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Classic Connectors, Inc.

ClampStar® and Self-Damping Conductor

It is important to understand the peculiar mechanical properties related to the tensile loading of ACSR/SD conductor in comparison to that of "common" ACSR type conductor and how this is managed differently by the two different connector types, commonly referred to as "single die type" and "conventional – or – two-die type" compression connectors.

The following description excerpt from the Southwire® website:

ACSR/SD - Sometimes called SDC (Self Damping Conductor), ACSR/SD is a concentric lay stranded, self damping conductor designed to control aeolian type vibration in overhead transmission lines by internal damping. Self damping conductors consists of a central core of one or more round steel wires surrounded by two layers of trapezoidal shaped aluminum wires. One or more layers of round aluminum wires may be added as required.

Self damping conductor differs from conventional ACSR in that the aluminum wires in the first two layers are trapezoidal shaped and sized so that each aluminum layer forms a stranded tube which does not collapse onto the layer beneath when under tension, but maintains a small annular gap between layers. The trapezoidal wire layers are separated from each other and form (from) the steel core by the two smaller annular gaps that permit movement between the layers. The round aluminum wire layers are in tight contact with each other and the underlying trapezoidal wire layer.

ACSR/SD has been very effective in reducing aeolian vibration on transmission lines. However, most contractors charge a premium for installation because of special hardware requirements and specialized stringing methods.

F. Ridley Thrash, Jr.
Chief Engineer, Overhead Conductors
Wire & Cable Technology Group
Southwire Company

The following illustration and brief description are from the Alcan® website:

This photo, from the Alcan® website, illustrates the typical construction of ACSR/SD conductor. Alcan includes the following description: Alcan Cable's Self-Damping Aluminum Conductor Steel Reinforced (ACSR/SD) cable permits longer spans, provides increased reliability, and lowers overall line cost. It also reduces sag, as well as cuts ice and wind loads. The steel core and the two layers of trapezoidal shaped aluminum wires in this design are separated by a gap designed to provide self-damping characteristics to control aeolian vibration—eliminating the need for vibration dampers.

While intended as an ACSR (Aluminum Conductor Steel Reinforced), the unique construction of ACSR/SD conductor, having the annular clearance between the steel core and the inner aluminum strand layer, results in the core itself carrying a differing percentage of the tensile load in comparison to traditional or standard ACSR construction where an element of frictional engagement exists between the steel core and the innermost layer of aluminum stranding. Furthermore, per Mr. Thrash's comments above, the inner aluminum layer of stranding is trapezoidal shaped so that it forms "a stranded tube which does not collapse onto the layer" and while it will compress within the connector, the frictional engagement between this inner aluminum layer and the steel core will not be equal to that formed by a traditional or standard ACSR construction conductor. Therefore, the core-grip portion of the connector may be subjected to an increased degree of tension.

The "single-die" type compression deadends and splices rely on an aluminum component to carry the line tension.

Single Die Compression Deadend - Steel eye is pre-installed at the factory

The gripping unit, shown in the plastic bag in the photo above, serves as a filler component, and is designed to grip the steel core of an ACSR type conductor. This is an aluminum component, which is placed over/on the exposed core of the conductor, and then, along with the conductor, is inserted into the body. The body is then crimped onto the gripping unit with a "circular die" resulting in an elliptical shaped crimp section. The crimping is continued to the end of the connector, completing the process. The compression of the gripping unit is accomplished as a combined compression through the tempered aluminum body of the connector.

The result is a perfectly satisfactory connector for use with traditional or standard ACSR when operated within the parameters specified by the conductor manufacturers of a maximum continuous operating temperature of 75°C, and is well documented by testing, according to conventional and accepted standards methodologies. I would note however, that this testing is conducted on recently compressed connectors (usually within a few hours of the test procedure), at ambient temperature, typically between 15°C and 35°C (59-95°F). The reason I point this out is that as temperature increases, significant changes occur with this structure. Because the gripping unit and the connector are made of aluminum, and aluminum has a thermal coefficient expansion factor of approximately 2-1 compared to steel, as the connector heats up, the aluminum expands faster than the steel core, and therefore the purchase of the steel core by the aluminum core grip is reduced.

Furthermore, as with most metals, the mechanical properties of aluminum are reduced as temperature increases; i.e., it gets softer. Along with that, extreme stress is induced through the forces of compression, plastically deforming the aluminum during installation. The residual stress that remains after installation is subject to static creep, even at ambient temperature over long periods of time, and those stresses, which provide the resultant grip force or purchase of the steel core stranding will relax over time. This is accelerated with increased temperature, and is cumulative over a number of thermal cycles, being progressively reduced with each thermal cycle. As this grip force is reduced, the steel core of ACSR/SD conductor may begin to slip, and eventually "let go" resulting in the type of failures that have been experienced previously.

One could compare this, to a degree, to ACSS type conductors, where the resultant installation is one in which the entire tensile load (for all practical purposes) is supported by the steel core alone, and is the reason that neither Hubbell Power Systems or ACA Conductor Accessories recommend the use of "single-die" type compression connectors on ACSS. In a similar fashion, under the dynamic conditions of practical application, ACSR/SD conductor will progressively distribute an increasing portion of the tensile load to the steel core due to the tubular structure provided by the trapezoidal stranding, which intentionally allows the core to move freely within the center of the conductor. Thereby a dynamic stress is introduced at the gripping unit through cyclic stresses, resulting in fatigue perturbed creep. This is evinced when a failure occurs where the connector "lets go" and the steel core is said to "run" up the conductor because it is under higher tensile stress than the aluminum stranding. This does not occur, at least not to the same degree, with conductor of traditional or standard ACSR construction.

While some connector manufacturers may have recommended "single die" type connectors for application on "SD" type conductor, I know during my time with Hubbell Power Systems, that I would certainly not have recommended them for use on SD conductor. Note that I am no longer affiliated with Hubbell Power Systems, and they, or another manufacturer, very well may have recommended the use of this type of connector, either before my employment with them, or may today. The present Hubbell online catalog contains the following note under the section of "full tension splices" and the category of "Uni-Grip® One Die Splice - Full Tension ACSR Conductors": *2. For Self-Dampening (SD) and Trapezoidal (TW) and metric ACSR conductors consult factory.* To my knowledge, ACA (the other prominent supplier of "single die" type connectors) has no such limitations published, and I cannot comment on their recommendations.

One might perceive therefore, that both Hubbell Power Systems and ACA Conductor Accessories recommend or allow the use of this type "single-die" connector for use up to 100°C conductor operation. When I carried the responsibility of making that recommendation, I cautioned to never use this type of connector on conductors operating at or above 93°C. The reason for this is that 93°C is accepted as the thermal point of the onset of long term annealing of this type of tempered aluminum alloy. It would be prudent to note that the original design criteria for aluminum compression connectors was a maximum continuous conductor operating temperature of 70°C! Some say 75°C, which still remains the published maximum continuous conductor operating temperature of ACSR type conductors by their manufacturers!

There exists with this "single die type" connector, an un-crimped section of aluminum between the factory crimp that secures the steel eye component of this connector, or the opposed end of a splice, and the field installed crimps. This portion of the aluminum tubing supports the entire tensile load.

Operating the connector at temperatures above 93°C will result in annealing the aluminum components of this style connector, thus risking mechanical failure.

Single Die Compression Deadend failure due to excessive heat on conductor

Recent testing programs conducted by EPRI have concluded that elevated temperature operation of 125°C conductor temperature with ACSR type conductor and these “single-die” type compression connectors will result in fairly rapid failures of the connectors.

The type of connectors recommended for application on ACSS, and from my perspective, ACSR/SD type conductor is commonly referred to as the “conventional” or 2-die compression connector design for full tension, which consists of an aluminum body component, and a separate, field installed steel eye component, which is compressed directly onto the steel core of the conductor.

Steel Eye Component

Aluminum Body

This design does not rely on any aluminum component to carry the tension load supported by the steel core of the conductor. With the splices, as with the deadends, a steel sleeve or component is provided which is pressed directly onto the steel core. Both components being steel, there is no notable differential in the coefficient of thermal expansion, and therefore no measureable difference of tensile purchase performance to the steel core. Furthermore, a much higher temperature would be required before any notable differential in tensile strength would be measurable with the steel components. Normal sag tensions will not exceed the breaking strength of the steel core in normal conditions. Therefore, one may be of reasonable assurance that loss of strength of the aluminum will not result in a catastrophic failure of this type of connector.

While the "single-die" type compression connectors are faster, easier, and therefore less expensive to install initially, if it were my transmission grid, I would not use them, and any that were in the air would soon be covered with ClampStar® Connector Correctors! The eventual failure of single-die type compression connectors and automatic connectors were the specific reason ClampStar was invented in the first place.

The photo below is of a ClampStar installed over a conventional two-die splice on a 115kV line. There are two distinctive features which differentiate this splice from a "single-die" type splice. (1) the comparatively long "un-crimped" section in the center that covers the "steel sleeve" insert underneath, and (2) it is crimped with a type AH "hex-die."

Photos of the splice below have the characteristics typical of "single die" connectors, being the "short" un-crimped section in the center and crimped with a type CD "round die" as opposed to hex dies.

These being single die type connectors, because of the "tubular structure" of the inner strands of ACSR/SD conductor and their resistance to compression, the ClampStar by itself will not likely provide sufficient compression to hold the core stranding without the aid of the gripping units of the connector.

The recommendation is to "over-crimp" the connector in combination with the ClampStar. The reason one cannot simply over crimp the connector to begin with is that it would reduce the cross-section required for current capacity. With the ClampStar in place, there is no current or temperature restriction for that matter. The portions of the connector on either side of the un-crimped center section can then be re-compressed using the next size smaller die. The re-crimp would begin approximately ¼ to ½ inch away from the un-crimped section in the center, and continue perhaps 3 or four compressions toward each end respectively, a sufficient distance to recompress the core-grip insert which may have relaxed over time, and perhaps a portion of the conductor stranding itself. This will re-establish a complete grip on the core stranding, and with the ClampStar in place, will never see any additional temperature which would serve to degrade it. The ClampStar will serve to carry the current, and any remaining tension requirements of the aluminum stranding. The line will therefore be up-rated for higher current capacity, which could not be achieved with repair sleeves, and depending on the condition of the conductor (which would have to be determined independently) provide an additional 30 to 50 years to the available service life of the line.

All this can still be accomplished on a live line without taking it out of service, and the re-compressing step will likely only require about an extra 10 minutes per installation.

- Carl Tamm