Fabrication of 4130 steel powder for 3D Printing

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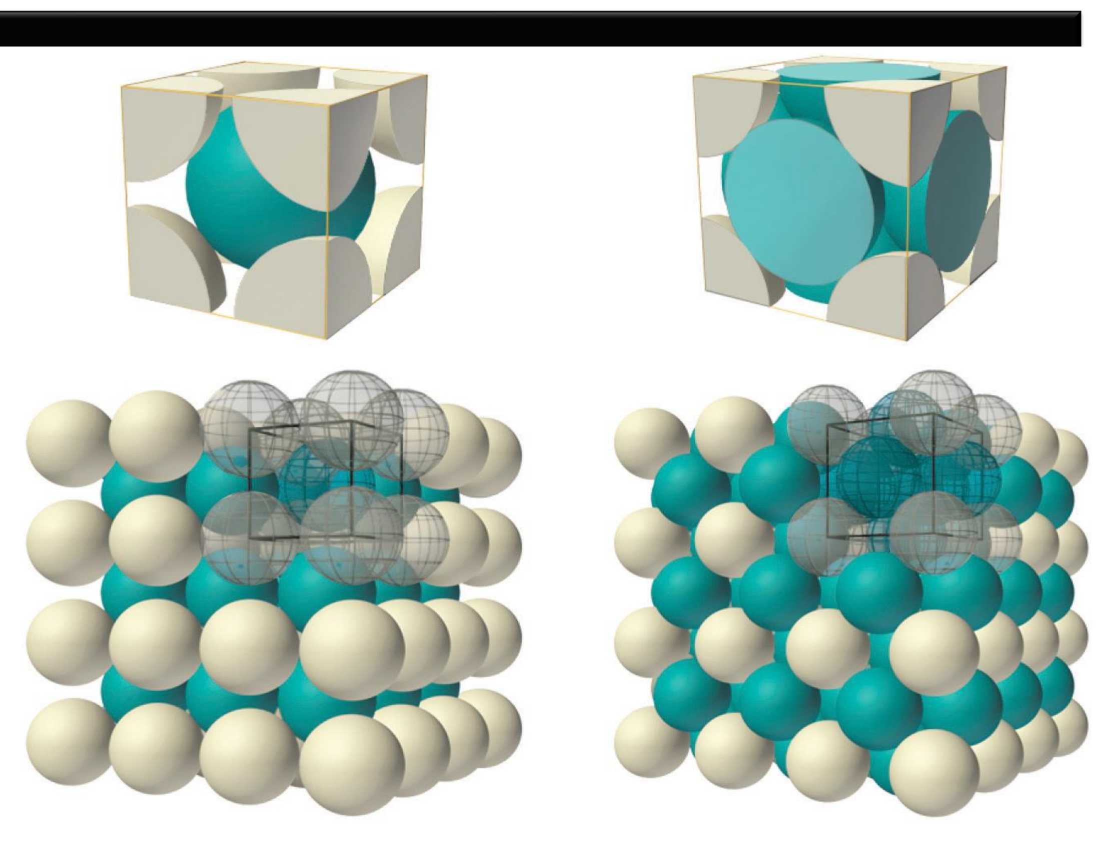
Abstract

- AISI 4130 grade is an alloy steel containing chromium and molybdenum as strengthening agents. The steel has a good strength, toughness, fatigue strength, weldability and machinability.
- These intriguing properties motivate us to obtain the 4130 powder via (1) mechanical/jet milling process and (2) atomization process.
- Studies show that cyclic jet milling enhances the flowability of iron powder to ~ 38 g/sec. Incorporation of chromium, manganese, carbon, silicon, molybdenum, sulfur, phosphorous reduces flowability of 4130 powder.
- The 4130 powder obtained by atomization process possesses flowability of ~ 32 g/sec. The EDS shows both mechanical mixed and atomized 4130 powder have good uniformity and the chemical composition.
- Using the COMSOL to predict the melting pool of 4130 powder.

a. Uniqueness of AISI 4130

The chemical composition of AISI 4130 alloy steel

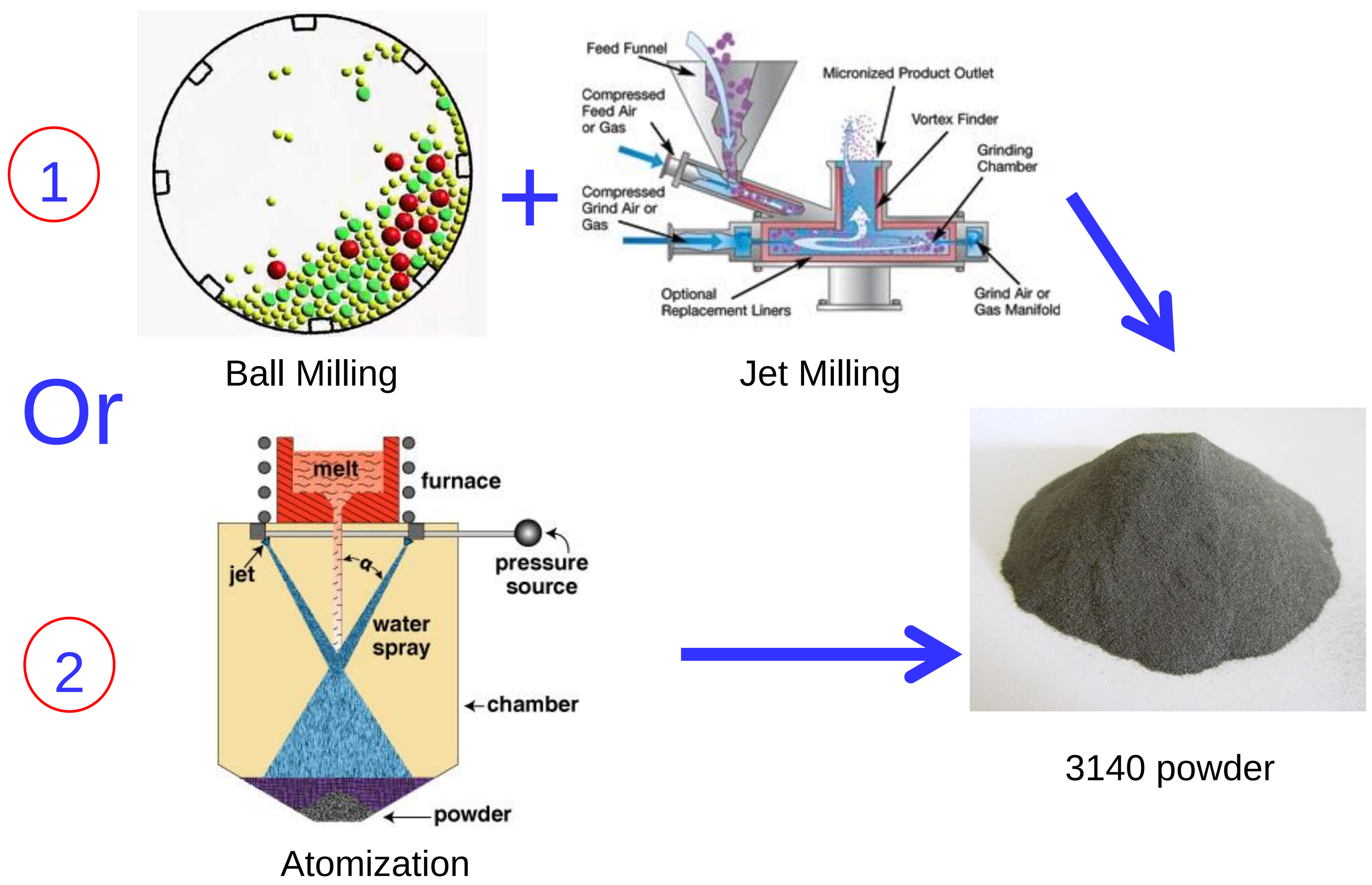
Element	Content (%)
Iron, Fe	97.03 – 98.22
Chromium, Cr	0.80 – 1.10
Manganese, Mn	0.4 – 0.6
Carbon, C	0.28 – 0.33
Silicon, Si	0.15 – 0.30
Molybdenum, Mo	0.15 – 0.25
Sulfur, S	0.04
Phosphorous, P	0.035



(b) Body-centered cubic (c) Face-centered cubic

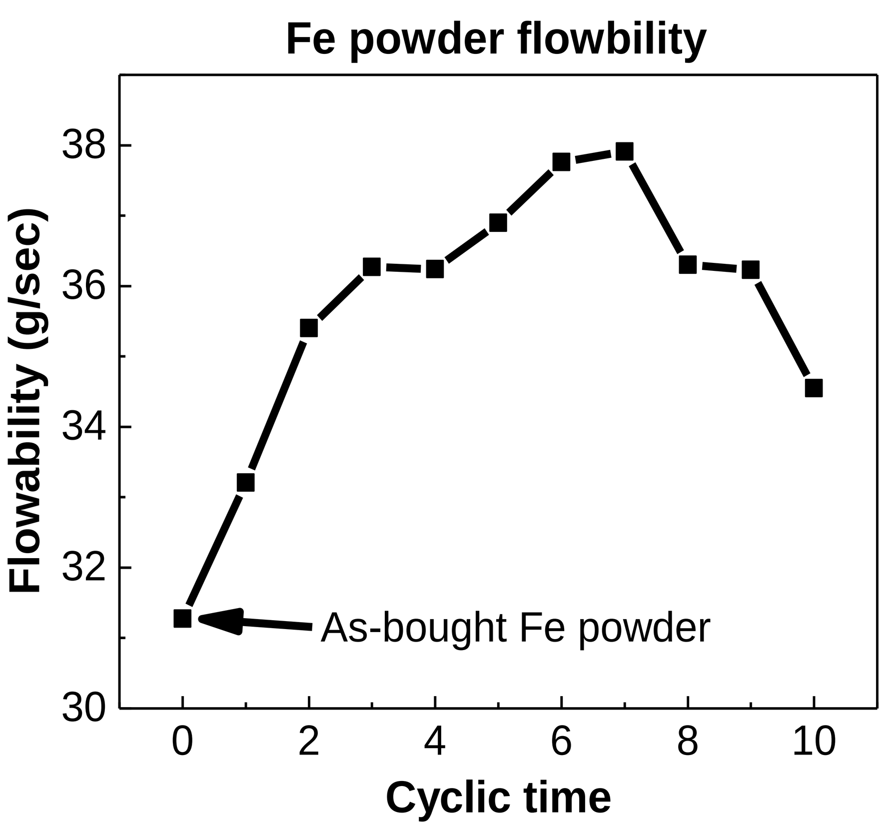
- AISI 4130 alloy steel contains chromium and molybdenum as strengthening agents. It has low carbon content, and hence it can be welded easily.
- AISI 4130 steel has good atmospheric corrosion resistance and reasonable strength up to around 600º F (315º C). It shows good overall combinations of strength, toughness. and fatigue strength.
- Above 871°C, the iron atoms have a Faced Centered Cubic (FCC) arrangement and carbon atoms are interspersed between atoms. If cooled slowly, the atoms will rearrange to a low stressed Body Centered Cubic (BCC) State.
- If quickly quenched from 871°C, the structure does not realign to a BCC structure, but rather a Body Centered Tetragonal arrangement, leaving a very highly stressed material (very hard and strong). This metallurgical structure is called **Martensite.**

b. Powder preparation – Mechanical mixing or Atomization

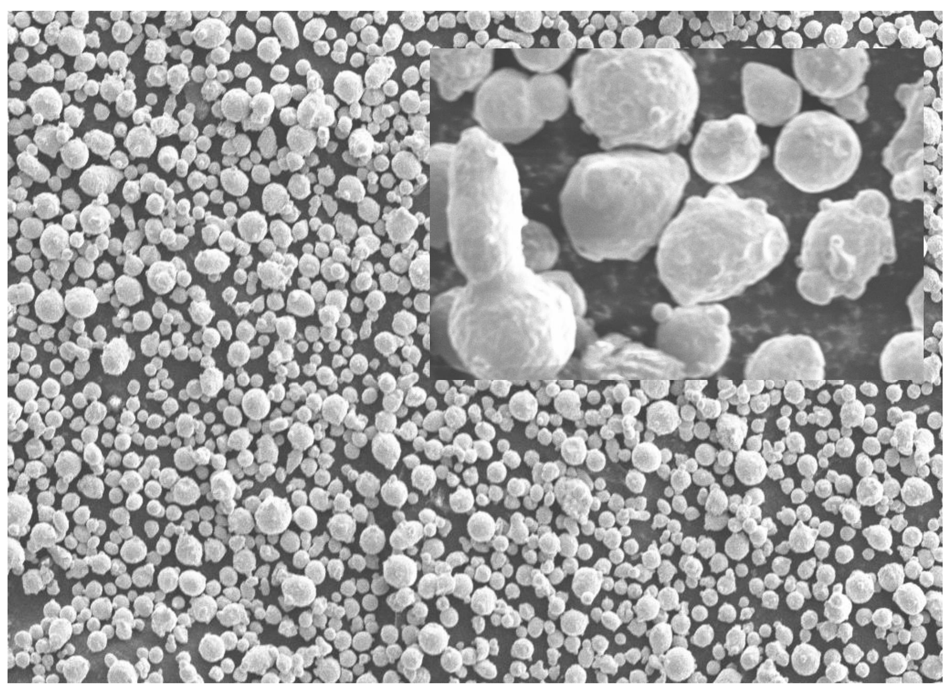


- Ball milling: To mix all 4130 chemical composition uniformly.
- Jet milling: To enhance the flowability of 4130 powder after ball milling .
- After the ball milling and jet milling, the 4130 powder is obtained. However, there is more room to improve the flowability of powder to meet the 3D printing requirement.
- Atomization: Spherical 4130 powder with good flowability (~32 g/sec) is obtained. The powder quality meet s the 3D printing requirement.

c. Powder characterizations



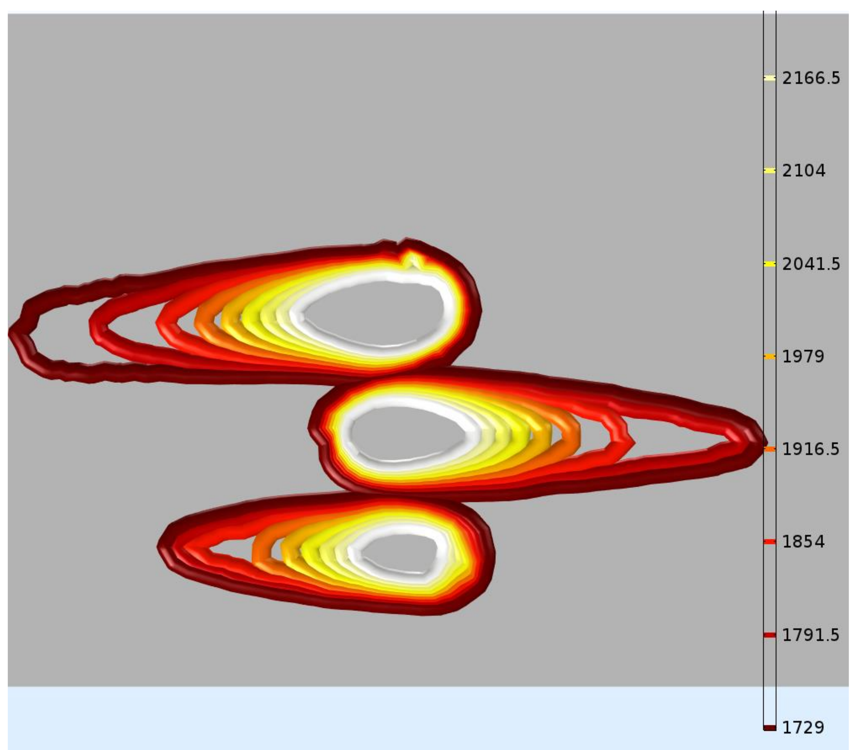
jet milling



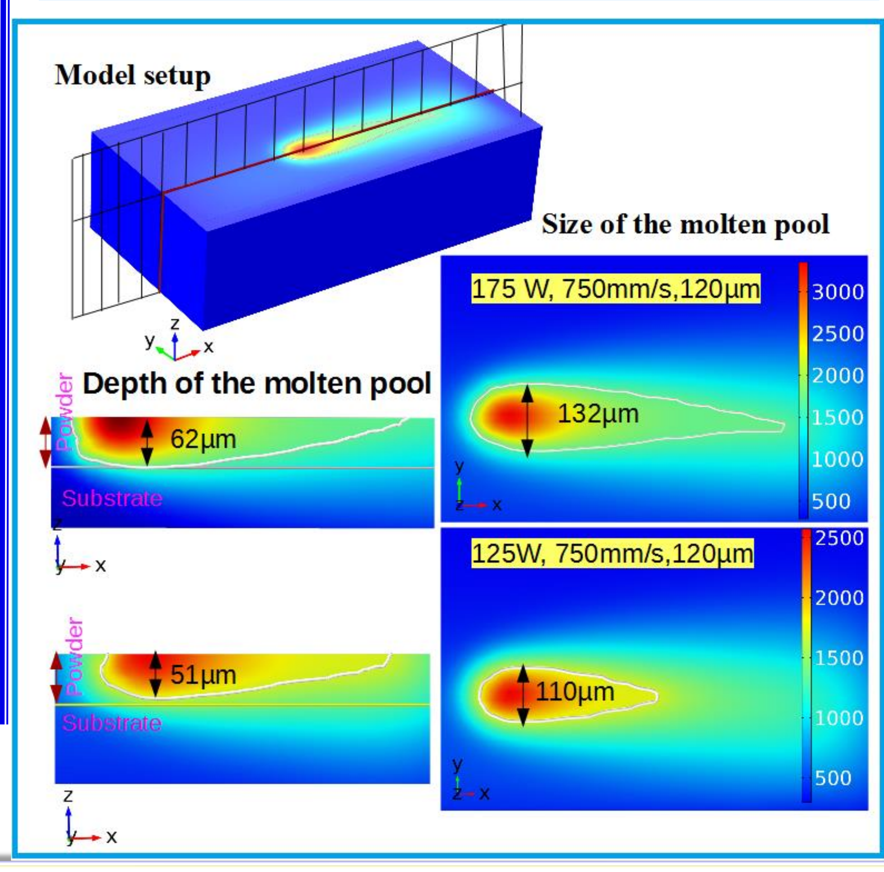
Atomization process

- The jet milling enhances the flowability of Fe powder by ~ 22% to ~38 g/sec.
- Incorporation of 4130 chemical composition degrades the overall flowability.
- 4130 powder via atomization process shows the spherical shape with its size of ~ 30 µm.
- The flowability of 4130 powder via atomization process is ~ 32 g/sec that meets the SLM printing requirement.

d. COMSOL 4130 modelling



- COMSOL Simulation results for SLM of 4130 powder.
- Using Heat transfer Model of COMSOL we were able to determine the best process parameter.
- The optimum values proposed by simulation: P=175W, scanning speed of 750 mm/s, hatch distance=120 microns, show a good overlapping of the molten pool tracks which reflects mechanical properties of the printed material.



- *For a laser power of 175W; a slight overlap for two consecutive scanning lines and a penetration up to a few micrometers in the bulk substrate are observed.*
- *When the power is reduced to 125W, the maximum temperature, overlapping of molten pool tracks and the depth of the molten pool are reduced. The new printed layer can not well stick on the already printed substrate.*

4. Summary

- The spherical 4130 powder with the good flowability are obtained. The 4130 compositions are uniformly distributed across the powder.
- Using the COMSOL, the SLM printing parameter is optimized. Several parts (tensile bar, plate, lattice, etc) are printed.

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