A PRIMER ON SMALL WIRE CRIMPING

Overcoming the challenges of small wire crimping

Introduction

Trends toward miniaturization and electronification, especially in the automotive industry, are driving increased demand for small wire terminations. TE Connectivity (TE) defines small wires as anything that has a wire cross sectional area of 0.35 mm^2 (22 AWG) and smaller. This article will focus on open-barrel F-crimps. Approximately 45% of wires in a typical mid-size car are 0.35 mm2 or smaller, and that percentage is expected to increase to 72% in the near future. Harness makers must be prepared to crimp higher volumes of small wires to keep up with these trends.

Small wire terminations present unique quality challenges due to their sizes. This article will describe some of these challenges, list common ways to inspect for quality, and outline how to overcome the challenges of small wire terminations.

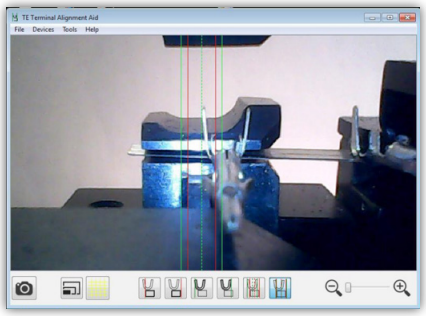
Comparing the size of a crimp with 0.17 mm2 wire cross sectional area to that of a U.S. dime

Small Wire Termination Challenges

There are several challenges inherent to small wire crimping due to the small size of the wire, terminal, and tooling. This is not a complete list, but users see these issues most often in small wire crimping.

1. Difficulty aligning the terminal over the anvil

   Setup issues and tooling quality can contribute to difficulty aligning the terminal over the anvil. Since the anvil is smaller, the target for the terminal is smaller. Applicator feed adjustments are more critical because smaller adjustment increments are needed to place the terminal where it needs to be.



Terminal misaligned over the anvil

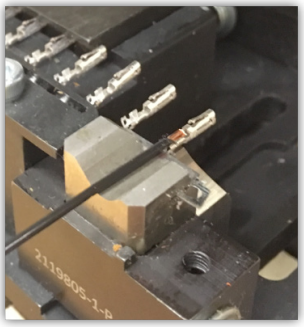
2. Terminals are easier to deform on the carrier strip

   Small terminals are easier to twist or bend on the carrier strip because the tab holding them to the strip can be very weak. Storing, routing, and feeding terminals can deform them on the carrier strip if users do not follow proper storage, handling, and setup procedures.

Terminal catching on a terminator guard

3. Wire memory, camber, or rigidity issues

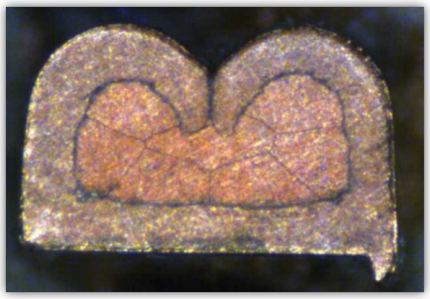
Small wires are more susceptible to memory issues and are more difficult to straighten. In addition, small wires may droop excessively if users or machine grippers hold them too far from the stripped end.



Placing a wire in the terminal

4. Flash issues

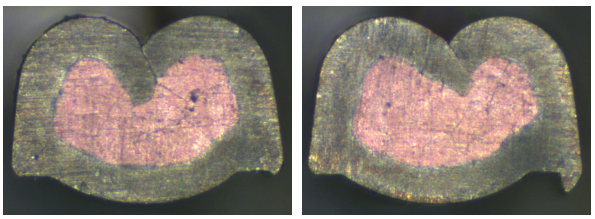
Crimp quality specifications typically relate the amount of allowable flash to the terminal material thickness. Terminal manufacturers typically use thin material to manufacture small terminals, so small amounts of flash constitute a higher percentage of terminal material thickness. Flash that would barely be noticeable on a larger terminal is significant on small wire terminals.



Flash on a 0.17mm² crimp

5. Crimp inconsistencies

Inconsistencies in terminal symmetry and flash are more common on small wire terminations. Small variations in the crimp tooling can have a significant impact on the resulting crimp cross section.

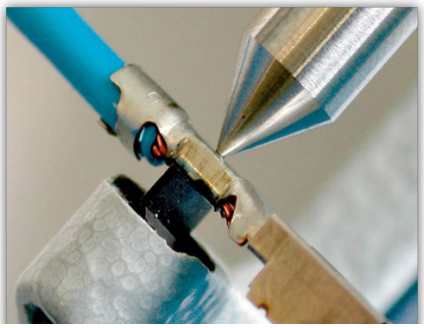


Two cross sections from the same batch showing inconsistencies in symmetry and flash

Inspecting Small Wire Terminations

Traditional inspection methods apply to small wires and large wires alike. Crimp height inspection, tensile tests, visual inspection, and cross sections are all important. We will briefly discuss the first three and focus more on cross sections.

Crimp height inspection: Inspectors can use crimp height micrometers to inspect small wire terminations, but often involve some operator skill to measure crimp height accurately. Bench or machine measuring stations are typically more accurate and repeatable than micrometers, especially with small wires. Inspectors should check crimp height periodically during production runs to ensure consistency throughout the run.

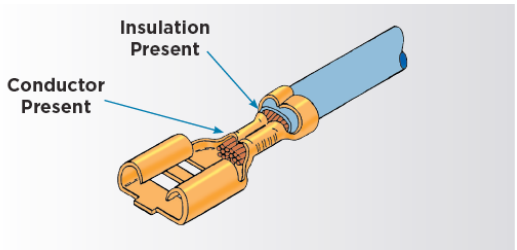


Crimp height inspection with crimp height micrometers

Tensile tests: Inspectors can typically perform tensile tests for small wire terminations on the same equipment used for larger wires. The clamps must be able to grip the terminal and wire without slipping. Inspectors must take care to disengage the insulation crimp on small wire terminations if the tensile test requires it. Many tensile test requirements specify the rate at which the tester pulls the specimen, so a motorized tester may be required.

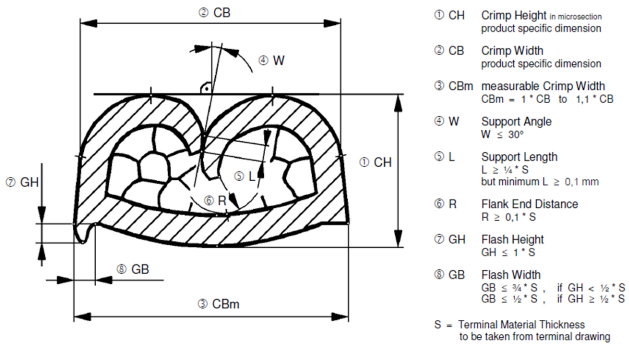
Tensil pull test

Visual inspection: The visual inspection criteria are the same for small wire terminations as they are for large wire terminations, but they can be much more difficult to see. Ample light and magnification are often required to perform an adequate visual inspection. Harness manufacturers must train their operators in the visual identification of crimp features that indicate whether the crimp is acceptable. TE publishes a poster for visual crimp inspection, which can be found at tooling.te.com and searching for part number 65780-4.



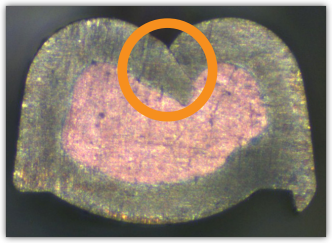
Excerpt from the visual crimp inspection poster

Cross sections: Cross sections provide the most complete view into crimp quality. Industry standards such as TE Connectivity specification 114-18022, USCAR-21, and UL 486A-486B define measurable requirements for crimp cross sections and different standards can have different requirements for the same terminations. Users must understand what the requirements are for their particular applications. Cross sections can be very difficult to create for small wire terminations and high quality equipment is required to create good cross sections. When we analyze cross sections for small wire crimps, the two most problematic areas are crimp asymmetry (as measured by the support angle, support length, and flank end distance) and flash. Several factors contribute to each of these issues, and this white paper will explore them in detail.



Crimp cross section measureable requirements from TE Connectivity specification 114-18022

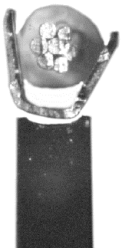
Asymmetry



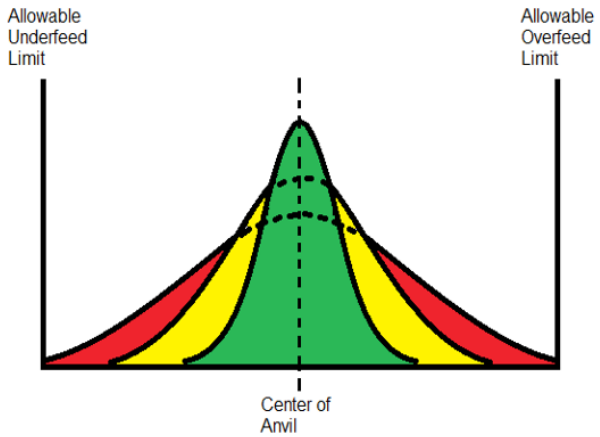
Terminal cross section exhibiting asymmetry

Asymmetry in excess of what specifications allow can reduce electrical or mechanical performance of the crimp, contribute to Crimp Quality Monitor variability, and reduce tooling life. It is important to note that some level of asymmetry and variation in symmetry from one crimp to the next is normal and will not affect crimp performance. Several variables that contribute to asymmetry are difficult or impossible to control. For example, the orientation of the wire strands can affect crimp symmetry. Harness makers should follow the specification requirements and not try to achieve perfect symmetry on every crimp. The main areas of focus in reducing asymmetry are applicator and terminator setup, tooling quality, and tooling condition. If the terminal is overfed, underfed, or twisted over the anvil, the cross sections will very likely exhibit asymmetry. Terminal overfeed and underfeed conditions are caused either by a bad terminal feed setup or poor terminal feed performance. Operators should check and adjust the terminal feed as needed every time they setup the applicator for a production run. Accurate and repeatable feed adjustments are very important to center the terminal over the anvil. After operators place the terminal over the anvil, they have to rely on the terminal feed to repeat the position of the terminal for every subsequent crimp. The quality of the terminal feed is crucial to achieving good feed repeatability. TE mainly uses pneumatic or servo terminal feeds for small wire applications because they have superior feed repeatability to mechanical feeds. Pneumatic feeds are more repeatable because they typically have hard stops at the ends of their stroke and users can throttle the stroke velocities for a smoother feed. The chart below shows feed repeatability distributions for three different classes of feeds. Higher quality pneumatic feeds (green distribution) have a Cpk around 2.0 for small wire applications. This distribution shows that, with proper setup, high quality pneumatic feeds will place the terminal over the anvil very consistently. Medium quality pneumatic feeds and high quality mechanical feeds (yellow distribution) have a Cpk around 1.4 for small wire applications. If operators can center the terminal perfectly over the anvil, the yellow distribution should be adequate, but this is extremely difficult to do in practice. Low quality feeds (red distribution) have a Cpk around 0.8 for small wire applications. Low quality feeds can exceed the feed limits even if operators are able to center the terminal perfectly over the anvil. Consistent crimps require high quality pneumatic feeds.

Misaligned terminal

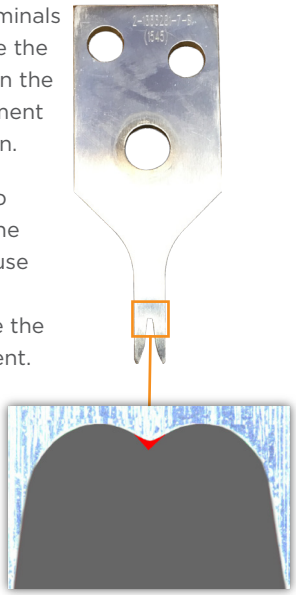


Twisted terminal



Applicator feed repeatability distributions

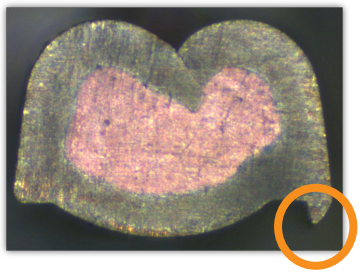
If the terminal is twisted over the anvil, it is likely that there is an issue with the terminal routing or applicator feed track setup. Handling terminals during transport and loading terminals into the applicator present the opportunity to deform the terminals. It is important to remove the deformed terminals before beginning the crimping process. In addition, terminals passing through guards can catch and twist on the carrier strip. Check to make sure terminals have adequate clearance through the guards. If operators adjust the applicator feed track too tightly, the track can twist the terminals as they pass through it. Make sure the feed track allows free movement in the feed direction and minimal movement perpendicular to the feed direction.



Crimper tip wear

Another significant cause of crimp asymmetry is crimper tip wear. The crimper tip wears over time with use and can break down to the point where it is no longer able to guide the crimp legs into consistent alignment. If the crimper tip has worn, it may allow one terminal leg to pass beneath the other at the interface point, which will cause asymmetry. If terminal asymmetry shown in cross sections is consistent on every crimp, it is likely a sign of a setup issue. Check to make sure the terminal is centered over the anvil and is not deformed on the carrier strip. If the asymmetry occurs periodically during the crimping process, it is likely a sign of a worn crimper or a poorly performing applicator feed. Check the condition of the tooling or feed and replace as needed with high quality equipment.

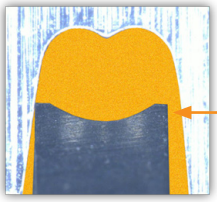
Flash



Terminal cross section exhibiting flash

Flash, also referred to as "burr", is the terminal material that extrudes between the crimper and anvil during the crimping process. Harness makers should reduce flash where possible because it can cause several issues. Flash may interfere with a connector housing during insertion, it may cut or damage seals or heat shrink tubing placed over the terminal, or it may break off the terminal and become conductive debris. Just as it is with symmetry, some level of flash will not affect crimp performance in many applications, so it is important to follow the requirements outlined in the crimping specifications. The goal is generally to minimize the amount of flash, but not necessarily eliminate it.

As was mentioned earlier, most crimping specifications allow a certain height and width of flash based on the terminal material thickness. As the terminal material thicknesses decrease, the amount of allowable flash also decreases. Flash forms because of gaps between the crimper and anvil. Some gap is necessary to prevent tool crashing at various crimp heights, but smaller crimping applications require smaller gaps. The image below shows the amount of allowable gap to cause significant flash as a function of crimp width. Please note that there are other factors involved in the production of flash, but these are general guidelines for tooling geometry.



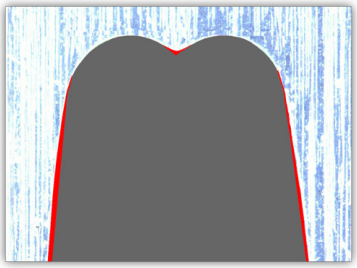
Crimp Width	Gap to Cause Significant Flash
1.4 mm [.055"]	0.08 mm [.003"]
1.0 mm [.039"]	0.05 mm [.002"]
0.8 mm [.032"]	0.03 mm [.001"]

Allowable tooling gap as a function of crimp width

The three factors that users can control most easily in an effort to reduce flash are tooling quality, tooling wear, and tooling alignment. Using quality crimp tooling is very important for all crimping applications, but is necessary in small wire crimping. The ability to control tooling gaps to this level of precision requires a combination of design and manufacturing methods that only certain tooling manufacturers can produce. Substandard tooling does not have the dimensional control required to minimize the tooling gaps while avoiding interference.

There are two types of flash performance: initial flash performance and flash performance over time. If tooling manufacturers design and manufacture the tooling properly, it will have good initial flash performance. If this tooling, however, does not have the proper material and plating selections, it will not have good flash performance over time. Tooling wear is the most significant factor in flash performance over time. In addition to the crimper tips, crimpers also wear on the sides where the terminal legs contact them. This wear happens over time, so crimpers will show progressively more flash over the life of the tooling.

Wear on the sides of the crimper is particularly important because it contributes doubly to the tooling gap. Since the wear occurs on both sides of the crimper, the total tooling gap contribution is double what it is on one side if the crimping process pushes the entire gap to one side. This is another reason why it is crucial to use high quality tooling. All tooling will wear over time, but high quality tooling typically lasts much longer than low quality tooling. High quality tooling has the proper material and plating selections for long-term performance. To avoid frequent, costly tooling changes and potential quality escapements, only use high quality tooling.

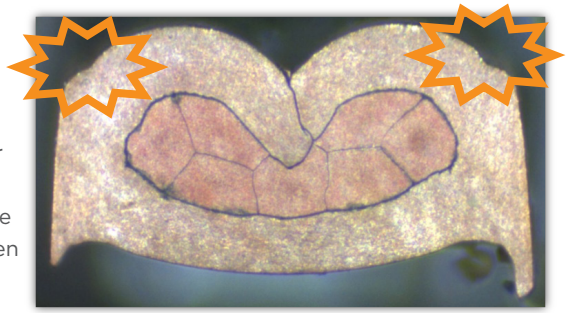


Crimper wear (red areas)

Tooling alignment is another significant factor in flash performance. Users should avoid allowing the crimping process to push the entire gap to one side of the crimper and anvil interface, and this effort starts with tooling alignment. Take, for example, a situation where the crimper and anvil for a terminal with 1.4 mm [.055”] crimp width has a total tooling gap of 0.1 mm [.004”]. If the crimping process pushes the entire gap to one side, the terminal will likely exhibit significant flash.

If the tooling maintains proper alignment throughout the crimp and divides the gap evenly on both sides, the terminal will likely not exhibit significant flash. Users should align the crimper and anvil at setup, which requires following an alignment procedure. Applicator tolerances are typically not good enough to allow a user to mount the crimper to the ram without using an alignment procedure.

One final note on flash is the occurrence of crashing. Because smaller tooling requires smaller gaps, the distance between the tooling separation at crimp height and at interference is small. Small wire tooling can be easier to crash than tooling for larger wires if users do not follow proper procedures. When adjusting the crimp height on the applicator, users should always start high and work their way lower. In addition, users should never cycle the applicator without a terminal and wire over the anvil. Finally, always use a ram collar when the applicator is not in use to avoid accidental contact between the crimper and anvil. Some sure signs of crashed tooling are excessive flash and shoulders on the crimper area of the cross section. Users should replace crashed tooling as soon as they detect it.



Terminal cross section showing evidence of crashing

Wire Placement Issues

Small wires are typically much more difficult for users or machines to locate in the terminals than larger wires are. Wire flexibility and camber are the main causes of wire placement issues. If users or machine grippers grasp the wire too far from the stripped end, the wire can droop to the point where it is very difficult to place consistently in the terminal. Users and machine grippers should grasp the wire as closely to the stripped end as is safely possible. Wire is usually stored in a coiled fashion, whether in barrels or on spools, and the process of coiling the wire induces a curvature, or camber into the wire. The smaller the core diameter, the smaller the radius of camber, and the more difficult it is to remove the camber. The wire can take a set or memory over time to the camber that can be difficult to remove. Users should keep the wire as straight as possible so they can place it in the terminal in a repeatable manner. Wire camber issues are usually more noticeable toward the ends of wire barrels or spools because the inner windings are at smaller radii than the outer ones. Many lead makers have wire straighteners on the wire infeed, so it is critical to adjust these straighteners to remove the camber. TE also recommends using wire barrels or spools with the largest core diameters too minimize the amount of initial camber in the wire.

SUMMARY

Small wire crimping presents a unique set of challenges, but harness makers can overcome these challenges with the help of the right application tooling partner. TE Connectivity works diligently to maximize the quality of its tooling so wire harness manufacturers can produce the best crimps.

Here are six keys to high quality small wire crimps:

1. Use only high quality tooling

High quality tooling includes the applicator, terminator, crimper, and anvil. The applicator must be easy to set up and must maintain consistent quality. Users must select a crimper and anvil designed and manufactured for initial quality as well as longevity.

2. Set up the applicator feed properly

Users must center the terminal over the anvil and the feed must be able to maintain this placement. The feed track must guide the terminals without deforming them on the carrier strip.

3. Align the tooling properly

Users must align the crimper and anvil with each other when they are installing them into the applicator. Simply mounting the crimper to the ram is not sufficient and users must perform an alignment procedure.

4. Be careful handling terminals

Terminals are very easy to deform on the carrier strip during transportation and storage. Practice good reel maintenance and handling to avoid any deformation.

5. Monitor tooling condition

All tooling wears over time and will eventually produce crimps that do not meet specifications. By monitoring tooling condition, users can replace tooling before it causes quality issues.

6. Beware wire placement issues

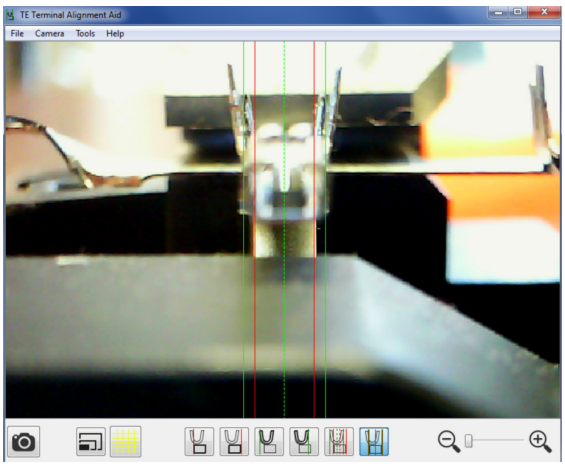
Wire memory or camber is a significant issue when trying to place the wire in the terminal. Try to use the largest diameter wire core and use wire straighteners to minimize wire memory effects.

What is EYE Check?

EYE Check is a terminal alignment aid for applicators. It utilizes a miniature camera system that can be installed in a TE 3K, 5K, or GII Terminator to aid in applicator feed setup and terminal alignment. The tool utilizes a mounting block for side feed applicators. The camera contains software that allows a user to connect to a PC or directly into a TE CQM II module.

Why is it important?

- Most crimping issues relate to terminal feed
- Proper terminal feed is a major contributor to longer tooling life
- Proper feed increases machine up-time by eliminating adjustments during production
- Proper feeding reduces scrap



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