The influence of processing parameters on roll compaction of titanium powder

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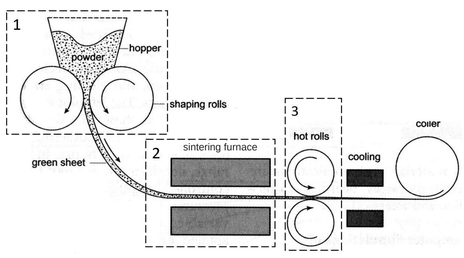
Introduction

Titanium has been investigated as a lightweight material to improve automotive vehicle fuel efficiency, and reduce emissions through weight reduction [1]. The high economic cost, and high extraction energy of titanium has restricted its use to specialized biomedical, and aerospace applications. Powder metallurgy is a production method proposed to reduce the processing energy of Ti products and further increase vehicle fuel efficiency [2].

Direct roll compaction (shown below) uses low cost metallic powders to achieve a more economic fabrication of thin sheet metal [3]. This work produces a dense strip using coarse Ti sponge powder typically not used in powder metallurgy. Cold rolling adds plastic deformation to increase densification limited by the poor sinterability of coarse powder.



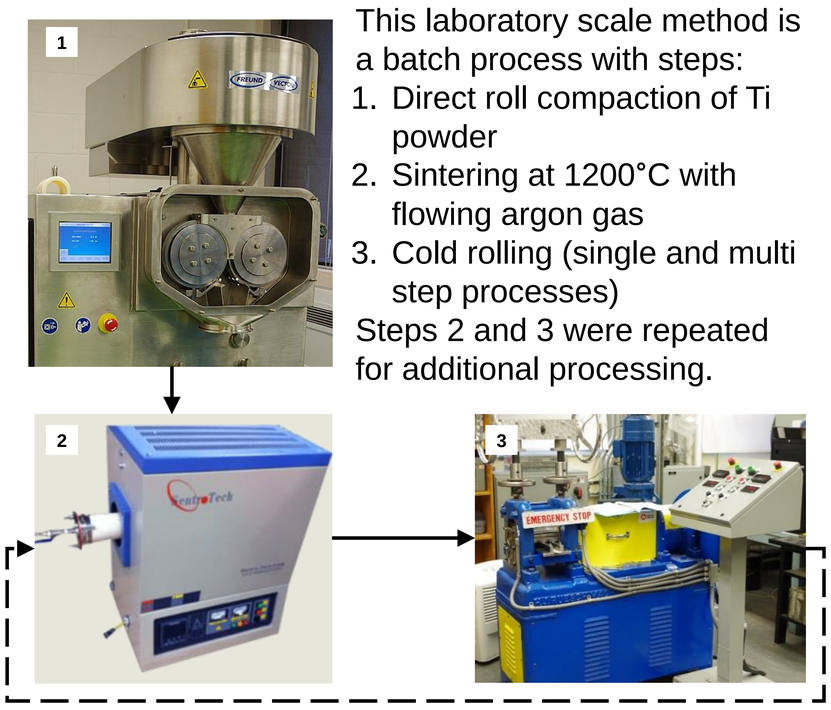
[4]

Materials and Methods

Grade 3 commercially pure Ti sponge powder was first sieved to different powder distributions (value in brackets is maximum particle size) as follows:

- -20 mesh (850 µm)
- -35 mesh (500 µm)
- -40 mesh (425 µm)
- -50 mesh (300 µm)

Each powder mixture was direct roll compacted in a Freund-Vector TFC-220 horizontal roll compactor with vertical hopper. The compactor utilizes a hydraulic controlled roll gap with adjustable roll force, and 200 mm diameter ridged rolls.



This laboratory scale method is a batch process with steps:

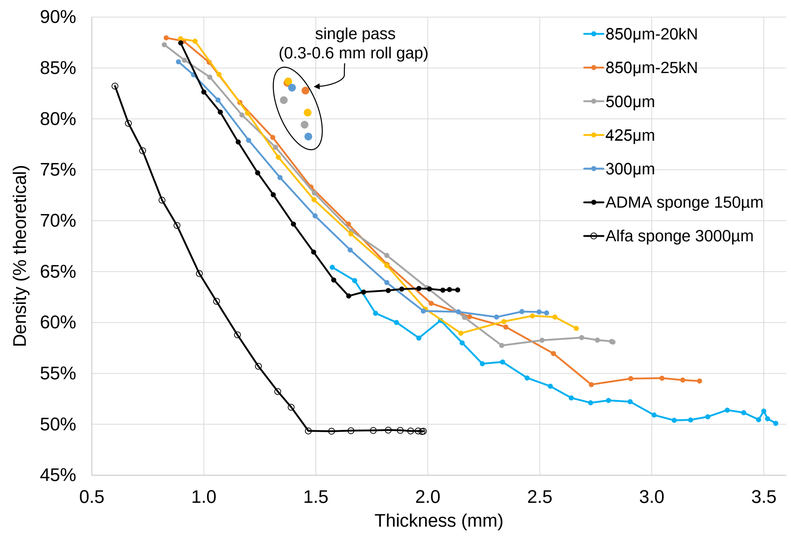
1. Direct roll compaction of Ti powder
2. Sintering at 1200°C with flowing argon gas
3. Cold rolling (single and multi step processes)

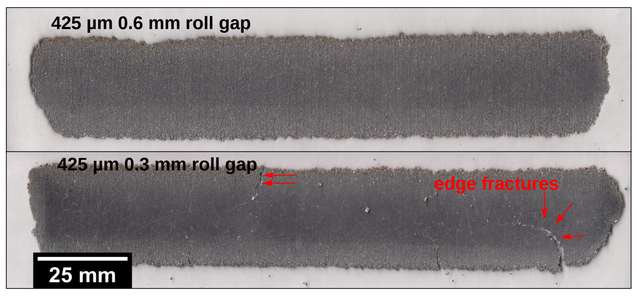
Steps 2 and 3 were repeated for additional processing.

Following each processing step the samples were macroscopically imaged and thickness, height, and mass were measured allowing for density calculations. Metallography was performed at key points in the process for microstructural analysis.

Cold Rolling

Initial roll compacting of various powder types and size distributions determined the most promising powder type to investigate for further processing. In the green state the strips achieved 48-58% density and sintering increased density by 2-7%. Multiple cold rolling passes (sequentially reducing the roll gap by 0.1 mm) produced an initial period of particle rearrangement (↓ height with no change in density or surface area) followed by densification increase and thickness decrease as shown below. 425 µm and 500 µm powders produced the highest density with the least amount of edge cracking and therefore were selected for more processing to determine best practices.

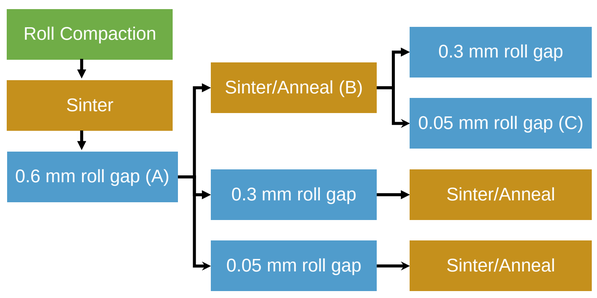


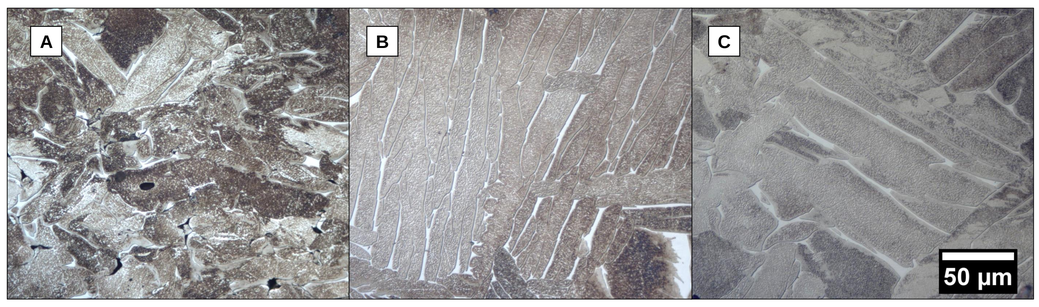


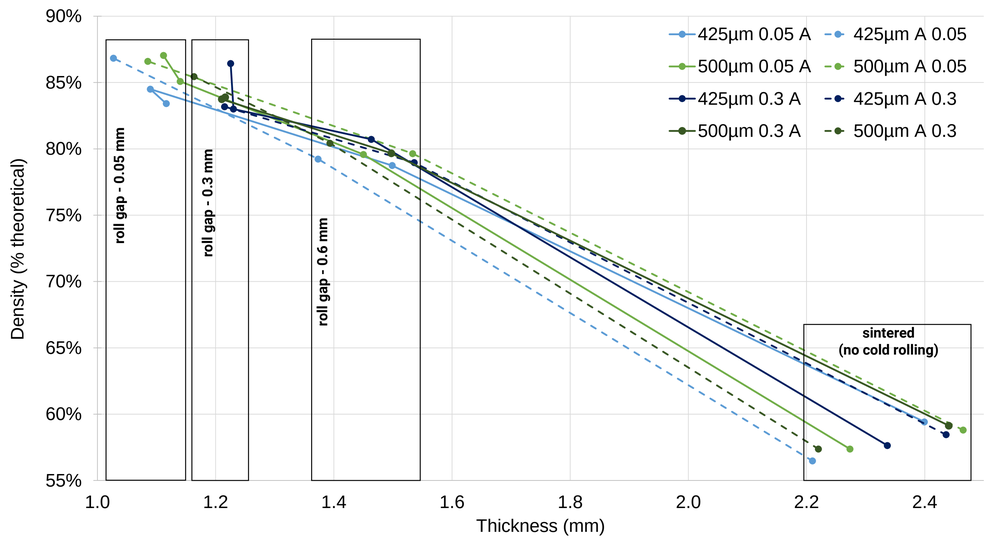
Single pass cold rolling was found to induce a higher density for a given thickness than a strip processed with multiple less aggressive cold rolling steps. A single pass roll gap of 0.6 mm showed good densification (increase from ~58% to ~80%) without significant cracking of sample edges. A roll gap of 0.3 mm created large fractures originating on the edge of the strip.

Cold Rolling + Sinter/Anneal

After an initial single pass of 0.6 mm, a second cold rolling pass was performed to further densify the strip without fracturing. A sinter/anneal (1200°C) step was added before or after the second pass to densify and continue sintering powder particles. The flow chart outlines the process and density results are plotted.







The more aggressive 0.05 mm roll gap showed slightly higher density than a 0.3 mm roll gap. Annealing the strips before or after the second cold roll pass had a minimal effect on density (increase of 0.5-3%) but may have provided stress relief to allow for further rolling. Metallographic analysis showed significant grain growth after annealing. Retained β-Ti was identified between plates of α-Ti.

Conclusions

- Titanium strips were successfully produced using a direct roll compaction, sinter/anneal, and cold rolling procedure. The highest density measured was 87%, achieved with powder size 425 and 500 µm using 0.6 mm, and 0.05 mm roll gaps.
- All strips subjected to double pass cold rolling exhibited areas of higher density in the centre of the strip. This region had a density of 99%.
- Annealing at 1200°C did not significantly contribute to densification but did cause grain growth. Grain size can therefore be controlled through the sequence of cold rolling and annealing in the process.

References

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