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# NEW PROCESS OF EXTRACTING VANADIUM FROM MOLTEN VANADIUM SLAG

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## Abstract

*A new process of extracting vanadium from molten vanadium slag by direct oxidation and sodium activating method was introduced in this paper. The feasibility and rationality of the new process was analysed, and then the simulation experiments were carried out in the laboratory. The results show that molten vanadium slag can be kept in good fluidity state in the roasting process. Vanadium water leaching efficiency ranges from 50~80%. Vanadium in roasted slag exists in form of $NaVO_3$. Thus, the feasibility of the new process is confirmed by the results.*

## Introduction

Vanadium, as one of the important rare elements, has been widely used in industrial production. The raw material for industrial production of vanadium consists of vanadium-titanium magnetite, oil ash, waste vanadium catalyst, bauxite and stone coal. In addition, 75% to 85% vanadium production was extracted from vanadium-titanium magnetite[1,2]. A well-known roast-leach process is employed in the production of $V_2O_5$ and $NH_4VO_3$ from vanadium-titanium magnetite. Vanadium-titanium magnetite ore is reduced in a blast furnace and vanadium is collected in the iron phase. In a subsequent operation, vanadium is transferred to a slag phase by oxygen blowing. The slag is then roasted, leached and finally vanadium is recovered as $NH_4VO_3$[3,4]. Vanadium oxide can be obtained from $NH_4VO_3$ decomposition by heating. In this vanadium extraction process, molten vanadium slag after natural cooling needs to be reheated. It is obvious that its physical heat has been wasted.

To make use of the energy from molten vanadium slag, a new process of vanadium extraction from molten vanadium slag by direct oxidation and sodium activating method was proposed by USTB[5]. After the treatment of molten vanadium slag by direct oxidation and sodium activating, a leaching method is used to the roasting clinker. There is no doubt that this process can save energy and reduce emission. Research progresses in this method are described in this paper.

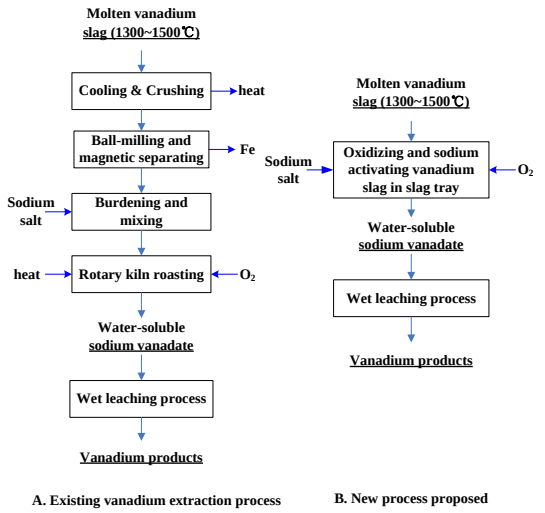


**Figure 1:** Flowchart of the existing vanadium extraction process and the new process

### The comparison of the new process with the existing process in vanadium extraction from vanadium slag

The roasting reaction temperature of existing process in vanadium extraction from slag is between 750~850°C, however, the temperature of the molten vanadium slag fresh out of converter is about 1450°C.Water-soluble sodium vanadate formation reaction could be done quickly in the treatment of direct oxidation and sodium activating to this molten vanadium slag since its kinetic conditions are improved. The comparison of the new roasting process with the existing roasting process is shown in Figure 1.

Using the new process, roasting operation in a rotary kiln or a multi-hearth furnace could be abandoned which can bring many benefits such as simplifying production procedure, reducing investment and run cost, saving energy and reducing emissions.

## Experiments

### Materials

The vanadium slag used in the study was provided from Kapok Iron and Steel Corporation. Its chemical composition was analysed by XRF and the results are presented in Table 1. It was also determined by X-ray diffraction that the slag contains ferrovanadium spinel, vanadium manganese spinel, fayalite and quartz. All the reagents used were of analytical reagent grade.

**Table 1:** Chemical analysis of the vanadium slag used for experiment

| Component | FeO | $SiO_2$ | $V_2O_5$ | $TiO_2$ | MnO | MgO | $Al_2O_3$ | CaO |
|---|---|---|---|---|---|---|---|---|
| wt% | 31.9 | 21.0 | 16.0 | 12.0 | 7.6 | 4.4 | 3.8 | 2.6 |

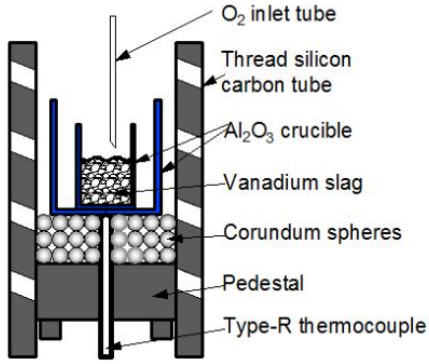


**Figure 2:** Experimental apparatus profile

### Molten vanadium slag roast-leaching experiments

In all the roasting experiments, an $Al_2O_3$ crucible containing vanadium slag was placed in a furnace and heated to 1450°C at the rate of 10°C/min in an open atmosphere. The whole apparatus profile is shown in Figure 2. Holding 1450°C for 5 minutes made the vanadium slag melt fully. Then the power was cut off and the $Na_2CO_3$ blocks pressed and were charged into the molten vanadium slag. Blowing oxygen into the slag by double-hole alumina tube was help of finishing oxidation reaction.

The roasted slag was leached in water at 90°C for 2 h. The ratio of liquid to solid was 5:1, and the stirring speed was 500rpm. After each test, the leach slurry was filtered immediately and washed with deionised water. The vanadium content in the leach solution was analysed with chemistry titration method.

## Results and discussion

Molten vanadium slag showed good fluidity in the roasting process. The effect of oxygen volume and $Na_2CO_3$ to slag ratio were considered in this paper, the ranges, values and corresponding leaching efficiency ($\eta_v$) of which are given in Table 2. At the fixed $Na_2CO_3$ addition, vanadium leaching efficiency increased with the increasing oxygen volume and did not change obviously when the oxygen volume exceeded 35L because vanadium slag had been oxidised fully. At the fixed oxygen volume, vanadium leaching efficiency increased with the increasing $Na_2CO_3$ addition. However, the leaching efficiency is not changed obviously when $Na_2CO_3$ to slag ratio is greater than 25%. It can be explained that besides $V_2O_5$, other acidic oxides such as $SiO_2$, $Al_2O_3$ could react with $Na_2CO_3$ and consume a number of $Na_2CO_3$[7]. Therefore, water-soluble sodium vanadate formation will be affected by less $Na_2CO_3$ addition. Throughout the experiments, the vanadium leaching efficiency ranges from 50~80%. XRD patterns of the roasted sample were determined by X-ray diffraction and the results showed that the vanadium in roasted sample exists in form of $NaVO_3$.

**Table 2:** Chemical analysis of the vanadium slag used for experiment

| No. | $O_2$ /L | $Na_2CO_3$/slag /% | $\eta_v$ /% | No. | $O_2$ /L | $Na_2CO_3$/slag /% | $\eta_v$/% |
|---|---|---|---|---|---|---|---|
| 1 | 15 | 15 | 32.1 | 7 | 35 | 15 | 50.7 |
| 2 | 15 | 20 | 47.1 | 8 | 35 | 20 | 69.3 |
| 3 | 15 | 25 | 50.3 | 9 | 35 | 25 | 80.4 |
| 4 | 15 | 30 | 51.6 | 10 | 35 | 30 | 72.5 |
| 5 | 15 | 25 | 62.2 | 11 | 50 | 25 | 80.9 |
| 6 | 15 | 30 | 63.8 | 12 | 50 | 30 | 71.9 |

## Conclusions

The new process of vanadium extraction from molten vanadium slag by direct oxidation and sodium activating method is reasonable and feasible. The experimental results show that in the new process, vanadium in the roasted slag exists mainly in the form of water-soluble sodium vanadate and the vanadium water leaching efficiency can reach to 80%, which can meet the requirement of industrial production.

## References


1. Y.Zhang, S.Bao, T.Liu, "The Technology of Extracting Vanadium from Stone Coal in China: History, Current Status and Future Prospects", *Hydrometallurgy*, **109** (2) 116-124 (2011).
2. R.R. Moskalyk, A.M. Alfantazi, "Processing of Vanadium: A Review", *Miner. Eng.*, **16** (9) 793-805 (2003).
3. B.C.Jena, W.Dresler, I.G.Reilly, "Extraction of Titanium, Vanadium and Iron from Titanomagnetite Deposits at Pipestone Lake, Manitoba, Canada",*Miner. Eng.*, **8** (2) 159-168 (1995).
4. W.Geyrhofer, B.Voglauer and H. P.Joergl, "Control of a Roasting Process for the Recovery of Vanadium", in *Proceeding of 2003 IEEE Conference on Control Applications(CCA 2003),*Istanbul, Turkey, 23-25 June 2003.
5. W.Song, H.Li, "A New Process for Vanadium Extraction from Molten Vanadium Slag by Direct Oxidation and Sodium Activating Method", *Iron Steel Vanadium Titanium* **33** (6) 1-5 (2012).
6. C.P.J. Vanvuuren, P.P. Stander, "The Oxidation of $FeV_2O_4$ by Oxygen in a Sodium Carbonate Mixture", *Miner.Eng.*, **14** (7) 803-808 (2001).
7. P.P. Stnder, "The High Temperature Oxidation of $FeV_2O_4$", *Thermochim. Acta*, **157** (2) 347-355 (1990).