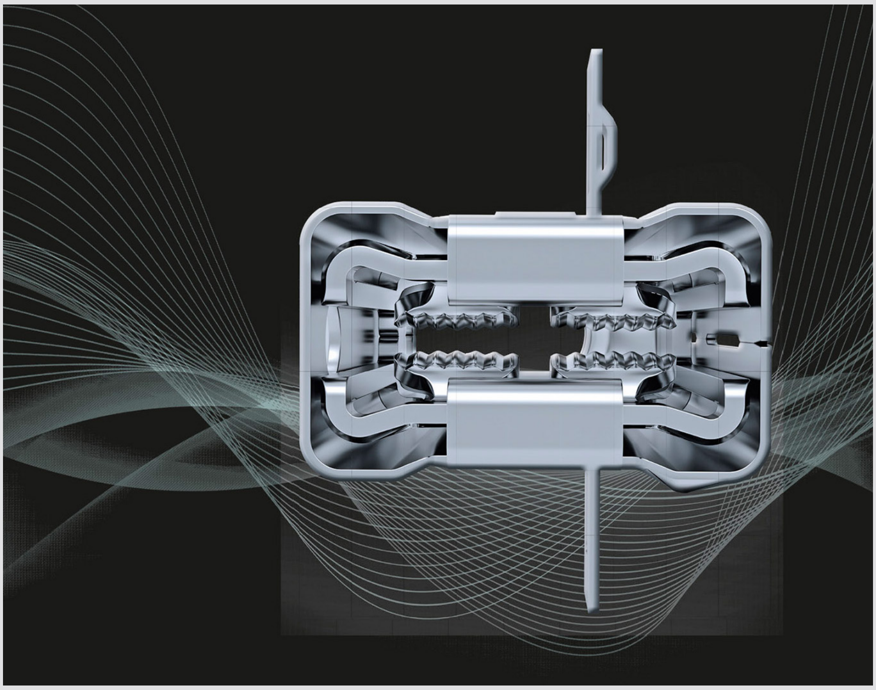
LITEFORCE CONTACT TECHNOLOGY

High pin-count automotive connectors with reduced insertion force and increased current rating or higher vibration resistance

Author:

Michael Leidner
Senior Principal Research & Development, Automotive



CONTENTS

1 | EXECUTIVE SUMMARY

Automotive innovation, driven by environmental, safety and lifestyle requirements, means that manufacturers are putting more and more electronic content in their vehicles with ever increasing numbers of electronic control units (ECU). This is leading to an increasing use of high pin count connectors whose assembly require greater levels of manual force. This additional physical strain placed on workers can cause ergonomic discomfort in the workplace and long term worker health issues with the resultant lost working time and potential industrial relations issues.

LITEFORCE is a new terminal design that helps address the conflict between technological requirements and manual workers' health. It's new "wave" form contact technology can facilitate connector mating forces by up to 52% compared to traditional "sphere-against-flat contact geometry". At the same time, it has the potential to increase the current capacity by up to 26 % as well as significantly increase vibration resistance.

2 | INTRODUCTION - THE CHALLENGE OF HIGH PIN COUNT CONNECTORS

Modern automotive electronic control units (ECUs) can require more than 300 electrical connections. However, such a high pin-count connector would require considerable engagement force and physical effort from assembly line workers. Over time this could lead to repetitive strain injury and loss of working time. In addition, manufacturers need to ensure that this physical effort does exceed what is permissible by local labor unions.

In order to reduce the physical effort of assembly line workers, such high pin count interfaces are achieved by grouping the total number of connections into multiple separate connectors. However, each module may still require a mechanical mating assist feature, such as a lever. In addition, the mounting position of connector interfaces in the vehicle is often difficult to reach and engaging connectors can pose a challenge to assembly line workers.

The challenge, is therefore how to facilitate the required high pin count connectivity without placing excessive physical strain on workers and without compromising the mechanical or electrical performance of the interconnection.

3 | HERTZIAN-STYLE CONTACTS AND THEIR LIMITATIONS

Traditionally, the electrical and mechanical contact between the mating partners (i.e. receptacle terminal and tab) is established by a spherical shape pressed against a flat, rectangular tab. Around the world, this is known as the "Hertzian-style" contact and is the standard contact design for tin-plated receptacle contacts, mated with solid rectangular tabs.

The Hertzian-style contacts are well established and understood. In order to establish a reliable electrical interconnection, the sphere-against-flat contact design requires a comparatively high normal force which permanently presses the spherical area against the flat tab surface.

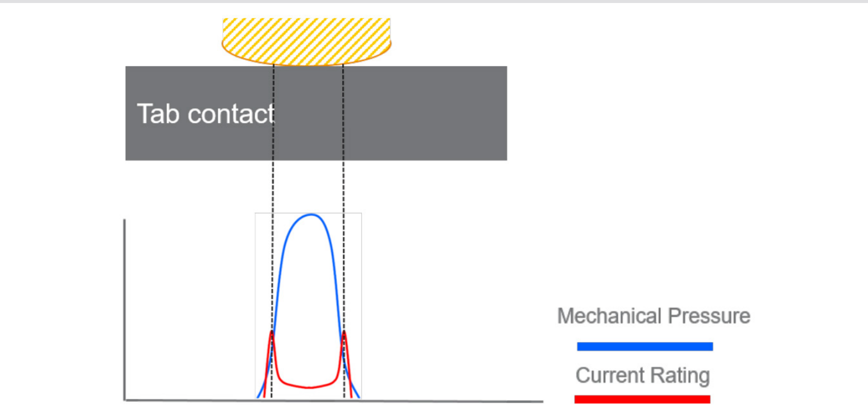


Fig. 1: Hertzian sphere-against-flat interconnection

It is exerted by the terminal's spring beams. The contact normal force is needed to break through the tin oxide layer which quickly forms on tin plated surfaces. This local removal of tin oxides is necessary to bring the metal lattices of terminal and tab in direct contact. In addition, a high normal force is needed to ensure that the interconnection has a low electrical resistance and a high vibration resistance.

Due to the high level of contact normal force, the areas of maximal load and the electrical interconnection (current flow) do not coincide. This can be seen in the two curves in Fig. 1. The current rating, shown by the red curve, reveals that the optimum area for current flow is a somewhat ring-shaped zone encircling the maximum load area. In this ring-shaped zone, the so-called "a-spots" (surface asperities establishing the real contact area electrical) carry the maximum electrical load. Fig. 2 shows the effect from above.

An understanding of the functional principle of the Hertzian-style contact shows that a simple reduction of the contact normal force will not work. If the force applied to the tab is insufficient, the tin oxide layer will not be removed, the electrical resistance will increase, and the vibration resistance will be reduced. A solution to the increased insertion forces associated with high pin-count connectors can therefore not be achieved with Hertzian-style contact.

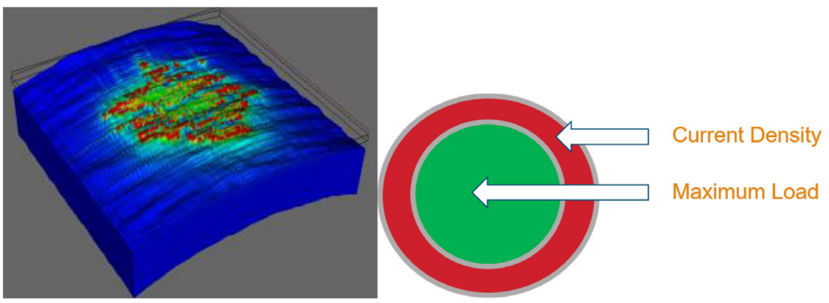


Fig. 2: Top-down view of a sphere-against-flat contact with maximum mechanical load (green) and maximum current rating areas (red)

The Hertzian-style contact also brings another disadvantage when deployed in automotive applications. If the interconnection between terminal and tab is subject to relative movement (e.g. caused by temperature changes) and/or vibration (another key challenge of automotive applications), the mechanical interconnection will be maintained longer than the electrical interconnection.

Shear traction and stick/slip effects can move the sphere geometry sideways or back and forth. During this displacement movement, the "a-spots" in the narrow ring-shaped current flow zone can break up along with the level of the lateral displacement because the level of adhesion is lower in the peripheral zone. In addition to increased mechanical wear this will cause the electrical resistance to rise. In extreme cases, it can lead to a complete loss of the electrical connection.

Put simply, for automotive applications requiring high pin-count connectors the Hertzian-style contact has a number or limitations when it comes to resolving the issue of increased insertion forces and excessive physical strain.

4 | WAVE FORM RECEPTACLE CONTACT GEOMETRY

TE Connectivity (TE) has developed an innovative terminal design that combines a spring beam design with a wave structure-based contact geometry that reconciles the paradox of lower insertion forces and durable high pin count connectors.

In order to reduce the contact normal force, two key technical requirements need to be fulfilled:

1. The tin oxide layer on the corresponding contact areas needs to be broken-up.
2. The areas where the a-spots form need to be enlarged because the constriction resistance, limiting the current, depends on the total surface for the electrical connection. To achieve the maximum current carrying capacity and vibration resistance requires that the right amount of pressure is applied exactly where the a-spots are established.

The initial approach to a modified terminal beam design followed the principle of avoiding separation between the areas of maximum load and maximum current rating. The terminal selected for development was TE's globally established and proven automotive-grade MQS.

The first step of modification was a contact geometry without a centered maximum load area as shown in Fig. 3. This experimental sphere-against-dimpled flat contact resulted in a higher current rating peak (cf. Fig. 1) by ensuring the maximum load and current areas coincided.

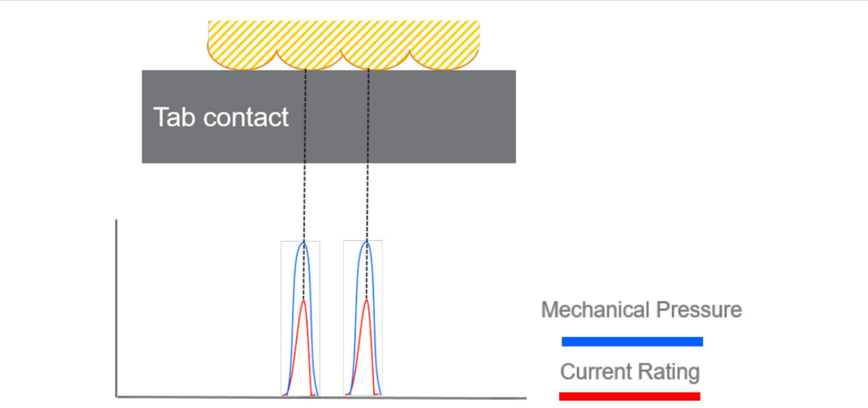


Fig. 3: Modified sphere-against-dimpled flat contact with higher peak current rating areas coinciding with the mechanical load

Although this suggested that the underlying principle was viable, from a practical point of view it was clear it would be a challenge to ensure a precise match of the two contact partners during connector engagement in a manufacturing environment. The risk of a potential mismatch appeared particularly high in dense high pin count applications with minimum tolerances.

The second approach was a spherical contact with a circular wall shape and a dimple in the middle. By avoiding the maximum pressure zone in the middle of the sphere, maximum load and maximum current rating again coincided. The rim of the circular wall also proved an efficient way of breaking open the tin oxide layer. During this phase of development, the first of the two technical requirements had been achieved.

Allowing for a potential axial and/or radial misalignment between terminal beam and tab, an even pressure distribution between the circular rim of the dimpled sphere and the flat tab surface could not always be ensured. This meant that half the incremental benefit could potentially be lost due to an angled contact pressure.

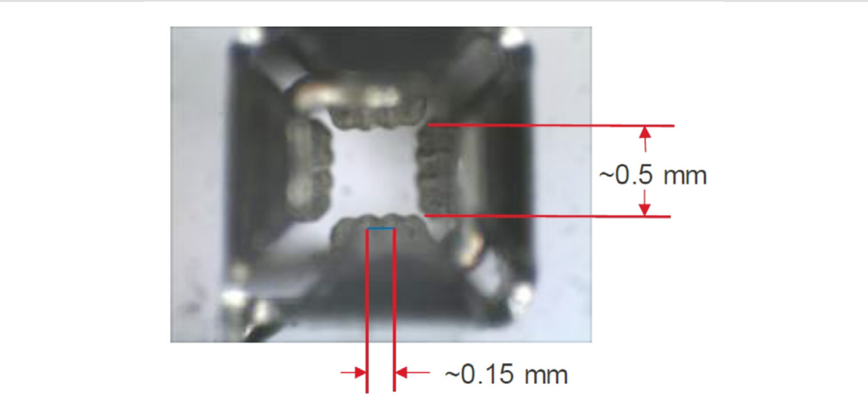


Fig. 4: Modified MQS terminal with two angled wave-structured beams

The solution was finally found in a sinusoidal wave structure, as shown in Fig. 4. During the connector engagement, the wave rims break up the tin oxide layer and bring the tin metal lattices in direct contact. Since the areas of peak mechanical load and peak current rating coincide, a lower contact normal force is sufficient to establish the optimum electrical and mechanical interconnection. See [1, 2, 3] for further details.

This innovative wave structure proved a highly effective way of breaking-up the tin oxide layer - depositing the oxide in the wave "troughs" where they do not cause disruption. In addition, the contact geometry features four waves, ensuring a sufficient number of maximum load/current areas and a-zones are formed even in the case of an axial misalignment between the terminal beams and the flat tab.

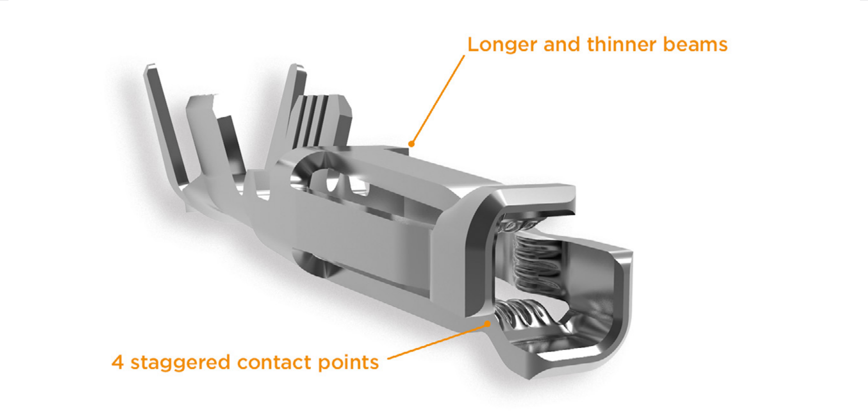


Fig. 5: Modified MQS terminal with longer, narrowed beams, exerting a lower contact normal force onto the two angled beams with the wave structure contacts

Provided at least two waves on each beam are in contact, the electrical and mechanical requirements are achieved.

Finally, in order to reduce the contact normal force, the terminal spring beams were narrowed and extended and the points of contact staggered (Fig. 5).

This new wave structured contact geometry combined with the new spring beams comprises TE's innovative LITEFORCE terminal technology that reduces the insertion force required for high pin-count connectors while at the same time increasing their current rating somewhat or alternatively (without reduction of the contact normal force) increasing vibration resistance and current rating notably.

5 | LITEFORCE - ELECTRICAL AND MECHANICAL PERFORMANCE

The following section provides and overview of the results demonstrating the benefits in terms of reduced insertion force, higher current rating and increased vibration resistance achieved by the MQS terminal modified with the LITEFORCE contact technology.

In tests, the LITEFORCE contact technology revealed several advantageous characteristics in comparison to standard sphere-against-flat contacts:

Either

- Insertion force could be reduced by up to 52 %.
- Current carrying capacity went up by 16 %.
- Vibration resistance remained the same.

Or

- Insertion force remained the same.
- Current carrying capacity went up by 22%.
  For other terminals (AMP MCP) current capacity went up by up to 25%.
- Vibration resistance improved by one vibration class. For other terminals (AMP MCP) vibration improvements of up to 2 classes have been achieved.

This can lead to the following benefits to automotive manufacturers:

5.1 | REDUCED WORK PLACE INJURIES AND LOST WORKING TIME

The lower mating force can significantly reduce the physical strain placed on manual workers working with high pin-count connectors. Ultimately this can lead to fewer work place injuries and lost working time. In addition, it can help automotive manufacturers remain in compliance with labor regulations limiting the maximum permissible physical stress in the work place.

5.2 | SIMPLER AND LESS COSTLY CONNECTOR DESIGN

Depending on the pin-count of the connector, the lower mating force can reduce the need for costly installations aids, such as levers. In addition, contact lubrication and its potential long-term effects can be avoided completely.

5.3 | INCREASED VIBRATION RESISTANCE

The four redundant contact areas ensure that the impact of axial misalignment between the terminal beams due to vibration is reduced. In addition, if the contact normal force is left unchanged, the wave structure technology can greatly increase the vibration resistance in comparison to a standard sphere-against-flat contact (Table 1).

Tests	Reference	Variant A: Mating force reduction	Variant B: Enhanced current and vibration performance
Description	Original MQS terminal [2)]	MQS terminal with reduced normal force and LITEFORCE geometry	Terminal with standard normal force and LITEFORCE geometry
Insertion force (1 cycle)	4.3	2.1 (-52 %)	4.2 (-3 %)
Retention force	3.4	2.3	3.3
Current carrying capacity (0.75 mm²)	100 %	116 %	122 %
Vibration Class SG1	Ok	Ok	Ok
Vibration Class SG2	No	No	Ok

Table 1: Test results of modified MQS terminals with lower contact normal force (variant A) versus unchanged contact normal force (variant B) and the original MQS terminal.

6 | SUMMARY AND OUTLOOK

TE's LITEFORCE contact technology has been developed for use in high pin-count connectors. It can meet and exceed the mechanical and electrical performance of standard Hertzian contacts. The wave structure contact geometry on the terminal beams was tested and verified on a modified MQS terminal. Other terminal deployments of the wave from technology are already in the market and in series applications.

LITEFORCE contact technology can resolve the potentially conflicting goals of ensuring assembly line workers' health and meeting technical performance requirements of connectors as well as potentially reducing the complexity and cost of connectors by eliminating the need for additional mating assist features.

7 | REFERENCES

[1] Leidner, M, Myers, M., Schmidt, H., Schlaak, M.: A New Simulation Approach to Characterizing the Mechanical and Electrical Qualities of a Connector Contact. Eur. Phys. J. Appl. Phys. 49, 22909 (2010)

[2] Leidner, M., Schmidt, H., Myers, M.: Simulation of the Current Density Distribution within Electrical Contacts. Proc. 56th HOLM Conf., 2010, pp. 505 – 513

[3] Leidner, M., Myers, M., Schmidt, H., Sachs, S., S. Thoss, S.: Enhancing the contact interface by matching the surface pressure and current density distribution. 27th International Conference on Electrical Contacts, Jun 22-26, 2014, Dresden, Germany

ABOUT TE CONNECTIVITY

TE Connectivity (NYSE: TEL) is a $12 billion global technology leader. Our commitment to innovation enables advancements in transportation, industrial applications, medical technology, energy, data communications, and the home. TE's unmatched breadth of connectivity and sensor solutions, proven in the harshest of environments, helps build a safer, greener, smarter and more connected world. With 75,000 people – including more than 7,000 engineers – working alongside customers in nearly 150 countries, we help ensure that EVERY CONNECTION COUNTS – www.TE.com

TE Connectivity Germany GmbH
Ampèrestrasse 12-14
64625 Bensheim | Germany

www.TE.com