Investigation of Iron-Based Powders produced by water and gas atomization of melt

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A study was made for powder materials of three iron-based alloys: soft–magnetic alloy 1SR with alloying materials B, Si; 5BDSR with alloying materials B, Si, Cu, and Nb, made by gas atomization and amorphous metal powder AP-02-C, made by water atomization.

The SEM images of powders show that particles of all investigated materials have spherical and rounded shapes. For the AP–02–C powder, manufactured by water atomization, there are elongated particles and small particles adhering to larger ones (satellites). For powders 1SR and 5BDSR, manufactured by gas atomization, there are satellites as well. The results of the measurements of powders particle size distribution are presented in Table 1.

Table 1. Distribution of particles by size of the studied powder materials

Material	d_{10}, μm	d_{50}, μm	d_{90}, μm
1SR	13,6	41,8	75,3
5BDSR	21,3	38,9	67,3
AP-02-C	6,3	21	44,6

According SEM images and the particle size distribution data, it can be noted that the powders obtained by gas atomization are larger than the powder obtained by water atomization. The study of technological properties of metal powders is presented in Table 2. Powders obtained by gas atomization have higher apparent and skeletal densities, since the particles are round and spherical, as seen in SEM images.

Table 2. Physical and technological properties of the investigated powders

Material	Flow rate, s/50g	Apparent density, g/cm^3	Skeletal density, g/cm^3
1SR	12.96	4.21	7.414
5BDSR	not flow	4.06	7.268
AP-02-C	not flow	3.63	6,785

DSC peaks are observed on each curve, indicating phase transformations upon heating. Metallic amorphous alloys are thermodynamically unstable materials. Processes of structural relaxation and crystallization occur during heating. This process proceeds for 1SR alloy powder in the temperature range from 520 to 560°C, and for 5BDSR from 512 to 570°C. For the AP-02-C powder, similar processes occur in the temperature range 540–680 °C.

On the X-ray diffractograms obtained from samples 5BDSR and 1SR there are only narrow diffraction peaks that are characteristics of the crystal structure. The observed XRD results can be described by the following crystalline phases: α–Fe, Fe_2B for the initial powder 1CP. In 5BDSR, there was a crystalline Nb_3Fe phase and α–Fe.

The AP-02-C powder was also analyzed by XRD analysis, the corresponding amorphous halo phase was identified.

Using transmission electron microscopy, it was found that one of the phases of 5BDSR (surface layer) has an amorphous structure. The second phase is a region with chemical inhomogeneity, where rounded particles have a higher silicon content and have a crystalline structure, and the area between them has a higher content of niobium and an amorphous structure.

The study of the fine structure showed that the AP-02-C powder obtained by water atomization has an amorphous structure. The results of the study of 1CP powder: there are two phases in the investigated powder, one of which has a crystalline phase, and the second has an amorphous phase.

The study of the magnetic properties of powders is presented in Table 3.

Table 3. Magnetic properties of the investigated powders

Material	Coercivity, Oe	Saturation magnetization, emu/g	Residual magnetization, emu/g
1SR	33	180	1,55
5BDSR	18,77	134	0,99
AP-02-C	2,62	145	0,08

The 5BDSR and AP-02-C powders have close saturation magnetizations of 134 and 145 emu/g. The saturation magnetization for the 1CP powder is noticeably higher and amounts to 180 emu/g. The studied materials are referred to soft–magnetic, since they are magnetized to saturation and remagnetized in relatively weak magnetic fields up to 4 kA/m.

Conclusion

1. As a result of the study of powders made by water and gas atomization, it was determined that the powder made by water atomization had an amorphous structure. And the powder made by gas atomization consisted of crystalline and amorphous phases and an amorphous shell. The physical and technological properties of the studied powders were also determined. Materials obtained by gas atomization have higher skeletal and true densities due to the shape of the particles.

2. The thermal stability (amorphous–crystalline transition) of the powders was determined by differential scanning calorimetry. It was shown that the decomposition of the amorphous phase in 1CP occurs in a narrow temperature range of 520 to 560°C, in 5BDSR from 512 to 570°C, and the crystallization of the AP-02-C powder occurred in the range from 540 to 680°C.