Chemical Reaction Effects on the Tensile Strength of Lignite by Hydrogen Peroxide

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1. Introduction

Lignite seams of the Tempoku coalfield in Hokkaido, Japan, are being considered to produce biomethane by subsurface cultivation and gasification method (SCG, Aramaki et al., 2015). Formation of low-molecular-weight-organic-acids (LMWOC) by induced oxidation using hydrogen peroxide (H_2O_2) is the first stage of this method. Subsequent stages include methanogen cultivation to produce biomethane, using the LMWOC as a substrate, and the last stage corresponds to gas recovery. This study focuses on the influence of the formation of LMWOC via chemical reactions on the tensile strength of the lignite, from an engineering perspective.

2. Experiment

Lignite blocks were collected from a streamside outcrop at Horonobe, Hokkaido, Japan. Firstly, 30 mm diameter core specimens were prepared. Next, the core ends were cut and polished, having the thickness between 11-30 mm. The specimens were immersed into a 1 wt.% solution of H_2O_2 or H_2O that had a liquid-to-solid ratio of 5:1 (Fig. 1). The specimens were kept immersed under atmospheric pressure and the temperature at 25±1°C for 26 days when the H_2O_2 concentration became zero. P-wave velocity and density of core specimens were measured before and after the immersion. A series of Brazilian tests was carried out on the P-wave velocity measured specimens of both chemically reacted (H_2O_2-immersed) and unreacted (H_2O-immersed) specimens.

The average P-wave velocity and average density decreased by 3.82±1.85% and by 1.16±0.55%, respectively by the reaction (Fig. 2). The decreases were associated with microcracking caused by swelling and grain boundary change due to leaching forming LMWOC (Alam et al., 2016).

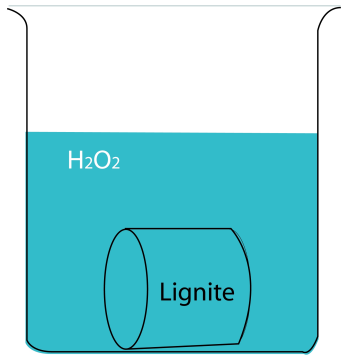

Fig. 1 Disc specimen immersion into H_2O_2 solution.

3. Tensile strength

A series of Brazilian tests was carried out by MTS 815 loading frame at a displacement rate of 0.036 mm/min. The load was applied perpendicular to face cleat, and the main fracture formed in that direction (Fig. 3).

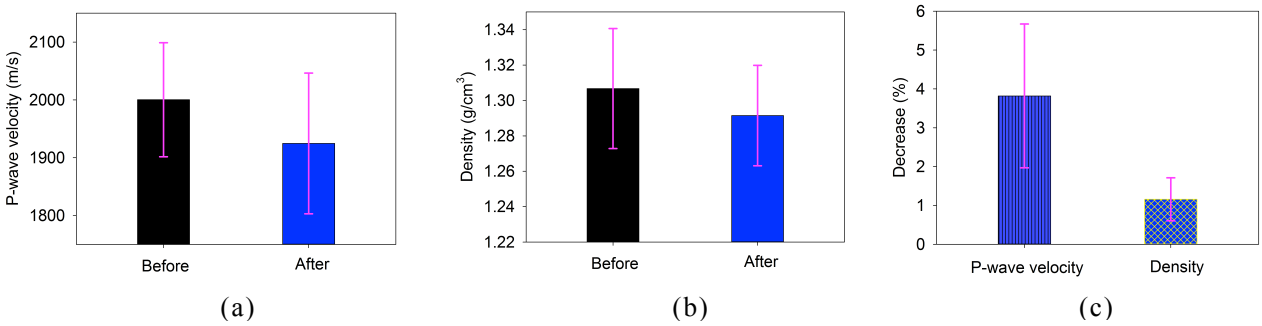

Fig. 2 Changes in P-wave velocity and density due to oxidation. (a) Average P-wave velocity; (b) average density; and, (c) decrease in P-wave velocity and density.

The tensile strength showed a positive correlation with P-wave velocity (Fig. 4), which can be expressed as follows.

$$\sigma_T = 1.51(V_p - 1.14) \quad (1)$$

where σ_T is the tensile strength in MPa and V_p is the P-wave velocity in km/s.

The slight decrease in P-wave velocity (Fig. 2a) should have induced the slight decease in tensile strength because the average P-wave velocity decreased with decrease in density of the lignite caused by the chemical reaction. However, it was in the range of the data scattering.

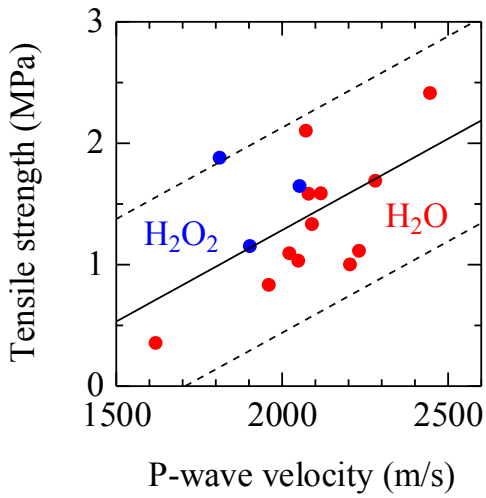

Fig. 4 P-wave velocity and tensile strength. Broken lines represent 95% confidence intervals.

4. Concluding remarks

P-wave velocity slightly decreased producing LMWOC, which is the substrate for methanogen cultivation to produce biomethane by the SCG method. The influence of the chemical reaction of lignite with H_2O_2 at a liquid-to-solid ratio of 5:1 for 26 days under the atmospheric pressure and a temperature of 25±1°C on tensile strength was small despite the formation of LMWOC. Damage of the lignite by H_2O_2 at the condition can be ignored in designing SCG reactors.

References

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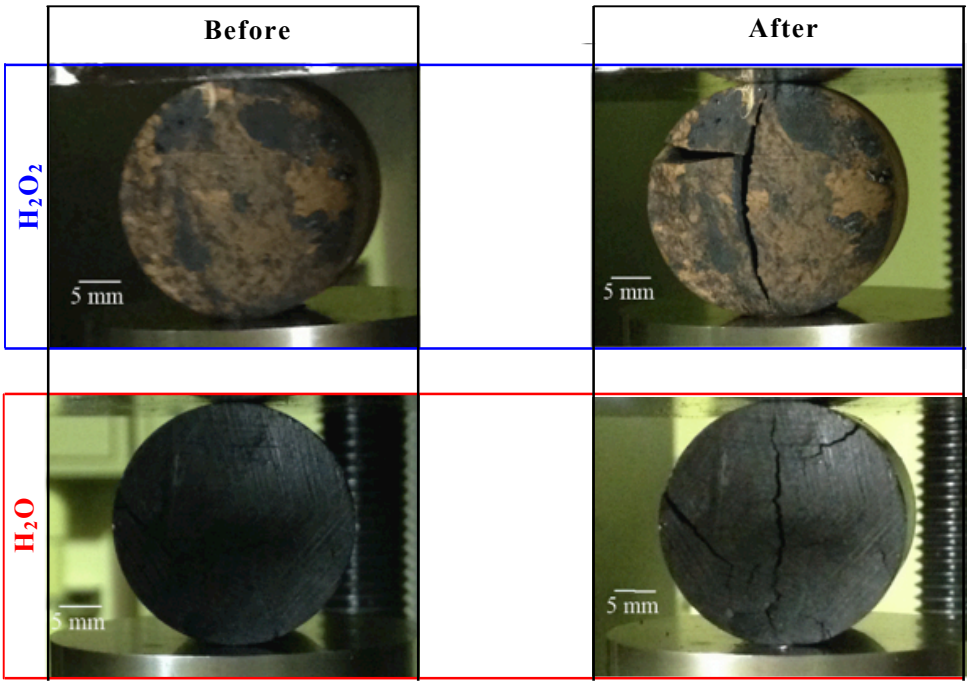

Fig. 3 Specimens before and after the Brazilian tests.