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A REVIEW ON STUDY OF DESICCATION CRACK FORMATION

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Abstract
This is a short review on the formation of crack patterns focusing on two artificial clay-systems:Bentonite and Laponite and also some biological fluids under various physical conditions. For last few decades the study of crack patterns attracted researchers of various fields for its diverse applications in a typical fields, like geophysical systems, biophysics and so on. Practically, the study of desiccation cracks can be useful either to prevent crack formation or to make use of them. We have also tried to focus on physical conditions of formation of cracks, such as layer thickness, temperature, drying rate, the property of the substrate, solvent property etc.

Keywords: Bentonite, Desiccation cracks, Laponite, layer thickness, electric field.

1.0. Introduction :

Formation of cracks on pure metals or plastics or on ductile materials completely different than each other. Crack patterns depends on the material in which it is forming. For example, the water existed on the surface of the Mars was first concluded after observing the desiccation crack pattern on the Mars-surface [1].
From the last two decades lots of experiments have been conducted on crack formation. Various researchers from different fields were interested to observe the electromagnetic effect on crack formation and crack patterns[2, 3]. Many of them were interested to observe crack formation due to mechanical excitations [4, 5]. Apart from the researchers from geophysics, some biophysicists are also excited to observe crack formation on blood drop or blood plaza. It is found the crack patterns on blood plasma are quite different in nature for the anaemia patient or the cancer patient than the normal human being [6].

Desiccation crack forms when a process of extreme drying is imposed on a system of particles. It causes extreme stress and lead to cracking. Since our concern is wet mud surface or wet biological samples, the formation of crack here will not involve interatomic braking or fracture. For brittle materials the fracture is irreversible but for wet granular materials the fracture consists of a reversible component which acts between the adjacent layers of particles. Energy involve here are much lesser(0.1 J/m^2) than the interatomic fracture(1 to 10 J/m^2). For this kind of materials Fracture theory of Griffith is applicable. According to his theory, "the energy required for fracture can come from the strain energy stored around a crack, as a crack will tend to release tension in its vicinity" [7]. Therefore, it is clear that new surface area is created when a material forms cracks. Sometimes inside a material a potential energy is developed due to stress and then there is a formation of crack.

Figure 1: Crack pattern near Kaolin deposit

Applications of Cracks:
There are many applications of cracks. The list is given below:

Coating Industry: [8] Different printing agencies, paint industry, ceramic coating industry etc is interested in crack formation experiments.

Medicine and Forensic: Crack patterns formed in dried droplet of blood can be used to detect illness [9].It can also be used to find out the circumstances and time when blood was spilled example in investigation of murder [10] etc.

Biophysical fracture: Crack patterns are formed on many biological beings like leaves and on the skull of old Mummy. These patterns captured the interest of bio scientists in various times.

Lithography: Controlled crack formation is involved new technology in the field of Lithography [8].

These are the basic examples, there are other many fields where crack formation involved. Due to this vast applications of cracks and newly founded novel crack patterns we got interested to write a short review on the experiments researchers observed during last few decades.

2.0. Crack formation in the clays- Bentonite and Laponite for layer of different thickness:
There are many works on clay system for layer of different thickness. Some previous work related to this in the following:

Tajkera Khatun (Tajkera, 2014) [11] studied the crack patterns formation on desiccation film on two clay system: Laponite and bentonite by varying layer thickness. As suspension of Laponite in methanol and suspension of bentonite in water was taken .It was found that there was a critical thickness, above this critical thickness the deserted cracks come together and join one another. They showed that when crack patterns are observed at greater resolutions with different layer thickness, then the total accumulative area of cracks are observed at definite resolution.

Noor Mohammad (Noor Mohammad, 2020) [12] conducted experiments to determine the effect of both layer thickness and inceptive water level in formation of cracks on bentonite clay. A slurry of bentonite in water was developed and the inceptive water level was between

1200-2200%.They found that there is a notable effect of thickness of layer and water level in crack formation and they can be used to prevent the desiccation cracks.They developed a model depend upon thickness of critical cracking.

Mal et al. (Mal et al.; 2007) [13] studied the cumulative area with minimum crack width, varying the layer thickness of a film of Laponite methanol mixture. All the bends for different layer thickness merge to a one master bend in a log-log plot when the smallest crack width is scaled by the layer of thickness of the film. He experimentally showed that with the increase of layer thickness, the number of cracks decreased and average crack width increased.

Sadhukhan et al. (Sadhukhan et al, 2008) [14] studied the formation of crack pattern on varying the thickness of layer in clay film. They observed in computer simulation study that the number of cracks decreases and average crack width increases with the increase of layer thickness. When the top view of final crack pattern is observed at different resolutions an interesting scaling law is found. At a certain resolutions only crack above a certain minimum crack width are observed. Total area covered by crack above a definite smallest crack width is the cumulative area for that minimum crack width.

Bohn et al. (Bohn et al.; 2005b) and Groisman and Kaplan (Groisman and Kaplan, 1994) [15] observed the characteristic distance between the cracks scales approximately linearly with the layer thickness of the film.

3.0. Electric field induced crack patterns in circular geometry:

There are many previous works on clay systems in the presence of electric field such as: mechanical field, magnetic field, directional drying etc. Some previous work done related to this is as follows:

Ankita Ghosh (Ankita Ghosh, 2018) [16] studied the effect of uniform static electric field between 357 to 928 V/m. in the formation of desiccation crack in a layer Laponite RD gel in water .They found that the cracks formed are tree shaped. Initially at positive end a huge number of cracks approximately 70 appeared. While proceeding towards negative end, several cracks merge with each other. They observed that with increase in field strength, initial number of cracks increases. The disc-like Laponite RD clay particles in aqueous medium behave as negative charged .The bare Laponite disc repel each other to create the crack at positive end.

Fraden et al. (Fraden et al.; 1989) [17] studied experimentally the behaviour of colloidal particles when exposed to electric field. They observed the final fluid velocity depends directly to the square of applied electric field. They also reported that the fluid velocity has an inverse relation with frequency.

Sujata Tarafdar (Sujata Tarafdar, 2018) [18] studied the behaviour of desiccation cracks when exposed to direct and alternating current. A voltage of 120V DC is applied to Laponite gel. It was found that the formation of crack pattern and nature of crack depends on the direction of the field and on field strength. Under external alternating field cracks have tendency to curve around. They observed AC field the crack pattern show a special curving

right angled to the direction of applied field which is different from normal crack formation when exposed to DC field.

Tajkera Khatun et al (Tajkera Khatun et al, 2012) [19] studied the cracks patterns formed in Laponite gel under electric field generated by DC (direct current) source and AC (alternating current) source. They found that the AC (alternating current) fields and Dc field produces extra –ordinary patterns in a radially uniformity set-up. They also reported essence of patterns depend on field strength.

4.0. Crack patterns in drying droplets:

There are several works on drying droplets. Some works on "memory effect "of crack patterns are as follows:

Annarelli et al. (Annarelli et al.; 2001) [20] performed experiment on evaporation and crack formation on a protein solution bovine serum albumin droplet. They found that the average of crack spacing depends on the layer thickness. They also found that the cracks at gelling corner were regular patterns. The mean crack spacing decreases as the thickness of the droplet increases but normally, the crack spacing increases with increase in the thickness of droplet.

Brutin et el. (Brutin et al.; 2011) [21] examined the effect of evaporation on drying droplet of blood. They noticed the process involved in the drying of blood droplet (the blood droplet gathered from a well person).

Sobac and Brutin (Sobac and Brutin, 2011) [22] demonstrated that there are two different stages in evaporation of drying blood droplet. They found that the breaking occurs at a specific mass concentration in drying of deposited droplet of whole blood.

The "memory effect "of cracks was studied by Nakahara and his co-workers (Nakahara and Matsuo, 2006; Matsuo and Nakahara, 2012) [23], [24] on large systems not on a small droplet. They applied mechanical perturbation, such as: vibrations, rotation, oscillations etc on paste for some specific time interval, then they found that crack appeared after the perturbation was stopped. It was observed that the final crack patterns are different for different types of perturbation. "Persistence memory" depending on which future crack formed.

5.0. Conclusions:

The present short review describes the formation of various crack patterns by different methods such as layer thickness and the crack patterns on dried droplet and effect of field on the formation of cracks. The review indicates that cracks have tendency to curve around.Crack patterns could be one of the most important characteristic for diagnose disease, but further studies are needed to conclude anything about the diagnosis field.

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