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Tang Termination

by

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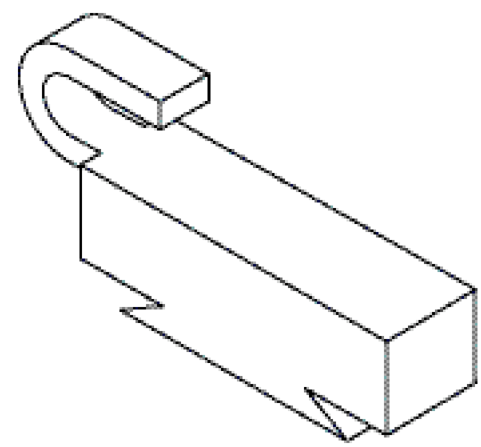
Tang termination is a method of joining film insulated magnet wire (also called winding wire) without prior removal of the film insulation, as well as un-insulated electrical wires, to a very simple and inexpensive terminal, using the Tang Fusing process. Tang Fusing automatically removes the magnet wire's insulation during the fusing process.



Tang Type Commutator Segment

History

Fusing was originally developed in the early 1950's for use in the manufacture of small universal or D.C. electric motors. At the time, electric motor production for mass markets was quite small. Armatures were machine wound with low temperature film insulated magnet wire, and the lead magnet wires were inserted into slots in the commutator, by hand. The armature's commutator was then dipped into a solder bath. The solder burned the lead wire's film insulation away, and joined the wires to the commutator. This worked well in small production, and is still being done in some small factories.

As production increased and higher temperature film insulated magnet wire insulation systems became available, a faster and more reliable system was needed. A fusing method was developed to connect the film insulated lead wires in the commutator's slot. It is still used today for high performance motors. The method of fusing wires into slots is also used for other limited applications. We will discuss the fused slot termination method in this paper.

As motor production increased, manufacturers wanted to eliminate the need to place the armature's lead wires into slots. Winding machines were developed to place the wire around pins or hooks, to which the wires were then soldered.

Soldering was then eliminated by the introduction of commutator fusing of tangs. It is used today to manufacture at least 85% of all the universal or D.C. electric motor armatures produced in the United States, and at least 80% for the rest of the world. Fusing of slotted commutators increased the statistics to over 98% of the U.S. and 90% for the rest of the world. Fusing is the accepted method, used worldwide, for electric motor production.

In 1959, a machine specifically for commutator fusing (both tang and slotted) was patented (U.S. patent 3,045,103). The commutator fusing machine patented in 1959 is basically the same machine used throughout the world today. The new versions differ only in the types of electronics used to control the fusing time, fusing pressure and fusing current.

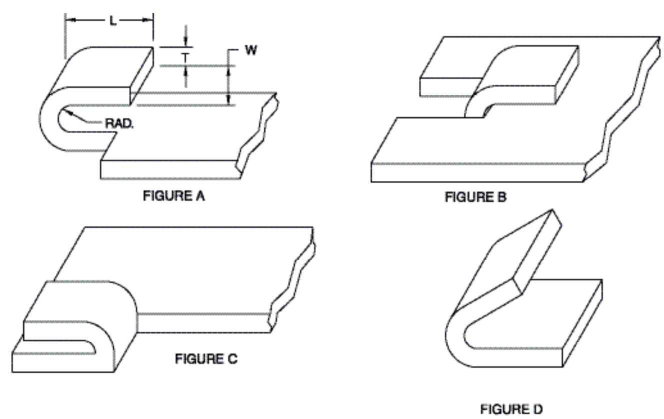
In the early 1960's, fusing machines were developed for other than commutator fusing. Most were for terminating bobbin windings to tang terminals, set in the bobbin's plastic spools. As time went on, tang termination systems were developed for attaching both bare stranded wire and magnet wire to electric motor brush boards, and resistance heating wire to stranded copper wire. Today, tang termination can be used instead of most crimped terminals, plus many applications where crimped terminals cannot handle the job.

Structure of the Tang

The tang terminal is normally formed from copper or brass, but is also produced in nickle, nickle alloys, various types of steel, etc. For tang termination purposes, the only part of the terminal we are interested in, is the tang. The other part of the terminal can be made any way the user wishes. The tang terminal can be a part of a commutator segment, bobbin termination system, printed circuit termination system, wire terminal, etc. Imagination is the only limit to the type of terminal and tang combination possible.

Normally, tang terminals are used with solid copper, copper alloy, silver, brass, or nickel film insulated magnet wire, in which the insulation is automatically removed during the termination's fusing process. It is also used with aluminum magnet wire, but a special, more complicated tang must be designed for use with this metal. A full discussion of tang construction for connection of aluminum or aluminum alloy magnet or stranded wires will be presented later in this paper. Bare solid and bare stranded copper wires are also terminated, as is copper or aluminum strip.

The tang terminal's shape is normally the same as a 'U' on its side. Sometimes the shape of a 'V' is used, but this shape has a tendency



Tang Terminals for Copper Wire

Fig. A shows a typical Commutator Tang.

L = the minimum length of the Tang from the Tang's end to the start of the radius.
T = the thickness of the Tang.
W= the width of the Tang.
R = the radius of the Tang's bend.

Fig. B shows the type of Tang terminal normally used on coil winding bobbins, terminal strips, etc.

Fig. C shows a Tang terminal that accepts the wire axially.

Fig. D shows a very simple Tang terminal made by just bending copper or brass strip.

to weaken fine wires during the termination process. The 'V' shaped tang will either cut into the wire being fused, or force the wire out of the front of the tang, while the tang is being closed.

The shape of the tang is very important. If not designed properly, it will weaken the termination. The width of the tang must be equal to at least the wire's diameter. The length of the tang, from the center point of its radius, should be about two wire diameters for the first wire under the tang. For each additional wire added, an additional wire diameter's dimensions must be added to the tang's length. This means that if four wires are placed under the tang, the length of said tang must be at least equal to about the diameters of five wires. The thickness of the tang must be equal to at least the wire's diameter.

If the tang's width is not larger than the wire's width, the tang can easily cut through the

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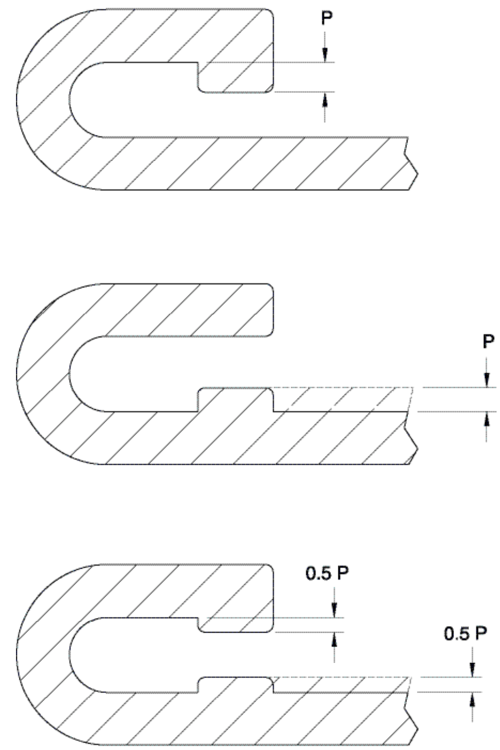
wires being terminated. On the other hand, if the thickness of the tang is not larger than the wire's width, the tang can be cut through by the wire, or sometimes the wires will be excessively flattened when fusing. If the length requirement is not followed, the tang will not close properly around the wires. This could cause an open electrical contact, loose wires, or susceptibility of the joint to corrosion. The radius of the bend of the tang must be at least equal to 0.8 times the wire's diameter. Another way to look at this dimension is a space at least 1.6 times the diameter between the top and bottom of the tang.

As you will notice from the above, the term "at least" is used. Any dimension larger than given for the tang's width and length are normally valid. However, reason must be used for excessively large dimensions. Too thick a tang will not properly conduct heat during the fusing process, while too large a radius in the tang's bend will not allow the tang to close properly around the wire.

When making the tang bend, excess metal will spew out of the edges of the tang. This must be removed, as well as any burrs on the inside edges of the tang, or the wires being terminated can be weakened or even cut.

The best material for use as a tang is copper. If very rigid material must be used, so that the terminal's other shapes can be accommodated, copper rich brass is the best choice. If the terminal is to be used with film insulated magnet wire, then the material must be able to conduct very large amounts of heat and current. The heat and current are applied during the fusing process. If uninsulated wire is used, then a higher resistance alloy can be used for the tang's material.

Non-copper alloys, such as nickel, stainless steel, and aluminum have been used for special tangs, with both insulated and uninsulated wires. A special fusing process must be used with tangs made of those alloys.



Cross sections of Tang Terminals specifically designed for use with soft alloys such as Aluminum. The Letter 'P' refers to the dimension in the column entitled "Height of Tang Projection for Aluminum Wire" which can be found on the Joyal Tang Terminal Design Chart.

Tang Construction for Aluminum Magnet Wire

Conventional techniques have long been known for fusing both insulated and uninsulated wires to tang type commutator segments and electrical terminals. Normally, the composition of the wire is copper or a rich copper alloy, but on occasion, steel, nickel, silver and/or their alloys have also been used. These metals are relatively hard, and cannot easily be deformed.

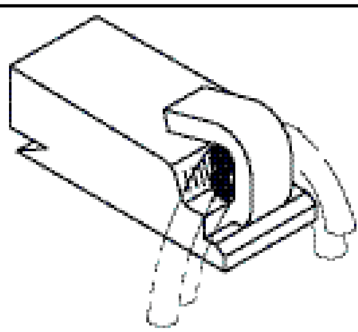
The tang engulfs itself around the wire, as it is closed. If the alloy of wire is not physically strong enough, it will be crushed to a point when the tang is mechanically closed, and crushed further and even sheared, when the fusing current is applied. Therefore, when fusing soft metals, such as aluminum, under a tang, the aluminum wire would be crushed to a point where it would be useless or even sheared, because it has lost all its body and cross section. By designing a tang that will absorb the mechanical pressure, we can fuse soft wires, such as aluminum, under the tang terminal.

The tang terminal for aluminum wire can be used with either solid or stranded wire, that is bare or insulated with magnet wire film. The fusing process automatically removes the insulation, while making an airtight joint.

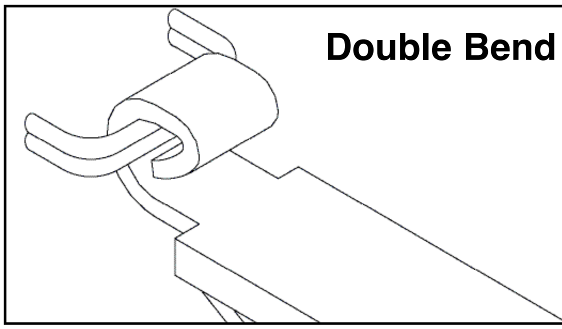
A problem might occur because of the possibility of electrolytic corrosion between the aluminum wire and the copper-rich tang. A partial solution is to coat the tang material with tin or, possibly, indium. This pre-coating of the tang material cannot guarantee the total elimination of electrolytic corrosion. The only way to obtain this guarantee is to after-coat or seal the fused joint, so that moisture and oxygen cannot reach it, and possibly assist in corroding it.

The preceding section on the structure of the tang relates to the design of the tang terminal for both copper and aluminum wires, but if the aluminum wires are used, the following must also be taken into account.

An enlargement must be included in the design of the tang terminal to absorb all pressures that are applied to the wire. As stated before, the wire is subject to both the mechanical pressure of closing the tang, and additional pressure during fusing. The wire is hot during fusing, and has much less mechanical resistance, so that it is crushed even more than when only mechanical pressure is applied at normal room temperature. The enlargement which must absorb this hot and cold pressure, is normally a part of the tang. Drawings that are part of this paper show some of the various configurations of the tang terminal with enlargements for absorbing this pressure. Notice the dimension ‘P”. This dimension can be found on Joyal’s tang terminal design chart in the column entitled “Height of the tang projection for aluminum wire”. The length of this enlargement or projection is normally not less than 0.9 times the wire’s diameter, but might have to be larger, depending upon the tang’s construction and support base. The other dimensions of the tang are the same as for the non-projection tang.



Drop Tang



Double Bend Tang

Special Tangs

There are two other moderately common special patented tangs, the Double Bend Tang and the Drop Tang.

The Drop Tang allows very large wires to be fused under a relatively small tang. This tang shape was designed for use is small automotive starter motors, but can be used for other applications.

The Double Bend Tang, is also patented, and has two different uses. One use is to pack a much larger number of different size wires into the tang, at the same time, without them possibly slipping out of the tang. The other use is to braze or solder the tang closed, when required, without the external addition of either brazing or solder alloy. Brazing or soldering alloy is coated on the inside of the tang.

Termination Process

The termination process is quite simple. The wire is placed under the tang, the tang is mechanically closed, and then fused.

The wire can be placed under the tang by hand, or automatically by machine. Various electric motor armature winding machines automatically hook the wire under the tang, while winding the armature. The same is true with coil winding machines, which automatically hook the wire to the tang during winding.

The wire can be placed under the tang without being wrapped around it. The connection will be as valid, if there is only one single wire under the tang, or if it is wrapped around the tang three or four times. When placing the wire by hand it is sometimes practical to loop it around the tang a few times. This stops the wire from falling loose during or prior to closing the tang.

Normally, the tang is closed at the same time fusing is taking place. On some automatic coil winding machinery, the tang is closed first, so the wires will not move, as the tang and its supporting structure are moved first from the coil winding station, to the fusing station. In this situation, the tang is not completely closed or the wires can be crushed. Usually, the tang is closed just enough to hold the wires.

Fusing and Surface Adhesion

Fusing is a method of joining low resistance metals with a type of resistance welding machine, but without appreciable distortion of the parts being joined. Normally, when copper or aluminum is resistance welded, it is drastically distorted. This does not occur in fusing. What actually happens in fusing, is that the parts are heated and pushed together until all the air between them is eliminated, and the high points of one part are pushed into the low points of the other, and vice versa. A surface adhesion contact will then hold the parts together.

This surface adhesion contact is not a weld. It is a compression joint, which affects only about 0.0002” (0.005 mm) of surface depth with no amalgamation of metals. As the strength of the joint is not too great, it must be used only with parts specifically designed to be fused, such as a tang terminal.

Welding or Fusing

The words fusing and welding are used interchangeably by most people. There is a great difference between the two processes and their machinery. Resistance welding (spot welding) is the process of joining metals by locally heating them to their plastic state, and then forging this plastic metal together. The metals being joined are heated internally by passing current through them. The resistance of the metal determines the amount of current and the time that the current must be passed, to bring it to its plastic state. Because we want the metal being welded to heat internally, we must make sure that the devices conducting the current have a lower resistance than those being welded.

When fusing, we want just the opposite. The current carrying devices get hot because they have a higher resistance than the parts being fused. These hot current carrying devices (electrodes) dissipate their heat into the parts that are being fused.

Fusing heats the tang under pressure, and passes this heat into the wire. Any insulation around the wire is vaporized at this time. As the tang gets hot, it softens and engulfs the wires. Theoretically, the wires should only be slightly deformed, but occasionally they are deformed too much because of improper fusing machine settings. Wire flattened to no more than 200% of its original diameter is acceptable, in most cases. More than this will weaken the wires to a point where they might break from the slightest movement, such as when a surge of current is passed through them.

As stated above, the wire is heated during the fusing process. The heat at the surface of the tang can reach 3,000° F to 4,000° F (1,648° C to 2,204° C). This heat is usually not sustained for more than 240 milliseconds. Normally, for small wires, from 64 to 160 milliseconds, is the average fusing time. During this time, insulated magnet wire with any known film or plastic insulation, will lose this insulation in a puff of smoke.

As the heat buildup in the wire is so fast, the insulation is flash vaporized. Another aspect of this sudden heat is that both the wire and tang, and sometimes the rest of the terminal, are flash annealed. Proper terminal design, as well as intelligent fusing machine setup, can protect the body of the terminal, but it is an advantage for the wire and tang to be annealed. This advantage is quite important when determining the validity of the tang termination system. The annealed tang wires lose all their elastic memory. They are now elastically set in their new terminated position. This is quite important when using certain brasses as the terminal material.

As the tang is closed around the wire under heat and pressure, a surface adhesion type connection is produced, which drives all the air and foreign matter from the interface of the tang and wire. This basically creates an electrical and mechanical seal, which will not open by itself, because of the metal's new elastic memory; or thermal expansion between alloys in the tang and wire, because of the surface adhesion effect.

In welding, we need a cooling system to protect the welding transformer, electrodes, and other current carrying devices from any heat transferred from the part being welded. As heat is developed in the parts themselves, the cooling system will not have to absorb the majority of the heat, as the work will dissipate most of this heat throughout itself. When fusing, the heat is developed in the electrodes and dissipated between the work and the rest of the current carrying system. Therefore, the cooling system must be much larger when fusing versus welding. Heat is developed equally for their sizes, in either a fusing or welding transformer, but a fusing transformer must have a higher thermal rating, as more heat will travel to it from the electrodes.

In the welding system, pressure must be exerted on the parts to forge them together, when they reach their plastic state. The pressure must be regulated, so that there is just enough to forge the parts, as too much pressure will cause the current to pass through them more easily without heating them to their plastic state. If "just enough" pressure is used, there will also be some surface resistance between the parts being welded themselves, and sometimes the parts and the electrodes.

When fusing, we must have more pressure applied on the work, as we try to force the metals together, without them reaching their plastic state. This means that we are only softening the work slightly, and relying on pressure to force them together. We must have constant heavy pressure exerted on the work through the electrodes. Therefore, the fusing head is much heavier than a welding head, assuming the current carrying capacities are the same. As mentioned before, in welding we are amalgamating the metals, but in fusing, we are only compressing them and relying on surface adhesion to hold them together.

In fusing, we treat the wires as not being a part of the joint, until we remove the insulation, if any, oxides or foreign matter. This means that we must apply enough current to the electrodes to heat them to a point where they can dissipate enough heat to remove this insulation or foreign matter. As the wire itself can be damaged, this heating must be carried out in a very short time, and the insulation cannot be fused to the terminal. The only way to do this is by flash vaporization. Usually this means an electrode temperature of a few thousand degrees for from 60 to 240 milliseconds. Normally, a resistance welding system would overheat, if we applied current densities per given time as great as used in fusing, even with the best of cooling systems.

With fusing machinery, we must use heavier current carrying devices, more iron in our transformers, transformers with higher secondary voltages, and a completely different type of electrode system, in comparison to resistance welding machinery.

Tang termination does not require tin on either component to properly complete the termination process. Tin neither helps nor hinders the tang fusing process. Tang terminals are coated with tin for reasons that have nothing to do with the fusing process, such as avoiding corrosion.

SN-Fusing

SN-Fusing (also called Tin Fusing), is a method of joining copper electrical conductors, which results in an excellent electrical connection, without the need for any type of terminal or other mechanical holding device. Both bare and film insulated conductors (magnet or winding wire) can be joined. It is possible to join film insulated conductors, without prior removal of the insulation, which is automatically removed during the fusing process. It is also possible to use special very low cost terminals with the SN-Fusing process.

SN-Fusing requires that one of the conductors being joined be coated, or better, plated with Tin. The Tin acts as a cleaner or purifier of the metals that are to be fused. Without the Tin coating, a joint might be obtained, but it would not be strong enough to be effective. It is also possible to use Silver in the place of Tin, but normally silver is not practical, because of its cost.

For a valid joint to be obtained, all insulation and foreign matter must be removed by the fusing process. After this occurs, the Tin wets the un-tinned conductor and purifies the copper (or a copper rich alloy, such as brass) at the joint's interface. The fusing process continues to heat the joint, which results in the Tin being removed from the joint area. The joint area then consists of ultra-clean copper touching ultra-clean copper (or a rich copper alloy), under heat and pressure. Clean metals clamped tightly together and heated until just before they melt result in a diffusion weld or bond. The metal surfaces fuse and a bond is created.

Diffusion Bonding [also called Diffusion Welding] • "A solid state welding process that produces a weld by the application of pressure at an elevated temperature with no microplastic deformation or relative motion of the work pieces".

The definition above is from JEFFERSON'S WELDING ENCYCLOPEDIA, which was published by the American Welding Society of Miami, Florida - USA, in 1997, and is the industry standard definition, as defined by the American National Standards Institute (ANSI) standard A3.0-94, first published in 1940, and most recently revised in 1994.

The SN-Fusing process cannot normally be performed with a tang terminal. This is because heat levels much higher than required for tang termination are required for SN-Fusing. This higher heat would normally damage the structure that holds the tang.

Machinery

The fusing machine is in some ways similar to a resistance welder. The differences have been explained previously. One point which might be worth exploring is the pressure follow-through system on the machine.

The most foolproof pressure follow-through system is a pressure system which fires the fusing transformer when a given pressure is reached. This has proven superior to any other system for wires smaller than number 8 awg (0.1285 inches — 3.26 mm). With this system, the electrode pressure is consistent, even if the line pressure of the air or hydraulic supply changes, or a dimension of the terminal or wire changes.

There are no expendables in the fusing process. The electrodes are made of refractory alloys, which give extremely long service, before redressing is needed. On very large automation

Fusing Chart for Commutator Slot and Tang Terminal Dimensions

AWG SYSTEM

AWG (American Wire Gauge) Number	8	Cir Mils	16,510.00
Approximate IEC* Standard Metric Size	3.35	Sq MM	8.36150
Approximate SWG Number	10	Sq Inches	0.012960350

*International Electrotechnical Commission

	Inches	Millimeters
Nominal Bare Diameter	0.1285	3.2639
Nominal Coated Wire Diameter	0.1319	3.3503

Commutator Slot Dimensions

The saw diameter for which this chart was calculated is 7/8 Inch (0.875 Inch - 22.22 MM)

	Inches	Millimeters
Width of Slot for Manual Insertion	0.1492	3.7891
Width of Slot for Machine Insertion	0.1282	3.2563
Length of Cut for Radius Cut	0.5093	12.9354
Depth of Cut for Radius Cut	0.4776	12.1313
Depth of Cut for Non-Radius Cut	0.4241	10.7724
Fusing Electrode Tip Diameter	0.1848	4.6932
Orient Blade Thickness	0.1250	3.1749
Stuffing Blade Thickness	0.1154	2.9307

Tang Terminal Dimensions

	Inches	Millimeters
Minimum Tang Length from the Tang's End to the Start of the Tang's Radius	0.4184	10.6270
Miminun Tang Width	0.1321	3.3553
Minimum Tang Thickness	0.1261	3.2029
Minimum Tang Radius	0.0747	1.8983
Height of Tang Projection for Aluminum Wire ± 5%	0.0921	2.3392

An example of an available Fusing Chart. These charts can be obtained in American Wire Gauge (AWG), Sterling (British) Wire Gauge (SWG) and Metric dimensional systems. They are available directly from Allem. These charts do not supply data which takes into account wire insulation, electrode design, or commutator or terminal design, as well as other variables.

systems, automatic electrode dressing devices even eliminate this electrode servicing. By using a monitoring system on the fusing machine, all improperly fused tangs can be located before they leave the machine. These can be sorted and later fused again. Normally, if the machine is set properly, the reject rate for tang terminated connections will be less than a 1/10 of one per cent. The best monitoring system available, is one that compares the output of the fusing transformer in amperes, to a standard with preset tolerances. We know that if a secondary output of the fusing transformer falls within a specific amperage range, the termination will be valid. An even better method is to use a Thermal Monitor/Controller (TM/C), which actually turns off the fusing transformer, when a predetermined specific peak heat is reached in the area of the tang. The TM/C actually controls the fusing machine, in response to the output of the same machine – in other words, real time control.

The constant current fusing control is a closed loop electronic device that helps to assure consistent quality fused connections. A constant current fusing system is used because it can correct the one electrical variable, which is a detectable and correctable component of fusing, namely current. The fusing electrode(s) is the component in the closed loop fusing circuit that changes its temperature and thus resistance drastically, during the fusing process. All of the other components (fusing transformer's secondary circuit, electrode holders, tang terminals, etc.) are made of low resistance metal alloys, and maintain a relatively stable temperature and resistance. The fusing electrode(s) becomes hotter than the low resistance alloys in the closed loop circuit because its resistance is higher. Any metal's electrical resistance increases as its temperature is increased and vice versa. Therefore, we start with a high resistance fusing electrode(s), and pass electric current through a closed loop circuit where it has the highest resistance. As electric current continues to pass through the closed loop circuit, the fusing electrode(s) gets hotter, and its resistance increases. Then the fusing electrode(s) gets even hotter, and this resistance/heat cycle continues.

While the fusing electrode(s) is increasing in temperature, its resistance is also increasing. As the resistance of the fusing electrode(s) increases, the amount of the current passing through the closed loop circuit decreases, assuming the voltage is constant, which is a function of Ohm's Law. As a component of a circuit has a resistance increase, the circuit has a corresponding current decrease, again assuming the voltage component is constant. When fusing, a relatively stable voltage source is used, the utility mains lines.

When using a "normal" fusing control (without a constant current feature), actual fusing takes more time than when using a constant current control. This occurs because a specific level of energy is required to pass through the closed loop circuit, in order for the fusing electrode(s) to reach the exact "perfect" temperature it must reach, so that the joint is properly fused. As the level of current through the closed loop fusing circuit drops, less energy passes through the circuit. More time is, therefore, needed for the specifically required amount of fusing energy to be reached.

With a constant current control, a toroidal coil is placed around one of the leads of the secondary of the fusing transformer. This coil transmits a representation of the amount of current actually passing through the closed loop circuit, to a microprocessor control circuit which varies (raises or lowers) the voltage passing through the closed loop fusing circuit. Normally, when fusing, the current will drop; and the constant current control will compensate by raising the voltage. This cycle of monitoring the current and raising or lowering the voltage occurs for each mains power line cycle (1.0 hertz). Integrated with this raising or lowering of the fusing voltage is the ability to control preset power, and to start the fusing cycle with Up-Slope.

The constant current control is programmed by the fusing machine's user, by entering the current level desired in amperes, the number of fusing and up-slope cycles, and if desired, a pulsation rate that is used when fusing certain size terminals. The actual entering of these variables into the constant current control, can be done either by entering them into the control itself, or through a computer via a network connection. Various data can also be downloaded, in real time, from the constant current control, to a computer for later SPC (statistical process control) manipulation.

The constant current control (or the computer it's attached to, if any) can store a number of individual programs, each for a different terminal/wire combination. Therefore, if you have, say, three different terminal/wire combinations to fuse, you can keep their individual fusing settings or schedules in the constant current control, and activate a specific setting by just pressing a button.

What happens if the constant current control cannot correct the current to the desired level? This could happen because of a voltage line drop or brownout, insulation on the terminal where it makes contact with an electrode(s), change in terminal construction, etc. The constant current control will sense that it cannot compensate and will give an alarm signal which can be used to stop the machine, or reject the armature, coil or terminal on an automatic system.

Computer Control and SPC

There are various ways to control Tang Terminal Fusing machine functions. A recent development has been to combine the PC (personal computer) with a commercially available PLC (Programable Logic Controller) for controlling the machinery. The PLC is used to actually control the machine, while the PLC feeds variable information to the PC. The PC processes this information and acts as a front end for the PLC to interface with human operators and/or set-up personnel.

The PLC, such as one manufactured by the Allen-Bradley Company, can easily be programmed and re-programmed by most set-up personnel. These PLC devices use a type of ladder diagram logic, which most electricians can understand, and even modify.

The PC computer, normally a 586 – 150 megahertz or faster unit, performs a number of functions. It can act as the PLC's front end, as mentioned above, can show the fusing process graphically in real time, can collect data for SPC (statistical process control) manipulation, and can process the collected SPC data to obtain process control and process capability indexes.

Process control (Cp) and process capability (Cpk) are the most accurate means of measuring production quality, by using statistical methods. Process control reflects the stability of the process, while process capability measures the built-in consistency of a product that is made by the process. The process is first brought under control by finding and eliminating special reasons for variation. The process is then predictable, and its capability to meet pre-defined expectations can be determined.

The PC would normally collect all or some of the following fusing machine data (assuming the fusing machine incorporates a constant current fusing control) a Thermal Monitor/Controller (TM/C), a load cell fusing electrode pressure measurement system, an electrode displacement measurement system, and a cooling water temperature measurement system):

- The actual peak current reached prior to terminating the fusing process
- The actual total fusing time used during the fusing process
- The actual temperature reached when fusing was terminated
- The actual peak fusing electrode pressure reached during fusing
- The actual final fusing electrode pressure that was

reached when fusing was terminated

- The actual maximum depth the fusing electrode moved below the surface of the closed un-fused tang
- The average temperature of the machine's cooling water supply

All of the above listed parameters, plus some others, can be collected for each fused connection. The data for each fused connection can be associated with a specific armature, coil, terminal, etc. The date and time of the actual fusing of an armature, coil, terminal, etc. can be captured. This data can be sent to an ink jet printing head, from which it will print the date and time or a code derived from this information, on the armature, coil or device which holds the terminal. Part numbers or other information can also be printed at the same time.

At any time, SPC data and graphic charts can be displayed on the PC's monitor. Calculations can be performed from the stored data using X-BAR-10, X-Bar-100 and/or R-Bar-100, to obtain a sigma index which will be a guide to production management, as to the relative quality of the output from the fusing machine.

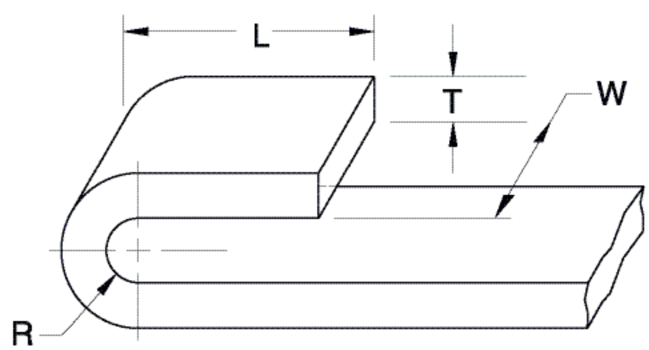
The use of a PC computer as the front end of the PLC machine control system gives a number of benefits, but the SPC data capture and processing capabilities are added benefits that cost almost nothing. As manufacturers of coils and motors attempt to certify their quality control programs, SPC on fusing machines will become essential.

Conclusion

With the proper monitoring equipment on the fusing machine, foolproof connections can be assured. These connections will be electrically superior to either a soldered, crimped, or brazed connection. Mechanically, the connection will only be as strong as its weakest component — wire or tang. For practical purposes, the mechanical strength is more than adequate for even the most critical use.

Millions, if not billions of tests have been performed over the years, which have proven the tang termination method. Further proof is the number of motors and coils produced each year with this method, and those millions upon millions still in service. n

Minimum Tang Dimensions For
Two Copper Insulated Conductors
Under A Tang



W = 1.0 x Coated Wire Diameter
T = 1.0 x Coated Wire Diameter
R = 0.5 x Coated Wire Diameter
L = 3.0 x Coated Wire Diameter

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