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Influence of fenugreek-gum and particle size on performance of talc flotation

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Abstract: Talc usually exists as a gangue mineral in copper-nickel sulfide, molybdenite etc. In order to separate precious metals, naturally hydrophobic talc should be depressed effectively in flotation process. The effect of fenugreek-gum (FG) on the flotation performance of talc with different particle sizes was studied. The depression mechanism was investigated extensively through tests of flotation, adsorption and zeta potential, as well as infrared spectroscopy and laser particle size analysis. Flotation results indicated that the FG had a strong depression ability for talc with the particle size of -0.074 + 0.037 mm, -0.037 mm and -0.010 mm when proper dosage of FG was added. The coarse talc was completely depressed by 2.5 mg/ dm^3 FG. When the particle size decreased, more FG was required to obtain the maximum depressing effect, which was verified by adsorption tests. FG reduced the electronegativity on the talc surface by chemical adsorption, and flocculation of talc powders caused a high efficient depressing effect.

Keywords: talc, particle size, fenugreek-gum, depression, flocculation

1. Introduction

Talc is the most common hydrophobic mineral associated with complex copper-nickel sulfide ore or occurred in the ore of platinum group metals (Beattie, et al., 2006a). The Mohs hardness and relative density of talc are 1 and 2.58~2.83, respectively. Pure talc is always pink, light gray or celadon caused by different impurities (Chen, 2005). The molecular formula of talc is $Mg_3[Si_4O_{10}](OH)_2$, and talc is mainly composed of 31.7% MgO, 63.5% SiO_2, 4.8% H_2O (Liang and Xue, 1994). Talc, as a chemically stable substance, does not react with strong acid and alkali (Deng, et al., 1995; Zhang, et al., 2014).

Talc, as a gangue, usually associates with complex sulfide ores (Jiang, 1999; Dong, et al., 2006; Jiang, et al., 2012). Separation of talc from sulfide mineral is still a major challenge due to its natural floatability (Li, 1998). High MgO content in sulfide concentrate requires high temperature and causes high slag viscosity in smelting process, which definitely increases the cost of smelting process (Pietrobon, et al., 1997; Feng, et al., 2012). Therefore, it is urgent to improve removal rate of talc as much as possible in flotation process.

At present, many methods have been used for solving the problem mentioned above, e.g. desliming in advance, preferential talc flotation, adding talc depressant prior to the flotation of sulfide minerals (Chen, et al., 1999). In the industrial practice, macromolecular polysaccharides (like guar gum and carboxy methylated cellulose) are widely used as depressant for talc in flotation process (Beattie, et al., 2006a, b; Zhang, et al., 2011). However, polysaccharides suffer from high reagent dosage and high price, and thus increase the cost of talc depression in flotation process (Wiese, et al., 2007). Previously, Zhao et al. found that fenugreek-gum (FG) was superior to the guar gum for talc suppressing due to easy preparation and low cost (Zhao, et al., 2015b). However, there is little information on depression mechanism of FG for talc with different particle sizes.

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In this study, FG was used to depress talc, and the depressing performance of FG was investigated by single mineral flotation tests. The effect of flocculation on talc powders was examined through laser particle size analysis. In addition, the adsorption mechanisms of FG on talc surface were determined by adsorption tests, zeta potential measurements and infrared spectrum analysis.

2. Experimental

2.1 Material and reagents

A sample of pure talc was obtained from Donghai, Jiangsu, China. The talc was crushed, manually sorted to remove quartz, ground with porcelain ball mill, and sieved into three size fractions of -0.074 + 0.037 mm, -0.037 mm and -0.010 mm, hereafter abbreviated as Ta-1, Ta-2 and Ta-3, respectively.

The chemical analysis of talc is shown in Table 1. The X-Ray diffraction (XRD) of talc is displayed in Fig. 1. Table 1 and Fig. 1 indicate that the purity of talc is more than 90%, which meets the requirement of flotation tests.

Table 1. Chemical analysis results of talc

Element	MgO	SiO_2	Al_2O_3	Fe_2O_3	CaO
Grade(mass fraction, %)	30.43	57.15	0.29	0.63	0.17

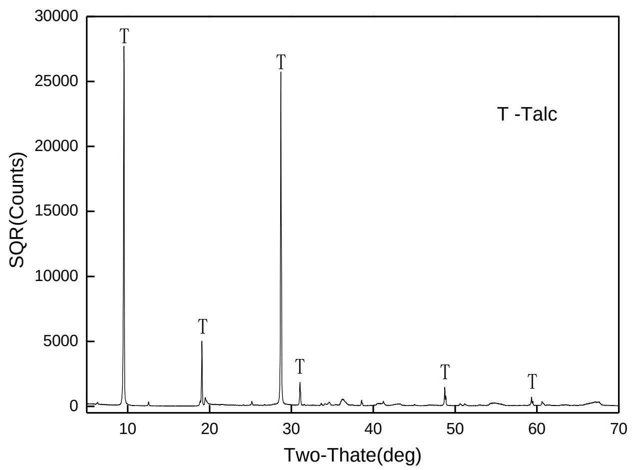

Fig. 1. The XRD spectra of talc

Fenugreek-gum [FG, $(C_{12}H_5O_5)n$, purity>93%], a new generation of polysaccharide gum, was supplied by the IMUMR Flotation Reagents Limited Company, China (Zhao, et al., 2015b). The molecular weight of FG was about 300,000. FG solution was prepared by dispersing a known weight of FG in distilled water at 25 °C and then dissolving it in hot distilled water (80 °C). The potassium amyl xanthate (PAX), guar gum and methyl isobutyl carbinol (MIBC) were used as collector, depressant and frother, respectively. The pH was adjusted with sodium hydroxide (NaOH) or hydrochloric acid (HCl) solutions. The chemicals were of analytical grade, and distilled water was used throughout experimental tests.

2.2 Methods

Single mineral flotation experiments were carried out in the XFG flotation machine (Fig. 2) with the impeller speed of 1900 rpm. For each test, 2.0 g mineral was placed in a 40 cm^3 flotation cell, followed by stirring the slurry for 1 min after adding 35 cm^3 distilled water. The pH of pulp was adjusted by HCl or NaOH for 2 min. Subsequently, the desired dosages of FG and MIBC were added in sequence into the flotation cell and mixed for 4 min and 1 min, respectively. The conditioned slurry was floated for 3 min. Both the concentrates and tailings were filtered, dried and weighed to calculate mineral recovery in mineral flotation.

For adsorption tests, 2.0 g talc was mixed with 35 cm^3 distilled water, and desired reagents were added in the same order as in flotation tests. The suspension was then centrifuged for 20 min and the supernatant was analyzed using the TU1810 UV–Vis spectrophotometer.

Fig. 2. XFG flotation machine for single mineral flotation tests

2.3 Analysis

Zeta potential measurements were carried out using a Coulter DELSA440S II Type electro-kinetic instrument. Specially, 2.0 g talc was ground to below 2 μm by agate mortar. Small quantities of talc powders were added into a beaker with 40 cm^3 distilled water. Same reagents as used in flotation tests were added, and the slurry was ultrasonicated for 3 min and magnetically stirred for 10 min. The suspension pH adjusted using HCl or KOH. Zeta potential of samples was then measured separately.

A 2.0 g talc was added into 30 cm^3 aqueous solution with or without 20 mg/dm^3 depressant at pH 5.5, and ultrasonically treated for 5 min. The pulp was then centrifuged and washed at least three times with distilled water. Finally, the sediments were air-dried at room temperature. The infrared spectra of samples were recorded using a Model Nexus 670 Fourier transform infrared spectrometer (FT-IR).

A 2.0 g talc was mixed with 35 dm^3 distilled water in a 1000 dm^3 beaker. Next, the same reagents were added as used in flotation test, and the slurry was stirred for 5 min. The average particle size of pulp was finally measured with the Mastersizer 2000 laser particle size instrument.

3 Results and discussion

3.1 Effect of FG on talc flotation

The effect of pH on the flotation behavior of talc with different particle sizes is shown in Fig. 3. The flotation recovery of Ta-1 fluctuated slightly around 85% in the whole pH range. Ta-2 also showed good natural floatability, although the recovery was slightly lower than Ta-1. However, the floatability of Ta-3 became very weak, and the flotation recovery was constant at 44%.

The effect of FG on flotation behavior of talc with different particle sizes as a function of pH is shown in Fig. 4. The dosage of FG for talc was controlled at 20 mg/dm^3 since the depression effect at 0.5 mg/dm^3 was insignificant. FG essentially had no influence on flotation of Ta-1 under acidic conditions. Fig. 3 and Fig. 4 indicated that the flotation recovery was decreased at a FG dosage of 0.5 mg/dm^3. The depression ability of FG gradually increased with the increase of pH value. The flotation recovery of Ta-1 decreased to 45% as the pH value increased to 11.5. For the Ta-2, the recovery decreased with increasing pH value under acidic conditions, but without obvious changes in the alkaline conditions.

For the Ta-3, the recovery varied slightly in the whole range of pH values. Meanwhile, Fig. 4 also indicated that in comparison with guar gum, FG showed stronger depressing effects with Ta-3, which was in agreement with previous results (Zhao, et al., 2015b). The relationship between the pH and the depressing effect of FG on talc suggested that the depression effect on talc became weaker and slightly affected by pH when the particle size of talc dropped.

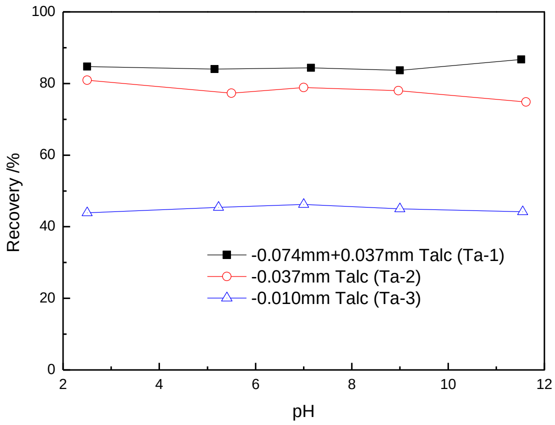

Fig. 3. Effects of pH values on flotation behavior of talc with different particle size ($PAX=1\times10^{-4}$ mol/ dm^3, MIBC=9 mg/ dm^3)

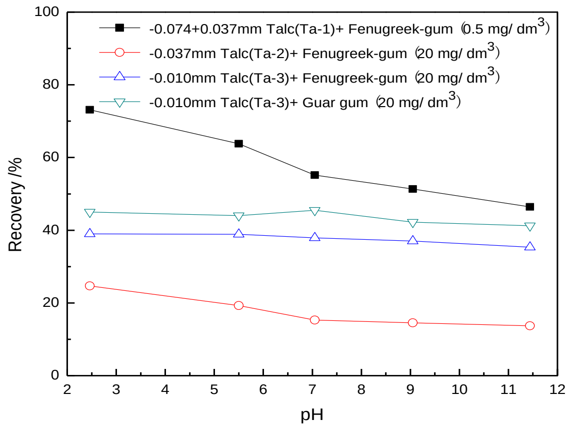

Fig. 4. Effects of FG on flotation behavior of talc with different particle size as a function of pH ($PAX=1\times10^{-4}$ mol/ dm^3, MIBC=9 mg/ dm^3)

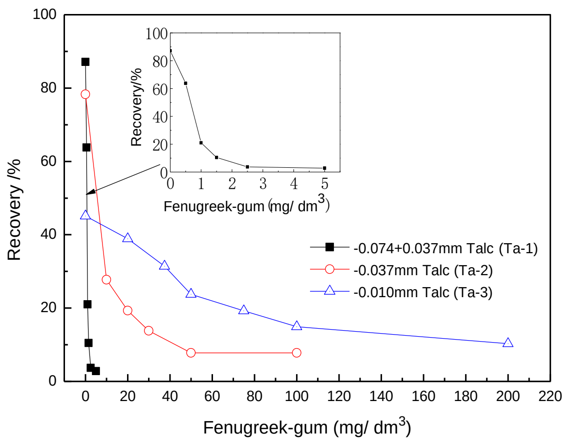

Fig. 5. The effect of FG concentration on flotation behavior of talc with different particle size (pH=5.5, $PAX=1\times10^{-4}$ mol/ dm^3, MIBC=9 mg/ dm^3)

In this study, the depression of talc was evaluated according to copper-nickel sulfide flotation system. Previously, Zhao et al. (2015b) proved that the preferable pH for the separation of talc from copper-nickel ores was 5.5. Therefore, pH value of 5.5 was chosen for following experiments and analysis.

Fig. 5 displays the effect of FG on flotation behavior of talc with different particle size at pH 5.5. Fig. 5 revealed that FG had great depressing effect on Ta-1 and Ta-1 was completely depressed by 2.5 mg/ dm^3 FG. For Ta-2, the flotation recovery decreased rapidly with the increase of FG dosage. Complete depression of Ta-2 was achieved at FG dosage of 50 mg/ dm^3. However, the recovery of Ta-3 was less than 10% when the FG dosage is 200 mg/ dm^3.

3.2 Adsorption behavior of FG on talc surface

Fig. 6 shows the effect of FG on adsorption of talc at pH 5.5. The adsorption capacity of FG on Ta-1 was better than that of smaller powders with the same dosage of FG. It was due to that the absorbed FG per unit area decreased as the particle size reduced and specific surface area increased. There are differences in the adsorption behavior for different dosages of FG on talc. With increasing the FG dosage, the adsorption quantity of FG on Ta-1 surface increased slightly, the increase of the adsorption quantity on Ta-2 became smaller, while the adsorption capacity on Ta-3 increased. When the depressant dosage of FG increased, the adsorption density on Ta-2 increased from 0.25 mg/m^2 to 0.92 mg/m^2, and the adsorption density on Ta-3 increased from 0.12 mg/m^2 to 0.65 mg/m^2. The adsorption capacity of Ta-1 was larger than that of Ta-2 and Ta-3, especially under low FG dosages. In addition, Ta-1 was basically independent of the depressant dosage and maintained an adsorption density of about 0.9 mg/m^2. Besides, a large adsorption space for Ta-3 was observed at all concentrations of FG. The adsorption behavior of FG on talc surface was consistent with the flotation results for talc with different particle sizes.

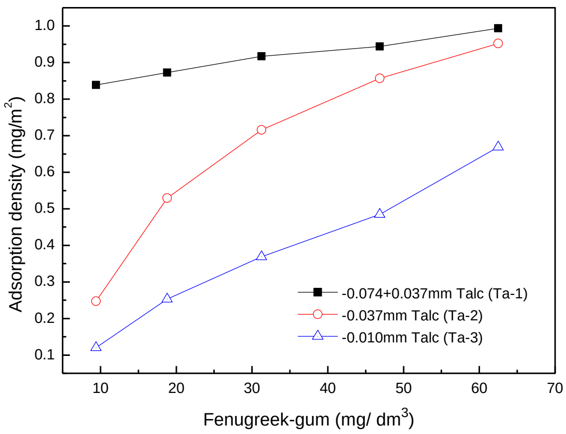

Fig. 6. The effect of FG concentration on adsorption of talc with different particle sizes (pH 5.5)

3.3 Effect of FG on the surface zeta-potential of talc

The zeta potential of talc untreated and treated with FG as a function of pH are displayed in Fig. 7. The results indicate that talc surface was negatively charged within the pH regions. In addition, zero isoelectric point was not detected. With the increase of pH, FG had a great influence on surface electricity of talc. Because adsorption of nonionic FG on talc surface prevented the adsorption of hydroxyl ions on mineral surface (Zhao, et al., 2015b), the zeta potential of talc was gradually shifted to positive after interacting with FG, and the absolute value of zeta potential was smaller than that of untreated talc.

3.4 Infrared spectroscopy analysis

The FT-IR spectra of talc before and after interacting with FG are shown in Fig. 8. In the spectrum of talc, the sharp bands near 3676 cm^{-1} and 1018 cm^{-1} corresponded to the stretching vibration of -OH and

C-O, respectively. The bands near 673 cm^{-1} and 472cm^{-1} were due to flexural vibrations of Mg-O and Si-O, respectively (Amekura, et al., 2003). In the spectrum of FG, the characteristic bands near 3452 cm^{-1} and 2889 cm^{-1} were due to -OH stretching vibration and -CH_2 stretching vibration, respectively. The band near 1651 cm^{-1} assigned to the stretching vibration of the ring of six-member carbon oxygen ring, and the band near1431 cm^{-1} and 1018 cm^{-1} were due to -COO stretching vibration and C-O stretching vibration (Derrick, et al., 1999; Argun and Dursun, et al., 2006; Yang, et al., 2011; Hebeish, et al., 2013). A strong sharp band of -OH appeared near 3441 cm^{-1} in the spectrum of talc after treating with FG. Meanwhile, the band of near 1018 cm^{-1} shifted to 1010 cm^{-1} (Xia et al, 2014). The results implied that FG was adsorbed on talc surface by chemical adsorption (Zhao, et al., 2015b). This was the reason why FG had greater depression effect on talc.

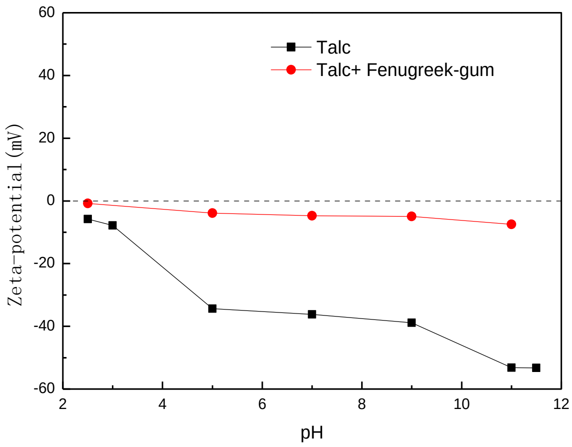

Fig. 7. The zeta potential of talc as a function of pH in the presence and absence of 20 mg/ dm^3 FG

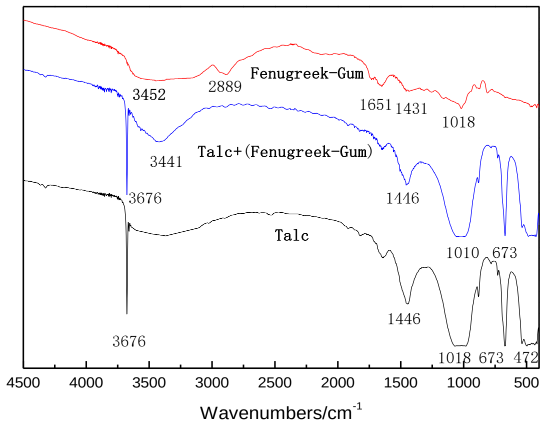

Fig. 8. Infrared spectra of talc before and after interacting with 20 mg/ dm^3 FG (pH 5.5)

3.5 Flocculation effect of FG on fine talc

Fig. 9 displays the effect of FG on the average particle size of talc. The average size of Ta-1, Ta-2 and Ta-3 was gradually increased with increasing FG dosage. When the FG dosage was 50 mg/ dm^3, the average particle size of Ta-2 and Ta-3 increased from 26 μm and 7 μm to 31 μm and 11 μm, respectively, suggesting the flocculation effect of FG for talc. Fig. 7 and Fig. 8 indicated that addition of FG decreased the absolute value of surface charge and the inter-particle repulsion, which reduced inter-particle dispersibility. Therefore, the inter-particle flocculation became more easily.

4 Conclusions

In this work, the effect of fenugreek-gum (FG) on the depression of talc with different particle sizes and the depression mechanism were systematically investigated. The floatability of talc was influenced by the granularity, and the floatability of talc in different particle sizes followed the order: -0.074+0.037mm > -0.037mm > -0.010mm. FG had a strong depressing effect on talc, especially for coarse talc, the -0.074+0.037mm size fraction of talc was completely depressed by 2.5 mg/ dm³ FG. The depressing effect of FG for talc was influenced by particle size. Larger dosage of FG was needed in order to completely depress talc with smaller particle size. The absolute value of talc surface charge and the inter-particle repulsion decreased in the presence of FG, causing easier inter-particle flocculation. FG interacted with talc surface by chemical adsorption.

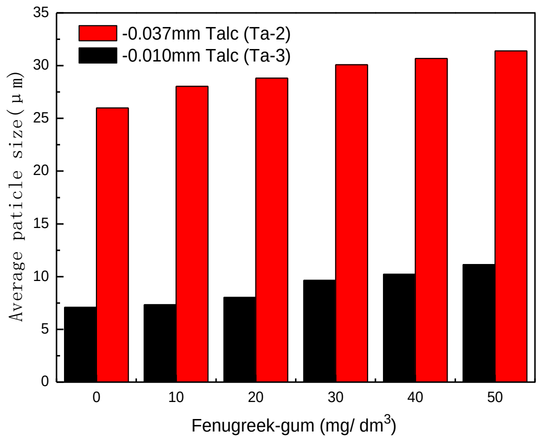

Fig. 9. The effect of FG concentration on the average particle size of talc (pH=5.5).

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References

AMEKURA, H, UMEDA, N., OKUBO, N., KISHIMOTO, N., 2003. Ion-induced frequency shift of 1100 cm^{-1}, IR vibration in implanted SiO_2: compaction versus bond-breaking. Nuclear Instruments & Methods in Physics Research, 206(03), 1101-1105.

ARGUN, M. E., DURSUN, S., 2006. Removal of heavy metal ions using chemically modified adsorbents, J. Int. Environ. Appl. Sci. 1 ,27–40.

BEATTIE, D.A., HUYNH, L., KAGGWA, G.B.N., 2006a. *The effect of polysaccharides and polyacrylamides on the depression of talc and the flotation of sulphide minerals*, Miner. Eng. 19, 598-602.

BEATTIE, D.A., HUYNH, L., KAGGWA, G.B.N., RALSTON, J., 2006b. *Influence of adsorbed polysaccharides and polyacrylamides on talc flotation*. Int. J. Miner. Process. 78, 238-249.

CHEN, G., GRANO, S., SOBIERAJ, S., RALSTON J., 1999. *The effect of high intensity conditioning on the flotation of a nickel ore, Part 1: size by size analysis*. Miner. Eng. 12, 1185-1200.

CHEN, Z.Y., 2005. *(Master Degree Thesis) Study on dispersion of talc in the flotation of sulfide ores.* Central South University, China.

DENG, D.B., 1995. *The elementary discussion on the exploitation and utilization of tale ore in Yongfeng*. Conservation and Utilization of Mineral Resources. 4, 16-18.

DERRICK, R.R., STULIK, D., LANDRY, J.M., 1999. *Infrared Spectroscopy in Conservation Science, 1st ed.* The Getty Conservation Institute, L/A, U.S.A.

DONG, S.Z., 2006. *Experimental research on separation technology for processing molybdenum ore containing talc*. Multipurpose Utilization of Mineral Resources. 1, 7-12.

FENG, B., LU, Y.P., FENG Q.M., ZHANG, M.Y., GU, Y.L., 2012. *Talc–serpentine interactions and implications for talc depression*. Miner. Eng. 32, 68-73.

HEBEISH, A., HASHEM, M., ABD, M. M., HADY, E., SHARAF, S., 2013. *Development of CMC hydrogels loaded with silver nano-particles for medical applications*. Carbohydr. Polym. 92, 407–413.

JIANG, J.X., JIAN, H.L., ZHU, L.W., ZHANG, W.M., 2012. *Development and application of the functional polysaccharide gum.* China Light Industry Press, China, pp. 5–90.

JIANG, Y.Z., 1999. *A study on experiment of comprehensive recovering talc from poly-metallic ores containing copper*. Conservation and Utilization of Mineral Resources. 6, 41-43.

LIANG, Y.Z., XUE, W.Y., 1994. *Study on foam stability and behavior of talc flotation*. Non-Met. Mine.4, 21-23.

LI, A.Q., 1998. *Dongguashan copper ore difficult principle of program selection sorting.* Nonferrous Metals (Mineral Processing Session). 1, 6-9.

PIETROBON, M.C., GRANO, S.R., SOBIERAJ, S., 1997. *Recovery mechanisms for pentlandite and MgO-bearing gangue minerals in nickel ores from Western Australia*. Miner. Eng. 8, 775-786.

WIESE, J., HARRIS, P., SHAWBRAD, D., 2007. *The response of sulphide and gangue minerals in selected Merensky ores to increased depressant dosages*. Miner. Eng. 20, 986-995.

XIA, L., HU, Y.H., ZHANG, B.H., 2014. Kinetics and equilibrium adsorption of copper(II)and nickel(II) ions from aqueous solution using sawdust xanthate modified with ethanediamine, Trans. Nonfer. Met. Soc. 24, 868–875.

YANG, S.P., FU, S.Y., LIU, H., ZHOU, Y.M., LI, X.Y., 2011. Hydrogel beads based on carboxy methyl cellulose for removal heavy metal ions, J. Appl. Polym. Sci. 119, 1204–1210.

ZHANG, M.Y., 2011. *(Master Degree Thesis) Study on sync suppression of multiple magnesium silicate minerals in the flotation system of sulphide ore.* Central South Univerty, China.

ZHANG, S.J.,2014. *Mechanism of carboxymethyl cellulose to inhibit the flotation of talc*. Journal of Luoyang Normal University. 5, 62-64.

ZHAO, K.L, GU, G.H., WANG, C.L., DENG, W., LIU, X.,2015a.*Experimental study on beneficiation of pyrrhotite-rich copper-nickel sulphide ore*. Min. Metall. Eng.3, 40-43.

ZHAO, K.L., GU G.H., WANG, H., WANG, C.L., WANG, X.H., LUO, C., 2015b. *Influence of depressant foenum-graecum on the flotation of a sulfide ore which contains hydrophobic gangue*. Int. J. Miner. Process. 141, 68-76.