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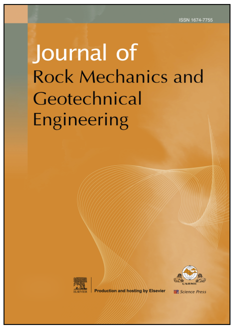


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# Insights into the radial water jet drilling technology - Application in a quarry

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**Abstract:** In this context, we applied the radial water jet drilling technology to drill five horizontal holes into a quarry wall of the Gildehaus quarry close to Bad Bentheim, Germany. For testing the state-of-the-art jetting technology, a jetting experiment was performed to investigate the influence of geological heterogeneity on the jetting performance and the hole geometry, the influence of nozzle geometry and jetting pressure on the rate of penetration, and the possibility of localizing the jetting nozzle utilizing acoustic activity. It is observed that the jetted holes can intersect fractures under varying angles, and the jetted holes do not follow a straight path when jetting at ambient surface condition. Cuttings from the jetting process retrieved from the holes can be used to estimate the reservoir rock permeability. Within the quarry, we did not observe a change in the rate of penetration due to jetting pressure variations. Acoustic monitoring was partially successful in estimating the nozzle location. Although the experiments were performed at ambient surface conditions, the results can give recommendations for a downhole application in deep wells.

**Keywords:** acoustic monitoring; drilling performance; trajectory; permeability; rock properties; radial water jet drilling (RJD)

## 1. Introduction

Applying high pressure water jets to penetrate rocks is extensively studied since the middle of the 20th century (e.g. Farmer and Attewell, 1965). Applications range from cutting/carving applications (e.g. Harris and Mellor, 1974; Summers and McGroarty, 1982; Hagan, 1992) to downhole drilling (e.g. Maurer et al., 1973; Deily, 1977; Pols, 1977a,b). In recent years, the application of the radial water jet drilling (RJD) technology is increasingly investigated to perforate and stimulate low performing wells (e.g. Buset et al., 2001; Bruni et al., 2007; Cirigliano and Talavera Blacutt, 2007; Seywald and Marschall, 2009; Abdel-Ghany et al., 2011; Elliott, 2011; Cinelli and Kamel, 2013). For the RJD technology, a bottom hole assembly, generally referred to as ‘deflector shoe’, is connected to a tubing and lowered to the target depth. For cased hole intervals, a coiled tubing conveyed milling assembly is lowered through the tubing. At the bottom, the deflector shoe deflects the milling bit towards the casing. After milling a hole into the casing, a jetting assembly is lowered through the tubing. The coiled tubing conveyed jetting assembly consists of a self-propelled jetting nozzle attached to a flexible hose. This assembly is capable of jetting up to 100 m into the formation.

Recently, the RJD technology has gained considerable interest for stimulating low performing geothermal wells, motivating numerical investigations to estimate the benefit from applying this technology (e.g. Peters et al., 2015). For enhanced or engineered geothermal systems, it is considered as a viable alternative to conventional hydraulic stimulation technologies and has triggered several research projects (e.g. Reinsch and Bruhn, 2016). As one of the first application in a geothermal environment in Europe, RJD stimulation was performed in a low performing injection well in Klaipeda, Lithuania. RJD was applied to jetting 12 laterals with a length up to 40 m each, leading to an increase of injectivity of about 14% although a maximum increase of 57% was suggested by numerical modelling (Nair et al., 2017). Analysing the sensitivity to different model parameters like lateral direction and length, which influences the predicted increase by up to 10% for individual parameters, underlines the importance of proper monitoring equipment to measure the laterals’ geometry (Nair et al., 2017).

While rock penetration experiments can be performed in the laboratory with good access to the process parameters as well as the jetted holes afterwards, RJD operations are performed downhole with limited access to process parameters and no option to investigate the jetted holes (for a review on different laboratory and field experiments, please see Blöcher et al., 2016). In order to bridge this gap, we performed a jetting experiment in a quarry with the state-of-the-art RJD technology. Monitoring and influencing process parameters like fluid pressure and flow rate could easily be implemented. In addition, the jetted holes were accessible afterwards for geometry measurements and could be surveyed visually. Although jetting individual holes at ambient surface conditions is not comparable to downhole applications with regard to the reservoir pressure and temperature conditions as well as saturation and stress conditions within the rock, various aspects of the technology can be investigated:

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