PREFUSED CALCIUM ALUMINATE FLUX *VS.* FLUORSPAR FOR SLAG CONDITIONING OF STAINLESS STEEL – A COMPARATIVE LIFE CYCLE ASSESSMENT STUDY

Rodrigo LENCINA[1], Emmanuelle HENRY-LANIER[1], Andrea DI MARIA[2]

[1] IMERYS, 75015 Paris, France
[2] KU Leuven, Department of Materials Engineering, 3001 Leuven, Belgium

rodrigo.lencina@imerys.com, emmanuelle.henry-lanier@imerys.com, andrea.dimaria@kuleuven.be

Introduction

Metallurgical fluxes or slag conditioners are today added during stainless steel production to significantly improve the formation of the top slag in the ladle or converter. For decades, fluorspar was predominantly used in combination with lime to produce the high basicity slags required for desulphurisation. However, certain steel producers have started to use calcium aluminate-based slags in order to avoid the presence of fluorine in the final slags. According to Yan *et al.* slags in the CaO-Al_2O_3 system can achieve desulphurisation effects that are comparable to CaO-CaF_2 slags.[1] This was subsequently confirmed by industrial experiences.[2] Although different fluxes can form slags with equal process performance, they may present significantly different environmental impacts.

The study compares the environmental impacts of two slags practices using two different metallurgical fluxes: (i) a newly developed LDSF® pre-fused calcium aluminate flux (CA flux) and (ii) the traditionally used metallurgical grade fluorspar. Life cycle assessment (LCA) is used as environmental assessment methodology, analysing all life cycle stages of the fluxes production processes, from extraction of raw materials to the end-of-life of the waste generated.[3] The process data are collected directly at the fluxes production plants, while the use of the fluxes is described using case studies drawn from real industrial experiences. The results are presented for three different geographical zones: Europe, Asia and Latin America.

Life cycle assessment modelling

The chemical composition and the quantity of fluxes are two among the main controlling factors of optimal slag properties. Therefore, for the purpose of the study, the two fluxes cannot be compared directly in a kilogram per kilogram basis. For this reason, the functional unit considered in this LCA is the conditioning of a slag with the right properties to ensure the refining of 1t of steel that complies the quality

standards for AISI 321 steel grade. Additionally, due to the scope, the results are considered relevant only for steel produced in either Europe or Asia or Latin America.

To calculate the environmental impacts associated with the functional unit defined above, the study includes, together with the steel refining stage, also: (i) the production of metallurgical fluxes and their supply, (ii) the production of electricity, (iii) the production of slag making materials necessary for the refining operations, (iv) the production of refractories necessary for the maintenance of the refining equipment, (v) the production of incremental alloying materials necessary as compared to the lowest consumption among alternative scenarios considered and (vi) the slag end-of-life. The main stages of the life cycle are illustrated in Figure 1.

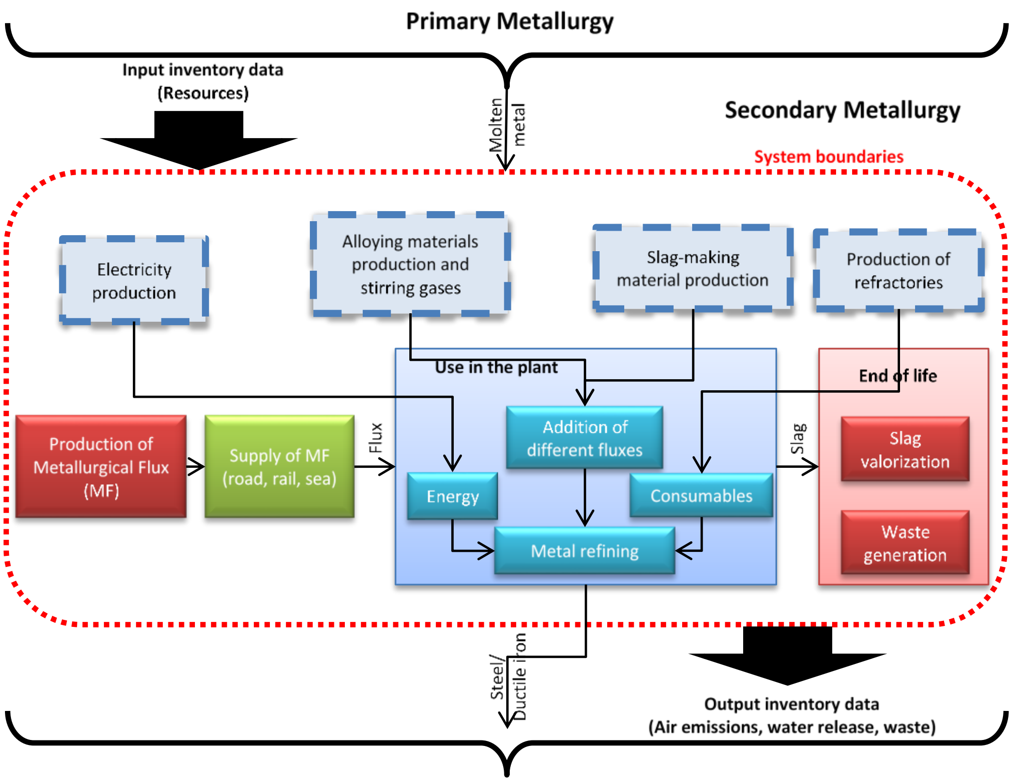

Figure 1: System boundaries of the study

The modelling was carried out with the life cycle assessment software TEAM 5.3. For CA flux, manufacturing data refers to the production of the Imerys plants in 2015, while the data used for raw materials, Fluorspar ore beneficiation, energy production and transportation is extracted from the European Life Cycle Database provided by ETH[4]. The metallurgical data employed in this study was collected directly from plants with the EAF - AOD - LMF - CCM route, which is representative of the industry. The geographical zones were selected on the basis of the extensive use of pre-fused CA

fluxes in general. Therefore, the impacts of the location of the flux production site and transportation can be considered as representative.

LCA results and interpretation

Table 1 shows comparative results provided per different geographical area for the main environmental impact indicators defined by CML3.

Table 1: LCA results for all indicators considered in the study

Indicator	Fluorspar			CA Flux		
	Eur.	Asia	L. Am.	Eur.	Asia	L. Am.
Global warming (kg eq. CO_2)	38.1	51.2	31.0	28.8	42.4	23.2
Air pollution (m^3)	5909	7848	5120	2334	4358	1736
Acidification (kg eq. SO_2)	0.196	0.337	0.126	0.199	0.355	0.160
Abiotic depletion potential – fossil (MJ)	443	673	319	324	561	221
Abiotic depl. pot. – elements (kg eq. Sb)	7E-05	7E-05	7E-05	6E-06	4E-06	4E-06
Waste generation (kg)	21.7	26.0	21.3	21.7	26.0	21.3
Primary energy consumption (MJ)	508	576	417	366	441	295

The processes producing the highest contribution for the considered impact categories are the ones related to the use of the fluxes during the steel production, such as the quantity of electricity and the slag-making materials required. As an example, Figure 2 shows that the contribution to the greenhouse effect is mostly due to the production of electricity consumed in the ladle and the production of slag making materials especially titanium consumed with fluorspar. Also, to a lower extent, the impacts depend on the flux manufacturing process especially for CA flux, which require high temperature processes. Finally, to a more limited extent, the impacts depend on the location of the steel plant.

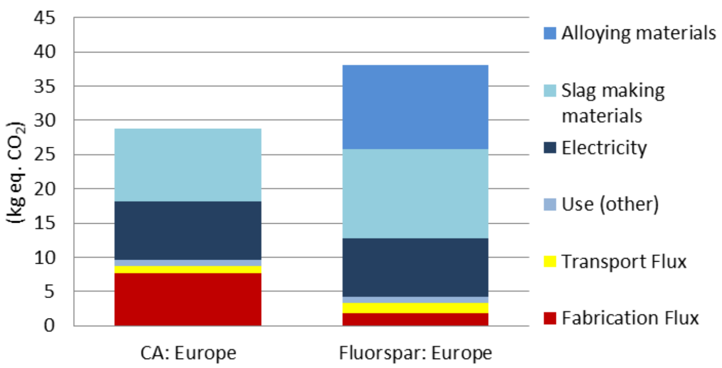

Figure 2: Global warming potential in Europe

Figure 3 shows the comparison of the relative impacts of all indicators and all geographical zones. The results are normalised to the flux with the highest impact for a given category, expressed as 100%. The environmental impacts of CA flux are

significantly lower (25% to 95% lower) than fluorspar for all indicators except acidification. In the particular case of acidification, the fabrication of the CA flux has higher impact than the relatively simpler beneficiation process of fluorspar ore. For Asia and Latin America, the trends are similar to Europe, which indicates that the locations of the fusion plants (China and France) have a relatively low impact in comparison to the parameters related to the application of the flux in the metallurgical plant (electrical energy, lime consumption).

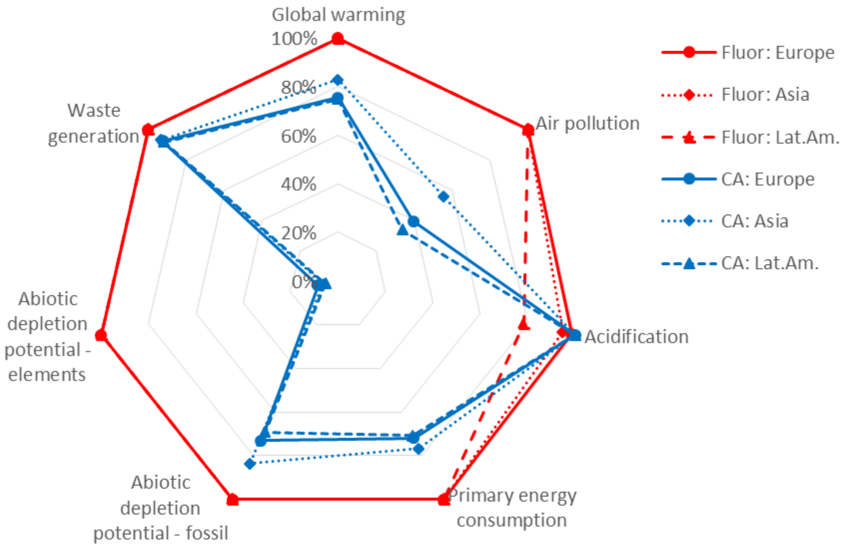

Figure 3: Relative impacts for all indicators and geographical zones

Conclusions

Results show that stainless steel refining process using calcium aluminate flux has lower environmental impact for most of the indicators considered in the study, such as greenhouse gas emissions, air pollution, abiotic depletion potential and total primary energy consumption. In conclusion, the analysis showed the potential of calcium aluminate fluxes to reduce the environmental impacts during the slag conditioning of stainless steel.

References

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