Density and amorphization of selective laser melted Fe–Si–Cr–B alloy

Danil Erutin, Evgenii Borisov, Anatoly Popovich, Vadim Sufiiarov

Peter the Great St.Petersburg Polytechnic University, Russia, 195251, St.Petersburg, Polytechnicheskaya, 29

The aim of this work was to investigate the effect of scanning strategy and substrate preheating temperature on phase composition, amorphization degree and density of selective laser melted AP–02 magnetic alloy samples.

As part of the study, 3 rectangular samples were manufactured via chessboard scanning strategy. Selective laser melting regimes used for sample manufacturing are presented at Table 1.

Table 1. Selective laser melting regimes

Regime	Laser power, W	Scanning speed, mm/s	Layer thickness, µm	Hatch distance, µm	Scanning strategy	Substrate temperature, C^0
1	140	1200	50	140	Single	300
2	140	1200	50	140	Single	400
3	140	1200	50	140	Double	400

Density measurements results are presented at Table 2.

Table 2. Density measurements results (isopropyl alcohol, $T = 26\ C^0$)

Sample	Air mass, g	Liquid mass, g	Density, g/cm^3
1	1,776	1,544	6,101
2	5,491	4,851	6,707
3	5,882	5,217	6,913

The values obtained indicate an increase in the density of the samples, both when using a higher substrate temperature and when using a double–scanning strategy.

Higher substrate preheating temperatures result in a lower temperature gradient and, consequently, a lower heat dissipation during cooling.

Relatively slow cooling increases the degree of filling of the pores formed and also reduces thermal stresses, the magnitude of which determines the degree of cracking of the sample.

Using a double-scan strategy involves remelting each layer, resulting in additional mixing of the metal and filling of the pores. It also heats the solidified layers, which causes a partial relaxation of internal stresses.

The data presented in Table 2 indicate that when the substrate temperature is increased from 300 C° to 400 C°, the increase in density of the sample is approximately 10%, and when the double scanning strategy is used instead of a single scanning strategy, it is approximately 3%.

The obtained XRD results indicate that the samples have the same phase composition: solid solution α–Fe and iron boride Fe_2B

The data on crystallization enthalpies and degrees of amorphization for samples and initial powder obtained from DSC analysis are presented in Table 3. The amorphous phase content in the samples was determined by the ratio of the crystallization enthalpy of the sample to the crystallization enthalpy of the completely amorphous initial powder.

Table 3. Crystallization enthalpies and amorphous phase content of initial powder and samples

Sample	Crystallization enthalpy, J/g	Amorphous phase content, %
Powder	111,78	100,0
1	1,674	1,5
2	0,000	0,0
3	0,642	0,6

The data of differential scanning calorimetry of samples and initial powder indicate the presence of a small amount of amorphous phase in samples 1 and 3 (1.5 % and 0.6 % respectively) and the absence of such in sample 2.

The substrate preheating temperature has a strong influence on the degree of amorphization of the samples, since the amount of amorphous phase directly depends on the cooling rate of the liquid metal, so increasing it from 300 C^0 to 400 C^0 did not make it possible to obtain even a small amount of amorphous phase in the sample.

Application of the double–scanning strategy allowed to increase the amount of amorphous phase due to homogenization of the melt, leading to partial elimination of areas with reduced amorphization ability in the volume of the sample.

However, the cooling rate has a greater effect on the degree of amorphization of the sample, so the double–scanning at an elevated substrate temperature applied in the production of sample 3 did not achieve a degree of amorphization greater than or equal to the degree of amorphization of sample 1.

Conclusion

1. Using a higher substrate preheating temperature and applying a double-scanning strategy produces denser selective laser melted samples. For the AP–02 alloy, increasing the substrate preheating temperature from 300 C° to 400 C° results in a 10% denser sample, and the use of a double–scanning strategy results in a 3% increase in sample density. Such a change in sample density is associated with a decrease in internal stress levels (effect of substrate temperature), more intense stress relaxation (effect of double scanning) and improved pore filling (effect of both factors).

2. The use of a higher substrate preheating temperature reduces the degree of amorphization of the samples due to their slower cooling. For the AP–02 alloy, increasing the substrate temperature from 300 C° to 400 C° reduces the amount of amorphous phase from 1,5% to 0,0%. Double–scanning increases the degree of amorphization of the sample through homogenization, but the substrate temperature affects the amorphization of the sample more significantly. For the AP–02 alloy application of double–scanning at a substrate temperature of 400 C° allows to obtain 0,6% of the amorphous phase.