Department of Mechanical and Industrial Engineering

# Deformation of Iron Manganese Steels with Nitrogen and Aluminum

by

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# Introduction to Hadfield Steel

Hadfield Steel:

- Excessive deformation and wear resistance requiring applications (e.g.,railroad frogs).
- High toughness.
- High ductility.
- High work hardening capacity.
- Work hardening mechanism not fully understood yet.

# Hadfield Steel Single Crystals

Reasons for using single crystals:

- Orientation dependence of mechanical properties, such as yield strength, work hardening, ductility, and toughness.
- To go one step further in applications by introducing combination of mechanical properties at a higher level compared to polycrystalline form.

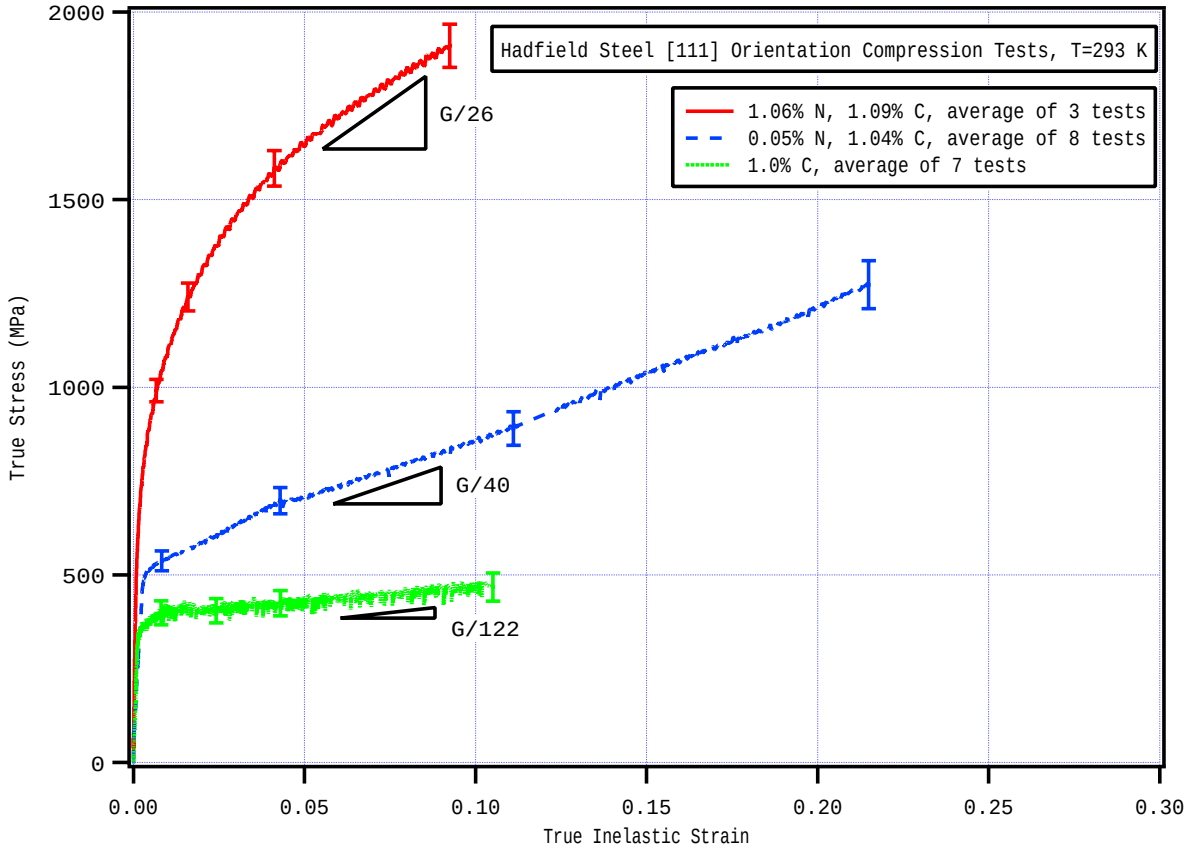
# Alloying Hadfield Steel

- By alloying Hadfield steel, a new microstructure is introduced.
- By changing the microstructure, difference in the deformation mechanisms and accordingly better mechanical properties, such as high strength combined with high ductility and higher rate of work hardening, are aimed.

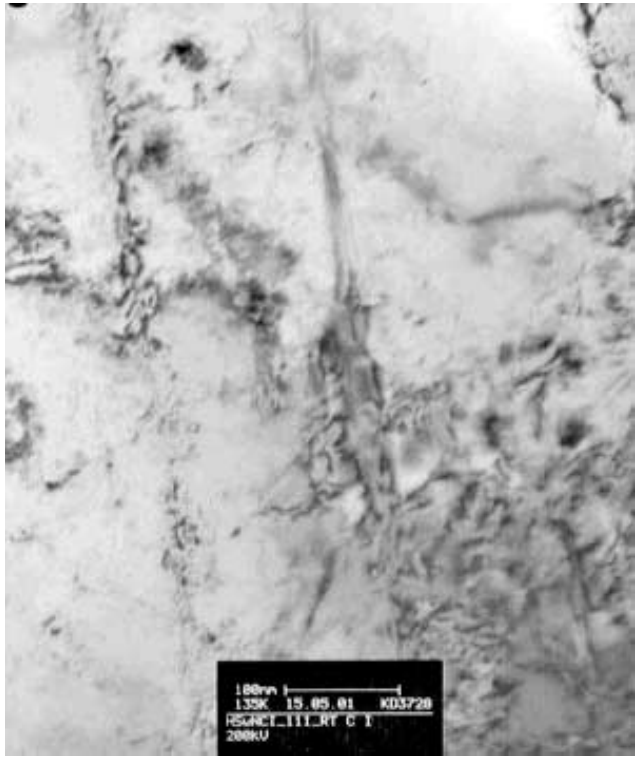
# Effect of Nitrogen on the Deformation Behavior of Hadfield Steel

- Work done on nitrogen alloyed stainless steels, previously.
- Nitrogen added to Hadfield steel mainly to achieve higher strength.
- Work hardening behavior investigated.
- In this study, three different compositions compared: 0%N, 0.05%N, 1.06%N (Same amount of C, and Mn).

# Hadfield Steel [111] Orientation Single Crystals under Compressive Loading



# TEM pictures showing microstructural state of different compositions after deformation



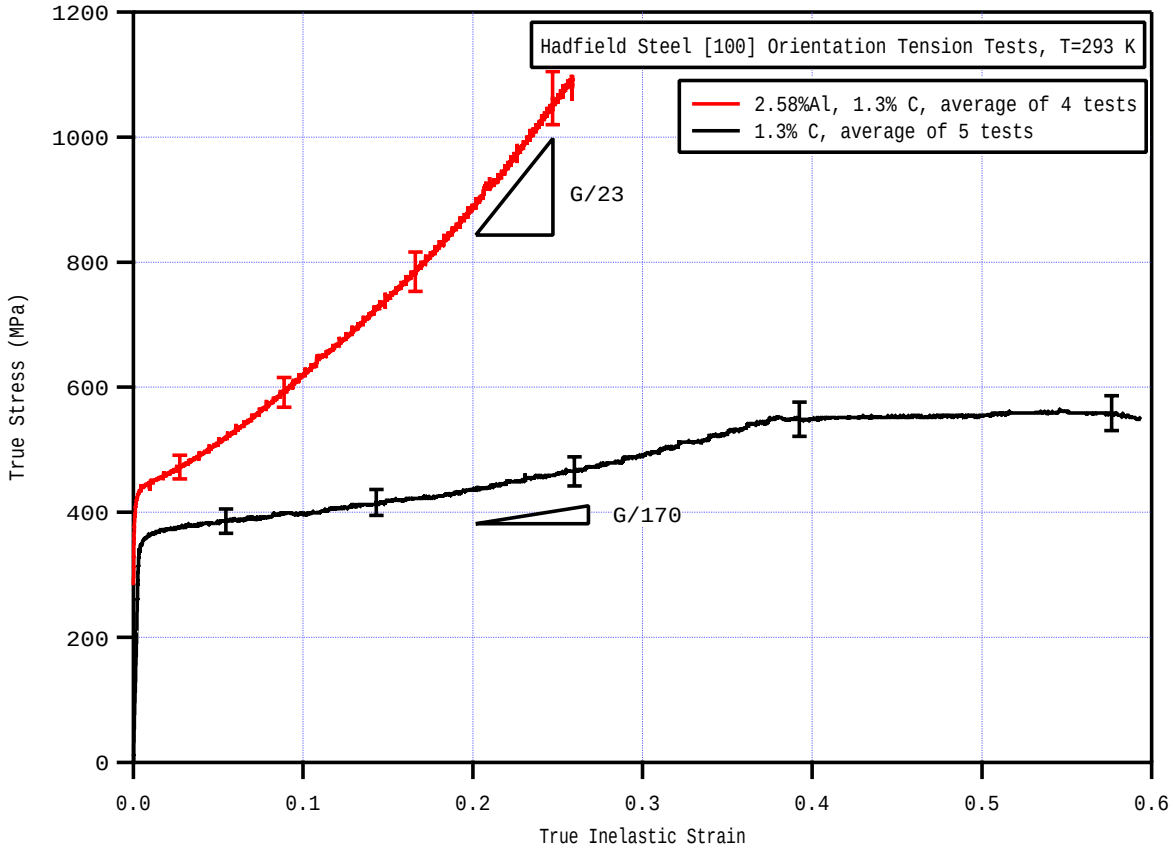
# Effect of Nitrogen

- Drastic increase in yield strength with increasing nitrogen content.
- No significant change in ductility.
- Orientation dependence of mechanical properties: Same trend for all three compositions.
- Important role of precipitation hardening in increasing the strength.
- Significant difference in the deformation behavior of materials with the same crystallographic orientation but different nitrogen contents.

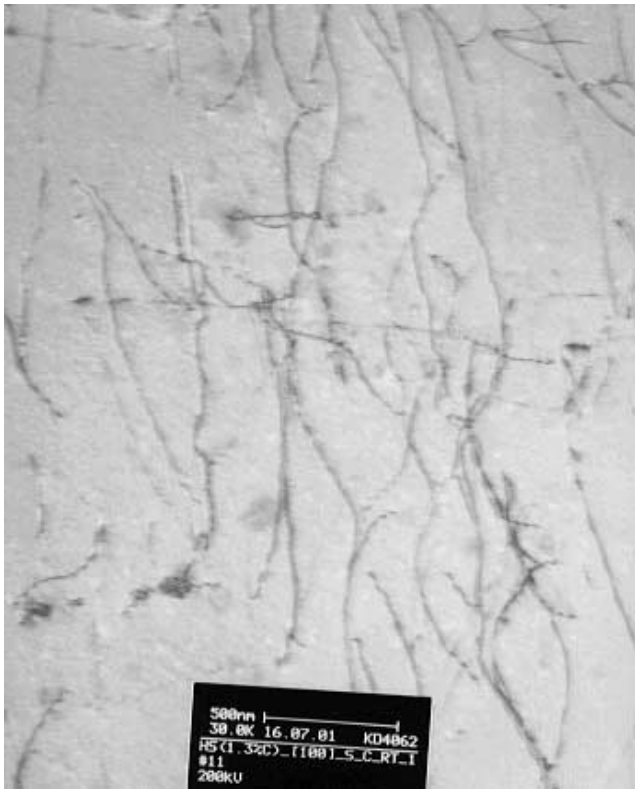
# Effect of Aluminum on the Deformation Behavior of Hadfield Steel

- Work done on aluminum alloyed Hadfield steel polycrystals with different chemical compositions, previously.
- Aluminum added to Hadfield steel mainly to suppress twinning and thereby modify the work hardening behavior.
- In this study, two different compositions compared: 0%Al, 2.6%Al (Same amount of C, and Mn).

# Hadfield Steel [100] Orientation Single Crystals under Tensile Loading



# TEM pictures showing microstructural state of different compositions after deformation

# Effect of Aluminum

- Increase in yield strength with increasing aluminum content.
- Loss of ductility, but not very brittle.
- Orientation dependence of mechanical properties.
- Twinning suppressed by alloying with Aluminum.
- Significant difference in the work hardening behavior: Coefficient of deformation hardening in stage II increased drastically with Aluminum.

# Conclusion

- Addition of nitrogen resulted in a drastic increase of mechanical strength without significant change of ductility.
- Addition of Aluminum introduced a rapid work hardening combined with relatively higher strength.
- Better combination of mechanical properties may be obtained by properly alloying Hadfield steel.
- Different combinations of mechanical properties possible with different crystallographic orientations.