**Supplementary Materials**

Clean production of Fe-based amorphous soft magnetic alloys via smelting reduction of high-phosphorus iron ore and apatite

Hua Zhang1), Tuoxiao Wang1), Guoyang Zhang2), Wenjie Wu1), Long Zhao1), Tao Liu1),🖂, Shuai Mo1), and Hongwei Ni1),🖂

1) The State Key Laboratory of Refractories and Metallurgy, Wuhan University of Science and Technology, Wuhan 430081, China

2) College of Nuclear Equipment and Nuclear Engineering, Yantai University, Yantai 264005, China

The conventional production process of FePC amorphous alloys is to remelt the pure iron, FeP, FeC prealloys and then rapidly solidify to obtain amorphous ribbon samples as shown in Fig. 9. The production energy consumption is reported to be around 1.58×108 kJ/t and the melting process accounts for 80–85% [1]. Note that the production of the prealloys involves a complex reduction–refining–crushing process and consumes vast energy. Taking the production of 1 t target Fe90.42P7.40C2.18 wt% (Fe79.34P11.73C8.93 at%) amorphous alloy as an example, the required content of the pure iron, Fe–17wt%P and Fe–4wt%C prealloys as well as the production energy consumption of these prealloys are shown in Table S1. The production of industrial pure iron is blast furnace reduction–hot metal pretreatment–converter blowing–LF refining process and the energy consumption is around 1.61×108 kJ/t [2]. The FeC prealloy is actually the high C content pig iron after desulfurization and the production energy consumption is around 1.23×108 kJ/t [3]. The production of FeP prealloy is generally prepared by the reduction of apatite, coke, silica and iron chips in submerged arc furnace (SAF) and the energy consumption is 3000–3400 kWh [4–5], which can be converted to 1.08–1.23×108 kJ/t according to the national standard GB2589-81.

Table S1. Dosage and production energy consumption of the required pure iron, FeP and FeC prealloys for the production of 1 t target Fe90.42P7.40C2.18 (wt%) amorphous alloy

|  |  |  |
| --- | --- | --- |
| Raw material | Dosage / t | Production energy consumed / (kJ⋅t−1) |
| Pure Fe | 0.017 | 1.61×108 |
| FeP prealloy | 0.436 | 1.23×108 |
| FeC prealloy | 0.547 | 1.41×108 |

According to the data in Table S1, the production energy consumption of 1 t Fe90.42P7.40C2.18 (wt%) amorphous ribbons by using the conventional production process can be estimated as: 0.017×1.61×108 + 0.436×1.23×108 + 0.547×1.41×108 + 1.58×108 = 2.91×108 kJ/t. For our proposed short–process production of FePC amorphous alloy by smelting reduction of high–phosphorus iron ore (HPIO) and apatite, the energy consumption of the smelting reduction process by using SAF is 3000–6500 kWh/t, which can be converted to 1.08–2.34×108 kJ/t. For simplicity, 1.76×108 kJ/t is selected to calculate the energy consumption of the short–production process, which is estimated to be 1.76×108 + 1.58×108 ×15% ≈ 2.00 ×108 kJ/t. As a result, the production energy consumption of our proposed process can reduce (2.91×108–2.00×108)/(2.91×108) ≈ 30%.

**References**

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