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Beyond additive with robotic assisted induction casting in-a-box for fast, distributed and automated manufacturing

Future of manufacturing. The future form of metal manufacturing is to be able to put feedstock scrap materials into a box, and have it quickly output a part that may have geometrically complex features, with no defects and with tunable microstructures, while also gravimetrically separating any unwanted chemistries. We are on our way towards this reality with the growth of additive manufacturing (AM). However, the future of distributed and automated metal manufacturing relies on a modified form of an established technology that's been in existence for over six thousand years: casting. Here we propose a casting-in-a-box technology or rather, a melt-in-place process, that can turn recycled materials into geometrically complex parts, with tunable microstructures.

Proposed technology. In traditional sand casting a pre-formed mold cavity is infiltrated with liquid metal which then solidifies into a part when cooled. Sand casting is quick, scalable, and cost effective for making large parts. The proposed manufacturing technology of the future is twofold including 1) the integration of an age-old casting process with robotic assistance and 2) accommodating melt-in place casting, rather than liquid infiltration, of scrap metal materials, including gravimetric separation of unwanted slags or other phases.

An example technology workflow is shown in the figure to the right. First, a 3D printed polymer shell of a part is filled with scrap metal chunks and powders. It is then surrounded by robotic arms that have geometrically conformal inducting heating end effectors. A significant advantage of this process is being able to mechanically grind feedstocks from scrap materials, obviating the need
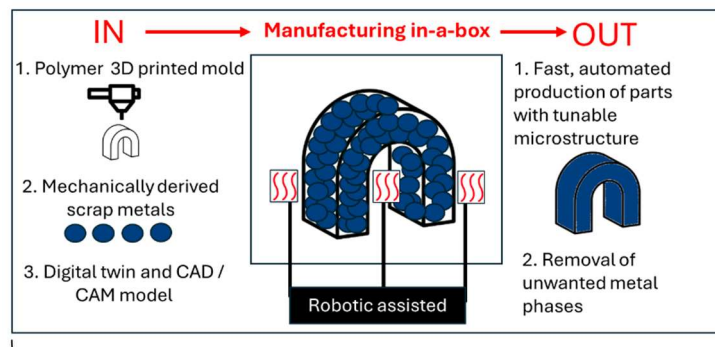
Distributed manufacturing in rural areas, austere environments (DoD), space (NASA), etc.

for specialty feedstock preparation processes (i.e. gas atomization). Next the system/box is filled with ceramic powder and the induction heating elements are turned on to both ablate the polymer scaffold and melt-consolidate the scrap materials in place, a process which may only take minutes. These conformal inductive heating elements will also be used to tune part microstructure. Unwanted phases or slag will be directed through convection, to either the top or bottom of the part for removal. Robotic end effectors will also be used for post-processing, including reducing surface roughness, or selective part annealing to tune microstructure. Technology development will not only rely on materials scientists and roboticists, but also computer scientists who will leverage physics-based models to quickly develop best processing conditions/practices.

Applications. Since this technology can also be used as a forge for the separation of metals, its highest value proposition may be in rural areas, where ferrous or aluminum-based scrap materials (scrap yards exist everywhere) can be upcycled into higher value parts at point of need, a true distributed and automated manufacturing process of the future. Further, the DoD can use this technology for force sustainment in austere environments. It will also serve NASA's needs for in-space manufacturing, as space is the ultimate supply chain bottleneck.