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Modelling and optimization of process parameters for beneficiation of ultrafine chromite particles by selective flocculation

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ABSTRACT

Chromite tailings are generated from chrome ore beneficiation plants, containing substantial quantities of ultrafine particles. Generally these ultrafine particles of chromite cannot be treated effectively using conventional beneficiation methods, because of limitations in particles size being treated by these processes. Selective flocculation process could be one of the alternative physico-chemical methods for treating these ultrafine particles. Here an attempt was taken to establish selective flocculation process for treating chromite particles using synthetic mixture of high grade chromite ore and kaolin. Box Behnken experimental design was applied to study the significance of operating parameters like flocculant dose, dispersant dose and pH on responses of selective flocculation process. Both pH and flocculant dose significantly affect selective flocculation process. Further, an optimization of process parameters were also carried out and optimized response was found to be 41.86% grade of Cr_2O_3 in concentrate with 69.73% recovery.

1. Introduction

Demand of chromium is increasing day by day because of its various applications in ferroalloys, catalyst, refractories, etc. Chromite is an oxide mineral and major source of chromium. Due to increasing demand, high grade chromite ore is depleting gradually [1]. This necessitates the use of low grade chromite ore after beneficiation. However, it is not possible to effectively beneficiate ultrafine chromite particles using conventional methods and they report to tailings. Safe storage and handling of generated tailings from beneficiation plant is now becoming a challenge to the mineral industry. Apart from land accusation problem these huge amount of tailings might cause environmental problems also.

Research has been going on over the years to recover more and more chromite values using conventional beneficiation methods like gravity separations, magnetic separations, and flotation [1–11]. However, all the above methods have limitations in handling ultrafine chromite particles. High hydrodynamic forces acting on these particles help them to escape the system before being beneficiated. These conventional methods are most effective for specific feed particle size range. Spiral concentrators can normally process particles having sizes between 3 mm and 0.045 mm [12–14]; magnetic separator can normally process particles having sizes between 1 mm and 0.025 mm; flotation can process particles having sizes between 0.1 mm and 0.025 mm. Chromite tailings contain substantial amount of ultrafine particles, which may not be effectively beneficiated by conventional methods and still report to tailings.

Selective flocculation is one of the alternative beneficiation methods available for effective beneficiation of ultrafine particles below 45 μm. Selective flocculation is a solid–solid separation process where desired minerals are selectively flocculated and undesired minerals remains in suspended state [15–17]. Process of selective flocculation has been successfully applied for beneficiation of oxide minerals like iron ore, and bauxite ore. In fact the process has been extensively applied to ultrafine particles of iron ore [17–24]. However, very limited works were carried out for enrichment of ultrafine chromite ore by selective flocculation [25,26]. Akdemir and Hicydmaz [25] studied the applicability of selective shear flocculation to synthetic mixture of chromite–serpentine mixture having grade of 29% chromite in 2 g scale. They had added sodium oleate to synthetic mixture, which when coated on the mineral created hydrophobic surface. Then they applied shearing force to selectively settle the chromite. They have mentioned that higher density of chromite particles contributed greatly

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Table 1
Particle size distribution (μm).

Component	d_{10}	d_{50}	d_{90}
Kaolin	1.97	7.801	35.052
Chromite	2.025	15.4	39.978

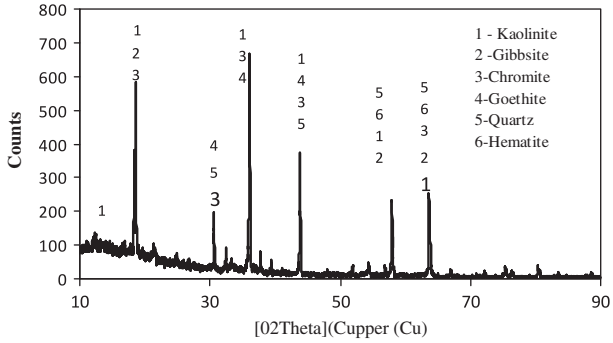
to selective settling of particles. Beklioglu and Arol [26] studied the applicability of selective flocculation to synthetic mixture of chromite–serpentine using corn starch as flocculating reagent. They claimed that process is only effective when weight percent of serpentine in the synthetic mixture is below 30%. These limited works available in literature are not enough to successfully establish the applicability of selective flocculation techniques for beneficiation of ultrafine chromite particles. More work is needed to establish the process.

Present paper aims at understanding the effect of different process parameters on performance of selective flocculation process for beneficiation of ultrafine chromite particles. Performance of selective flocculation was judged by grade (%) and recovery (%) of chromite concentrate obtained. Moreover, statistical approach was taken for modelling the performance of selective flocculation process. In addition to this optimization of process parameters was done. In current approach, Box Behnken experimental design was applied to selective flocculation process for analysing significance of major process parameters like flocculent dose (g/tonne), dispersant dose (g/tonne) and pH on responses i.e., grade and recovery. All experiments in this study were carried out using synthetic mixture of high grade chromite and kaolin.

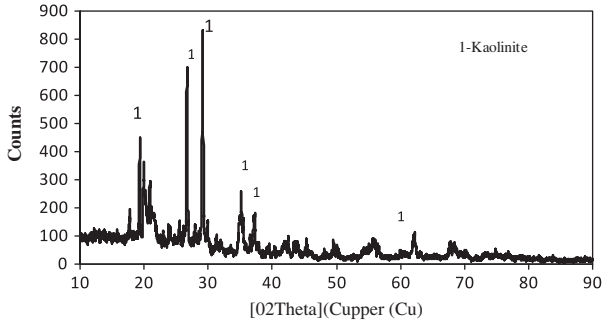
2. Materials and method

2.1. Materials

Kaolinite is one of the gangue mineral associated with chromite in Indian chromite ore. Because of which, in present study,



(a) XRD of Chromite Ore



(b) XRD of Kaolin

Fig. 1. XRD spectrum for (a) chromite ore and (b) kaolin.

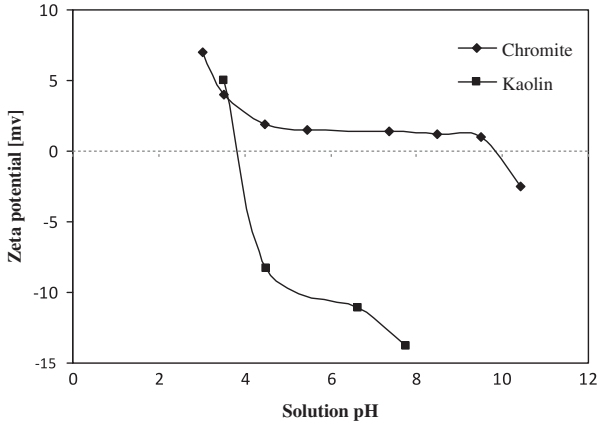


Fig. 2. Zeta potential of chromite and kaolin.

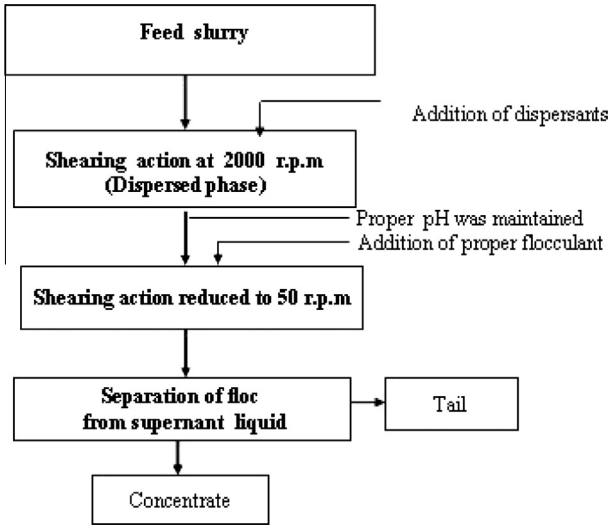


Fig. 3. Schematic diagram of selective flocculation process.

synthetic mixture of high grade chromite and kaolin with 1:1 ratio was used as feed material for conducting experiments. High grade chromite ore was collected from chrome ore beneficiation (COB) plant, Tata Steel Limited, Sukinda. High grade chromite ore was produced by beneficiation of low grade chromite ore in gravitational units present at COB plant. Chemical analysis shows that high grade chromite ore used for synthetic mixture preparation contains 47.93% Cr_2O_3, 10.9% Al_2O_3, 3.55% SiO_2 15.07% total Fe and 9.79% of MgO along with other minor elements. Collected high grade chromite ore was further grounded to pass 400 mesh (<37 μm), so that it can be used as feed for selective flocculation process. Analytical grade of kaolin was procured from LOBA chemie, which contains 26.84% of Al_2O_3 and 60.32% SiO_2 used for this study. Detail particle size distribution of both the samples was carried out using Malvern particle size analyser and results are given in Table 1. Synthetic mixture used in this study was made ready by

Table 2
Detail scope of experiments.

Sl. no.	Variables	Levels		
		(−1)	0	(+1)
1	Flocculent dose (g/tonne)	312.5	437.5	562.5
2	Dispersant dose (g/tonne)	625	937.5	1250
3	PH	8	9.5	11