ARCHIVES OF CIVIL AND MECHANICAL ENGINEERING 14 (2014) 682–690

Available online at www.sciencedirect.com

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journal homepage: http://www.elsevier.com/locate/acme

Original Research Article

Processing damages of material components of aerial conductors and their tribological behaviors under dry friction

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ARTICLE INFO

Article history:
Received 20 February 2013
Accepted 14 December 2013
Available online 8 January 2014

Keywords:
Wear
Conductor wire
Clad steel wire
AA-6101
AA-1070

ABSTRACT

In this study, materials AA-1070, AA-6101, Fe, aluminum clad steel (ACS) and aluminum clad steel (CS) tube used in manufacturing of aerial bare conductors for transmission lines have been presented by analyzing their interactions with processing tools of machines and friction properties of each other. To detect interactions of conductor metal and processing machine, analyses of samples collected from their manufacturing plant were performed by means of SEM and optical microscope. Tribological properties of components of bare conductors were analyzed experimentally under dry sliding to illustrate processing damaging of machines. Five different samples were carried out on pin on disk wear tester for that purpose. The effects of heat treatment on the tribological behavior of the samples were also investigated. As a conclusion, it has been detected that ACS wire clad with AA-1070 and Zinc coated steel wire can be preferred as high wear resistance metal components. On the other hand, under dry sliding condition, samples prepared from the materials AA-6101 (heat treated) and AA-6101 (non-treated) have lower friction coefficient values than other samples. These conductor materials are very vulnerable due to external effects and processing tooling. It requires perfect management of processing of the material in the plant.

1. Introduction

It is clear that transmission line investments of the countries depend on their level of social life, industrialization policy, level of energy consuming, area of country and settlement regions. Countries require as much as maximum of the service life of conductors. But, the combination of several heavy climatic factors reasons decreasing of the conductor life. Moreover, both micro and macro damages that are coming from some factors caused by metal–machine interactions at manufacturing stages and tribological behavior of materials in the bare conductor after installing to the trusses start excessive deterioration process together. Some damages onto the wires due to manufacturing are considered as ''metal–machine interactions'' which are combinations of collective reasons such as scratching of the conductor wires when passing into the drawing dies of the feedstock in drawing

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1644-9665/$ – see front matter
http://dx.doi.org/10.1016/j.acme.2013.12.003

machine, wires scratching in the stranding machine when passing guides, wear of wires and scratching under bending and torsional stresses due to pre-forming head mounted before stranding point of the wires. However these types of effects cannot be considered as an important phenomenon in stages of failure problems of a conductor. But these micro and macro damages cause big problems on the service life of the conductors. It is believed that most of the damages start after installing a conductor to transmission lines. If the conductor production process is managed inefficiently it causes very radical decreases at the end of the service life of the manufactured conductors. Decreasing of service life of the conductor is accelerated between trusses of transmission line by the collective effects of everyday stress, temperature fluctuations, wind loads, abrasive particle attack with storming and wear problems initiated separately by moving of the individual members of the conductors. In the literature, Zhou et al. performed a study related to metal and metal contact occurred in the multi layer constructions. They performed fretting wear tests under grease lubrication on an aluminum alloy, 52,100 steel and low-alloy steel [1]. Zhou, Gu and Vincent indicated that fretting fatigue was one of the most detrimental loadings for crack nucleation. Aeronautical aluminum alloys have been analyzed during the first cycle of fretting so as to determine the evolution of the maximum friction force and the friction coefficient [2]. Zhou et al. researched cyclic bending fatigue tests performed on a typical electrical conductor held by a suspension clamp. Surface damage of the aluminum wire has been induced during short duration tests [3]. Fadel et al. researched aerial conductors. The aim of their study is to evaluate the effect of a high mean tensile pre-load on the fatigue life of an Ibis type of steel reinforced aluminum conductor (ACSR) mounted on a mono articulated cast aluminum suspension clamp [4]. Azevedo et al. showed that the performance optimization of overhead conductors depends on the systematic investigation of the fretting fatigue mechanisms in the conductor/clamping system [5]. Horng et al. investigated the erosive wear and corrosion behavior of zinc- and aluminum-coated steels in simulated coastal environment. They worked with metal coated steel wires used in telecommunication systems. Their results showed that the aluminum-coated steel performed only 60% better than zinc-coated steel [6]. Depending on the information given in the literature mentioned above, in the present study, materials used in manufacturing of aerial bare conductors for transmission lines were analyzed by considering machine–metal interactions and wear tendency of them in the structures composed of the materials AA-1070, AA-6101, St, ACS wire and CS (clad steel) tube. Members of the conductors were analyzed experimentally under dry sliding to contribute manufacture and service life of the conductors in the energy industry.

2. Experimental study

Wires are stranded together under tension using a special pre-forming apparatus with the help of brakes mounted on the pintle mechanism of spool cradle to obviate wire passing from the guides loosely and clearances between of individual wires on the conductor. Moreover, when conductors are stringed to transmission towers, its dead weight applies tensile and bending stresses so that all layers work under compression and tensile stresses with combination of other environmental loads. The combination of tensile load applied owing to sagging arrangement of the conductor and stress caused by loads of environmental conditions which are temperature fluctuation, wind load and ice load trigger ''wear mechanism'' between individual members of the conductor. The wear mechanism of the conductor components between of truss is also contributed by the damages caused by processing tools in the manufacturing stage in the plant. Therefore experiments have been planned to detect contributing factors to processing damages and wear mechanisms related to conductor members. Analysis will also illuminate basic reasons of surface damages, possible initiating of crack and damage mechanisms related to machine–metal interactions which include damaging of metal guide machining to the soft conductive wires. Conductor samples taken from the production lines were separated to individual components and then used in the wear testing apparatus to determine tribological properties under dry friction. Material samples selected such as AA-1070, AA-6101, ACS wire, CS tube and Fe–Zn (zinc coated steel wire) were studied separately to investigate tribological properties. On the other hand, damages created onto the member of the conductor due to forming apparatus and steel guides used on the machines were observed carefully and detected at the conductor production plant on day by day basis. Thus a lot of damaged samples were picked up from real production lines. These samples were examined under microscope and SEM. Some views related to failed wires by manufacturing tools were interpreted. TE 53 Slim model pin-on-disk wear testing device, which was produced in pursuance of ASTM G77 standards by Phoneix Tribology Ltd., was used in analysis of friction and wear behaviors of test samples [7]. In wear tester, the diameter of disk was 60 mm, the diameter of pin was 3 mm and disk was produced by means of 95 HRB hardness with SAE 1040 steel. Samples used in the experiments were tested at various speeds. It was worked out at 0.62, 1.24, 1.86 and 2.48 m/s (200, 400, 600 and 800 rpm) speeds. Samples were scaled during the 20 min out of work in order to define wear loss. Thus, 940 m of sliding distance was obtained in each sample in consequence of this process. Temperature and humidity were detected respectively as 22 °C and 50%RH. Materials used in the experiment were prepared from the conductors such as ACSR type Cardinale (AA-1070 + Fe-Zn), OPGW (AA-6101 + CS tube + galvanized steel or ACS), AAAC type named as Upas (AA-6101). Here, AA-1070 aluminum and galvanized (zinc coated) steel wires were prepared from the ACSR type named as Cardinale conductor. AA-6101 wires are prepared from the AAAC Upas conductor. Aluminum clad steel (ACS) wire and aluminum clad steel (CS) tube were prepared from OPGW conductors. The samples of conductor wires (pins) were performed into U-shaped and they were sinked into suddenly solidifying adhesive in cubic form. Consequently, intimate contact of two flat surfaces under pin-on-disk configuration was obtained. SEM views of ACS wire and CS tube are shown in Fig. 1a and b.

Hardness of test samples is shown in Fig. 2. Zinc coated steel wire is the hardest sample and AA-6101 (non-treated) is the softest material.