Chapter I

Introduction

Casing is a large-diameter pipe lowered into an openhole and cemented in place to prevent the wellbore from collapsing. The casing must withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive brines. Casing is used to stabilize the sides of the well, to prevent pollution of fresh water reservoirs, and to prevent fluids from zones other than producing zones from entering the well. Casing may be damaged as a result of drilling the lower part of the wellbore, tripping equipment in and out of the wellbore, or chemical reaction. If the casing is damaged, it may not be able to withstand the burst or collapse pressure. On the other hand, scale may precipitate on the casing wall. The scale precipitation may appear as calcium carbonate or calcium sulfate forming on a surface of a casing. In case of monobore completion, this precipitation obstructs the flow of reservoir fluid to the surface.

To detect casing damage and scale precipitation, casing inspection measurements must be made. These measurements are helpful in assessing the overall condition of casing (for examples they can be used to evaluate the suitability of changing a producing well to an injector), or assessing the condition of intermediate strings during drilling operations.

To measure the radii of casing, the caliper tool (UBI, Ultrasonic Borehole Imager) [1] is lowered into the wellbore. Basically, the UBI is a continuously rotating pulse echo-type tool. The UBI sonde as shown in Fig. 1 consists of measurement sonde, in-line centralizer and rotating transducer subassembly which is also called "sensor" attached to the bottom of the tool string. The transducer is both a transmitter and a receiver, transmitting an ultrasonic pulse and receiving the reflected pulse. This transducer measures the fluid acoustic velocity, and distances (or radius) from the transducer to the inner casing surface may be calculated. Measurements are taken at every 0.5 foot interval. While the transducer rotates at each depth, it measures 72 positions (radii).

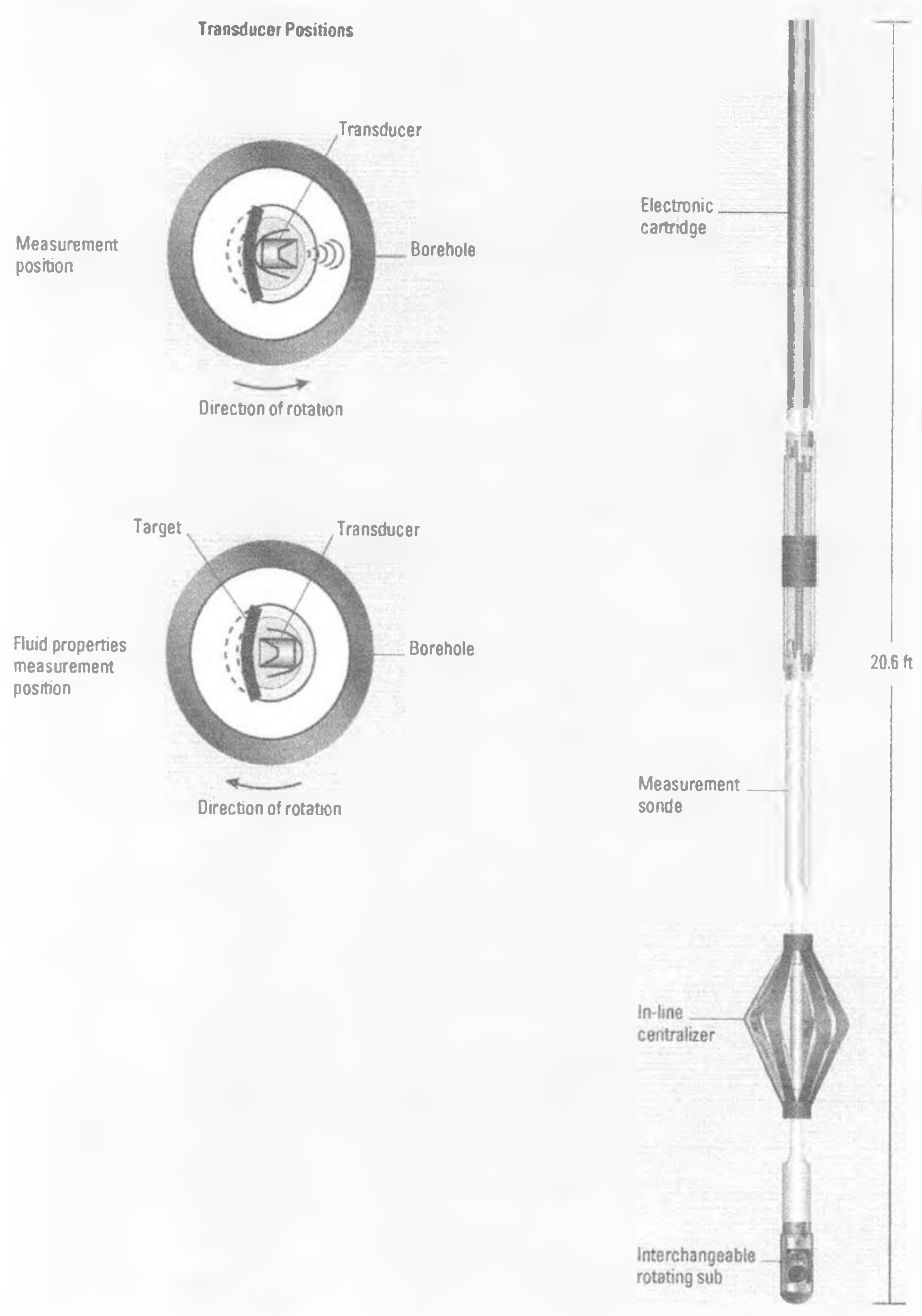

Figure 1.1: The schematic of Ultrasonic Borehole Imager

Using an efficient algorithm to process the data is crucial when examining the casing damage. The currently used algorithm is the vector sum. Since the tool may not be perfectly at the center of the wellbore, this method corrects for eccentricity based on an assumption that the casing is round. However, this procedure introduces errors since the casing may be elliptic rather than circular, especially when the casing is under stress and strain of different magnitudes. Thus, a new algorithm, called the ellipse fit, is proposed. When fitting data with an ellipse, the coefficients of the ellipse can be determined. The semimajor and semiminor axes of the ellipse are evaluated by calculating the coefficients of the ellipse equation. Then, the ellipticity of the casing is calculated by taking a ratio of the semimajor to semiminor axes. If the ellipticity is equal to 1, the casing is practically circular.

To identify locations of damage and scale precipitation, we must subtract the fitted curve (average radius in case of vector sum or ellipse curve in case of ellipse fit) by the radii (the eccentricity-corrected radii in case of vector sum or the raw radii in case of ellipse fit) for respective positions for all depths. Then, these differences at all depths are plotted to identify the damage and scale precipitation locations.

To evaluate the changing of the casing damage and scale precipitation, we conduct at least two sets of radius measurements. The first set of measurements is done after the casing is installed. The second set is collected after the well has been on production for a certain period of time. Then, the two sets of measurements are compared in order to detect development of damage or scale precipitation.

As the caliper tool rotates during the logging in the casing, the second set of measurements made sometimes later may not start at the same position as the first set of measurements. Normally, the caliper tool is lowered with a *deviation sensor* (or accelerometer) which can show where the low side of the casing is (called *relative bearing* when the low side is relative to the radii measurement at position 1). Currently, the deviation sensor is sent down along with the caliper tool for both sets of measurements determine the orientation of the measurements. Thus, we can synchronize between two sets of measurements using the relative bearing. In order to reduce cost of operation, we attempt not to use the deviation sensor in the second run.

Synchronization between the two sets of measurements will be done by shifting data positions until there is a match between two runs.

1.1 Problem Statements

The current algorithm used to process the data assumes that the casing is circular. However, the casing may be elliptic rather than circular, especially when the casing is under stress and strain of different magnitudes. So, an alternative approach called "ellipse fit" is proposed. The ellipse fit uses the elliptic equation to fit the data via least squares fitting.

1.2 Previous Work

Currently, Multifinger Caliper Tool development team, Schlumberger Engineering Department uses an algorithm called "vector sum" [2] to process data (measured radii of casing) obtained from caliper tools (UBI, Ultrasonic Borehole Imager).

The principle of the vector sum is outlined as follows :

1. The summation of all vectors equates to zero, Σ vector = 0, where each vector is the distance (or radius) from the tool sensor to the inner surface of the casing.
2. The casing is round.
3. The tool measuring the radii may not be at the center of a circle.

Schlumberger Engineering Department has found that, in some cases, the casing may not be circular because it may be under stress and strain of the rock. In these cases, the casing shape should be oval rather than circular. Thus, the assumption used in the vector sum is no longer valid. For this reason, a new algorithm to process an elliptical casing is needed.

Pilu *et.al.*[3, 4] presented the new method for fitting ellipses to scattered data by minimizing the algebraic distance subject to the constraint $4ac - b^2 = 1$. They used the ellipse fit algorithm to process data in the pattern recognition and computer vision.

1.3 Thesis Outline

This section shows an overview of this thesis paper which consists of six chapters and an appendix.

Chapter one is comprised of an introductory discussion of this thesis, problem statement, previous work and thesis outline. Chapter two presents two algorithms that can be used to process casing radius measurements. The two are vector sum (current approach) and ellipse fit (proposed approach). Chapter three discusses damage and scale identification and phase shift. Chapter four presents results and discussions. Chapter five contains conclusion and recommendation. References used in this paper are the subject of Chapter six. Finally, Appendix A shows the program used to process caliper data.