Platinum Furnace Modelling

Grad Workshop 2024

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Platinum/PMG metals

- Platinum is a noble metal (30 times rarer than gold).
- It resists tarnish, looks good, and so is used in the fashion industry.
- Additionally it has a very high melting point and has good electrical properties. Perhaps more important is its use as a catalyst.
- There are a number of other associated elements found with it called the PGM.
- S Africa has 80% of platinum reserves. (70% in Bushweld Complex in Transvaal)
- PGMs generally occur in nature with other metals (gold, copper ,iron, nickel, ...) in small quantities; in the form of sulphiides, oxides ...; not as a pure metal.
- The ore rich rocks are crushed, then a floatation process removes gangue (useless material). Then a furnace is used to separate out metal sulphides from useless material.
- Then PGMs are extracted; their melting point is generally very high.

The Furnace

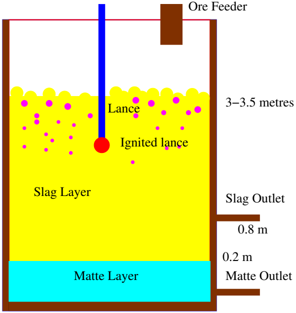

Figure 1: The PGM Furnace: The furnace is a cylinder container of radius 2 m and height about 20 m. A combustion lance is inserted from the top of the furnace and into the concentrate. This raises the temperature to about 1,600°C; above the melting point of the in-feed and sufficient to cause smelting. Metallic sulphide droplets are formed in the in-feed and drip down into the matte layer formed under the slag. The furnace is run continuously with in-feed added and matte and slag extracted at appropriate time intervals.

The Process

- A load is paced in a furnace and a lance inserts carbon and oxygen (or air) which burns thus heating/converting the feed.
- The feed consists of oxides and sulphates of metals (Cu, Pl, Ca, Fe, ...).
- At the higher temperatures droplets of metals are formed in the slag layer and drip into the matte.
- Metal oxides (the unwanted ones) are formed in the slag and gravitates upwards to form a slag layer. Typical slag/matte ratios 6/1.
- Noxious gases are released in large quantities; a violent and dangerous process.
- Slag and matte are extracted, and the furnace is 'topped up continuously'.
- The matt is further processed to extract PGM. Only a small proportion of the matt consists of platinum compounds.

The Chemistry

- Carbon burns producing heat and CO, CO_2
- CO strips off oxygen from the oxides and sulphides (endothermic). Noxious gases SO_2, CO ... are released.
- Further reduction occurs (at higher temperature) releasing the metals. Typically:

$$C + O_2 \to CO_2, \quad CO_2 + C \to 2CO$$

$$Fe_2O_3 + 3CO \to 2Fe + 3CO_2$$

$$CaO + SiO_2 \to CaSiO_3$$

$CaSiO_3$ and other (lighter) oxides float to the surface, and the (heavier) metal sulphides sink, and end up in the matte.

The Issues

The process is violent, so explosions can occur because there is a mis-match between the heat input 'needs' for the process and the heat supplied by the lance. This imbalance can occur because

1. The in-feed is not continuous so 'steady state conditions are not maintained.
2. The in-feed mixture is mis-judged, so example more/less heating may be required than that expected
3. Non-uniformity in the slag layer.
4. Fluid dynamic instabilities can occur because there are different bubble production raegimes.

The net effect can be dangerous or may effect the smooth operation of the process and quality of the output.

Questions

- How often to tap off the matte and slag? What effect?
- How to manage the carbon/oxygen lance input to ensure best processing?
- What instabilities to avoid?

For a start we should determine 'the simplest' model to describe the steady state set up. (ODE 1D system?). The aim here is to understand the issues. We should then refine the model, and think through the implications.