Summary

Layer-by-layer construction is applied to alloys to produce a high wear resistant free-standing material. The wear resistance and impact toughness values of the materials are more than two times greater than those of the commercially available bronze infiltrated S42000 material produced using the layer-by-layer construction process of the present invention. For example, the wear resistance of the material results in a volume loss of less than or equal to 183 mm^3 as measured by ASTM G65-10 Procedure A (2010) and the impact resistance of the material results in a toughness of greater than 58 J as measured per ASTM E23 (2012) on un-notched specimens. The structures that enable high wear resistance are preferably achieved in situ with the sintering and/or infiltration process and without the need for additional post-treating of the layer-by-layer build up with a thermal hardening process, such as by quenching and tempering or solutionizing and ageing. The layer-by-layer construction allows for the formation of metallic components that may be utilized in applications such as injection molding dies, molds, pumps, and bearings.

A method for layer-by-layer formation of a free-standing metallic part according to an aspect of the present invention comprises: (a) supplying metal alloy particles comprising at least 50 weight % Fe and at least 0.5 weight % B and one or more elements selected from Cr, Ni, Si and Mn, wherein said particles have an initial level of boride phases; (b) mixing the metallic alloy particles with a binder wherein the binder bonds said particles and forms a layer of the free-standing metallic part wherein the layer has a porosity in the range of 20% to 60%; (c) heating the metallic alloy particles and the binder and forming a bond between the particles; (d) sintering the metallic alloy particles and the binder by heating at a temperature of greater than or equal to 800 °C and removing the binder and forming a porous metallic skeleton; (e) infiltrating the porous metallic skeleton with an infiltrant at a temperature of greater than or equal to 800 °C and cooling and forming the free-standing metallic part, wherein during said step of sintering and/or infiltrating, there is an increase in the level of boride phases. The free-standing metallic part indicates a volume loss of less than or equal to 200 mm^3 as measured according to ASTM G65-10 Procedure A (2010) and an un-notched impact toughness of greater than or equal to 55 J according to ASTM E23-12 (2012).

A method for layer-by-layer formation of a free-standing metallic part according to another aspect of the present invention comprises: (a) supplying metal alloy particles comprising at least 50 weight % Fe and at least 0.5 weight % B and one or more elements selected from Cr, Ni, Si and Mn, wherein the particles have an initial level of boride phases; (b) mixing the metallic alloy particles with a binder wherein the binder bonds the particles and forms a layer of said free-standing metallic part wherein said layer has a porosity in the range of 20% to 60%; (c) heating the metallic alloy particles and the binder and forming a bond between the particles; and (d) sintering the metallic alloy particles and the binder by heating at a temperature of greater than or equal to 800 °C and removing the binder and forming a porous metallic skeleton having a porosity of 0% to 55%, wherein during the step of sintering, one increases the level of boride phases.

Brief Description of the Drawings

FIG. 1 shows the microstructure of a ferrous alloy powder A3 of the present invention.

FIG. 2 shows the microstructure of a second ferrous alloy powder A4 of the present invention.

FIG. 3 shows the microstructure of a bronze infiltrated ferrous alloy A3 skeleton of the present invention.

FIG. 4 shows the microstructure of a bronze infiltrated second ferrous alloy skeleton A4 of the present invention.

FIG. 5 shows an EDS elemental map of a bronze infiltrated ferrous alloy of the present invention for elements (a) Fe, (b) Si, (c) Cr, (d) B, (e) O, and (f) Cu.

FIG. 6 shows an EDS elemental map of a bronze infiltrated second ferrous alloy of the present invention for elements (a) Fe, (b) Si, (c) Cr, (d) B, (e) O, and (f) Cu.