Available online at www.sciencedirect.com

ScienceDirect

Physics Procedia 83 (2016) 336 – 343

Physics Procedia

9th International Conference on Photonic Technologies - LANE 2016

Advanced rock drilling technologies using high laser power

Frederik Buckstegge[a,*], Theresa Michel[b], Maik Zimmermann[a,c], Stephan Roth[a,c], Michael Schmidt[a,b,c]

[a]*Bayerisches Laserzentrum GmbH (blz), Konrad-Zuse-Straße 2-6, 91502 Erlangen, Germany*
[b]*Institute of Photonic Technologies (LPT), Friedrich-Alexander-Universität Erlangen-Nürnberg, Konrad-Zuse-Straße 3-5, 91052 Erlangen, Germany*
[c]*Erlangen Graduate School in Advanced Optical Technologies (SAOT), Paul Gordan Straße 6, 91052 Erlangen, Germany*

Abstract

Drilling through hard rock formations causes high mechanical wear and most often environmental disturbance. For the realization of an Advanced Adiabatic Compressed Air Energy Storage (AA-CAES) power plant a new and efficient method for tunneling utilising laser technology to support mechanical ablation of rock formations will be developed. Laser irradiation of inhomogeneous rock surfaces causes irregular thermal expansion leading to the formation of cracks and splintering as well as melting and slag-formation. This study focuses on the interaction of laser irradiation with calcite, porphyrite and siderite rock formations. A high power disc laser system at 1030 nm wavelength is used to investigate the specific energy necessary to remove a unit volume depending on interaction times and applied power. Specific energies have been measured and an increase of fragility and brittleness of the rock surface has been observed.

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH

Keywords: rock drilling; ablation; tunneling

1. Introduction

The RICAS2020 Design Study for the European Underground Research Infrastructure related to Advanced Adiabatic Compressed Air Energy Storage (AA-CAES) is an EU research project consortium to formulate a design study for an AA-CAES. This storage power station can be build almost anywhere, thus providing energy storage

* Corresponding author. Tel.: +49-9131-85-23268 ; fax: +49-9131-97790-11 .
E-mail address: f.buckstegge@blz.org

Peer-review under responsibility of the Bayerisches Laserzentrum GmbH
doi:10.1016/j.phpro.2016.08.035

capabilities in an infrastructure of regenerative energy that is, unlike pumped storage hydro power, independent of the local geography. One part of this design study is the development of an advanced tunneling technology that allows for the fast excavation of large caverns in hard rock with minimal strain on surrounding rock. This will be achieved with a combination of classic mechanical ablation and pre-damaging the rock by laser irradiation. Interactions of lasers and rocks have been studied since the late 1960s starting with the availability of reasonably high powered CO_2 lasers (Moavenzadeh et al. (1967), Farra (1969)), but still suffered from the relative youth of laser technology. More recently, experiments by Parker et al. (2004), Gahan et al. (2006) and Xu et al. (2003, 2004) focused on laser drilling of limestones, sandstones and shale using high power CO_2 and fiber lasers. The following paper will describe preliminary experiments on laser ablation of limestones and siderites from the Erzberg region in Austria as well as Carrara and Jura marble to help understand the influence of laser irradiation on these materials. The aim of these experiments was to measure the specific energies of rock ablation to estimate the laser power necessary for a tunneling machine based on laser ablation, and to study the effects of laser irradiation on surface brittleness and strength for a concept of a tunneling machine combining laser technology and mechanical ablation.

Nomenclature

SE Specific Energy in J/mm³, SE = P/dV/dt
P Laser power in Watts
ROV Rate of Volume Removal in mm³/s, ROV = P/SE

2. Experimental setup

2.1. Samples

The samples studied were three samples of rocks commonly occurring on the Erzberg in Austria and two types of commonly used marble, Carrara and Jura. The Erzberg samples consisted of two roughly similar limestone rocks and a siderite sample. Sample A is a light-coloured limestone of average crystallization and purple discolourations with an average density of 3.14 g/cm³. Sample B is a siderite material composed of large crystallites packed together and is of a dark, reddish colour. Crystals are visible on the surface and the sample has an average density of 4 g/cm³. Sample C is similar to sample A in that it is a white limestone of similar average density, but with greenish discolourations. The samples were cut into 3 cm thick slabs in the preparation workshop of the Geozentrum Erlangen using a circular saw. In addition to these samples, several 2 cm thick slabs of Carrara and Jura marble were procured to provide a comparison with limestones of low crystalisation and comparatively high homogeneity as well as clean and flat sample surfaces for using a moving laser spot. The average densities of the rock samples used in the experiments is shown in table 1. Photographs of the samples are shown in figure 1.

Table 1. Densities of rock samples.

Sample	Material	Average density [g/cm³]
A	Limestone	3.14
B	Siderite	3.73
C	Limestone	3.09
M	Carrara marble	2.66
N	Jura marble	2.51