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Grassland fire effects on barbed wire

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Abstract

Fire and its effects on rangeland plants, animals, soils, habitats, and watersheds has been studied extensively. Few studies have been devoted to fire effects on rangeland developments and no studies to our knowledge have been done on the effects of fire on barbed wire. From fire records and a known fence age at the Cross Timbers Experimental Range near Stillwater, Okla., we were able to determine the effect of varying fire frequencies on the breaking strength and zinc coating of traditional 2-point, double-stranded barbed wire. Samples from 4 burning frequency treatments, 8 locations each, of either 4 or 5-wire fencing were collected and stripped of their zinc coating for mass determination. Weight of zinc coating remaining on the wire was determined after being subjected to 0X, 1X, 2X, or 6X burn treatments over a 14-year period. A subset of 4 wires from 1X, 2X, and 6X burn treatments was tested for breaking strength. Photomicrographs and coating thickness measurements were also taken on samples from 1X, 2X, and 6X burn treatments. All tests were compared with unused wire of the same lot that had been in storage since fence installation. For the 6X burn treatment, breaking strength of 5,160 Newtons (N) and zinc coating thickness of 18.5 μm were equivalent to unused wire breaking strength and zinc coating (5,160 N, 16.6 μm respectively). It appeared that repeated fires did not adversely affect the corrosion resistance or breaking strength, and therefore service life of relatively new barbed wire fence.

Key Words: range developments, fence, fencing, fire effects

The effects of fire on rangelands have been studied extensively. The results of numerous studies are available from throughout North America and elsewhere on the response to fire of plants, animals, soils, habitats, and watersheds. Still, few studies have been published on the effects of fire on rangeland developments. Fencing is a rangeland development exposed to fire for which little is known except for the effects of fire on preservative-treated wood fence posts (e.g., McCarthy et al. 1972, Evans et al. 1994).

Most rangeland fence is constructed of 2-point or 4-point, double-stranded, zinc-coated barbed wire that is labeled and marketed according to quality standards specified by the American Society for Testing and Materials (ASTM 1995a). The American Society for Testing and Materials has published 12 and 20 year long-term studies of the effects of various environments and climates on barbed wire (Reinhart 1961, Kelly 1975), but not the effects of fire on barbed wire. No formal studies to our knowledge have been conducted previously on rangeland fire effects on wire. A common perception is that fire, either by reducing the strength or by removing the corrosion-resistant zinc coating, reduces the life of wire. Because we had records of fence materials and fire events on the Cross Timbers Experimental Range (CTER) west of Stillwater, Okla., we were provided the opportunity to investigate the effect of grassland fire on barbed wire in the same manner as other long-term environmental effects studies. Specifically, we determined the influence of varying fire frequencies on both the breaking strength and zinc coating on wire.

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Methods and Materials

We collected 60-cm sections of 12 1/2-guage, 2-point, double-stranded barbed wire manufactured by CF&I Steel Company, Pueblo, Colo. (Table 1). Wire age was about 14 years. Wire samples were collected in September 1996 from 32 locations on CTER of fence constructed in late 1982 and early 1983. We collected a sample of each wire from 4 and 5-wire fences and recorded the wire number (with the top wire noted as number 1) and the distance of the wire from the ground. Four additional wire samples were obtained from each of 3 stored, unused rolls of the same lot of wire.

Treatments were unused wire, and wire from fences subjected to 0, 1, 2, and 6 burns (unused, 0X, 1X, 2X, and 6X respectively) (Table 1). Fences subjected to fire were located in tallgrass prairie fuels and burned in the late dormant season (February to early April). The 1X treatment was a wildfire and the first fire of the 2X treatment was a wildfire. All other fires were prescribed fires. Each fire crossed the fence after the grass fuel was ignited at least 3 m from the fence. Fire behavior and fuel loading were not measured, but fuel loading and fire behavior in these grazed pastures were comparable to fires on nearby tallgrass prairies burned in the late dormant season (Bidwell and Engle 1992).

We subjected the wire to 2 standard quality tests for newly manufactured wire according to ASTM A 121-92a (ASTM 1995a). A 30-cm subset (4 wires each of unused, 1X, 2X, and 6X) of the samples was tested as double-stranded wire for breaking strength by the Quality Assurance and Technical Services laboratory of the Wire Mill, CF&I Steel, L.P. in Pueblo, Colo.

Table 1. Samples taken in September 1996 from fence constructed in 1982 and 1983 on the Cross Timbers Experimental Range near Stillwater, Okla. for testing breaking strength and zinc coating.

Sample I.D.[1]	Number of fires	Years of fires
unused[2]	0	--
0X	0	--
1X	1	1996
2X	2	1991, 1996
6X	6	1985, 1986, 1987
		1990, 1993, 1996

[1]Samples from 2 independent fence locations.
[2]Unused wire was uninstalled wire in storage since fence installation, and 0X refers to wire installed and in use but never subjected to fire

Table 2. Breaking strength of double-stranded, 2-point barbed wire collected on the Cross Timbers Experimental Range near Stillwater, Okla. subjected to different grassland fire treatments (n = 4; values in parentheses are standard errors).

Number of fires	Breaking strength
	(N)
unused	5160 (13)[1]
1	5030 (71)
2	4980 (116)
6	5160 (31)

[1]Means of wire did not differ (P = 0.21) in breaking strength. ASTM minimum standard for breaking strength of new, Class 1 wire is 4230 N

We separated the double-stranded wire and tested single strands of wire (unused, 0X, 1X, 2X, and 6X) with barbs removed for mass of zinc coating following the procedure outlined in ASTM A 90/A 90M-93 (ASTM 1995a). Zinc coating was determined as the difference in mass of single-strand sections before and after zinc was removed in a bath of hydrochloric acid.

Several outlier samples with higher than normal zinc coating values appeared in all but the 6X fire treatment. We removed any sample value which was greater than 180 g m^{-2}, roughly twice the ASTM standard. Our justification was that some of these samples might represent Class III wire, which in contrast to our Class I wire, has a minimum ASTM standard zinc coating of 245 g m^{-2}. When wire was purchased for CTER, > 145 km of barbed wire strands were installed. It is possible that in order for the company to fill our Class I wire order, it was necessary to add some Class III wire in the shipment. It is also a common practice with wire manufacturers as a whole, to sell any wire that falls below the Class III minimum standards as Class I wire (R. Davison, Keystone Steel & Wire Co., Peoria, Ill., personal communication). This may explain several high values near the Class III standard while the majority were near the Class I standard.

To determine the effects of fire on alloying, we characterized the coating structure of unused wire with wire subjected to fire (i.e., 2 rolls of unused wire and the bottom 2 wires from 1X, 2X, and 6X burn treatments). The double-stranded wires were seperated and each single strand sample was cut, mounted, and polished for metallographic examination of the coating cross section as outlined in ASTM E 3-95 (ASTM 1995b). Two photomicrographs, one of the thinnest and one of the thickest coated area were taken of each wire. All photomicrographs were at a magnification of 500X. Optical coating thickness was measured using a calibrated eyepiece on a microscope. Average thickness was determined from 10 locations around the circumference of each sample.

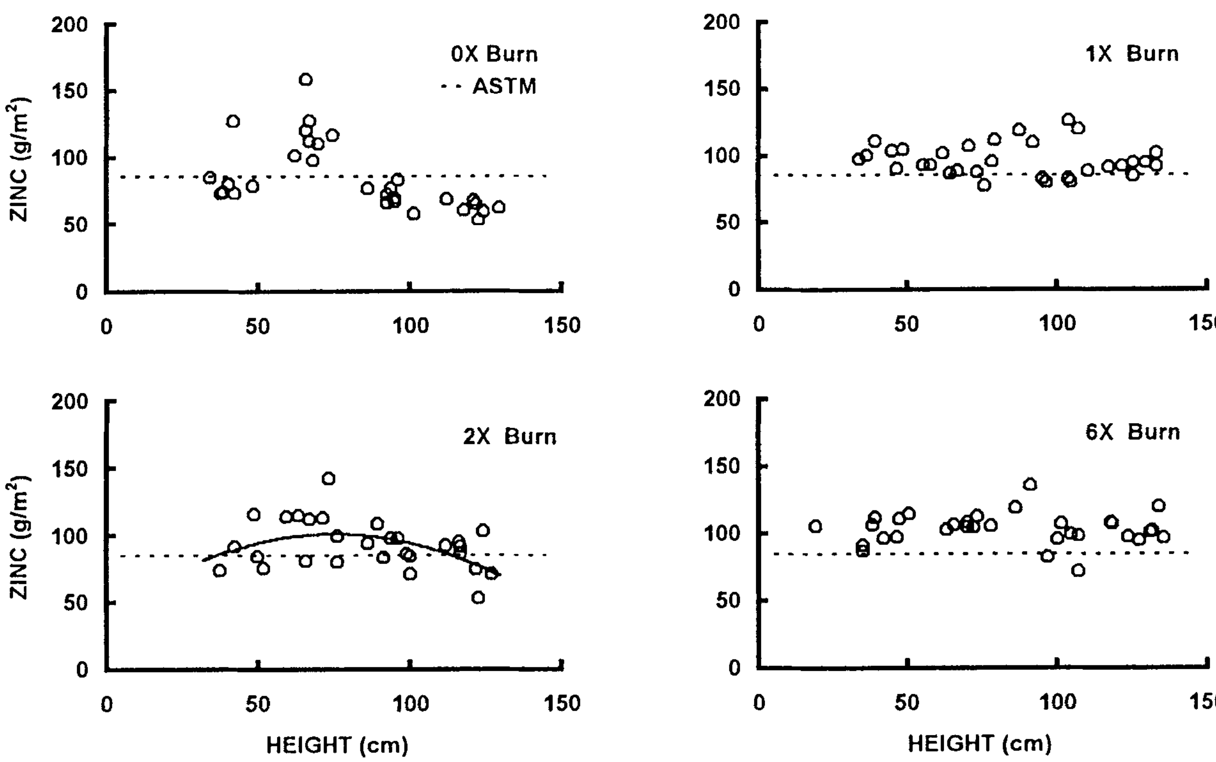

Fig. 1. Zinc coating remaining on double-stranded, 2-point barbed wire collected on the Cross Timbers Experimental Range near Stillwater, Okla. subjected to different grassland fire treatments. Horizontal dashed line is the ASTM standard for Class 1 wire (85 g m^{-2}). Equation for the 2X fitted curve is, $y = 42.16 + 1.56x - 0.01x^2$.

Strength data were subjected to analysis of variance with fire treatment (i.e., unused and number of fires [1X, 2X, and 6X]) arranged as a completely randomized design. The null hypothesis was that wire from fences subjected to different fire treatments on CTER did not differ in breaking strength. Zinc coating data were subjected to analysis of variance with wire height nested within fire treatment (i.e., number of fires) arranged as a completely randomized design. The null hypothesis was that wire from fences subjected to different fire treatments on CTER did not differ in mass of zinc coating from wire in the 0X fire treatment. In the presence of a significant interaction of fire treatment and wire height on zinc coating, we used polynomials in multiple regression as a means to model zinc coating in response to height of wire above the ground within the 1X, 2X, and 6X fire treatments. These models were used to test the null hypothesis that height within and above the flames had no influence on mass of zinc coating. Optical coating thickness data were also subjected to analysis of variance with fire treatment (i.e., number of fires) arranged as a completely randomized design. The null hypothesis was that wire from fences subjected to different fire treatments on CTER did not differ in optical coating thickness. In the presence of a significant F-test ($P \leq 0.05$), means were separated by LSD at the 0.05 level.

Results and Discussion

Wire subjected to 1, 2, or 6 burns had no difference in breaking strength ($P = 0.21$) than unused wire (Table 2). In addition, breaking strength of wire subjected to all fire treatments was greater than the minimum standard for Class I wire of 4,230 N (ASTM 1995a). These results indicated that repeated grassland fire has no influence on wire breaking strength.

For zinc coating, fire treatment interacted ($P < 0.0001$) with height of wire, so we attempted to fit polynomial regressions of zinc coating as a function of height of wire (Fig. 1). The only significant model among the 1X, 2X, and 6X fire treatments was for the 2X treatment. Figure 1 suggests the zinc coating on the barbed wire not exposed to fire (0X) may corrode more quickly than wire that has been subjected to periodic fire. Zinc coating on wire from unburned fences ranged from 53 to 159 g m^{-2} with most samples across heights below the ASTM standard of 85 g m^{-2}. More sample points lie above the ASTM standard with fire applied than without. Only 3 of 32 samples of wire subjected to 6 fires tested below the ASTM standard.

Figure 2a represents a photomicrograph of various iron-zinc alloy layers possible in a hot dip galvanized coating. Not all hot dip galvanized coatings contain all the layers shown, nor do the layers exist necessarily in these relative proportions. Coating

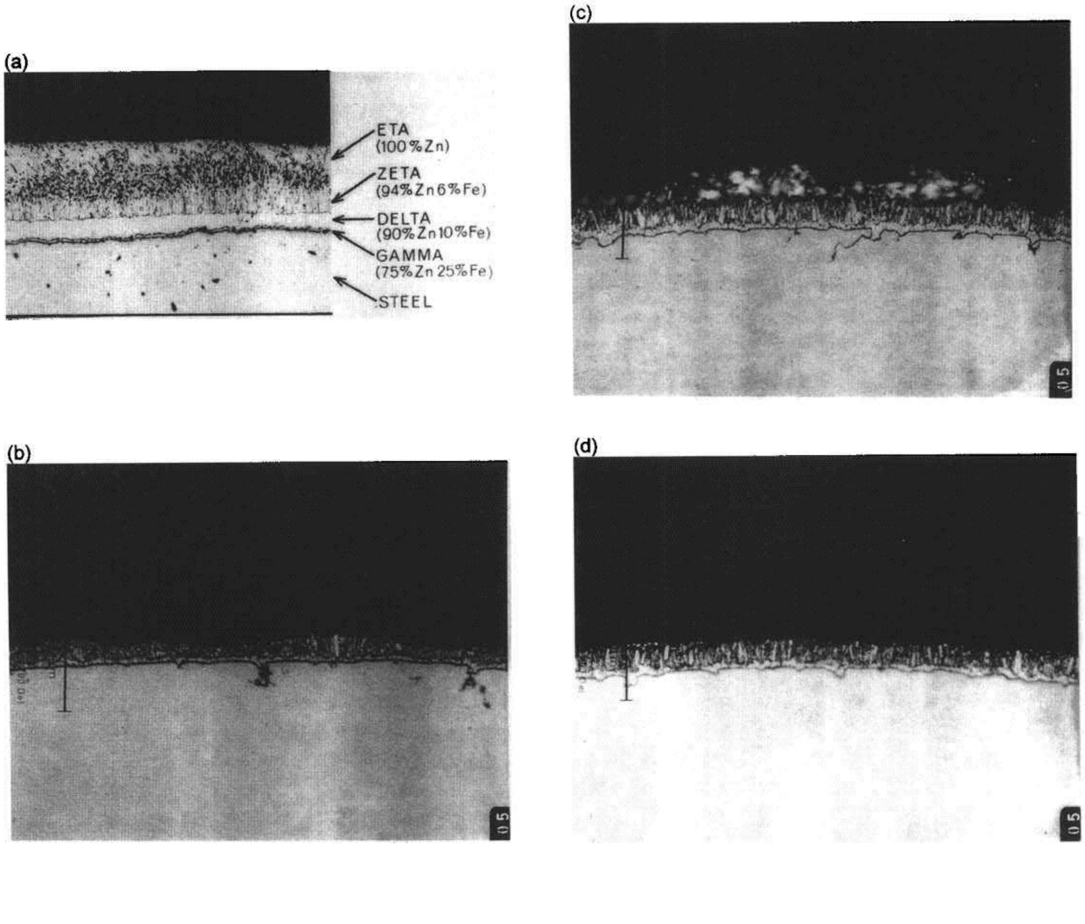

Fig. 2. Photomicrographs (500X) of a) the various iron-zinc alloy layers possible in a hot dip galvanized coating, b) thinnest section of wire burned 6 times, c) thickest section of wire burned 6 times, and d) unused wire.

Table 3. Average optical coating thickness of single strands of barbed wire collected on the Cross Timbers Experimental Range near Stillwater, Okla. subjected to different fire treatments (n = 20; values in parentheses are standard errors).

Number of fires	Optical coating thickness (μm)
unused	16.6 (0.5)a[1]
1	24.7 (3.7)bc
2	28.7 (2.3)c
6	18.5 (1.4)ab

[1]Values with different letters are different at P = 0.001.

thickness and structure are influenced by a number of factors including steel chemistry and galvanizing process variables. Samples from wire subjected to the 6X fire treatment (Fig. 2b and 2c) exhibited a microstructure of a blocky delta layer overlaying the steel substrate covered by a columnar growth of zeta crystals. These iron-zinc intermetallic layers were covered by a layer of pure zinc. The coating microstructure for the unused wire (Fig. 2d) exhibited a full-alloy development with only a very thin layer of pure zinc on the outer surface. This examination suggested that the zinc coating is unchanged in spite of being subjected to 6 fires. All samples exhibited good adherence of the zinc coating to the steel substrate, indicating fire did not adversely affect the metallurgical bond of the galvanized coating.

As is commonly observed in wire from burned rangelands, some of the wires exhibited staining or discoloration of the galvanized surface. This should not be interpreted as coating failure. As shown in Figure 2a, the galvanized coating consists of a series of iron-zinc alloy layers covered by a layer of pure zinc. The alloy layers contain varying amounts of iron depending on their structure. Normal environmental exposure of the galvanized product will cause corrosion of the pure zinc layer, thereby exposing the underlying iron-zinc alloy layers. These iron-containing layers can stain, which can be interpreted erroneously as coating failure. Red rust indicates total coating failure and corrosion of the underlying steel. The discoloration we noted occured in the iron-zinc intermetallic layers within the coating.

Optical coating thickness varied, but most fire treatments had greater thickness than unused wire (Table 3). The variation in coating thickness observed around the circumference of these wires is typical for galvanized wire products. Galvanized wire is produced in a continuous manner whereby the individual wire strands are pulled through the processing line. As the freshly galvanized strand exits the molten zinc bath, the zinc flows to the underside of the wire resulting in a "drip line." Most galvanized wire exhibits this accumulation of zinc on the underside of the product.

Conclusions

Grass fires did not adversely affect the breaking strength or zinc coating of Class one 12 1/2 gauge barbed wire under the field conditions of this study. We conclude that subjecting zinc-coated barbed wire to grassland fire will not reduce its service life or its corrosion resistance.

The effect of fire on wire older than the wire of this study is not known. Because normal environmental exposure causes corrosion of the zinc layer, thereby exposing the underlying iron-zinc alloy layers and eventually the steel, heating of older wire may have a different effect. However, there is no reason to believe that older wire with intact zinc coating, even though of less mass than younger wire, would be more adversely affected by fire than wire with more zinc coating.

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