ARTICLE IN PRESS

Journal of Rock Mechanics and Geotechnical Engineering xxx (2018) 1–14

Contents lists available at ScienceDirect

Journal of Rock Mechanics and Geotechnical Engineering

journal homepage: www.rockgeotech.org

Full Length Article

An approach for wellbore failure analysis using rock cavings and image processing

Christopher Skea [a], Alireza Rezagholilou [a,*], Pouria Behnoud Far [b], Raoof Gholami [a], Mohammad Sarmadivleh [a]

[a] Department of Petroleum Engineering, Curtin University, Perth, Australia
[b] Department of Petroleum Engineering, Amirkabir University of Technology, Tehran, Iran

ARTICLE INFO

Article history:
Received 4 December 2017
Received in revised form
28 March 2018
Accepted 3 April 2018
Available online xxx

Keywords:
Caving shape
Cuttings
Drilling
Image analysis
Wellbore failures
Roundness
Sphericity

ABSTRACT

There have been interests to link different cuttings/cavings to various wellbore failure types during drilling. This concept is essential when caliper and image logs are not available. Identification of wellbore failure during drilling gives more chance of immediate actions before wireline logging program. In this paper, an approach was presented based on the image processing of ditch cuttings. This approach uses the sphericity and roundness of cuttings as input data to classify caving types and subsequently determine the dominant failure type. Likewise, common definitions of cavings were discussed initially before a new criterion is suggested. This quantitative criterion was examined by observations from caliper and acoustic image logs as well. The proposed approach and criterion were implemented on ditch cuttings taken from a well in Western Australia. Results indicate that the primary failure is shear failure (breakout) due to high levels of angular cavings. However, another failure due to the fluid invasion into pre-existing fractures was also recorded by blocky cavings.

1. Introduction

Cuttings are a valuable source of information when drilling oil and gas wells. One of the major issues that may arise during drilling is the presence of abnormal cuttings/cavings which indicate that a failure has occurred downhole. The cost induced by wellbore instabilities is estimated to be 15% of the overall drilling budget for the well (Zausa et al., 1997). A quick interpretation of these cuttings is vital to remedy the problem, avoiding downtime and increased costs. This study aims to achieve a fast and reliable method of cutting analyses using image processing technique in order to determine the mode and size of failure without running wireline logging tools. Due to the vast number of different wells and even greater number of variables, this study will focus on ditch cutting produced from a vertical well in the southern part of Perth Basin in Western Australia. The well was drilled to a total depth of 2913.8 m TVDSS (true vertical depth subsea), and cuttings were collected at various depths. The well mainly intersected sandstone, although traces of claystone and siltstone were detected. The wellbore was at risk of instability due to the long open-hole completion. A detailed evaluation of the ditch cutting samples was undertaken to assess the relationship between cavings and wellbore instabilities. The study covers the shape, size and type distributions of cavings in available samples. Accordingly, image processing technique is employed by using ImageJ software to evaluate the particle's shape features. This method allows for a depth-dependent characterization of the dominant failure types in the well.

Although this method is a common practice for cuttings, there is very little work on its application or characterization of caving. For cuttings, real-time monitoring of particle size distribution (PSD) is coupled with a Coriolis flow meter measuring flow density. This system is programmed to identify cuttings vs. caving ratio based on the shape factor (length/width) and return volume, and thus can give an alert of escalating caving percentage to drilling engineer (Karimi, 2013). Real-time PSD is not feasible for cavings due to their large size. However, the image analysis technique applied in this paper can be beneficial to study samples in required situations. It provides a fast analysis

* Corresponding author.
E-mail address: ali.rezagholilou@curtin.edu.au (A. Rezagholilou).
Peer review under responsibility of Institute of Rock and Soil Mechanics, Chinese Academy of Sciences.

https://doi.org/10.1016/j.jrmge.2018.04.011
1674-7755

Please cite this article in press as: Skea C, et al., An approach for wellbore failure analysis using rock cavings and image processing, Journal of Rock Mechanics and Geotechnical Engineering (2018), https://doi.org/10.1016/j.jrmge.2018.04.011

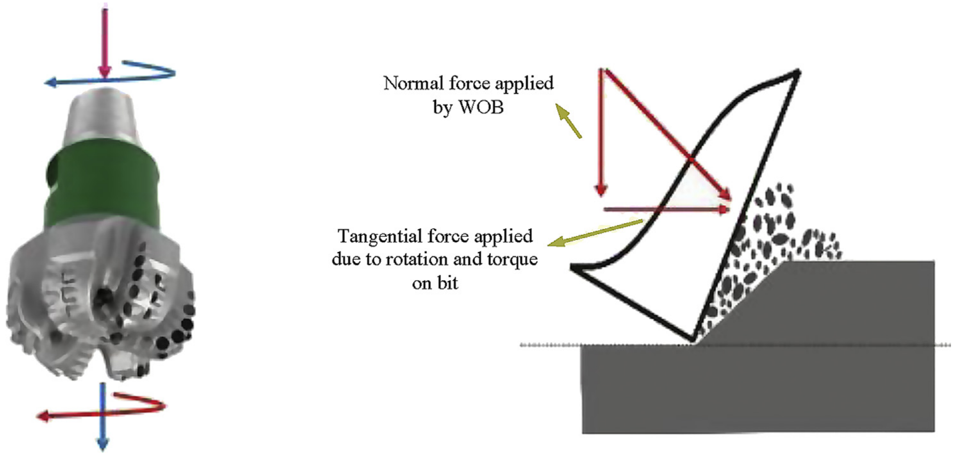


Fig. 1. Cutting mechanism of a drill bit (modified after Mostofi and Franca, 2014).

of caving shape, size and distribution regardless of the size of cavings presented.

2. Particle descriptions

2.1. Cuttings

Drill cuttings are an important piece of data coming to the surface, providing a real-time description of subsurface lithology. Mud engineers can identify the likely type and location of wellbore failure by monitoring these cuttings. As a result, good knowledge of cutting size, shape and color is required for judgment. However, distinguishing cuttings generated by the drill bit from those created by the wellbore failure is not an easy and straightforward task due to a variety of bits and phenomena included in the generation of cuttings. This section aims to provide an insight into the differences between the cuttings created by the bits and those induced by stresses around the wellbore.

2.2. Drill bit cuttings

The type of drill bit is important for size of cutting, and its selection depends on formation type, required rate of penetration (ROP) and service-life of a bit. Weight on bit (WOB) and rotation per minute (RPM) are two important parameters in the creation of cuttings. RPM induces the tangential force with the help of WOB, while WOB provides the normal force on the wellbore floor. When these two forces are transferred to the wellbore through bit teeth, rocks are crushed, and cuttings are generated, as shown in Fig. 1.

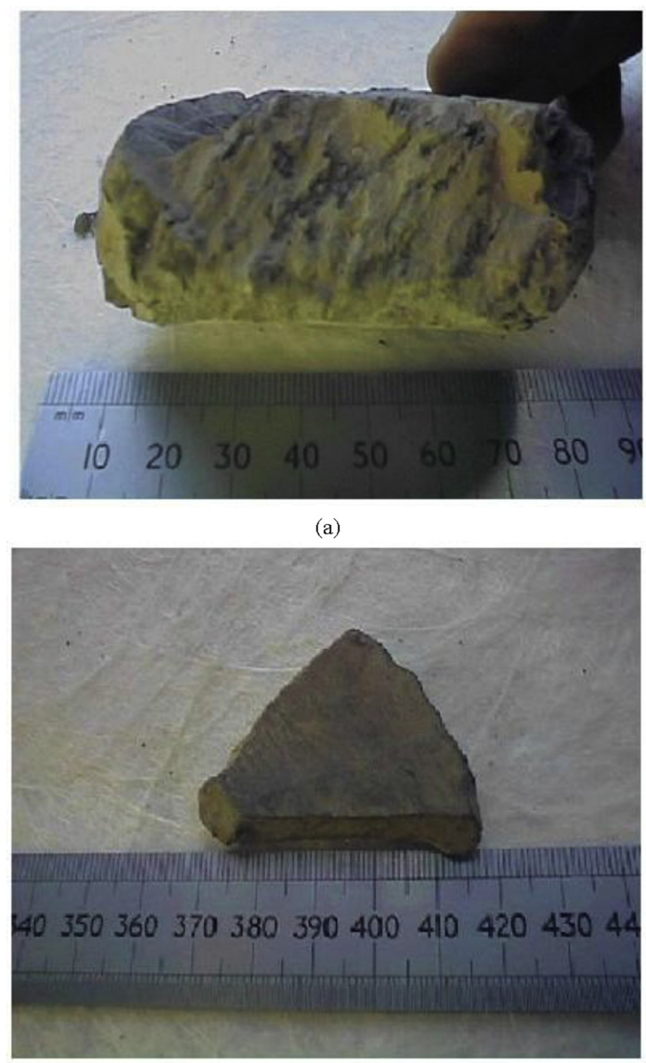
Size of cutting produced from a roller cone bit depends on the tooth length and formation hardness. Large tooth roller cone bits are used in soft formations producing large cuttings while small tooth bits are employed in hard formations generating very small to almost powder-like cuttings (Seubert, 1995).

A polycrystalline diamond cutter (PDC), on the other hand, uses synthetic diamond material as sharp fixed surfaces to scrape or grind the rock. A PDC cutter induces a shear failure along the shear planes of the rock face and is suitable for soft to medium strength rocks (Bar-Cohen and Zacny, 2009).

Table 1
Cutting characteristics with respect to formation types (Egenti, 2014).

Cutting size (in)	Rock type	Shape	Grain density (g/cm^3)	Bed porosity (%)
Large (0.275)	Limestone	Angular	2.57	41
Medium (0.175)	Limestone	Angular	2.57	36
Small (0.009)	Sandstone	Round	2.6	39

Note: 1 in = 25.4 mm.



(a)

(b)

Fig. 2. (a) Naturally fractured (blocky) and (b) weak plane (tabular) cavings (Kristiansen, 2004).