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A new method for detecting wire rope defects

Abstract

Wire ropes are very regular machine elements. Any deviation from the regular rope pattern can be used to determine defects resulting from the rope manufacture, from the installation procedure or from rope deterioration during service. This paper describes a novel method for detecting defects and changes in the wire rope geometry.

1 Introduction

From a safety point of view, the first wire rope in history, manufactured in 1834 by the German mining engineer Wilhelm August Julius Albert, had a great advantage over all other steel wire rope designs that were developed later: it did not have a metal core, and it did not have wires inside its strands (Figure 1). Therefore, during a visual inspection, every single wire of the rope could be inspected.

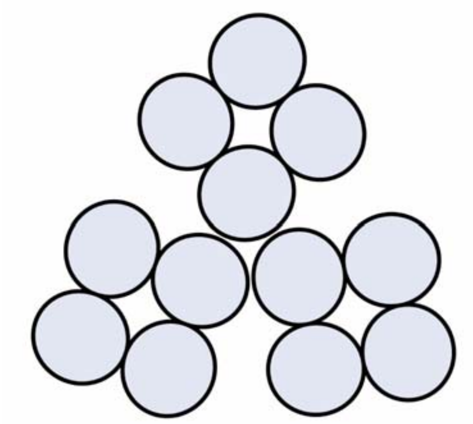

Figure 1: Cross section of the Albert rope. Every wire can be visually inspected.

In steel wire ropes manufactured today, however, a great percentage of the metallic area cannot be visually inspected at all.

In a rope 36 × 7, as an example, the steel core, which cannot be visually inspected, accounts for about 50% of the metallic area (Figure 2).

The outer strands make up the remaining 50%. But even here, the centre wires cannot be visually inspected either. They are covered by another layer of wires (Figure 3).

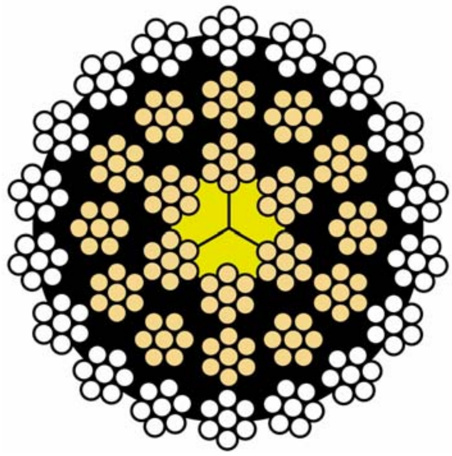

Figure 2: Cross section of a rope 36 × 7. The core, which makes up about 50% of the metallic area of the rope, cannot be visually inspected.

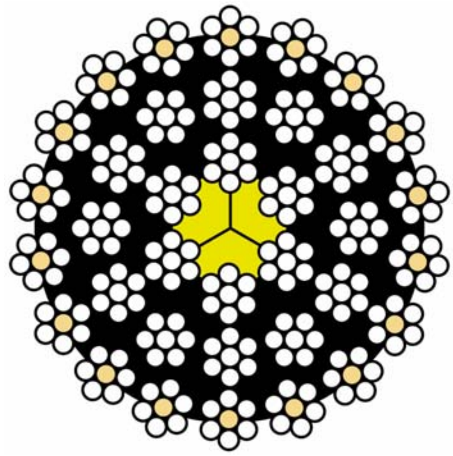

Figure 3: Cross section of a rope 36 × 7. The centre wires of the outer strands, which make up about 10% of the metallic area of the rope, cannot be visually inspected.

The only wires which can be visually inspected are the outer wires of the rope. These represent about 40% of the metallic cross sectional area. But even these wires disappear inside the rope on about half of their lengths, leaving only about 20% of the rope's cross section accessible for a visual inspection (Figure 4).

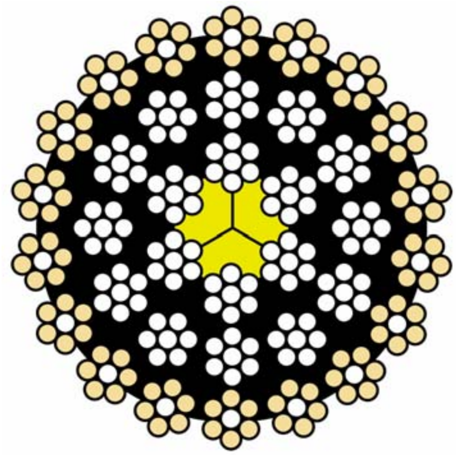

Figure 4: The outer wires, which make up about 40% of the rope, can only be inspected on about half of their lengths.

Similar percentages will be obtained for most other ropes with a steel core.

Because you can only visually inspect such a small percentage of the steel wire rope cross section, visual rope inspections must be performed with great care. But even then a great uncertainty about the overall condition of the wire rope remains:

Visual rope inspection =

20% evidence + 80% hope

In order to also gain information about the remaining 80% of the steel wire rope cross section, non destructive (magnetic) test methods have been developed. In many applications, such NDT tests are mandatory and performed at regular intervals, e.g. every 6 months.

But what happens in the long period between those NDT tests? Rock fall might damage a mining rope one day after the magnetic inspection and create a safety critical rope condition. Therefore, visual wire rope inspections must still be carried out daily.

Now consider the following example:

A deep shaft mine is equipped with 4 hoist ropes of a length of 2,000 m each. It also has 8,000 m of balance ropes. A visual inspection would therefore have to be done on 16,000 m of rope.

If the inspector would spend only two seconds on every rope metre, the inspection of the 16,000 m of rope would take 9 hours. Of course, during such an inspection, the shaft could not operate. The visual rope inspection would therefore cost the mine a few 100,000 Dollars in downtime.

Of course, the mine could place 4 inspectors next to each other, everyone of them inspecting one of the ropes. This would reduce the inspection time to 2 ¼ hours, but even that would cost a fortune.

2 The new test method

This paper is going to present a method which in the future will allow regular visual rope inspections at normal operating speeds and without any downtime costs.

2.1 Strands

Steel wire strands are very regular bodies. Their geometry repeats itself after every lay length. 1000 photographs of a brand new and undamaged strand taken at distances of exactly one strand lay length should therefore all look identical (Figure 5).

A cinema projector playing these 1000 photos in a sequence should therefore produce a static, not changing image. This would be a boring movie, I admit. But it would tell me that the strand is not damaged externally.

Now think of the same strand, but with a few defects. Now 1000 photographs taken at distances of exactly one strand lay length will no longer all look identical: Some pictures will be different (Figure 6). And a cinema projector playing these 1000 photos in a sequence will now produce a static image where from time to time objects will flash, making it easy to locate the strand lays which have an external defect.

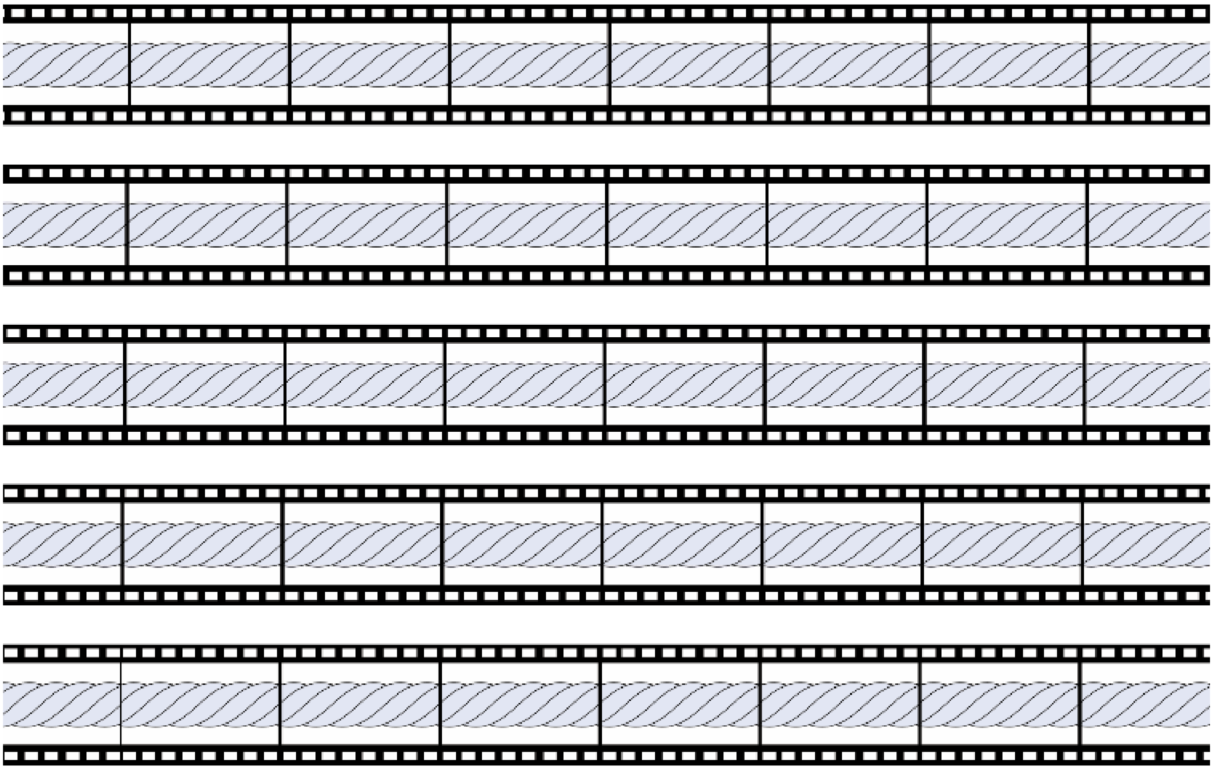

Figure 5: Pictures of a brand new strand taken at steps of one lay length would all look identical.

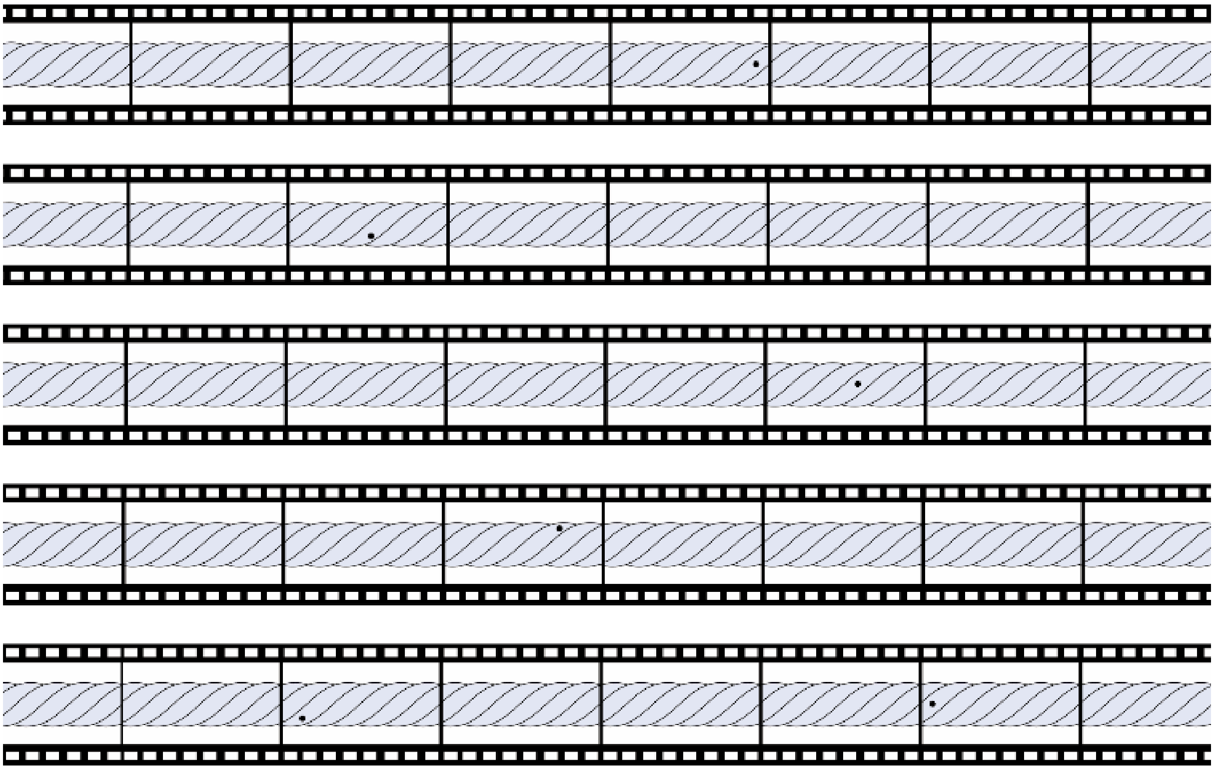

Figure 6: Pictures of a damaged strand taken at steps of one lay length would no longer look identical.

With a strobe light flashing at the correct speed or, even better, with a flash light triggered by a lay length or speed sensor, this effect can easily be studied: Although travelling at high speed, the strand seems to stand still, and only from time to time an abnormality (e.g. a wire break) produces a short flash.

These high speed pictures can be recorded in different ways for later, more thorough examination of the defect areas, or in order to let a computer find these defects in the first place. One method of how this could be done is explained here:

If you superimpose a positive black and white image of one lay length with the negative black and white image of the next (and identical) lay length, the result will be a black image (Figure 7). A cinema projector playing 1000 such superimposed photos in a sequence should therefore produce a dark screen only. This again would be a very boring movie. But, again, it would tell us that the strand has no external defects.

If, however, you superimpose the positive black and white image of one lay length with the negative black and white image of the next, defective lay length, the result will be a black image in all areas where the two lays look the same, but the negative of the defect will stand out (Figure 8). A cinema projector playing 1000 such superimposed photos in a sequence should therefore produce a dark screen where, from time to time, defects produce a flash.

You will therefore not see everything, you will only see what is *different* from the normal condition.

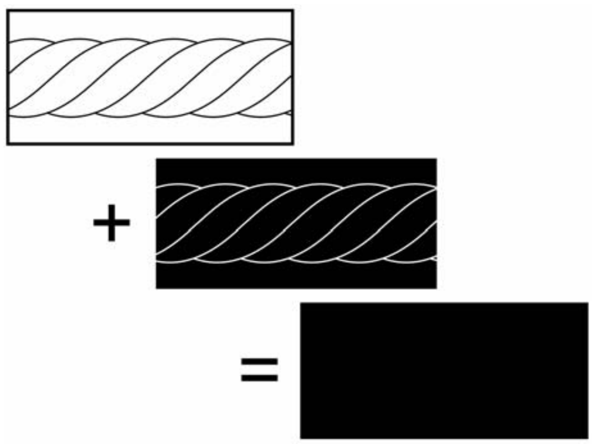

Figure 7: A superposition of a positive photograph of one lay and a negative photograph of the next lay of an *undamaged* strand will produce a black image.

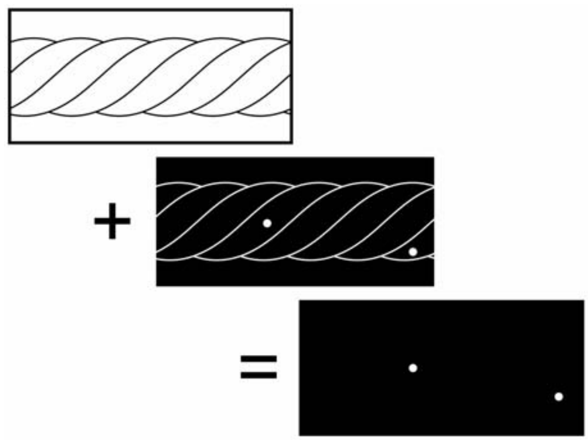

Figure 8: A superposition of a positive photograph of one lay and a negative photograph of the next lay of a *damaged* strand will produce a black image with the defect standing out.

Similar methods are used by astronomers in order to find a new comet or a new star (nova). They will not attempt to count all 5 million dots on a photograph of a certain region in the skies in order to see if there is one more dot than a week ago. They will use a blink comparator which will alternately display the old and the new photograph. A new comet or a nova will immediately become visible as a blinking dot.

This is exactly what we want: We do not want to see the *whole* strand surface, we only want to know where it looks different than normally.

The sequence of photographs could be produced using high speed cameras, taking photographs from different directions in order to inspect the total rope surface (Figure 9). It might be more favourable, however, to take continuous photographs of the whole strand or rope length (this can already be done today using cameras with a slit aperture (Figure 10)), which the computer could then fragment into pictures of one or more lay lengths for further analysis.

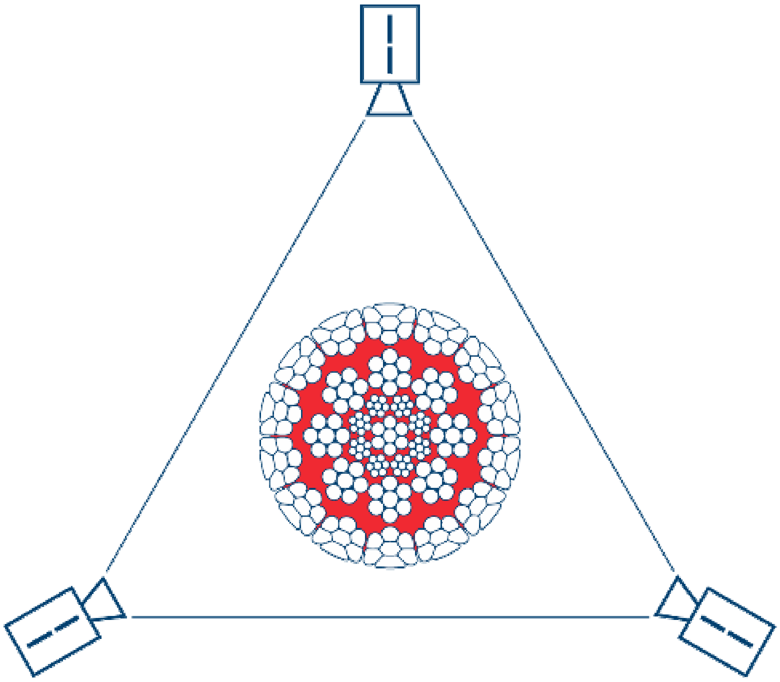

Figure 9: The photographs can be taken from different directions in order to inspect the total rope surface.

Figure 10: Round shot camera with a slit aperture to produce a continuous image.

2.2 Ropes

Steel wire ropes are also very regular bodies. Their geometry also seems to repeat itself after every lay length. 1000 photographs of a brand new and undamaged rope taken at distances of exactly one rope lay length should therefore again all look identical. But this is not entirely true: The strands will again be in the same positions in every photograph, but the position of the wires within the strand might have shifted.

A cinema projector playing these 1000 photos in a sequence will therefore produce a movie where the rope itself will again stand still as if it was nailed to the screen. But depending on the combination of strand and rope lay lengths, we might see the strands within the rope either stand still as well, or we might see them rotate around their own axis at low speed. (This is an impressive view.)

During a first field trial of the method, the author has seen a newly installed steel wire rope where in the “frozen” picture of the rope all strands were standing still except for one which was rotating around its own axis at high speed (you have to see it in order to believe it!). Apparently this strand was either manufactured with a different lay length than the others or it was closed with a different back-twist (which would produce the same result). The author predicted that because of the different behaviour of this one strand the rope would not reach its expected lifetime. In fact, it had to be discarded shortly afterwards. This example shows that the new inspection method could also be used for the quality control in a wire rope production plant.

If the pictures taken from a strand or a rope are triggered by the lay length, the strand or wire used to send the trigger signal will always be in the same position of the image. The other rope elements will change their relative position according to the change of the rope or strand geometry. If e.g. the lay length of the rope increases, the rope in the movie will stand still but become longer over time. Similarly, if the rope reduces in diameter over a certain length, the rope in the movie will again stand still but become thinner over time. These changes could of course also be measured continuously and later be plotted as a function of the rope length.

A first prototype manufactured by the author will in the future be optimised in cooperation with the Institute of Materials Handling and Logistics of the University of Stuttgart and will hopefully become commercially available soon.