Electrohydraulic Discharge (EHD) Stimulation in Water Conditions and Its Application for Coal Fracturing

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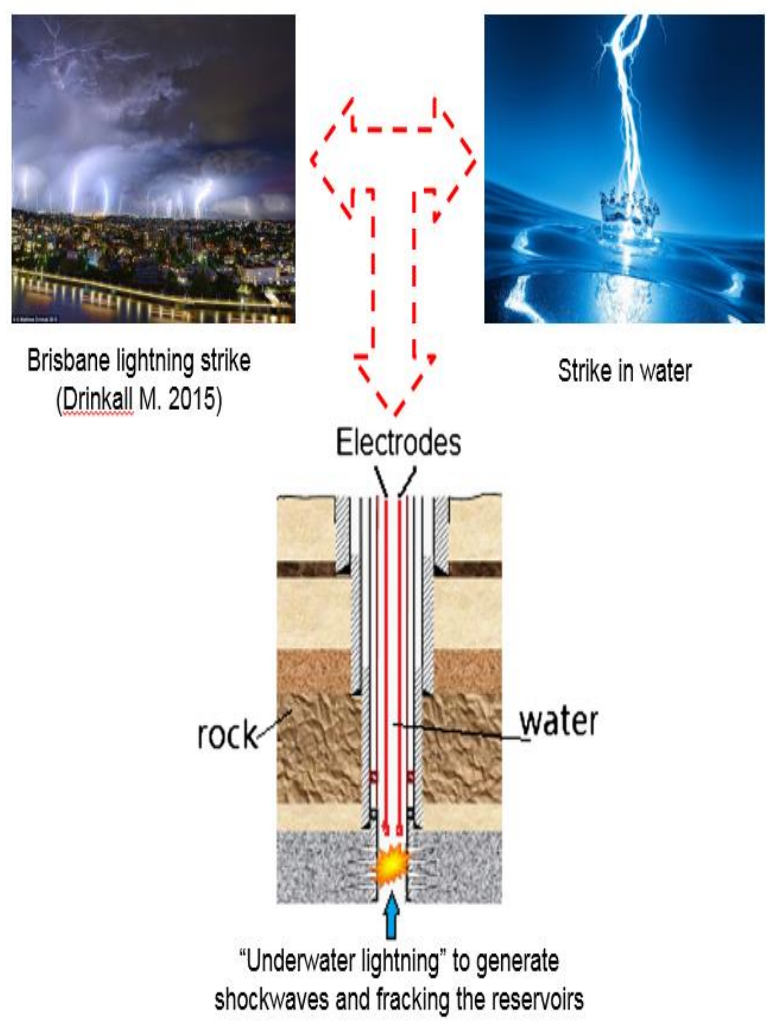
RESEARCH BACKGROUND

High-voltage electrohydraulic discharge (EHD), a technique that deposits the electrical energy in fluids via two pin-to-pin electrodes for a short period of time (nanoseconds to microseconds) and generates dynamic shocks, is considered a potential stimulation method to enhance coal permeability and facilitate coal seam gas (CSG) development.

Compared to classical stimulation methodologies like hydraulic fracturing or acidizing, EHD is more environmental-friendly as there are no any outside chemical additives imported into the testing system during the operation process. Moreover, the dynamic force-loading generated by EHD tends to create more distributed microcracks rather than a few localized major cracks, which may be more effective for enhanced CSG production (Mao et al., 2012).



RESEARCH AIMS

- Investigate EHD circuit settings and the corresponding effects on the shock pressure amplitude
- Develop and apply the generated dynamic shocks in water conditions for coal core stimulation
- Evaluate the coal spatial structure evolution and void/fracture extension before and after EHD stimulation using micro-computed tomography (μ-CT)
- Characterise the EHD impacts on coal features at micro-scales

METHODOLOGY

A high-voltage EHD electrical circuit with a PVC reaction chamber was established and arranged for testing two scenarios:

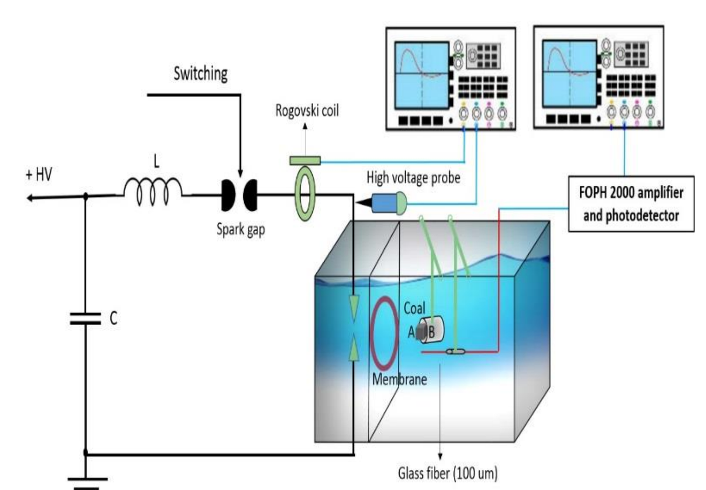


Fig. 1 Schematic of shockwave strength measurement and coal stimulation setup from side view

Fig. 2 Sub-bituminous coal cubes from Surat Basin (Dimension of 15 mm)

1. A fibre optic probe hydrophone FOPH 2000 was set for shockwave shockwave pressure strength measurement, at different distances (180-205 mm) for different charge voltages (22-30 kV) (Fig. 1) .
2. Sub-bituminous coal cubes (Fig. 2) were prepared and set up in the system to evaluate the shockwave impact on coal and validate its stimulation effect by means of coal property improvement (Mercury Intrusion Porosimetry) and fracture/crack evolvement (CT & SEM).

RESULTS

Results for scenario 1:

- Figs. 3 & 4 show that the breakdown voltage U_b is not strictly subjected to the charging voltage U_c;
- In general, the peak pressure of shockwave is proportional to U_b, the larger the U_b, the higher the peak pressure of shocks.

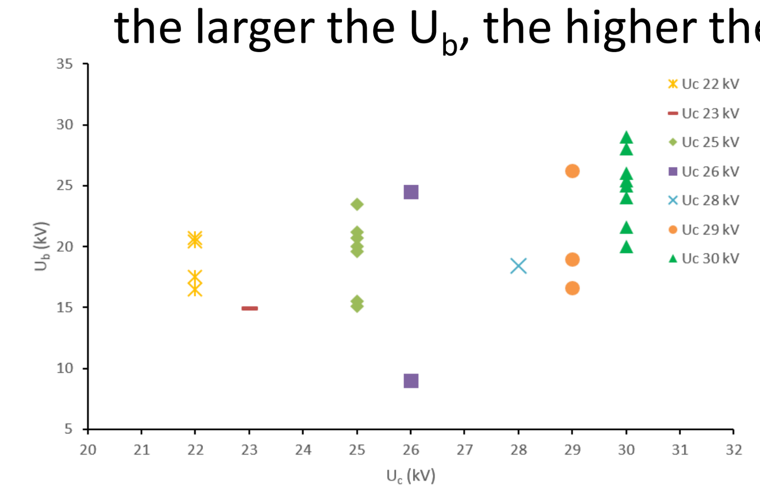


Fig. 3 Correlation between breakdown voltage U_b and charging voltage U_c

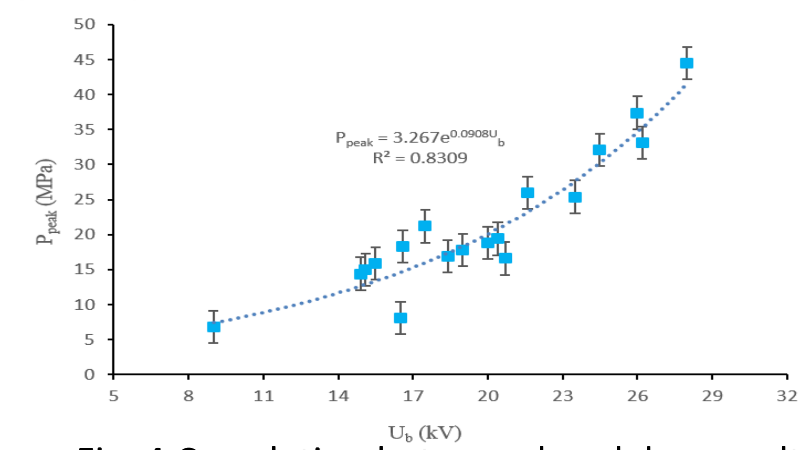


Fig. 4 Correlation between breakdown voltage U_b and peak pressure at the distance of 200 mm

- Figs. 5 & 6 indicate that, at different distances from the electrodes, the closer the distance to the electrodes, the faster the growth of peak pressure will be.

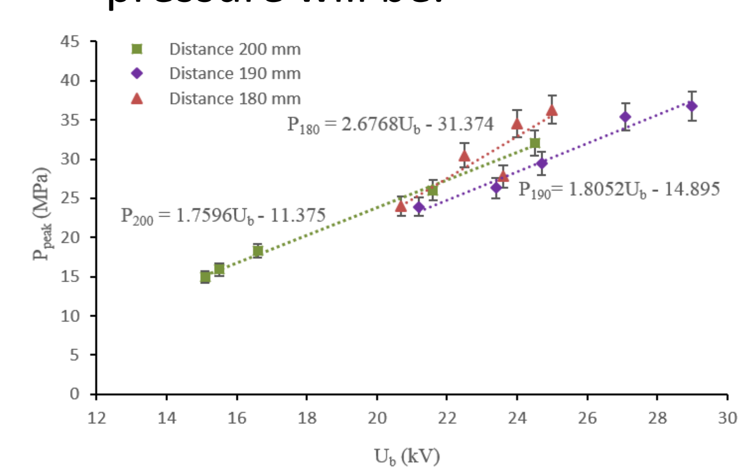


Fig. 5 Peak pressure increase ratio with breakdown voltage at the distance of 200mm, 190mm and 180mm

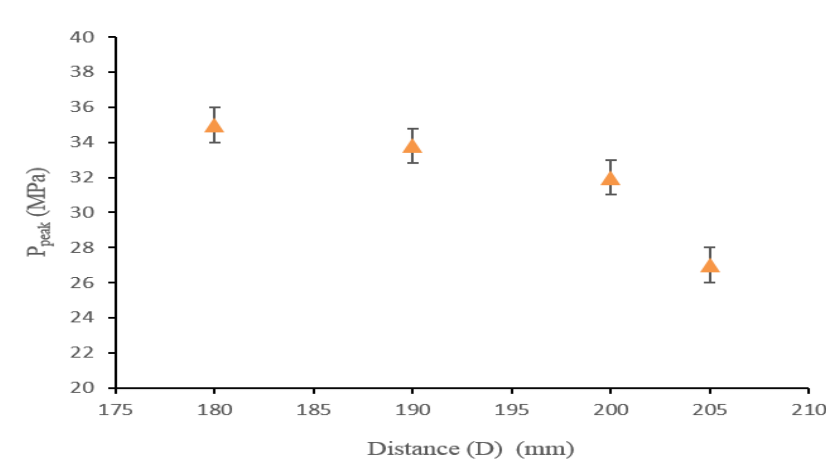
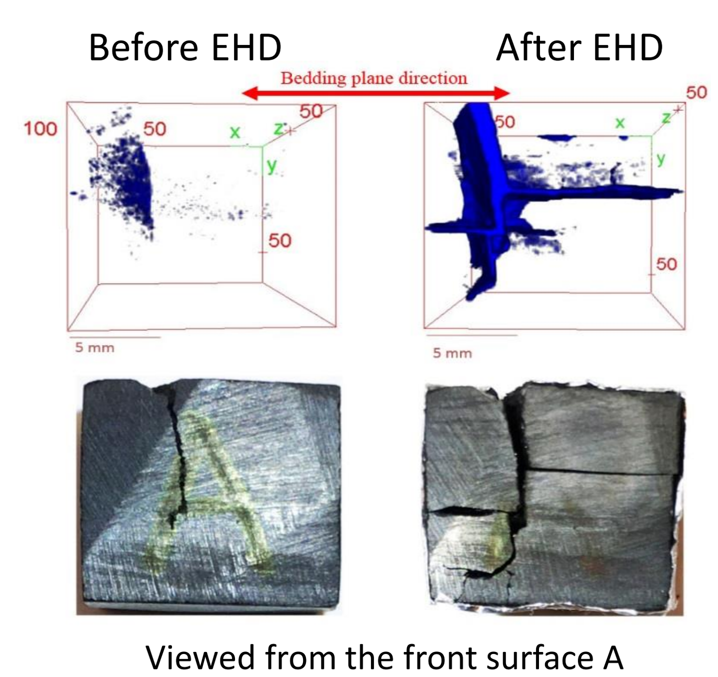


Fig. 6 Peak shock pressure measured at different distances with a breakdown voltage of 25 kV

Results for scenario 2:

- After EHD, the newly induced fractures tend to form along the pre-existing fracture and/or parallel to the bedding plane direction (Fig. 7).



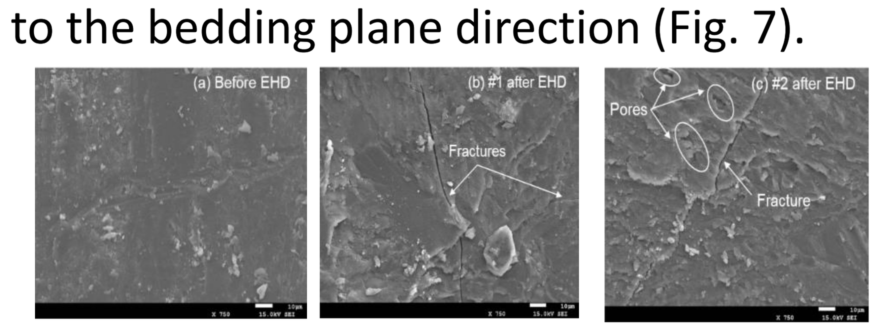


Fig. 8 Microscopic features of New Acland coal before and after EHD

- Not only are the newly induced cracks and pore identified by SEM (Fig. 8) at the exterior coal surface, but also revealing the capacity of EHD to create more multi-scale pores in the interior coal (Fig.9).

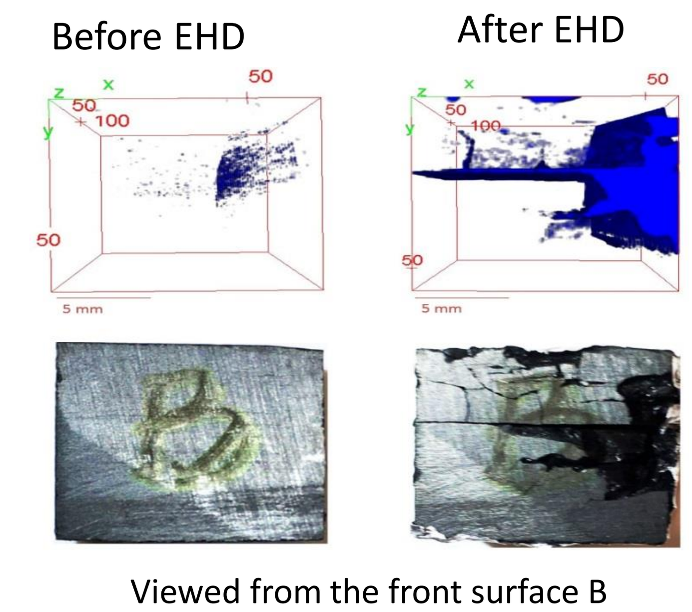


Fig. 7 Fracture and void map and corresponding surface image of the coal #1 before (left) and after (right) EHD stimulation

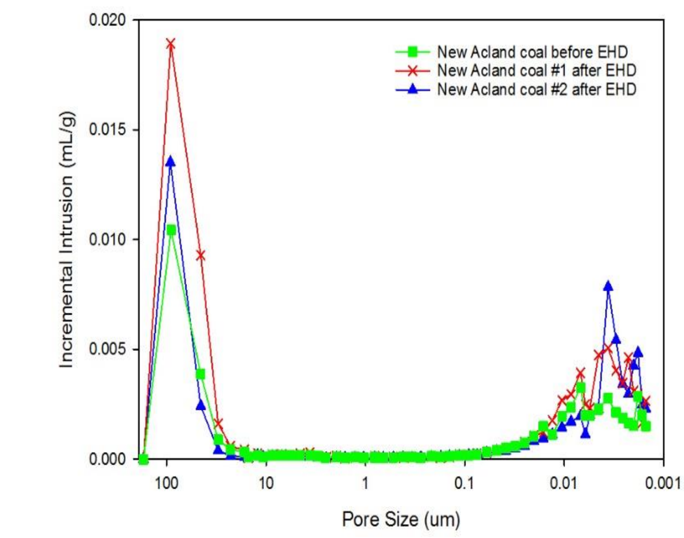


Fig. 9 Comparison of pore size distribution of New Acland coal before and after EHD

DISCUSSION & CONCLUSIONS

❖ **Optimization of shockwave generation** (Fig.10)

- In order to facilitate shock generation, the time delay T_b before water breakdown should be shortened;
- Enhancement of peak pressure is closely associated with reduction in the time T_b and increasing U_b.

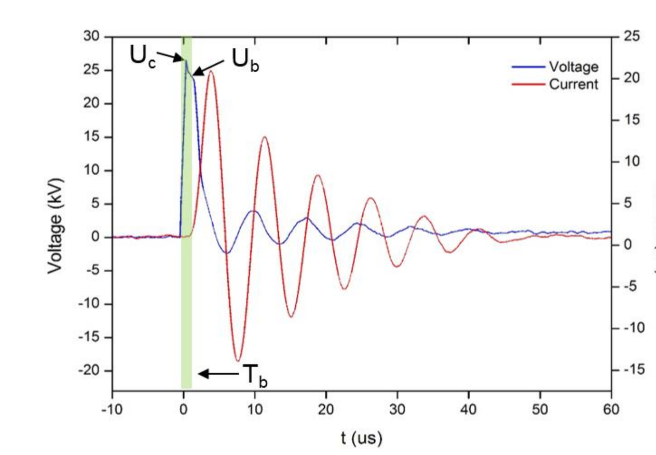


Fig. 10 Typical waveforms of output voltage and current during shockwave generation

❖ **Shock impact on coal fracturing** (Fig.11)

- The 3D computed-tomography analyses of coal cores demonstrate an enormous amount of cracks and voids were induced in the coal after being exposed to the EHD shocks at micro- and macroscales.

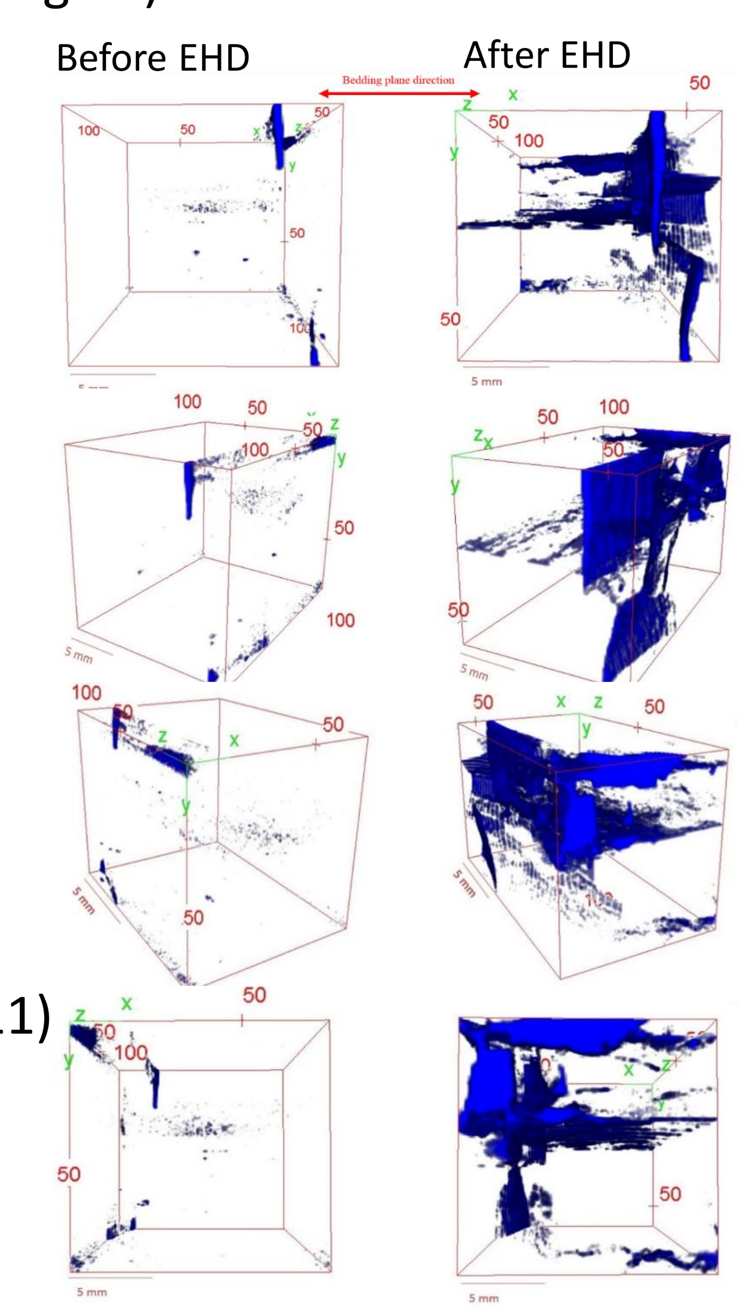


Fig. 11 3D pore network maps of coal #2 at different angles before (left) and after (right) EHD stimulation

- ✓ Breakdown voltage U_b is more closely associated to shock strength rather than the initial charge voltage U_c;
- ✓ The CT maps of coal cores demonstrate an enormous amount of cracks and voids were induced in the coal after being exposed to the EHD shock;
- ✓ Meanwhile, the SEM and MIP analyses further reveal the coal responses at both the exterior microscale and interior microscale of the coal samples, showing the capability of EHD stimulation to produce new pores and flow channels in the coal.

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