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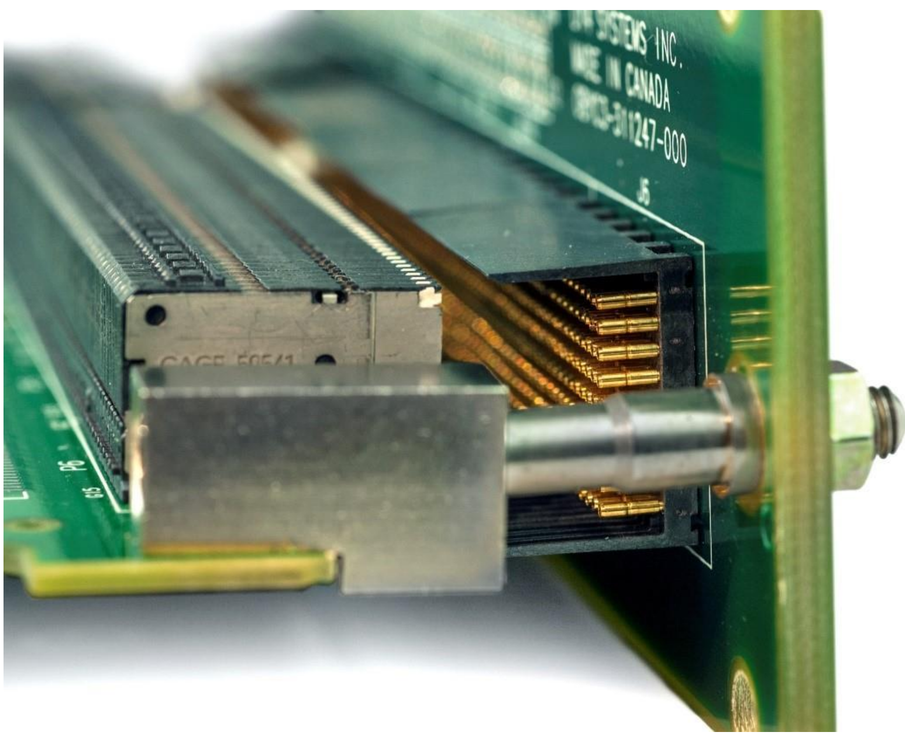
White Paper

Understanding Fretting Corrosion in Ruggedized Backplane Connectors



Smiths Interconnect KVPX connectors

Understanding Fretting Corrosion in Ruggedized Backplane Connectors

Electrical connectors are critical components in high-reliability applications such as aerospace, defence, medical, and test, where they are frequently exposed to harsh conditions like vibration, temperature extremes, and mechanical shocks. Under such conditions, connectors can suffer from fretting corrosion, a phenomenon that occurs due to micro-movements at the contact points of the electrical connections. In this article, we examine fretting corrosion, its causes, and solutions, with a focus on advanced contact technologies like Smiths Interconnect's Hypertac® Hyperboloid contact system.

What is Fretting Corrosion?

Fretting corrosion refers to the wear and degradation that occurs between two contact surfaces subjected to repeated tangential movements, often due to vibration or thermal cycling. These micro-motions, typically only a few thousandths of an inch, cause the contact surfaces to rub against each other, gradually wearing away the protective coatings on the connector's contact points. In electrical connectors, the contacts generally consist of a male pin or blade and a female receptacle. These contacts are usually plated with a thin layer of gold, which is chemically inert and resistant to oxidation. However, gold is a relatively soft metal and is prone to wear. Beneath the gold plating, a layer of electroless nickel acts as a barrier between the gold and the substrate. While nickel is more durable than gold, it is susceptible to oxidation, which forms non-conductive oxide layers when exposed to air.

As micro-motions occur, the gold plating wears away, exposing the nickel underneath. The nickel then oxidizes, and these oxide particles accumulate in the valleys of the asperities. Asperities are tiny peaks and valleys in the surface structure of the metal. When the asperities flatten due to the applied force between the connector contacts, they increase the surface area for electrical current to flow. However, as the fretting cycle continues, oxide particles trapped in these valleys increase the electrical resistance. This buildup of oxides hinders current flow, which leads to power loss, signal distortion, and eventually complete connector failure.

Causes of Fretting Corrosion

The primary cause of fretting corrosion is micro-movement between the contact surfaces, often induced by vibration, thermal cycling, and mechanical shocks. Vibration is one of the most significant contributors to fretting corrosion, especially in applications like military aircraft, drones, and power distribution systems where connectors are subjected to high levels of vibration. Vibration-induced fretting is common in environments such as engine controls and power units, where the motion between connector contact points may be small but continuous. MIL-STD 810 defines the vibration profiles for military aircraft: different parts of military aircraft experience varying vibration frequencies, such as those in the tail section versus the cockpit, which leads to differential effects on connectors.

Thermal cycling is another important factor in fretting corrosion. When connectors are subjected to repeated heating and cooling, the materials they are made from expand and contract. This thermal expansion and contraction causes micro-movements at the contact points, which in turn leads to fretting. Additionally, power cycling, which involves turning power on and off, exacerbates thermal cycling and accelerates the oxidation process. The higher the temperature, the faster the non-noble metals like nickel oxidize, contributing to the formation of oxides at the contact points.

Mechanical shocks, such as those experienced during equipment transport or operational impacts, can also induce fretting. Even when connectors undergo fewer cycles than in vibration, the impact of these shocks can still cause damaging micro-movements. The repeated shock disrupts the integrity of the electrical contact, leading to the buildup of oxides and, eventually, connector failure.

Solutions to Fretting Corrosion

There are several approaches to mitigating fretting corrosion in electrical connectors, each offering specific advantages and limitations. One common approach is increasing the contact **force** between the mating surfaces of the connectors. The idea behind this method is that by ensuring the contact points remain firmly in place, relative motion between them is minimized. However, there are physical limits to how much force can be applied. Too much contact force can cause premature degradation of the connector, reducing its lifespan. This solution is more suited to less demanding applications where high reliability is not as critical.

Lubrication is another potential solution, as lubricants can reduce friction between the contact points, which helps improve the lifespan of the connector. Various types of lubricants, including grease, dry lubricants, and wet lubricants, can be used to create a protective barrier between the contact surfaces. However, lubricants have limitations, as they can attract dust and dirt, which can degrade performance. Additionally, lubricants may not be suitable for high-temperature environments and may require periodic maintenance.

Another strategy involves using mechanical **locking mechanisms** to prevent motion between the connectors. For instance, in MIL-DTL-38999 connectors, a coupling mechanism locks the connectors in place, preventing any relative motion that could induce fretting. Similarly, alignment and locking hardware in PCB connectors can be used to secure the connectors. While this approach is effective, it comes at a higher cost and may not be ideal in applications where board space is limited.

Regular maintenance and inspection of connectors are also essential for preventing fretting corrosion. During maintenance, signs of wear, such as discoloration or the presence of foreign materials, can indicate the onset of corrosion. Cleaning or replacing the contacts, when necessary, can help extend the lifespan of the connectors and prevent costly repairs or replacements.

Redundant contact points are also a reliable solution to combat fretting corrosion. By designing connectors with multiple contact points, the failure of a single point does not result in a complete connector failure. Distributing the electrical load across several points reduces the likelihood of failure due to fretting corrosion.

Contact Technologies

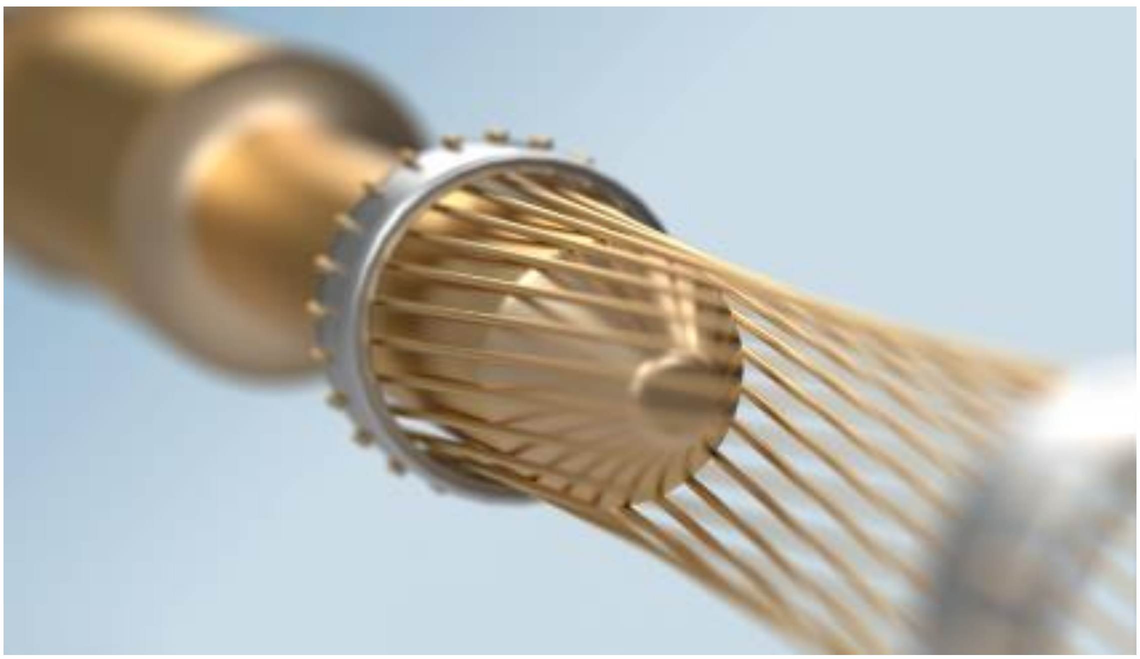
Traditional contact technologies are the Pin and Socket, Tuning Fork, and Bent Metal contacts.

The traditional **Pin and Socket contact** is one of the most used types in industrial applications. These contacts are typically made from beryllium copper, which is known for its excellent conductivity and strength, and are plated with various amounts of gold and electroless nickel. The female socket contact can be either machined or stamped, with the ends of the female contact formed into a circular shape to make contact with the male pin. This design provides a cost-effective solution suitable for some industrial applications, where few mating cycles are expected. However, the construction of these contacts makes them prone to fretting corrosion, especially in applications exposed to vibration, shock, or thermal cycling. The susceptibility to fretting corrosion limits the reliability of these connectors in harsh environments.

The **Tuning Fork** style contact shares similarities with the Pin and Socket contact but has a distinct design. These contacts are typically stamped from flat stock and formed into a fork-like shape. Tuning Fork contacts are often supplied in tape and reel formats, and the female portion is selectively plated to reduce costs. The male contact in this design is square-shaped and is typically insert-moulded into commercial PCB connectors. Like the Pin and Socket contact, the Tuning Fork style contact provides two points of contact between the male and female portions. However, it also has a relatively low mating life, generally less than 500 cycles, and is similarly prone to fretting corrosion. These contacts generally perform poorly in harsh environments, including those subjects to vibration, shock, or temperature extremes.

The **Bent Metal** contact, sometimes referred to as a shield or ground contact, is a stamped contact that is selectively plated and typically provided in tape and reel formats. This contact design is simple, featuring a single point of contact, and is often used in low-cost applications such as battery contacts. While Bent Metal contacts are cost-effective and straightforward in design, they have a notable weakness: if the contact becomes over-compressed, it can suffer from cold setting and permanent deformation. As a result, this type of contact is not recommended for high-reliability applications, where consistent performance and durability are required.

As an advancement on traditional contact technologies, Smiths Interconnect offers the **Hypertac® Hyperboloid contact**, a high-performance solution designed specifically for harsh environments. Originally developed in the mid-1950s to address electrical intermittencies caused by high vibration in rail applications, the Hypertac® contact system has since become renowned for its reliability in demanding applications. The Hypertac® contact features a hyperboloid-shaped basket made from wires strung at angles to the axis of the socket. These wires are plated with electroless nickel and gold, with a gold thickness of 50 microns. When the male pin is inserted into the basket, the wires stretch around it, creating a high number of redundant linear contact points. These contact points provide a low-resistance electrical path between the pin and the basket.



Hypertac® Hyperboloid contact

Because of its design, the Hypertac® Hyperboloid contact has a higher current rating than comparably sized contacts, and it is rated for up to 100,000 mating cycles. This makes it particularly suited for applications that demand high reliability, such as those exposed to shock, vibration, and thermal extremes. The reliability of the Hypertac® contact system has been recognized in industries such as aerospace, defence, space, medical, and test applications. Over the years, as the Hypertac® contact technology has been miniaturized, its exceptional performance has made it the contact of choice for high-reliability applications across a variety of sectors.

Smiths Interconnect KVPX Series

Smiths Interconnect's KVPX connector system integrates the Hypertac® Hyperboloid contact technology to deliver a rugged and reliable solution for harsh environments. These connectors are designed for use in defence, aerospace, and high-speed applications, where connectors must withstand extreme conditions like vibration, shock, and thermal cycling. Smiths Inteconnect KVPX connector uses space-qualified 0.4 mm hyperboloid sockets, which offer exceptional resistance to fretting corrosion due to the multiple linear contact points and low insertion forces. The self-wiping action of the contact helps ensure reliable electrical performance, even in the most challenging environments.

KVPX connectors meet the high-speed electrical requirements of VITA 46 and VITA 48 standards, for embedded systems in aerospace and military applications. These connectors are capable of data speeds up to 16 Gbps for differential signals and up to 8 GHz for single-ended signals. In addition, they exceed vibration standards, with successful tests showing they can withstand up to 15 Grms of vibration and 100 Gs of shock, surpassing the requirements set by VITA 47. Smiths Interconnect KVPX system is rated for over 4,000 mating cycles, making it a robust choice for high-reliability applications.

Fretting corrosion remains a significant challenge in connectors used in rugged environments, but it can be effectively mitigated through a combination of design improvements, proactive maintenance, and advanced technologies such as the Hypertac® Hyperboloid contact. Smiths Interconnect's KVPX connector system, utilizing the Hypertac® contact technology, provides a reliable solution for high-reliability applications in aerospace, defence, and other demanding industries.

For more information on Smiths Interconnect's KVPX connector series, please contact your local Smiths Interconnect Sales team, or visit www.smithsinterconnect.com

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