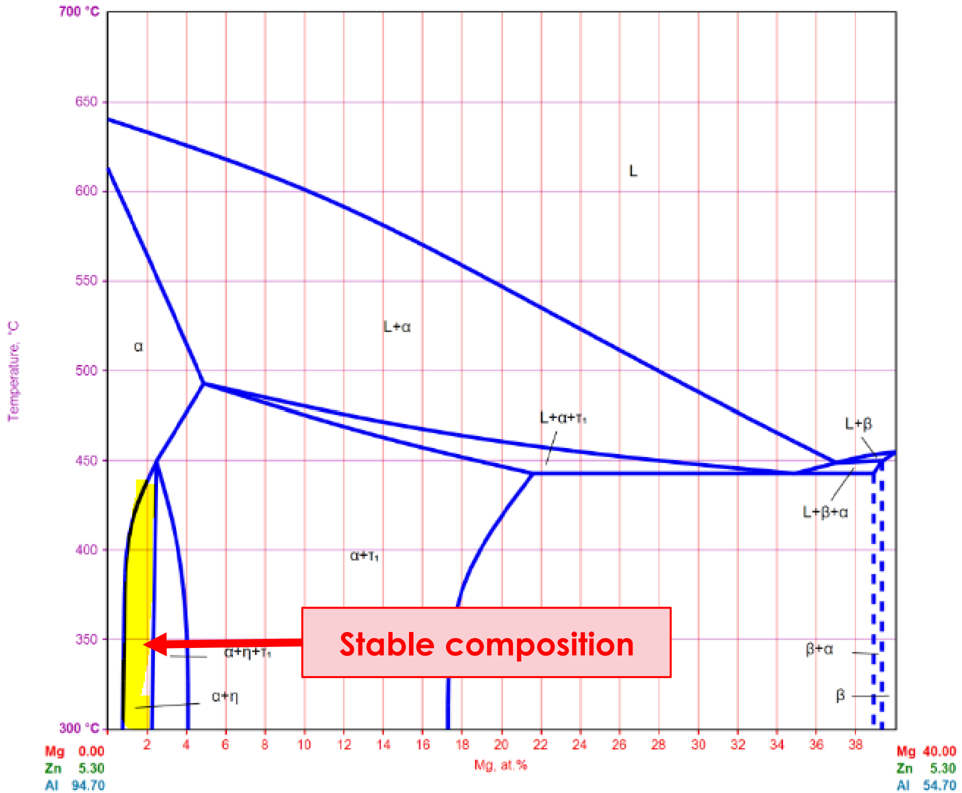


Fig. 7: Vertical section at constant 5.32 at.% Zn

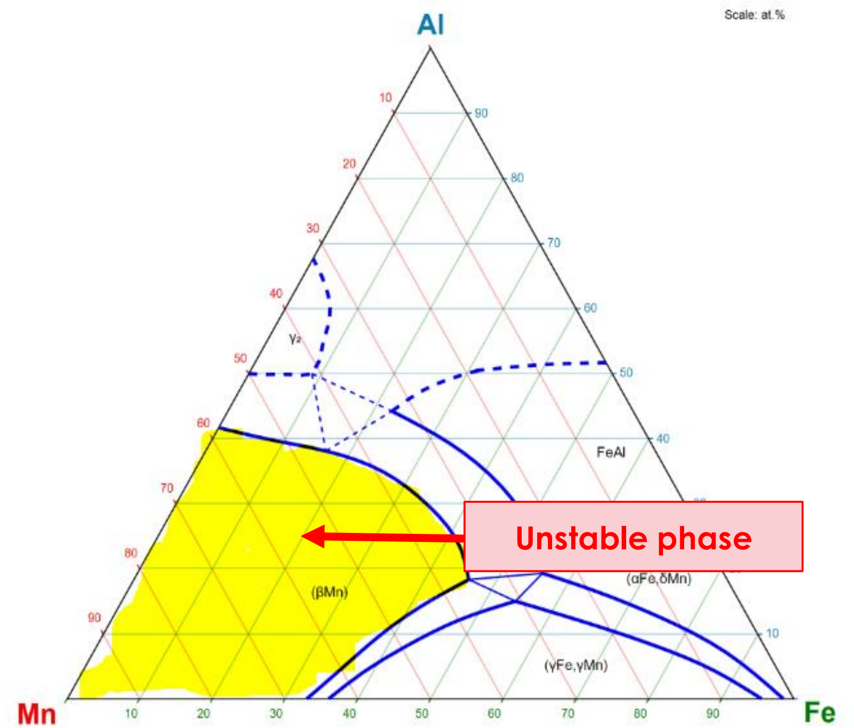
Phase diagrams in real life

Designing materials that won't fail

Search by Elements: select **Al – Fe – Mn,** refine by "phase diagram" under *properties*

THE SCENARIO: we want to create **an alloy** that is able to sustain high temperatures for use in **fuel injection pumps**, **furnace mufflers**, **heat-treating fixtures**, or **gas turbines**.

- Alloys used to for high temperature applications contain **Manganese (Mn)** in them as it provides:
  - High strength
  - High resistance to corrosion
  - Good welding characteristics
  - Makes alloys easier to cast
- However, Mn has an **unstable phase** (β Mn) at higher temperatures that can lead to cracks and failure of parts.
- **Phase diagrams** allow you to determine the alloy composition that will **fail under high temperatures**



MSI Fig. 6: Partial isothermal section at 800°C