Characterization of Welding Fume from Stainless Steels and High-Mn Consumables

An investigation on fume chemistry and phase identification for SMAW and FCAW consumables.

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Introduction

Welding fume generated by SMAW and FCAW consumables consists of metallic oxides and fluorides. There is much speculation over the relative toxicity of welding fume in the industrial environment. The characterization of welding fume is integral to the understanding of fume behavior.

Technical Approach

Two stainless steel consumables, one SMAW and one FCAW, were deposited on a 304L plate using a nominal, midrange heat input. Two high-Mn consumables, one SMAW and one FCAW, were deposited on an A36 plate, also at a nominal heat input. Fume was collected with an AWS F1.2:1999 (modified) fume hood and an Electrical Low Pressure Impactor (ELPI). The fume hood collected bulk fume particles of all sizes, while the ELPI collected and separated fume into 13 different size ranges (30 nm to 10 μm). Characterization techniques consisted of SEM, XEDS, XPS, XRD, TEM, SAD, and Cr(VI) testing.

Results/Discussion

-Stainless Steel Consumables:

XRD results show that the SMAW fume contained $K_2(Fe,Mn,Cr)O_4$. Potassium chromate (K_2CrO_4) was unequivocally identified in the SMAW fume by selected area diffraction in the TEM. SEM showed that the fume morphologies of the two stainless steel consumables are similar, but XEDS analysis shows that the metals content of the FCAW fume is significantly higher than that of the SMAW fume. XEDS analysis showed an elevated potassium content in the SMAW fume, accounting for nearly 50 at% of the bulk fume composition. The FCAW consumable did not contain any K_2CrO_4 when analyzed with either XRD or SAD. Based on these results it is clear that the K_2CrO_4 content of the SMAW fume is significantly higher than the FCAW fume. Hexavalent chromium levels in the SMAW fume were nearly sixteen times higher than that of the FCAW fume.

-High-Mn Consumables:
XRD results reveal that the SMAW fume contains Fe_3O_4, $MnFe_2O_4$ and $FeMn_2O_4$. Results from the FCAW fume showed that a Fe_3O_4 type compound and $MnFe_2O_4$ are present. Fluoride peaks were identified in the diffraction pattern for the FCAW fume. XPS revealed that fume from both SMAW and FCAW consumables had increased Mn content following Ar-ion etching, and that the Mn is present as either Mn^{2+} or Mn^{3+}. TEM analysis showed that SMAW fume contains $(Mn,Fe)_3O_4$, an Fe-rich crystal structure, and Mn-rich particles. The Mn-rich particle did not exhibit a noticeable diffraction pattern. The FCAW fume contained $MnFe_2O_4$ and Fe_3O_4 crystal structures, as well as many Mn-rich particles.

Conclusions

Regarding the stainless consumables, the alkaline content of the SMAW consumable was much higher than the FCAW consumable. Conversely, the FCAW fume had a significantly higher metals content than the SMAW fume. XRD and SAD analysis of the stainless FCAW fume showed no evidence of K_2CrO_4. Fume from the high-Mn SMAW consumable contained $(Mn,Fe)_3O_4$ as well as Fe-rich and Mn-rich particles, while the FCAW consumable contained Fe_3O_4 and $MnFe_2O_4$. XPS results reveal that the valence state of the Mn in the fume is either Mn^{2+} or Mn^{3+}.