A Study of Inspecting the Stress on Downhole Metal Casing in Oilfields with Magnetic Memory Method

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Abstract

This paper introduces a surface experimental model machine of metal magnetic memory inspection (MMI) which is co-developed by Daqing Logging & Testing Services Company (DLTS) and EDDYSUN Company (Xiamen). The model machine is compared with the instrument which was introduced from Russia and an experimental study of casing enforcing inspection on 25 casings is carried out with the finding of good corresponding relationship between the stress on casing and the information of magnetic memory. It provides a criterion of four-class semi-quantitative evaluation on the casing stress distribution. On the basis of this, a model machine of down-hole 8-electrodes inspecting the metal casing magnetic memory is developed and field test has been done successfully. It provides the basis for overcoming the difficulty of evaluating the downhole casing and tubing lifetime in the oilfield and for putting this model into commerce in the future.

Key Words: oilfields, casing damage, stress, magnetic memory, inspection

0 Introduction

The technology of metal magnetic memory inspection is firstly addressed by Doubov, a Russian scholar, in the late of 1990s. The method is not only the only effective way for early diagnosing the safety of metals, but also a quick way for inspecting the location of the happened or potential metal flaw. It has intensive applying prospects in railway, bridge, aviation and pipeline, etc. Unfortunately, there is no any study report about this technology applying for evaluating the stress distribution domestic and overseas. At present, the downhole casing damage is severe in oilfields of China including Daqing oilfield, which influences the normal production of crude oil badly. The available technologies for casing damage inspection such as mechanic caliper, ultrasonic imaging, magnetic leakage and eddy current are various and mature, but all of these are post-inspected, they can not predict the happening of casing damages. This study realizes the classified semi-quantitative evaluation on casing stress distribution, presents the risk classes of casing damage pre-happening, hence the prediction of casing damage is achieved.
1 Basic concepts of Metal Magnetic Memory

The fundamental principle of metal magnetic memory is when the iron device in earth-magnetic environment is under the working load, the magnet domain irreversible reorientation with magnetostriction will happen, and the biggest magnetic leakage field \( H_p \) in stress and deformation concentrated area will be formed, see Fig 1.

The tangential component of magnetic field \( H_p(x) \) obtains the max. value, while the normal component \( H_p(y) \) changes its polarity and obtains zero crossing point. This irreversible magnetic field change will remain after the working load is eliminated, hence the stress concentrated location of the device will be inferred accurately through measuring the normal component \( H_p(y) \) of magnetic leakage field\(^2\).

![Fig1](image)

Fig1  Distribution of magnetic leakage field in stress concentrated area

2 Design of inspecting tool

At present, there are two kinds of domestic relative instrument, one is the EMS2000 metal magnetic memory diagnostic tool\(^2\) developed by EDDYSUN Company ( Xiamen ), another is palm metal magnetic memory inspector\(^3\) developed by Qinghua University. Combining with the detailed demand of oilfield engineering logging, a 4-path simplified surface experimental inspecting system and oilfield downhole casing stress 8-electrode magnetic memory inspector are designed and developed by DLTS and EDDYSUN Company ( Xiamen ). The electrical principle sees Fig 2.
Where, (1) sensor: the key element of the tool, high-sensitive magnetic sensor produced by EDDYSUN Company (Xiamen) is chosen due to the weak magnetic field; (2) temperature compensation: the magnetic-sensitive sensor is sensitive to temperature, so the temperature compensated circuit is needed. (3) amplifying circuit: in different environments, the distances between sensor and device are different or memory magnetic field of device itself is various, so the sizes of the signal are very different. In order to ensure the proper signal dynamic range, the gain of amplifying circuit should be changeable and controlled by CPU; in addition, the amplifying circuit is also needed to complete the task to give the lowest power level demanded by A/D transformer; (4) A/D transformer: in order to maintain the proper resolution, suitable bits are required by A/D transformer, the passing time by time A/D transformer is selected by the tool, meanwhile in order to simplify the circuit, multi-path input A/D transformer is used, here a 12-bit, 8-path input MAX197 chip is selected.
The mechanical design difficulty of oilfield downhole casing stress 8-electrode magnetic memory inspector lies in the sensor measuring system, the motor driving structure is adopted shown in Fig3 with the temperature rating of 125°C, pressure rating of 60MPa and O.D of 90mm.

3 The surface inspecting experimental study with mental casing pressurized

3.1 Casing pressurizing experimental means

Casing pressurizing experiment is shown in Fig4. The casing with the length of 1m, O.D of 139.7mm and wall thickness of 7.72mm is located in the middle of hydrolic platform of hydropress. The medium position of the casing is chosen to perform the pressurizing experiment for eliminating the end effects; Put the pressure of 20 KN, 30KN, 40 KN … 240 KN separately with 10-minnte for every lasting time. After every time of pressurizing, the casing is took away and is vertically located at some constant post, then the scan inspection from top to bottom inside the casing with 4-path simplified surface experimental inspection system, sees Fig5.

3.2 Comparing experiment with the introduced tool from Russia

Fig 3. Downhole sensor measuring system structure

Fig 4. Casing pressurizing experiment drawing

Fig 5. Magnetic memory surface inspection
Fig 6 shows the magnetic memory response curve measured by Russian hand-hold portable magnetic memory inspector before casing 4 is pressurized. Fig 7 shows the magnetic memory response curve measured by self-developed magnetic memory inspector before casing 4 is pressurized. After removing the boundary effect of two curve ends, the shapes of two curves are similar absolutely[4].

![Image](image1.png)

**Fig 6** The MMR curve before casing 4 is pressurizing (by Russian MMI)

![Image](image2.png)

**Fig 7** The MMR curve before casing 4 is pressurizing (by self-developed MMI)

Fig 8 shows the response curve measured by Russian inspector after the stress concentration is created on casing 4 after pressurized. Fig 9 shows the response curve measured by self-developed one in same situation. It can be seen that the shapes of two curves are basically consistent. It is the casing deformed area shown in Fig 5 which corresponds to the medium peak-to-peak. It indicates that the developed magnetic memory inspector meets the demand of engineering design, further study should be performed.
3.3 Surface inspection experiment and data analysis

Fig 10 is drawn by surface pressurizing experimental data of casing 11, it is characterized by peak-to-peak of MMR, which changes with the pressure. The vertical axis represents the peak-to-peak of MMR (A.m$^{-1}$), the horizontal axis represents the pressure given. In order to keep in agreement with casing parameters, the pressure is transferred into MPa.

From the figure, the peak-to-peak of magnetic memory response rises with the pressuring. The MMR peak-to-peak decreases while the pressure is achieved to 100 MPa resulted from casing plastic deformation and pressure released effect.

Fig 11 is drawn by surface pressurizing experimental data of casing 15. To every given pressure, the pressurized position on the scan line is scanned several times. The MMR peak-to-peak is derived after uniforming the slight deviated data. Then the curve is drawn according to the peak-to-peak varying with the pressure. This experimental method removes the uncertainty effect of sensor routines in experiments. It proves that there is a rising relationship
between magnetic memory peak-to-peak and pressurizing.

![Figure 10: The curve of peak-to-peak changes with pressurizing of casing 11](image1.png)

![Figure 11: The curve of chosen uniform peak-to-peak changes with pressurizing of casing 15](image2.png)

The above experiments proved that the magnetic memory response inspection did accomplish four-class semi-quantitative evaluation on different casing stress distribution. After pressurizing experiments on 25 downhole casing test pieces in same size, and contrastive analyzing all of experimental data, the four-class semi-quantitative evaluation method is derived for evaluating the risk class of potential casing damage of the casing with O.D of 139.7mm, wall thickness of 7.72mm, see Table1.

When the pressure is above 85 MPa to 110 MPa, the severe uneven concentrated plastic deformation may happen. Due to the pressure release effect, the measured value decreases instead, the casing damage inspector should be combined for casing damage evaluation.

In addition, the series study is also conducted on the casing of 139.7mm O.D and 6.2mm wall thickness. The similar regulation and four-class semi-quantitative evaluation are also derived.

<table>
<thead>
<tr>
<th>Pressure (MPa)</th>
<th>Peak-to-peak of MMR (A.m⁻¹)</th>
<th>Casing Damaged Status</th>
<th>Casing Stress Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 20MPa</td>
<td>&lt; 400 A.m⁻¹</td>
<td>No deformation</td>
<td>Not dangerous</td>
</tr>
</tbody>
</table>
### 4 Field application

The downhole casing stress MMI model machine has successfully recorded the experimental data of Well-L15B264. The logging interval is from 400m to 100m. for convenient indication, only the stress concentrated interval from 325m to 293m is drawn in Fig12. The field experimental magnetic memory curve of Well-L15B264 is drawn in Fig12 with MMI signal after denoising. In the figure, the curve has strong surges at the points of 293.5m, 304m and 314.4m resulted in casing collars. It can be seen there is zero crossing point around 307m and the peak-to-peak around zero point is appeared, obviously it should be stress concentrated area. 8-pathed magnetic memory peak-to-peaks abstracted are shown in Table 2.

#### Table2 Magnetic Memory Peak-to-peaks of Stress Concentrated area at 307m

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>PathI (A/m)</th>
<th>Path II (A/m)</th>
<th>Path III (A/m)</th>
<th>Path IV (A/m)</th>
<th>Path V (A/m)</th>
<th>Path VI (A/m)</th>
<th>Path VII (A/m)</th>
<th>Path VIII (A/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>307.55</td>
<td>541</td>
<td>248</td>
<td>381</td>
<td>655</td>
<td>966</td>
<td>215</td>
<td>183</td>
<td>384</td>
</tr>
</tbody>
</table>

From Table2, the maximum peak-to-peak appears in pathV:966 A/m. The stress evaluation is performed according to the casing size of 139.7mm O.D, 6.2mm wall thickness, the risk class is III, i.e. sub risk class, the stress concentration has been produced, but without plastic deformation.

### 5 Conclusions

The peak-to-peak of magnetic memory response increases gradually along with the pressurizing, this rising relationship is proved by magnetic memory inspection experiments on the surface with casing stress magnetic memory inspection model machine. The magnetic memory inspection can not only identify the stress concentrated area, but also the peak-to-peak can evaluate the stress distribution of casing with four-class semi-quantitative evaluation method. This evaluation method represents the new advances of metal magnetic memory detecting method application study. The technology provides the direct basis for casing damage prediction and stimulate the oilfield development.
Fig12 Field Experiment curves of Casing Stress MMI in Well-L15B264

References


