COPRODUCTION DEVELOPMENT OF MINERAL WOOL AND LOW NICKEL-FeNi BY FEEDING OF ALUFLUX

Theofani TZEVELEKOU[1], Athanasia FLAMPOURI[1], Konstantinos PANTAZIS[1], Paraskevi LAMPROPOULOU [2], Dimitrios PAPOULIS[2], Basilios TSIKOURAS[3], Spyridon PAPAEFTHYMIOU[4], Eygenia METAXA[2]

[1] ELKEME - Hellenic Research Centre for Metals S.A., 56thkm Athens-Lamia National Road, 32011 Oinofyta, Greece

[2] University of Patras, Department of Geology, Section of Earth Materials, 26504, Patras, Greece

[3] UniversitiBrunei Darussalam, Faculty of Science, Physical and Geological Sciences, JalanTungkuLink, Gadong BE1410, Bandar Seri Begawan, Brunei Darussalam

[4] National Technical University of Athens, School of Mining & Metallurgical Eng., Physical Metallurgy Lab, 9, Her. Polytechniou, Zografos, 15780, Athens, Greece

ftzevelekou@elkeme.vionet.gr, aflambouri@elkeme.vionet.gr, kpant@elkeme.vionet.gr, p.lampropoulou@upatras.gr, papoulis@upatras.gr, basilios.tsikouras@ubd.edu.bn, spapaef@metal.ntua.gr, eygenia_1990@hotmail.com

Introduction

Mineral wool is produced at the plant of FIBRAN in Greece by melting a mixture of mineral raw materials, amphibolite, limestone, dolomite, bauxite in Electric Arc Furnace (EAF) and subsequent centrifugal fiberisation of the melt (slag). Chemical and mineralogical analysis of raw materials has been presented elsewhere[1]. After addition of adhesive resin, oil and special silica compounds, fibres enter the polymerisation furnace. Compressing and cutting machines are used to shape the final products in sheets and rolls of a yellowish to brown appearance, strongly depending on the iron oxide content (FeO_x) of the raw materials. Lighter (whiter) coloured mineral wool products are desirable mostly for aesthetic purposes. The addition of ALUFLUX, a by-product of the secondary aluminium alloys production of ELVAL plant in Greece, in the raw materials mix of FIBRAN has been studied. ALUFLUX's main characteristics are: Al_2O_3 carrier (~40-45%), thermitting reduction agent and energy media (Almet~25-30%, AlN~13-15%). By the addition of ALUFLUX, besides partial bauxite replacement, the desirable %FeOx reduction of the produced slag was targeted followed by whitening of the produced mineral wool fibres, while preserving or improving the high-quality specifications of the final product. Simultaneous iron and nickel recovery, through aluminothermic reduction, from amphibolite and bauxite in raw materials mixture, leading to the coproduction of low nickel FeNi, was investigated. Use of recycled alumina-bearing raw materials in the mineral wool industry has been reported[2,3]. However, since these materials are recovered from the processing of aluminium salt slag - a residue generated during aluminium remelting-, they have limited reduction efficiency and are energy downgraded compared to ALUFLUX due to significantly low $Al_{metallic}$ content < 3%.

Theoretical process model

A simplified theoretical model has been elaborated to predict the effect of ALUFLUX addition on the chemical composition and most important physico-chemical properties of the mineral wool melt. The expected co-produced metal analysis is also included. The model uses as variables the raw materials feed ratio, composition and melting temperature and includes fully parameterised mass balance, taking into account the thermodynamics of the heterogeneous metallurgical reactions. Calculation of slag basicity, density[4], surface tension[5] and electrical conductivity[6,7] are performed based on selected literature available equations. The viscosity toolbox was used for the estimation of slag viscosity[8]. The model has been used for the design of the industrial campaigns performed in FIBRAN, but also comprises a flexible user friendly tool for offline process study and optimisation. It could be further optimised to include kinetics considerations.

Industrial campaigns

Two series of industrial campaigns with ~ 7 wt% and ~ 2 wt% ALUFLUX (A and B, respectively) in raw materials mix were performed in the plant of FIBRAN. Bauxite consumption was reduced by 55% and 37%, respectively, relatively to standard process. Grain size distribution (mainly sandy gravel to gravel) and homogeneity of ALUFLUX allowed its unhindered mechanical incorporation in the raw materials mixture without any pre-treatment. Slag, fibres and metal sampling, and recording of critical operating process parameters, (melt temperature, electrical energy consumption) during the trials were performed.

Results

In total, ~100 t of lighter coloured mineral wool (compared to conventional products of the plant) have been produced (Figure 1). The chemical analysis of the corresponding slag and metal were in close agreement to the theoretical predictions. Iron oxide reduction in the levels of 75% and 26% has been achieved, while nickel recovery in the metal was complete, leading to production of ~0.8% avg. Ni-FeNi accumulated at the bottom of the EAF furnace. However, some areas of incomplete slag/metal separation were found denoting that further technical adjustments are required before the technique can be adopted by the industry. The involvement of the highly exothermic aluminothermic reduction, resulted in reduction of the electrical energy consumption of the process. The measured physical and mechanical properties of the two final mineral wool products of the campaigns A and B are shown in Table 1.

Table 1: Physical and mechanical properties of industrial trials' products

Properties	Product A	Product B
Compressive strength (kPa)	79.6	27
Tensile strength (kPa)	24.23	15.05
Point load at 5 mm deformation (N)	723	611
Thermal conductivity, λ (W/mK)	0.03827	0.03416
Water absorption 24 h (kg/m²)	0.24	0.28

Campaign A, produced slag and thus mineral wool material expectedly richer in Al_2O_3. Polotic and Scanning electron microscopic observations revealed a higher abundance of metallic inclusions in the product A[9] . A representative image of these cauliflower iron -rich aggregates (inclusions) is presented in Figure 2a. The higher alumina content of the first may also contribute to the increased mechanical properties [10]. The diameter of the fibres of campaign A were larger than those of campaign B, likely as a result of the more viscous nature of the melt. The porosity of product B is larger than this in product A, as a result of the thinner fibres in the first as shown in Figure 2b, 2c. Therefore, product B shows increased thermal expansion coefficient and enhanced efficiency of thermal insulation. Examination of selective samples from the fibres of campaign B met the required specifications for their bio-persistence, which is an important criterion of carcinogenic potential[11] (Note Q Directive 67/548/EEC, as revised by 97/69/EC)[12,13].

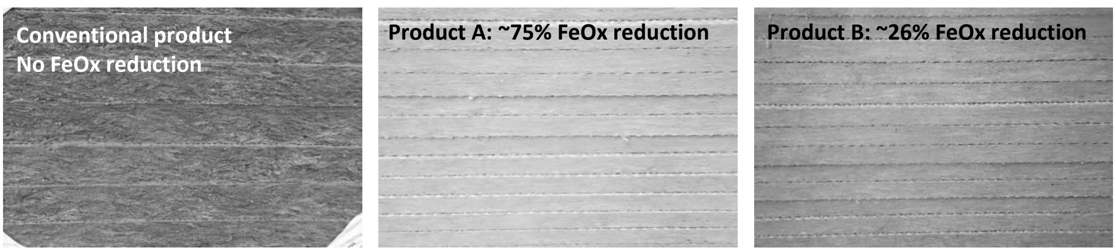

Figure 2: Mineral wool colour based on the iron oxide content

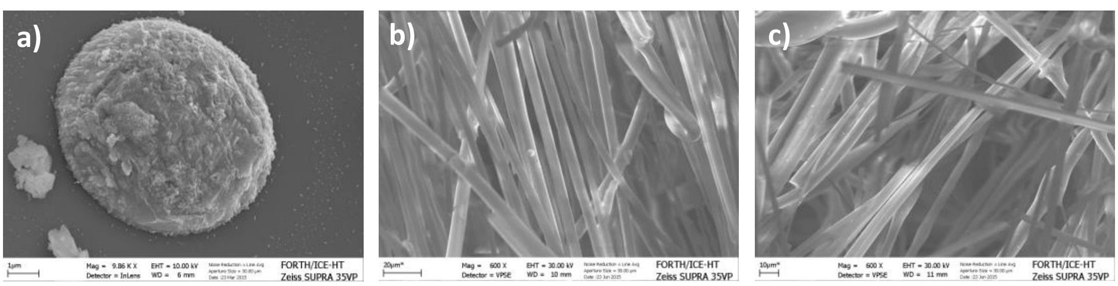

Figure 2: Backscattered images of: a) inclusion in product of Campaign A; b) fibres of Campaign A; c) fibres of Campaign B

Conclusions

It has been demonstrated that the use of ALUFLUX in the conventional production process of mineral wool in EAF as a partial substitute of bauxite, results in the co-

production of lighter coloured mineral wool with high level of technological properties and a low Ni-FeNi metal. Realisation of a circular economy concept with significant environmental and economic benefits can be achieved by suitable industrial adaptation of the process.

Acknowledgments

The research was carried out in the frame of the R&D project with acronym “Rock.FeNiAl” co-funded by the Industrial Research & Technology Development Program, ESPA 2007-2013, European Regional Development Fund ERDF (Project No 914-BET-2013). The present announcement is dedicated to the memory of Prof. D.C. Papamantellos, inspirator of this proposed innovative process. Special thanks to the FIBRAN and ELVAL for their excellent collaboration in the course of this research.

References

1. P. Lampropoulou, D. Papoulis, E. Metaxa, B. Tsikouras, K. Hatzipanagioutou, Th. Tzevelekou and A. Karageorgis, “Assessment of the quality of metamorphic and igneous rocks from Terpni (Serres, North Greece) for their use as raw materials in the production of stonewool”, in *Proceedings of the 14th Intern. Conference*, Bulletin of the Geological Society of Greece, vol. XLVIII, 2016.
2. M. O’Driscoll, “Alumina in a spin”, *Industrial Minerals*, August 2006. [Online]. Available: http://www.indmin.com/pdfs/697/67082/200608036.pdf.
3. “An unconventional Al2O3 alternative”, *ALSA’s SEROX range of recycled alumina-bearing raw materials*, December 2006. [Online]. Available: http://www.alumina.de/Serox_Industrial%20Minerals_200612.pdf.
4. B. Blagojeviæ, B. Širo and B. Štremfelj, “Simulation of the effect of melt composition on mineral wool fibre thickness”, *Ceramics – Silikáty*, **48** (3) 128-134 (2004).
5. A. Kuruk, A. Clare and L. Jones, “An estimation of the surface tension for silicate glass melts at 1400 C using statistical analysis”, *Glass Technol*, **40** (5) 149-153 (1999).
6. R. Hundermark, “The electrical conductivity of melter type slags”, Masters of Science Thesis, Department of Chemical Engineering - University of Cape Town, 2003.
7. Q. Jiao and N. J. Themelis, “Correlations of electrical conductivity to slag composition and temperature”, *Metall Trans B*, **19** (1) 133-140 (1988).
8. M. A. Duchesne, A. M. Bronsch, R. W. Hughes and P. J. Masset, “Slag viscosity modeling toolbox”, *Fuel*, **114** 38-43 (2013).
9. E. Metaxa, “Evaluation of industrial minerals and rocks as raw materials for stone wool production”, Master Thesis, Greece, 2015.
10. S. I. Gutnikov, A. P. Malakho, B. I. Lazoryak and a. V. S. Loginov, “Influence of Alumina on the Properties of Continuous Basalt Fibers”, Moscow: Moscow State University, 2008.
11. H. Ching-Hung and T. Stedeford, “Cancer Risk Assessment: Chemical Carcinogenesis, Hazard Evaluation and Risk Quantification”, *John Wiley & Sons*, 537-538, 2010.
12. Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, OJ 196, 16.8.1967, 1–98.
13. Commission Directive 97/69/EC of 5 December 1997 adapting to technical progress for the 23rd time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, OJ L 343, 13.12.1997, 19–24.