

Experimental study on the characteristics of sandstone subjected to acid corrosion

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Abstract. The purpose of this paper is to study the change of sandstone properties during acid corrosion. With the help of velocity detection and chemical analysis, the mass loss, longitudinal wave velocity and the concentration of Ca^{2+} dissolved in the solution are analyzed. Experimental results show that: within 0~30 days, the corrosion rate is the fastest, the mass loss rate, the wave growth rate and the growth rate of Ca^{2+} concentration are faster. Within 30~60 days, the rate of change of the indexes are slower, indicating that corrosion rate became slow gradually. Within 60~90 days, the indexes tend to be stable, indicating that corrosion rate tends to be stable, which shows that the acid corrosion of sandstone have certain stages. The corrosion rates of sandstone in solutions with different pH values are different. The stronger the acidity, the greater the corrosion rate, the rate of increase of Ca^{2+} and the increase rate of the wave velocity of the samples at the initial stage of the reaction.

1 Introduction

Wave velocity is a comprehensive reflection of the physical and mechanical properties of rock. In the process of acoustic wave propagation, kinetic energy and potential energy alternates transformation. The corresponding parameters is longitudinal wave velocity and amplitude, respectively. The influence of saturation on the longitudinal wave velocity and strength of the sandstone was studied by Deng HF [1], which showed the longitudinal wave velocity and saturated degree having obvious nonlinear relationship. Zhou WG, Yue LX[2~4], respectively, on the rough surface basalt, andesite, plagioclase amphibolite and hornblende plagioclase gneiss elastic wave velocity measurements carried out under high temperature and high pressure and intermediate experimental observations, they studied these rocks phase change and elastic wave velocity relationship. Zhou JY [5] simulated acid rain environment, and studied the effects of acid rain on the bedrock of the Leshan Giant Buddha. The results showed that the acid rain on erosion of sandstone from the surface to the internal development gradually. The dissolution rate was faster, the erosion hazard was greater. Cui ZA [6] studied corresponding relation on Ca^{2+} and Mg^{2+} cation release and the rock dissolve loss. The study showed that the dissolution rate was faster on mineral composition of complex carbonate rock than single component of carbonate in the process of dissolution. Lan J K [7] by simulation experiments of limestone on acid rain erosion, got the acid rain- CaCO_3 - CO_2 system balance model, and calculated the change relation between the Ca^{2+} concentration and pH value of solution in limestone reaction process, in order to reflect the process of the erosion of limestone. This paper measured solution



concentration and longitudinal wave velocity of the sandstone samples which were immersed in different concentration of HCl solution to analyse the change of cation concentration in solution, which can provide the basis data for the analysis of the rock wave velocity and corrosion degree in the process of acid corrosion.

2 Experimental

Test samples are dark gray particle containing calcium lithic feldspathic sandstone taken from a hydraulic engineering in ShanXi province. These samples were removed from a large block of complete sandstone with the method of core sampling, then the samples were processed into standard cylindrical specimens with $h=100\text{mm}$, $\phi=50\text{mm}$, in order to reduce the dispersion of the test results caused by individual differences in natural rock samples, samples were selected by acoustic tester and divided into three groups. Then the samples of each group were soaked in pH=2 and pH=5 HCl solution. Daily monitoring the change of pH value in each solution. Every 10 days, mass loss, longitudinal wave velocity and concentration of Ca^{2+} were tested. Diagram of test equipment are shown in figure 1.



Test of mass and velocity



792Basic IC Ion concentration chromatograph

Figure 1 Diagram of test equipment

3 The quality and wave velocity variation of sandstone under acid corrosion

3.1 The mass loss rate of the samples

The mass loss rate, A , is the ratio of the mass loss after soaking and the initial mass of the sample. The law of change in mass is shown in Figure 2.

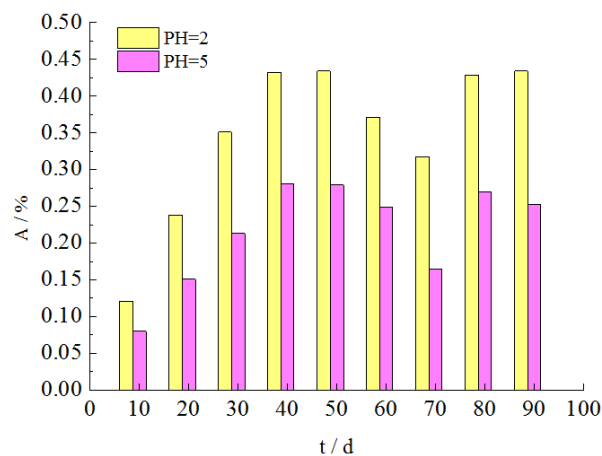


Figure 2 The variation of mass loss rate with time

Within 90 days, the maximum mass change rate of the samples was shown in the samples which were soaked in pH=2 HCl solution. The maximum mass loss rate reaches to 0.432% and 0.281% in pH=2 and pH=5 HCl solution, respectively on the fortieth day. Along with the extension time, the

seepage path lengthened, the chemical reaction rate slowed down. The mass loss rate decreases in the corrosion of 40 to 70 days and reaches to steady then. The minimum mass loss rate reaches to 0.317% and 0.165% in pH=2 and pH=5 HCl solution, respectively on the seventieth day. After 70 days, the mass loss rate of samples increases again, which showed that chemical reaction has obvious stage characteristics. The reaction was controlled by diffusion and reaction functions, and the two functions were mutually transformed in the whole process.

3.2 The longitudinal wave velocity of the immersed sample

Through three stages of the test, a representative sample was chosen to analyse from the HCl solution with different pH, and the results of the wave velocity of the soaked samples are shown in Figure 3.

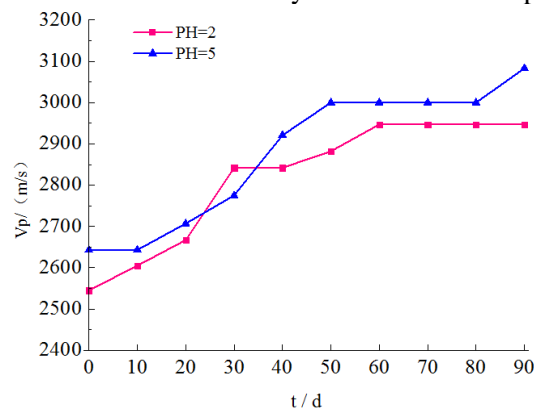


Figure 3 Wave velocity variation curve of the immersed sample in HCl solution

It can be seen from the above graph that the wave velocity of the samples increase rapidly after corrosion, and the stronger the acidity, the greater the rate of increase. After 30 days, the wave velocity increased by 265 m/s and 126 m/s, respectively. Within 30~60 days, the HCl solution concentration decrease, the chemical reaction rate slowed down. As the penetration length become longer, the porosity increased slowly, the growth rate of wave velocity changes slower, and the wave velocity increased by 99 m/s and 75 m/s, respectively. The growth amplitude is about 30% of which in 0-30 days. Within 60~90 days, the variation of wave velocity is stable, the wave velocity of the sample that soaked in pH=5 HCl increased by 79 m/s only, which showed that the weaker the acidity, chemical reaction is slower, the time to achieve stable for longitudinal wave velocity is longer.

3.3 The relationship between longitudinal wave velocity and porosity of the immersed specimen

The P-wave velocity and porosity of soaking samples has certain relationship, as shown in Figure 4: with the increase of the porosity, longitudinal wave velocity of sandstone gradually increased

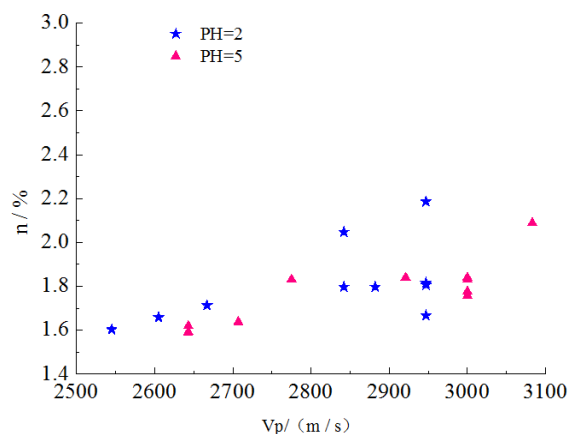


Figure 4 The relationship between longitudinal wave velocity and porosity

Because of its chemical reaction become more intense, a lot of cement was produced in pH=2 HCl solution. The wave velocity change is more concentrated in the range of the change of the porosity. Due to the lower concentration of acid solution in pH=2 HCl solution, chemical reaction is slower. Sandstone porosity variation range is in 1.6% ~ 2.0%. The acid solution concentration is lower, and the P-wave velocity change range is more centralized.

4 Law of chemical changes of corroded sandstone

4.1 The change of pH with time in the acid environment

The chemical reaction occurred when sandstone were soaked in acid solution. Two different concentrations of HCl were used to simulate the acid rain, the pH in different immersion time was shown in Figure 4.

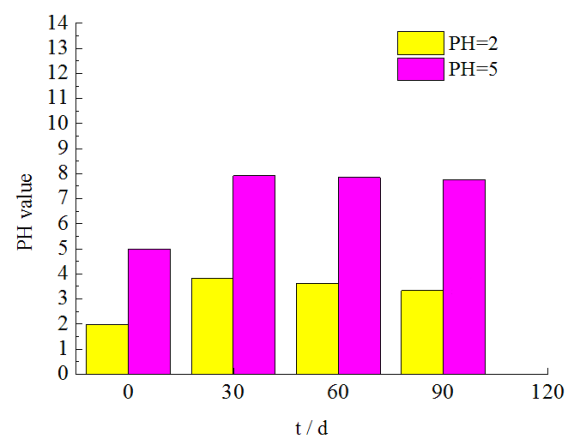


Figure 5 The change of pH in different concentrations of HCl

It can be seen from figure 4 that chemical reaction is more intense in pH=2 HCl solution. When the reaction becomes stable, the acid become weak in 0-30 days and 30-60 days. The rock surface has many bubbles and fine particle solute at the same time. Within 60-90 days the penetration path was lengthened, and the dissolved cement obstructs the acid solution to deeper penetration, chemical reaction appears delay phenomenon. HCl solution which PH value is 5 has a low hydrogen ion concentration, the chemical reaction is slow. In 30 days, 60 days and 90 days, the pH value is 7.92, 7.85, and 7.86, respectively. The final solution shows weak alkaline.

4.2 The change of Ca^{2+} concentration with time

The Ca^{2+} dissolution rate in different concentrations of HCl solution and different immersion time as shown in figure 5.

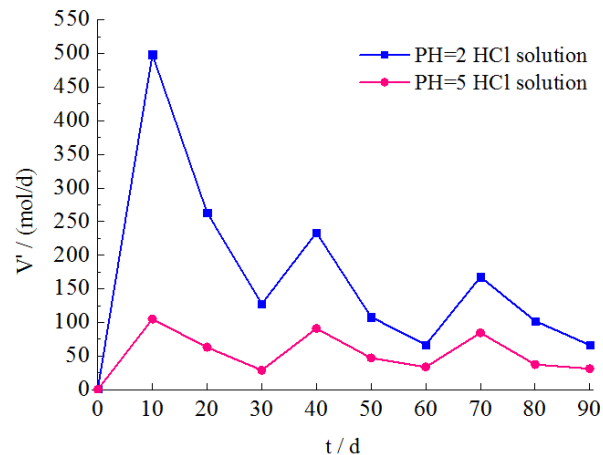


Figure 6 The change curve of Ca^{2+} dissolution rate

Figure 5 depicts the dissolution rate of Ca^{2+} , it can be seen from figure 5 that the trend of dissolution rate of Ca^{2+} first increased and then decreased is consistent of three different concentration of HCl solution in 0-30 days, 30-60 days and 60-90 days. The dissolution rate of Ca^{2+} in HCl solution which PH is 2 and 5 reached to the maximum, 489.50 mol/d and 104.88 mol/d, respectively in the tenth day. The hydrogen ion concentration and the dissolution rate of Ca^{2+} is larger in pH=2 HCl solution, which is four times as large as HCl solution of PH value is 5. Actually with the extension of corrosion time, the dissolution reaction enable hydrogen ion concentration decreases.

5 Conclusion

(1) In pH=2 HCl solution, within 0~30 days, the sandstone mass loss is larger, voids increased significantly, and the change rate of P-wave velocity is larger. Within 30~60 days, the sandstone mass loss rate decrease, and voids increased slowly, along with wave velocity increases slowly, chemical reactions have stagnant. After 60 days, the amount of mass loss increased, but the change of wave velocity tends to be gentle. The chemical reaction and the increase of P-wave velocity are slow in pH=5 HCl solution.

(2) In pH=2 HCl solution, the chemical reaction was faster in 0~10 days. The dissolution rate of Ca^{2+} reaches to the maximum on tenth day of 489.50 mol/d and 104.88 mol/d in pH=2 and pH=5 HCl solution, respectively.

(3) In 0~30 days and 30~60 days, chemical reaction is more intense in pH=2 HCl solution. The penetration path is lengthened, and dissolved cement obstructs acidic solution to sample deeper penetration, chemical reaction appears delay phenomenon in 60 ~ 90 days. The hydrogen ion concentration is low in pH=5 HCl solution, and the chemical reaction is slow.

References

- [1] Deng HF, Yuan XF, Li JL. Experimental research on influence of saturation degree on sandstone longitudinal wave velocity and strength [J]. Journal of rock mechanics and Engineering, 2013, 32(8): 1625-1631.
- [2] Zhou WG, Xie HS, Zhao ZD, et al. Compressional wave velocity and phase transformation for a trachybasalt at 2.0GPa and up to 1623K [J]. Progress in Natural Science, 1999, 9(4): 279-285.
- [3] Yue LX, Xie HS, Liu CQ, et al. Compressional velocity and attenuation in amphibolite at 2.0GPa and up to 1200 °C[J]. Chinese Journal of High Pressure Physics, 2002, 16: 176-182.
- [4] Jiang X, Zhou WG, Liu CQ, et al. Compressional wave velocity for hornblende plagiogneiss at 1.0GPa and up to 1200 °C: measured and calculated results [J]. Acta Petrologica Sinica, 2008, 24(10): 2441-2446.

- [5] Zhou JY, Li X, Peng B, et al. Impacts of the simulated acid rain on bedrock of the leshan great Buddha and its counter measure of prevention [J]. Journal of Geological Hazards and Environment Preservation, 2005, 16(1): 79-84.
- [6] Cui ZA. Experimental study on dissolution kinetics of carbonate under buried conditions [J]. Journal of Oil and Gas Technology, 2007, 29(3): 204-207.
- [7] Lan JK. The modeling calculation of the erosion process in the acid rain-CaCO₃-CO₂ system [J]. Journal of Guilin University of Technology, 1997, 17(4): 372-376.