DURABILITY OF A NEW MINE DETECTOR

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ABSTRACT

The results of testing of F3 mine detector have informed the designers, if their design or choice of material meets performance criteria. The tests have compared the performance of different designs and materials. As a result the tests have helped designers select designs and materials. Designers have also been informed of the performance of the detector. Tests have been conducted in many different areas relating to the detector, including coil plots, heating tests and deflection tests.

Component failure rates are being calculated in order to generate the mean time to failure and mean time between failure for the F3 mine detector.

KEYWORDS: coil plots, MTBF, MTTF

1.0 Introduction

Minelab Electronics is currently developing a new mine detector, the F3. The F3 will replace the current Minelab model the F1A4. The F3 mine detector consists of many mechanical and electronic systems. Minelab Electronics required detailed testing of the new detector and its systems. Minelab also needed the generation of two key failure times. A Mean Time To Failure (MTTF) and a Mean Time Between Failure (MTBF) needed to be generated.

1.1 Project Specification

This project on the durability of the F3 mine detector has two main parts.

1. The testing of the F3 mine detector.
2. An investigation into the reliability of the F3 mine detector.

2.0 Testing of Mine Detector

The aim of this first section of the project is to assist, through experimentation, the designers of the detector. The tests serve many purposes. The results of tests can inform the designers, if their design or choice of material meets performance criteria. The tests can also compare the performance of different designs and materials. As a result the tests help designers select designs and materials. Designers are also informed of the performance of the detector. This information can in turn be used to advise users of the device of the performance.

The designers of the detector ask for a system parameter to be tested. Under the supervision of Andy Baker, the test is then designed. The test is carried out and results recorded. A report with appropriate conclusions is then submitted to Andy Baker, who in turn passes the report to the relevant design team.

The individual tests are linked by the fact that they are required for the development of the F3 detector. The design and research of this section comes through the design, performance and analysis of the tests. The tests are of a varied nature. It follows that the quality of the design, performance and especially analysis improved as more experience was gathered.

16 tests have been designed, conducted, analysed and submitted to Minelab. Some of the fields in which the tests have been conducted are listed below.

2.1 Tensile Tests on Detector Connections

Three tensile tests were conducted on three connectors that were considered in the detector design. The connectors were different designs and manufactured from different materials and by different companies. The yield load, ultimate load and mode of failure of the connectors were compared.

2.2 Heating Tests on Detector Assembly

The temperature fluctuations in different coloured detector coils and the detector shaft during a hot day were investigated. A test was also conducted to investigate the effect of a hot day on the relaxation and recovery of the detector cable.

2.3 Deflection Test On Possible Shaft Material

Linear carbon fibre was one material being considered for the detector shaft. The carbon fibre would be expected to be notch sensitive. It would also be expected to be weaker under a bending load rather than a tensile or compressive load. The deflection test was designed to find the smallest failure load and mode of failure of the linear carbon fibre shaft.

2.4 Tabai Test on Detectors' PCBs and Cable

Tests using the company tabai to evaluate the performance of the F1A4, F3 and Explorer PCBs and cables were required at temperature extremes. A person not involved in the industry may wonder why some tests of the detector systems are conducted at –35^{o}C or 70^{o}C. Tests are conducted at these temperatures because there is a need for mine detectors in areas of the world with extreme temperatures. For instance areas in Alaska has been used as mine test fields for the American military. Considering the other extreme, an earlier test showed how a 39^{o}C day in the shade could create extreme temperatures in the mine detector assembly.

2.5 Results, discussions and conclusions using coil plot tests

Each of the 16 tests produced results to be analysed. The coil plot tests are used here as an example of analysis done. The coil plots of the old and new detector, took a substantial amount of time to perform and analyse. The first Test examined the sensitivity and shape of the output signal of the old detector to steel, aluminium and a test piece, as the distance is varied, at 2m/s and 1m/s. A swinging gate passes over the detector at a fixed speed. A strip of wood, with marks every 100mm, is attached this gate. The material being plotted on the coil is fixed to the highest mark. The information from the coil is recorded by computer software. The material is then shifted down to the next mark and the process is repeated.

The coil plots show the output shape of the coil. Each curve represents a distance of the material from the detector. As the material gets closer to the detector the signal increases in magnitude. The detector readings of the test piece are much smaller in magnitude and consequently are far more subject to noise. The speed of the swinging gate was changed from 2m/s to 1m/s and the procedure repeated. The detector appeared to perform better at this speed, with clearer output signals, less subject to noise. All the signals from the old detector show a long lagging edge.

From the signal output data, two additional figures were generated, Time for coil output to exceed 25 counts versus Height and Time for coil output to exceed 50 counts versus Height. If 25 or 50 counts indicate that a material has been detected, than these figures display how long it takes the test piece to be detected at different heights. Ideally this should be a flat horizontal line. If this were true it would indicate that the test piece is detected on the same position on the coil every time. This is not the case.

The second Test builds on the results of the first test. The second test repeats the procedure used in the first test for the new detector. The gate is only used at 1m/s, as this is found to be the better speed for the coil. The coil plots for the new detector are generated in the same manner as they were for the old detector. The results from the new detector are compared with the results using the old detector. The output signals do have a different shape. There is less of a lagging edge on the new detector output signals. The signals are less affected by noise, as seen by the smooth new detector curve of the test piece in comparison to the noisy old detector curve for the test piece.

The detection times for each material and each detector are investigated in the second test. The slopes of the detection times for steel have a similar slope for both the old and new detector. This slope is however not horizontal, as it has been suggested previously. The new detector has a flatter detection time versus distance curve for aluminium and the test piece.

2.6 Future Tests

The testing procedure will continue as before. A substantial amount of tests have already been conducted. The focus of the project has shifted towards the reliability analysis of the new detector.

3.0 Reliability of F3 Mine Detector

The second part of the project investigates the reliability of the new F3 mine detector. Reliability is the probability that the system can successfully meet an operational demand within a given time when operating under specified conditions (Smith, 1976).

3.1 Aims

The second part of the project has two aims.

1. *A Mean Time To Failure* for the new mine detector.
2. *A Mean Time Between Failure* for the new mine detector.

The company involved has not previously conducted any extensive mean time to failure and mean time between failure calculations for their products. These calculations are required due to the demands of their customers. Customers, such as national defense forces will expect such numbers to be provided with the product. In order to calculate these figures accurately, an extensive reliability analysis of the components and systems within the detector is required.

The mine detector consists of mechanical and electronic systems. The reliability study requires the detector to be broken down into a series of systems. A system is further broken down into the components that make up the system. The hazard rate data of the components is the basis of the reliability study.

3.2 Reliability Study Steps

(a) Preliminary Designs
  1. Parts count reliability study of preliminary designs.
  2. Compare reliability of different preliminary designs

(b) Detailed Design of system and detector
  3. Commence data collection of component time to failures.
  4. Use component data to find system and detector time to failures.

(c) Alterations to systems or detector design
  5. Undergo time to failure data collection of any new components
  6. Use component data to find altered system and detector time to failures.

(d) Detector placed in market

7. Collection of in field data and correlation to predicted data.

3.3 Data Collection

The first step in the reliability analysis is data collection. The hazard rate of each component is required in order to find the mean time to failure of a system, and ultimately, the detector. There are four main types of data used in reliability studies.

1. Company Experimental Data
2. Manufacturers Experimental Data
3. Public Model Data
4. Operational Field Data

3.4 Experimental Data

There are approximately 600 electronic components in the F3 detector. This is far too many for the Minelab to generate experimental data to a sufficient accuracy economically. A public model, MIL-HDBK-217F was used to generate the bulk of the data. Product catalogues and online resources were used to compile manufacturers data to be used in the public model.

3.5 Electronic Failure Rates

As mentioned, there are approximately 600 components. This is a large amount of components to gather individual data on. While there are 600 components, they are not all different components. For example there might be 5 10k 1% resistors or 5 10uF capacitors. There is still a large number of different components to find failure rates for. The procedure currently being undertaken is as follows.

1. Identify the component type and categorise e.g. resistor, capacitor, diode.
2. Use MIL-HDBK-217F to obtain equation, factors derive formula to give failure rate.
3. Use catalogue (Farnell is the preferred supplier, RS), bill of parts to obtain component specifications e.g. voltage rating, power rating.
4. Experimentally Find temperature of components, voltage load etc.
5. Substitute values into the appropriate formula to give the component failure rate.

Minelab supplied a bill of electronic parts. The procedure has been to proceed through this list. A component or a group of components is selected. This component is then categorized. There are several categories of components in the MIL-HDBK-217F public model, including capacitors, resistors, diodes and microcircuits. MIL-HDBK-217F is then consulted to give the relevant failure rate formula. An example of one of the simpler formulas is shown.

$$\lambda_{part} = \lambda_b \pi_E \pi_A \pi_Q \ldots \pi_n$$

λ_{part} = total part failure rate
λ_b = base or generic failure rate
π = application factor

The base failure rate and the application factors are dependent on the exact component and the conditions it is used in. For example one application factor might be a voltage stress factor. This factor will be a function of the rated voltage of the component and the voltage that is actually supplied to the component.

In order to generate these application factors and base failure rates, the component specifications are required. Most of these specifications such as power ratings and voltage ratings are found in catalogues (the Farnell catalogue is preferred as it is the preferred supplier), the bill of parts or manufacturers data.

The majority of the electronic components have been analysed to these first three steps. The failure rate formulas have been placed into microsoft excel files and the known application factor values and equations have been substituted into these equations. However in order to generate the component failure rates, the conditions under which the components are used are required. Values such as component temperature, power dissipated and voltage load on components need to be found.

3.6 Future Work

When the designers of the electronic systems were developing the detector, they would have known the voltages and currents passing through each component. It appears that for the majority of systems, these values were not recorded. If these values are not available from the designers, they will have to be measured from the detector along with component temperatures.

Due to the complexity of the electronic systems, the number of components involved and the lack of parallel reliabilities the modeling will not be complicated. It would be extremely time consuming to give a detailed modeling of 600 components, and it would not be much more accurate than summing the individual failure rates.

3.7 Mechanical Systems

There are far fewer mechanical components and systems. The mechanical system is modelled by finding the systems most likely to fail. The failure rates will be found by use of the public model, NSWC-98/LE1, in comparison with fatigue tests being conducted. The mechanical systems should be calculated in much less time than it has taken to find the failure rates of the electronic systems.

4.0 Acknowledgements

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