Electrical design of and reticulation to solar energy triggered microwave single mode system for sandstone processing: a feasibility study

A F Mulaba-Bafubiandi, M Marwala and B Paul
Mineral Processing and Technology Research Centre, Department of Metallurgy, School of Mining, Metallurgy and Chemical Engineering, Faculty of Engineering and The Built Environment, University of Johannesburg, P.O box 17011 Doornfontein 2028 South Africa

Email: amulaba@uj.ac.za

Abstract. Sandstone, a weathered sedimentary aggregated rock, has been found in abundance in the Drakensberg mountain chains. The construction boom of 2009-2010 prompted by the soccer world cup in south Africa led to an increased market share in the free state province in often family own small businesses, chisel and hammers are such intensive activity. Microwaves have been found to be able to ensure rock breaking especially along the grain boundaries of dissimilar minerals. The presence of a high solar intensity on the mountains of the free state province in QwaQwa and the possibility of designing and constructing a portable microwave cutter to effect the drilling and cutting of sandstones have been motivating factors. This paper elaborates on the feasibility of electrical design of and reticulation to solar energy triggered microwave single mode system for sandstone cutting. The design and construction of microwave single mode cavity to use is discussed while; the required health and safety related aspects are presented. The paper shows also possible applications of the cut sandstones.

1. Background

As depicted in the figure 1, sandstones are currently mined in Qwaqwa in artisanal way; hammer, chisels and pikes are often used.

Figure 1. Sand stones are artisanal mining of sandstone is made with hammer, chisels and square

Figure 2. Tools used during the artisanal mining of sandstones.

The availability of a huge solar irradiation especially in summer in the Free State Province of South Africa and the presence of mountainous sandstone reserves in the Drakensberg chain mountains lead to the combined usage of these two resources. It has always been a challenge to the people of QwaQwa who makes a living by artisanal mining of sandstone for different purposes, e.g. paving, building, and some use it to crafting different product. A socio-economic feasibility study [1] showed that business

around sandstone mining and trading in QwaQwa grew to the extent of exporting the commodity outside the country. Sporadic demand of a mass produced product is not often met with the use rudimentary tools (chisels and hammer). There in then a need to introduce cheaper new technology in the artisanl and small scale mining of the sandstone. The use of the availability of the natural renewable solar energy, combined with the particularity of the microwave selectively using minerals hence generating cracks in dissimilar mineral assemblages was attempted. A technological feasibility study on the use of microwaves in the mining of sandstones in Qwaqwa is a preamble to the design of a microwave "gun". In this project a microwave gun with a single mode cavity will be designed and constructed for the cutting of sandstone from the rock bed. The gun will be solar powered .

2. Sandstone application

2.1 Construction applications

The beauty of sandstones attracts people from a distance as sandstones are also used to make bricks. The figure 3 shows bricks that were made out of sandstones [11]

Figure 3. Sandstone used for construction. As bricks for housing in rural as well as in urban areas[18]

Figure 4. Sandstone used for the decoration of buildings.

2.2 Decoration

Sandstones are also used to make concrete fence and for paving, due to the fact that sandstone come in different colours the combination of those colours when they are tiled on the floor is attractive and artistic. This decoration aspect creates a market share for the sandstones.

3. Physical properties of sandstone

Sandstone also known as arenite is a sedimentary rock which contains different types of minerals such as quartz and many others. In geoformation bed, sandstone is cemented and bound by calcite, clays, and silica to make it a solid rock. it comes in different colours like brown, white cream white blackish, etc.

The use of this sand stone is for construction of fence, paving tiling etc.[6]. When rocks are broken into small pieces and are cemented together a sedimentary rock is formed. Sandstone is also formed when a grains of rock fragments and individual minerals broken down from other, older rocks. Sandstones can be formed on the land or even under water. This is mainly caused by or depend on the presence of oxygen in forming environment.



Figure 5. Artefacts design using sand stone

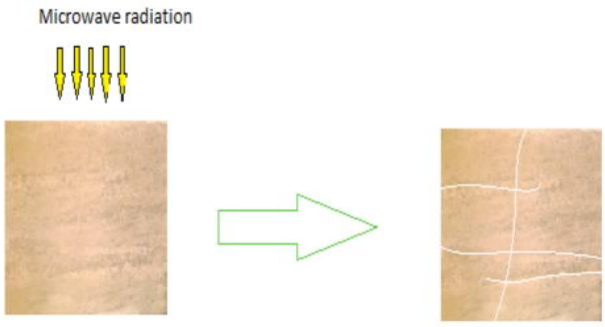
4. Ore breaking using microwaves

Most of the electrical applications of microwaves are in telecommunication. Only recently that microwaves have been suggested to be used in ore breaking. The difference in dielectric properties of different minerals, table 1, in an ore makes it easier to break the ore at inert and possibly also intra granular joints.

Table 1. Dielectric properties of minerals. Different minerals would heat differently when exposed to microwave irradiation, hence the differential dilation would create cracks in a dissimilar mineral ore

Minerals	Dielectric property
Anthracite	Over 33.7 under 81
Arsenopyrite	Over 81
Bauxite	10.85
Biotite	9.28
Calcite	6.36
Chalcopyrite	Over 81

As in indigenous knowledge, when rocks exposed to a very hot fire and then subsequently quenched in colt water break due to the sudden temperature change, microwave irradiation of an ore composed of dissimilar minerals would results in the ore cracking along the grain boundary m figure 6. can also be used for rock breaking [2]. Sandstone, made of different minerals which respond to temperature change differently when they are heated, will experience a temperature difference causing the stone to crack [3].



(a) (b)

Figure 6. Microwave ore breaking. Dissimilar mineral would differently hat creating cracks in the geological structure ore. Microwave irradiating a sample of sandstone (a). Flaws and cracks showing after microwave irradiation (b)

5. Uses of solar for electricity generation

The sun produces a large quantity of energy to be converted into the utilisable energy. The earth receives about $1.2x10^{17}$W **o**f solar power [4]. Energy produced by the sun cannot be used in its actual state, it needs to be converted into electricity. Solar energy is stored in one component called solar cell. Solar cells are made of silicon, they are also made up of other material which makes a combination of electrons in one part of the cell and another electron will be missing in the other part of the cell. When the sun shines on the cell, electrons move from the silicon by photons in the lights. In most cases an inverter is used to convert DC power produced by solar into AC. Solar power can also be generated using Photo voltaic cells which generate electricity from visible light by means of photovoltaic effect [4]. When the photovoltaic cells convert the incident energy of light it creates mobile charged particles in the semiconductor which are then separated by the device structure and produce electrical current.

when number of cells are connected together they generate more power and there are called a panel. Photovoltaic solar panels are dependent on weather, on a sunny day more power will be generated but on a cold day the photovoltaic cell won't be able to generate power since they don't use batteries like solar cells.

6. Health and safety aspects when using microwave devices

Microwave requires an input voltage of 220V and has an input power of about 1150W, this simply indicated that like any other electrical appliances a microwave must be handled with care. The magnetron which is the core of the microwave requires a high amount of power so anyone who can try to touch it might be seriously injured or die. When maintenance is done on a microwave device it should be done by a qualified person who will be able to know that he is supposed to switch it off before maintenance can commerce. Inside a microwave there are components like HV capacitor which stores electric power so a certain amount of power might still be available on the device even after switching off. [5]

Microwave must be used in an in a water free environment because if a certain amount of water can spill into components of microwave the microwave will explode when it is switched on. The connection pot or the plug where he microwave is going to be connected must be well earthed, this prevent the body of the user from becoming a conductor when a fault current start to flow through the micro wave. In every house today there is a microwave, but most people don't really understand the dangers or side effect of using a microwave. Human eyes have no cooling blood and when they are exposed to too much heat it might be seriously injured so, it is important that when a person is using a microwave oven, he/ she must avoid direct contact with microwave radiation, radiation also have some negative impact on the other part of the body. [3]. There is a certain amount of thorium and tungsten in the filament of a magnetron. Chances of getting cancer are very slim, but then if the filament is taken

out and crushed and inhaled it will cause health hazards [5] Standing next to a stove cooking is a thing of the past, most people prefer using a microwave because it is fast and very convenient, but it must still be treated with care. If the microwave is old it must just be replaced by a new one because, the rubber that prevent radiation from coming out of the microwave starts to worn out and cause the Microwave to start working very slow and the radiation wave can even burn your eyes. Everything that has a potential of going wrong can go wrong.

8. Suggested design

The solar panel supply the equipment with 220V, electromagnetic radiation is produced in the magnetron, the magnetron require 2KV this simply means the voltage that is supplied must be step up to a required level. A 220/1000V transformer will be used to step up the voltage; a voltage doubler circuit will also be connected on the device to step the voltage up from 1KV to 2KV. When a magnetron has been supplied with right voltage it produces an output frequency of 2.45Ghz 1.5 KW. The cavity of the equipment is a single mode to increase the intensity of the microwaves. Figure 6 shows the suggested cavity design for a single mode set up.

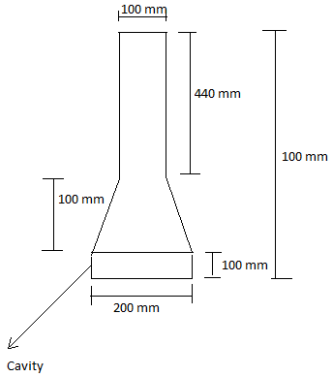


Figure 6. The suggested cavity design. A single mode cavity with a horn end would be used but the security of the worker would be of a concern. This design requires improvement.

9. Cost of design and equipment construction

The cost of the design and construction of the equipment include components, housing, miscellaneous, design of the single mode cavity, capex, training and infrastructure. Market value and inflation are taken into consideration.

10. Materials and testing equipment

Equipment and components that will be used to build the sandstone microwave cutter will compose of materials for the cavity (stainless steel), transformer, magnetron, capacitor, diodes, temperature probe, solar panel and battery (at least 1,5kw), inverter (if the battery is too small), microwave light, metal sheet, 4m extension cord. Equipment that will be used to test the results will include, digital multi meter and microwave leakage detector

11. Conclusion

A design of the microwave powered solar energy was discussed in terms of the single mode cavity and required materials. Health and safety implications are elaborated on while the materials selection and the construction of the cavity are discussed.

Reference

[1] Tshabalala Isaac, 2008 strategies for stimulating socio-economic growth from small scale mining operations in Qwaqwa (South Africa), MBA dissertation, Universuty of Kwazulu Natal, 2008, p222

[2] Mulaba, AF, & ML Lewis , ‘effect of microwave energy treatment on value liberation from Zn and C_O-C_U ores page 8-9
[3] Ferri Hassani and Pejman Nekoovaght ‘ The development of Microwave assisted Machineries to break hard rocks’, vol S20-6, page 679
[4] Tomas Mark art, solar electricity, ENESCO ENERGY ENGINEERING SERIES, pg 1
[5] http://www.engineerguy.com/elements/videos/video-microwave.htm