

Degradation Analysis of Flexible Film Cables in an Automotive Environment

James Henry Wrock, Pengying Niu, and Huairui Guo
FCA US LLC

ABSTRACT

Automobiles have a high degree of mechanical and electrical complexity. However, product complexity has the accompanying effect of requiring high levels of design and process oversight. The net result is a product creation process which is prone to creating failures. These failures typically have their origin in an overall lack of complete understanding of the system in terms of materials, geometries and energy flows. Despite all of the engineering intentions, failures are inevitable, common, and must be dealt with accordingly. In the worst case, if a failure manifests itself into an observable failure the customer may have a negative experience. Therefore, it is imperative that design engineers, suppliers along with reliability professionals be able to assess the design risk. One approach to assess risk is the use of degradation analysis. Degradation analysis often provides more information than failure time data for assessing reliability and predicting the remnant life of a system. In general, degradation is the reduction in performance over time leading to an observed failure. Many failures may be traced to an underlying degradation process. For example, one failure mode associated with Flexible Film Cable (FFC) is electrical short between circuits due to migration. Under certain conditions (e.g. elevated temperatures) the ribbon material becomes pliable and if the cable is under stress the encased wires may begin to migrate towards one another ultimately resulting in an electrically shorted condition. This type of situation is a kind of stochastic process; therefore, it could be modelled in several approaches. This paper presents the degradation analysis approach as applied to the FFC in an attempt to identify the merits, limitation, and applications of degradation analysis in generating system understanding by which to make informed decisions.

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INTRODUCTION

Today's state-of-the-art automobiles have become increasingly complex systems comprised of integrated hardware and software components. Many of these embedded systems must interface with the driver through various inputs (e.g. switches within the steering wheel) to provide the desired function. The steering wheel has evolved into a high-tech, electro-mechanical device with numerous added functions which has resulted in a large amount of complexity in a relatively small packaging area. In order to connect all of these devices some form of electrical interconnection must be deployed. These interconnections have evolved to incorporate Flexible Film Cable (FFC). Unfortunately, due to confined space these interconnections are sometimes subject to torturous paths and other environmental conditions which may result in potential failures.

Electrical cables are often the last component considered during system designs. However, cables are the system's lifeline - if a cable goes down, the entire system can become inoperable. System reliability is based on signal integrity and durability; thus, the ideal cable system should be engineered to last the life of the product in any environment.

The environments in which cable systems are being used today are becoming more challenging. A harsh environment is one in which the cable's reliability, signal integrity, and life performance can be compromised by the environment in which it is used. In essence, a harsh environment is one in which a cable may not perform. For example, automotive instrument panels may expose cables to such things as mechanical loading and flexing, abrasion, excessive temperatures and even chemical induced degradation. Additional factors can include the need for smaller, lighter packaging for cable systems that last longer and cost less. Therefore, it is essential to identify and study the potential factors that can affect the electrical performance of the system in order to manage the associated risks.

MECHANICAL AND ENVIRONMENTAL STRESS ON FFCS

Stress induced failure of FFCS may result from both mechanical and thermal induced stress. For example, temperature cycling due to both ambient and sun loading may affect cable materials, with low temperatures making them brittle and high temperatures causing them to become very soft.

It is not uncommon, in mild weather, for vehicle cabins to reach temperatures in excess of 100 to 115 °F (37-56 °C) which can occur in a closed vehicle in a short period of time [1]. At higher ambient temperatures >100 °F (38 °C) the vehicle cabin may reach temperatures in 126 to 162 °F (52-72 °C) conditions. In principle, every little temperature change of the component during its service life in field contributes to its total thermo-mechanical stress. For simplicity, only two thermal events per day are sufficient to determine cumulative effect of thermo-mechanical stresses. Based on this assumption the total number of temperature cycles can be calculated as function of the design life:

$$\text{Temperature Cycles} = 2 \times 365 \times 10\text{yrs} = 7300 \text{ cycles}$$

The magnitude of change in temperature may be measured in vehicle resulting in a temperature cycling profile for the automotive cabin, as summarized in Table 1.

Table 1. Temperature cycling profile for automotive cabin

Temperature Cycling Profile for Automotive Cabin			
ΔT in °C	%	# of cycles Lifetime (10yr)	Cumulative Cycles
10	8	584	584
20	14	1022	1606
30	27	1971	3577
40	21	1533	5110
50	19	1387	6497
60	7	511	7008
70	3	219	7227
80	1	73	7300
90	0	0	7300

Elevated temperatures combined with mechanical stress may result in unique application-specific stress for FFCs. Mechanical stress occurs due to routing constraints which subject the FFC to side loading, bending and movement. In the worst case, the FFC may become pinched inadvertently due to the tortuous path in which it must reside.

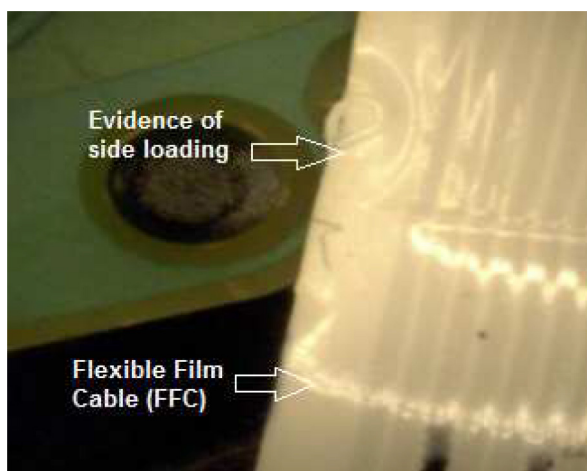


Figure 1. Flexible Film Cable (FFC) with evidence of side loading.

In the figure above (figure 1), the FFC shows sign of mechanical stress which is resulting in side loading of the neighboring circuits. Although this initial condition may not initially degrade signal

integrity, the complexities of this thermal-mechanical stress combined can cause premature failure of the FFC and ultimately compromise signal integrity.

In some instances, these adverse conditions are not understood fully and manifest themselves into customer complaints. It is important that the risk associated with these conditions be determined in order to minimize customer impact and make correct business decisions.

DEGRADATION ANALYSIS

Reliability testing typically generates product lifetime data, but for some tests, covariate information about the wear and tear observed during the life test can provide additional insight into the product's lifetime distribution. Instead of only monitoring product performance (e.g. loss of circuit) it might be more important to monitor physical parameters of the product (e.g. circuit separation). By monitoring the physical parameters, the onset of "hard" failures may be more predictable. Degradation analysis is the statistical tool for providing inference about the lifetime distribution based on monitoring physical parameter integrity.

Degradation analysis is tied to accelerated life testing (ALT). Both methods have evolved in recent years to suit reliability tests for which product lifetimes are expected to last far beyond the allotted test time. ALT is meant to expedite product failure during test intervals by stressing the product beyond its normal use. This helps to bring in more information if the link between the accelerated test environment and the regular use environment is known. The same is true of degradation analysis. If the link between the measure of degradation and lifetime is clearly known, the degradation data provides valuable information about product reliability. Accelerated degradation testing (ADT) combines both approaches by testing products in harsh environments and measuring the evidence of product degradation.

The ADT is designed to last until all Devices Under Test (DUTs) result in an observed failure. But in practice, it is not necessary to test to failure. The failure time estimate may be predicted based on the observed degradation. Once a failure level is defined, it is relatively easy to use basic mathematical models to extrapolate the measurements over time to a point where the failure would occur. Once these failure times are established, it is merely a matter of analyzing the extrapolated failure times in the same manner as conventional time-to-failure data under accelerated life conditions.

Using the life data obtained at each accelerated stress level, the analyst can use standard life data analysis techniques to estimate the parameters for the life distribution (e.g. Weibull, exponential or lognormal) that best fits the data at each stress level. This results in an overstress probability density function (*pdf*) for each accelerated stress level. Another mathematical model, the life-stress relationship, is then required to estimate the probability density function (*pdf*) at the normal use stress level based on the characteristics of the *pdfs* at each accelerated stress level.