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Adding Life to Water-Cooled Power Cables Through Innovation in Core Construction

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INTRODUCTION

Electric arc furnace (EAF) technology represents around 28% of global steel production.[1] Short-lived service of large EAF water-cooled power cables are an operational inconvenience and can be expensive to replace. Frequent maintenance of power cables exposes plant personnel, and equipment, to process safety and risk concerns. Plant engineers, operations and maintenance personnel must explore why water-cooled cable construction fails and how today's engineering aims to extend the cable life.

DISCUSSION

Key Construction Factors in Premature Cable Failure

Inadequate core construction and poor design will significantly affect the longevity and operational cost-efficiencies of water-cooled cables. Harsh and demanding operating conditions, including severe ellipting, can drastically shorten the life of a water-cooled power cable. Construction failures often occur due to poor conductor bundling, an improperly sized and designed core hose, and insufficient coolant flow.

Figure 1. Newly manufactured spare cables stacked in trays for safe storage. Innerworkings of cable are not visible from exterior.

During assembly the wire bundle package is sleeved with outer hose cover and is not visible to the user. Poor designs typically do not present symptoms until premature failure occurs. Copper conductors forming the wire package are bundled in designs to create the most efficient geometry for bend radius and for electrical efficiency. Bundled conductors formed around a proper center core design optimizes geometric mean distance reducing line inductance.

Figure 2. Example of normal wear and tear on copper conductor wire.

Inferior copper conductor wire bundling, coupled with an improperly sized and designed core hose, creates costly current transfer inefficiency. Premature wire breakage and damage to the core hose are often evidence of poor conductor bundling.

Figure 3. Example of broken conductor bundle caused by lack of core in original cable assembly.

Improper wire bundling is often exacerbated by an undersized, inadequately reinforced core hose. An undersized core hose diameter permits greater internal movement of the conductors during electrical cycling and mast head swing movement, creating excessive chaffing and friction wear on wire conductors. Improperly reinforced core hose is typically constructed with softer, low-durometer rubber compounds of single or 2-ply construction that collapse and offer little structural support.

In common construction, both ends of the core hose are not plugged allowing considerable coolant to travel to the inside of the hose depriving the copper wire bundle of effective cooling. Perforated holes, cut or drilled into the core hose to allow coolant further weakens structural integrity and support of the wire package structure.

Figure 4. Example of poor copper conductor bundling and an undersized core hose. Significant wire breakage and core hose abrasion is evident.

Figure 5. Example of poor copper conductor bundling and a perforated, undersized core hose. Significant wire breakage and core hose abrasion is evident.

Figure 6. Example of poor copper conductor bundling and a perforated, undersized core hose. Significant wire breakage and core hose abrasion is evident.

Figure 7. Example of undersized core hose permitting greater internal movement of wire conductors during electrical cycling, potentially resulting in excessive chaff and friction wear.

Figure 8. Example of weak low-durometer core hose with perforations, and no end plugs compounding inefficient flow of coolant to the wire conductor bundle.

Inadequate coolant flow increases operational temperatures, thereby increasing electrical resistance of the conductors. Without proper coolant flow, conductors can become embrittled. In excessive water deprivation cases, the copper wire inductors will catastrophically melt.

Figure 9. Example of catastrophic lack of coolant flow within power cable. Resulting heat exceeded melting point of solder. Perforated core hose is burned.

Premature water-cooled cable construction failure is often attributed to lack of consideration for proper conductor wire package bundling. Improper wire bundling is often created by undersized, improperly reinforced core hoses resulting in consistent current transfer inefficiency, premature wire breakage, and inadequate coolant flow. Optimum performance requires consideration of specific furnace applications and core design to improve service life.

Today's Water-Cooled Cable Engineering

A number of well-designed approaches to good core engineering exist. Suppliers often forgo good design to reduce manufacturing cost. Long term benefits of using better cable designs include reduced change-out frequency and inconvenience, and reduced future rebuild costs when conductors are reused during preventative maintenance servicing. The most important component of reliable and efficient power cable design is the wire package.

To efficiently carry current from the transformer to EAF electrodes, proper sizing and construction of the wire package is an engineered design effort. Properly designed wire packages not only have electrical efficiency advantages, and of equal importance, have mechanical advantages. Proper conductor bundling is contingent on wire size, arrangement, internal core sizing and structural integrity. Properly designed wire bundling mitigates premature stress breakage of the conductor, ensures adequate coolant flow, and extends cable hose cover life.

Additional considerations to reduce I^2r power losses include amount of current, cable length, number of cables per phase, amount of coolant, arrangement of cable installation, number and size of copper conductors, as well as terminal design.

Proven and effective water-cooled cable core design and construction includes

- six-ply polyester tire cord reinforced 60 Shore D durometer core hose construction,
- core hose is secured to the wire package to prevent movement, and
- eliminating the need for core hose perforations, which compromise structural integrity, by installing and securing high-temperature engineered plastic wedges to core hose ends forcing coolant around the conductor bundle. *See Figure 10.*

These design improvements will enhance structural integrity of the core hose and maintain wire bundle integrity adding to cable longevity.

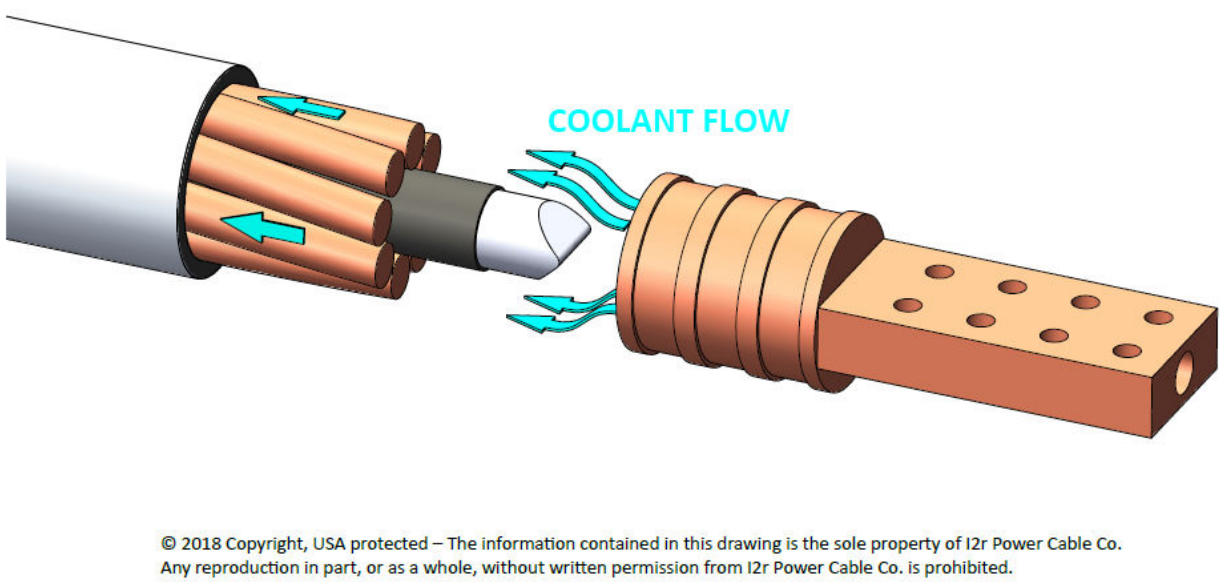

Figure 10. Illustration shows optimum coolant flow around wire bundle using a high-temperature engineered plastic wedge to seal core hose at ends.

CONCLUSION

Frequent maintenance and replacement of EAF power cables are an inconvenience that can be reduced. Premature water-cooled cable construction failures typically occur due to poor conductor bundling, an improperly sized and designed core hose, and insufficient coolant flow. Long term benefits of implementing better cable designs include reduced operational cost, reduced repair cost, and reduced electrical inefficiency. Confirm with your supplier a proper core design is carefully considered.

REFERENCE

1. 2018 Steel Statistical Yearbook, Table 6, p. 15-18.

