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Comments on "Solid freeform fabrication by extrusion and deposition of semi-solid alloys"

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Finke and Feenstra [1] recently discussed the feasibility of using semi-solid metals in a new solid freeform fabrication (SFF) process based on the fused deposition modeling (FDM) technique. Semi-solid metals are alloys processed at a temperature between the liquidus and the solidus temperatures, where solid and liquid coexist in the form of solid particles immersed in a liquid matrix. SFF is a manufacturing approach based on creating three-dimensional bodies by the addition of material layer by layer, without molds or machining. In FDM [2], the layers are created by the deposition of a hot thermoplastic polymer through a nozzle, which deposits adjacent, linear streams until each layer is completed. Finke and Feenstra's goal was to investigate if the similarities in rheological behavior between semi-solid metals and hot thermoplastic polymers could be used in a way similar to FDM, and they concluded that it is possible, yet further studies are necessary to accomplish a practical implementation able to make three-dimensional bodies.

This concept is not new, however. The feasibility of using semi-solid slurries for building layered freeform objects was demonstrated at MIT in the first half of the 1990's. The technology is described in a journal article [3], two theses [4, 5], and two U.S. patents [6, 7] predating [1], and it is commercialized by Semi-Solid Technologies Inc. (SST). We note that these publications were omitted in [1] and reasonably could have been referenced given their availability and the relevance of the results obtained. Publications [3–5] show a practical implementation of the methodology and several examples of three dimensional bodies (Fig. 1), results that are beyond those described in [1].

Many of Finke and Feenstra's findings are in agreement with [3–5]; nominally, the possibility of using semi-solids for SFF, the problem of segregation of solid particles, and the challenge of joining successive semi-solid layers. Other than the quality of the results, the most significant difference between [1] and our work is that we used a strirrer reaching to the nozzle to maintain a homogeneous slurry, as shown in Fig. 2. This type of stirrer helped maintain the slurry state. The problem of segregation still existed, but it was confined to a short initial transient of low solid fraction slurry. After this transient the slurry was homogeneous and of practically constant properties throughout the building of a component.

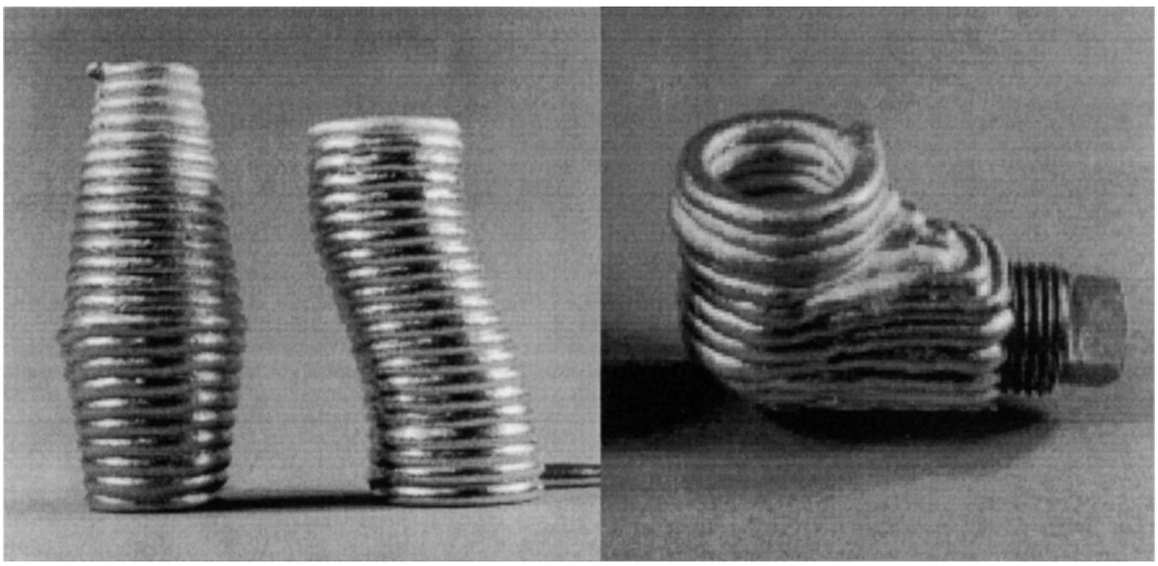

Figure 1 Three dimensional shapes obtained by deposition of a semi-solid metal [3].

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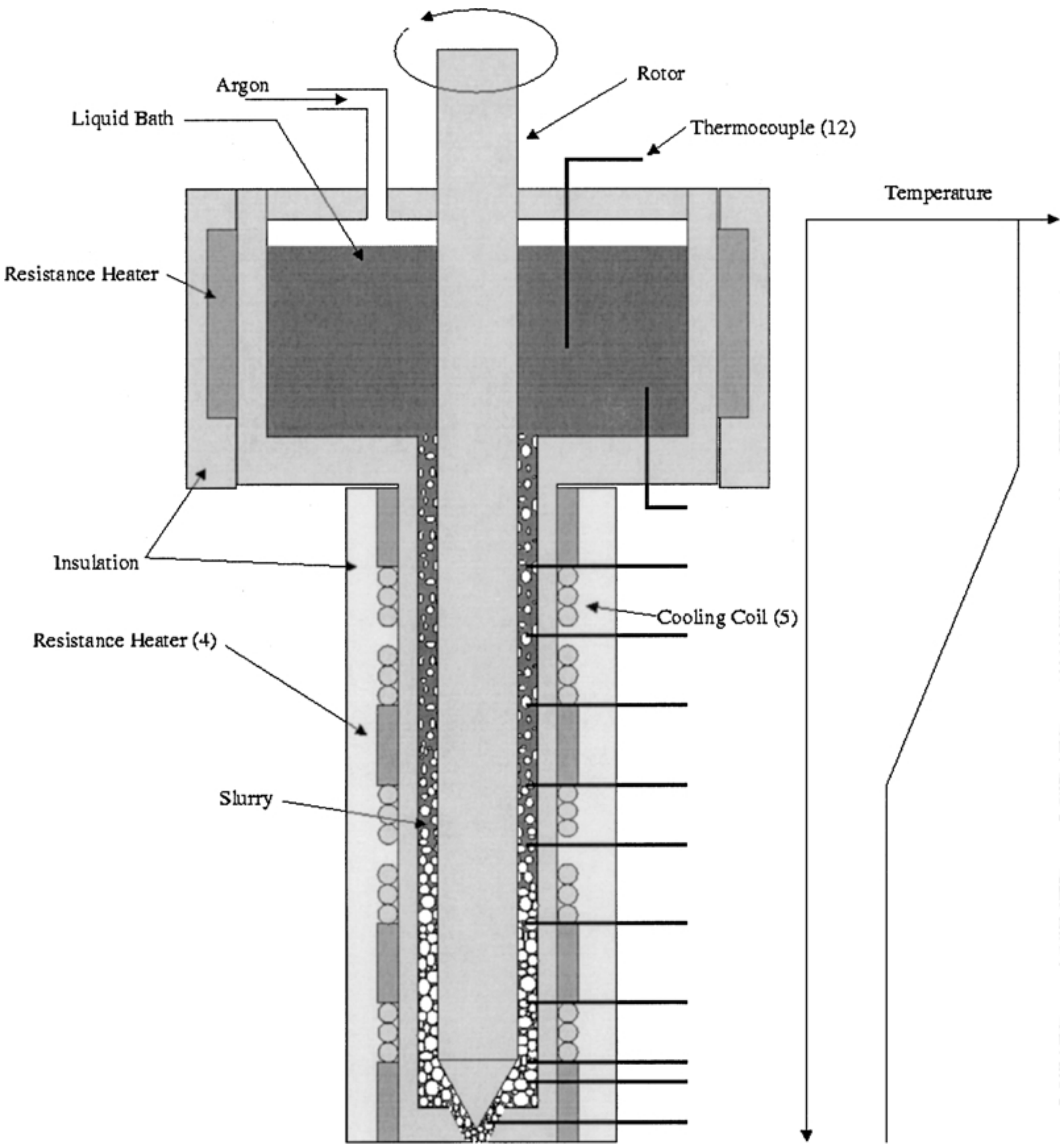

Figure 2 Machine used to produce semi-solid slurry for solid freeform fabrication [3].

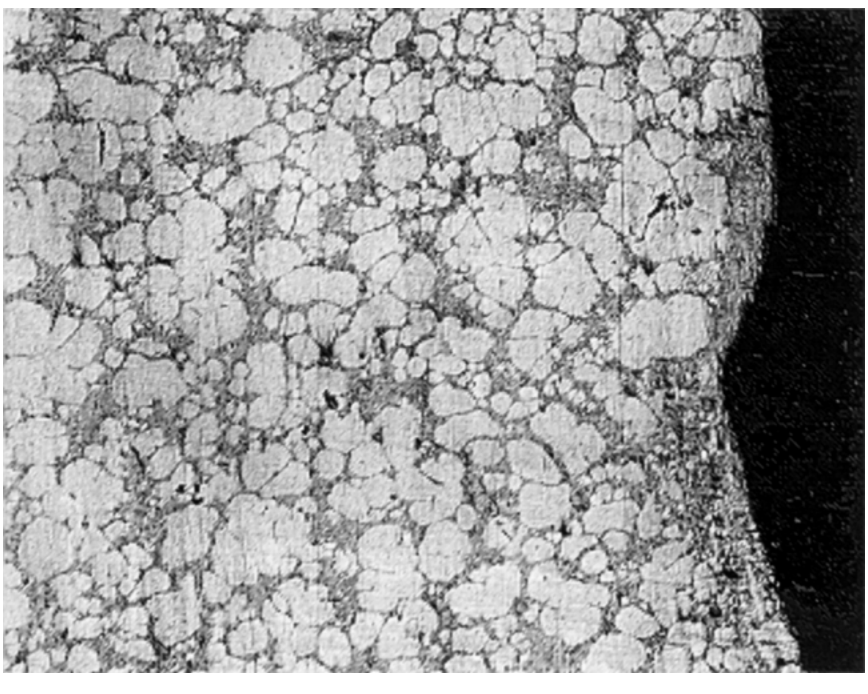

Figure 3 Cross section of joint between two semi-solid layers [3].

The problem of bonding between layers was addressed in [5] and [8], and a criterion for successful joining was proposed and tested. This criterion states that both sides of the interface between previously and newly deposited slurry has a maximum acceptable solid fraction. In the case of Sn-Pb, this solid fraction is approximately 15%. Figs 1 and 3 show a typical joint between two layers.

Despite the omission of previous research, Finke and Feenstra's paper is a worthwhile attempt to combine two new technologies: semi-solid metals and SSF into a new process with exciting prospects. Their work is a useful validation of previous findings, and contributes to set directions for future work.

References

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Comments on

"Comments on Solid freedom fabrication by extrusion and deposition of semi-solid alloys" by P. Mendez, C. Rice, and S. Brown [1].

We would like to take the opportunity and comment on the above-mentioned paper.

We certainly agree with the statement that the concept of depositing layers of semi-solid metals for SFF applications is not new. However, in our concept we did not only discuss the feasibility of using semi-solid metals in a new solid freeform fabrication (SFF) process based on the fused deposition modeling (FDM) technique [2], but also the process parameters related to partial re-melting and subsequent extrusion, e.g., rheological aspects, the preconditioning of the wire etc. In our opinion, the process described in [3] is characterized by two significant differences compared to that referred to in [1]: the semi-solid state of the material in [3] is achieved by *partial remelting* a wire to a temperature that corresponds to a pre-determined solid fraction. In contrast the process described by Mendez, Rice and Brown is characterized by *partial solidifying and stirring* a fully molten material to the desired semi-solid state. Secondly the wire drives the extrusion process and is the material that is actually deposited. It has to be in cold worked condition in order to obtain the desired globular structure during partial re-melting. Our paper should therefore be seen as an attempt of extending the well-established FDM technique and we regret that omissions have been made in referring to previous work in this field.

References

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