

# Metallographic Preparation of Steel Cord Cable Sections

Martin Braekvelt, NV Bekaert SA,  
Bekaert Technology Center,  
Bekaertstraat 2, 8550 Zwevegem,  
Belgium

## Introduction

Steel cord is the basic material for one of the oldest composite products in the automotive industry: tires. Steel cord filaments, twisted into cable cords, are imbedded in the rubber compound giving the tire its unique properties, such as low weight, low wear and heat generation, excellent fatigue properties which lead to a low fuel consumption, a high grip on the road and a good puncture resistance (see picture 1).

Ever since the first tires were produced, a lot of research has been done to improve the balance between increased lifetime and lower weight. Combining different steel cord cable constructions and rubber types is key for evaluating and/or developing new tire products. The microscopic investigation of the steel cable in the rubber plays a fundamental role in this development process. Microscopic analysis is done to investigate the construction of the cable cord, the rubber penetration in the cable cord and possible fretting and/or corrosion phenomena.

The microscopic sample preparation is however challenging, because of the different characteristics of both components: the rubber, which is soft, very elastic and therefore very difficult to grind/polish versus the steel cable, which exhibits a high hardness level and a restricted ductility.

This paper describes the development of a method to successfully prepare the combined rubber/steel samples for microscopic analysis.

Furthermore some specific information concerning the microscopic investigation and finally the optical microscopy photos are included.

## Preparation procedure

The preparation procedure consists of three consecutive steps which are described in this paragraph.

### 1. Sampling

The samples can be taken with a simple cord scissor. The section is made in the middle of a piece of cable cord with a length of 6 cm. 3 to 6 sections are taken from each cable cord. Depending on the cable construction, up to 60 sections are gathered in one sample mount. Here, the creativity of the investigator is needed to make a well-ordered mount.

### 2. Embedding

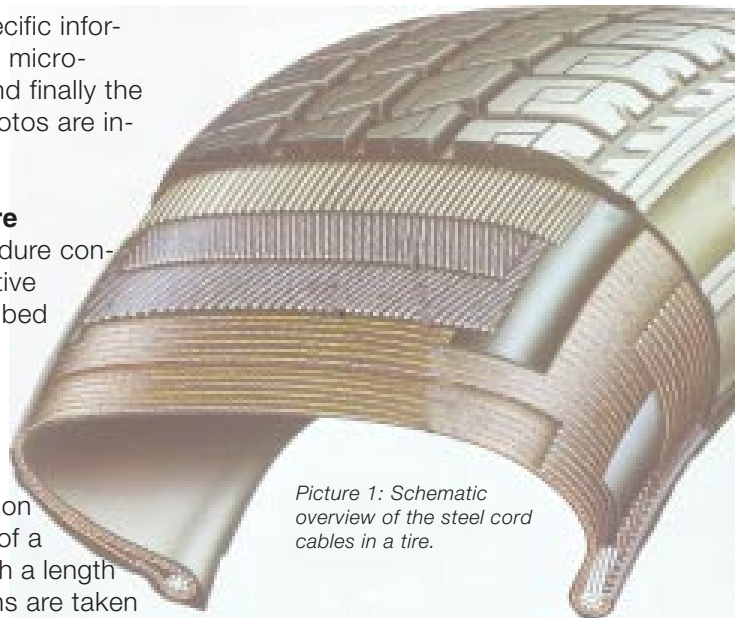
After sectioning the cable cord samples are embedded in Caldofix resin. The use of a vacuum equipment (e.g. Epovac) enhances the filling of all possible air gaps in the samples during curing. However, thanks to capillarity, the same result can be obtained by increasing the curing time.

If higher contrast is needed between cable, rubber and resin, the latter can be colored with a pigment (see picture included).

After embedding the samples are sectioned with a cutting machine using a universal sawing blade (Al-oxide or Si-carbide type).

### 3. Grinding and polishing

For a good interpretation of the surface/interface between rubber and cable filaments, the rubber should be kept as flat as possible



Picture 1: Schematic overview of the steel cord cables in a tire.

during grinding and polishing. In order to realize this, polishing surfaces which exhibit a sufficient friction rate in combination with a low pressure load should be selected. Furthermore, water-based diamond suspensions give better results and shorter polishing times than water-free diamond suspensions.

The grinding and polishing steps can be performed by a manual or a semi-automatic method. In some cases manual grinding and polishing is the only option due to:

- an extremely soft rubber.
- a large amount of rubber around the cable sections.

For both grinding and polishing methods, a sample preparation procedure has been developed to realize qualitative and reproducible metallographic samples.

#### 3.1. Manual grinding/polishing

Table 1 shows the consecutive steps of the preparation procedure for manual grinding and polishing. For this schematic overview, the tables from "The Metalog Guide (Struers)" are used.

Table 1: Schematic overview of manual grinding and polishing steps

Step	1	2	3	4	5	6	7
Surface	Paper	Paper	Paper	Paper	DP-Pan	DP-Mol	DP-Chem
Abrasive	SiC	SiC	SiC	SiC	Diamond Suspension	Diamond Suspension	OP-S
Grit/ Grain size	180	320	600	1200	9 µm	3 µm	-
Lubricant	Water	Water	Water	Water	Red	Red	No **
RPM	300	300	300	300	300	300	300
Force [N]	-	-	-	-	-	-	-
Time [min]	Until plane	*	*	*	3	3	2

\* Turn samples over 90° after each grinding step and grind until the previous grinding lines have disappeared.

\*\* Rinse the samples with soap and water during the last 30" to clean the sample surface.

In step 6, the DP-Mol cloth can be replaced by any other cloth of a woven type; flocked cloths are not suited due to their different friction properties.

The polishing cloth must be chosen in function of the rubber compound and/or the relative amount of rubber versus steel in the cord section. For softer rubber types and high relative amounts of rubber, more friction on the cloth is required because of the need to lower the pressure load on the samples to prevent damage of the rubber (pull-out or shrinkage).

### 3.2. Semi-automatic polishing

Table 2 shows the schematic over-

view of the preparation procedure for semi-automatic grinding and polishing. In this case, the polishing is done on a RotoPol-22 and a RotoForce-4 unit. The samples are polished in the single-pressure mode.

Between step 3 and 4, samples must be checked to see if all burr and grinding lines are removed.

Adaptations to the polishing procedure are necessary in function of the rubber type: the softer the rubber, the lower the applied pressure. The choice of an appropriate polishing cloth is most critical in the DP stage of step 4. The selection varies from MD-Dac over MD-

Mol to SP Polisat for rubber types varying from hard to soft, or from a high relative amount of rubber to a small relative amount.

### 3.3. Evaluation of polishing quality

A good polishing quality requires:

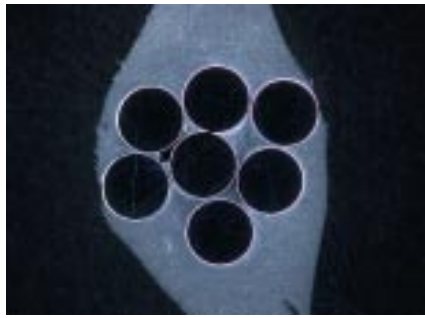
- Nice delineated filament cross sections.
- A flat rubber surface (i.e. no pull-out or shrinkage) with dull appearance (i.e. no shiny look).
- A burr free sample surface with no grinding lines left in the rubber matrix.

Table 2: Overview of the grinding and polishing steps in semi-automatic polishing.

Step	1	2	3	4	5
Surface	Paper	Paper	MD-Largo	MD-Mol	MD-Chem
Abrasive	SiC	SiC	Diamond Suspension	Diamond Suspension	OP-S
Grit/ Grain size	180	320	9 µm	3 µm	-
Lubricant	Water	Water	No *	Red	No **
RPM	300	300	150	150	150
Force [N]	45	45	30/45	30	30
Time [min]	Until plane	1	6	3	2

\* To keep the friction condition at an acceptable level, no lubricant is used. Otherwise this results in a too slow material removal and a shiny, pulled-out rubber surface.

\*\* Rinse the samples with soap and water during the last 30" to clean the sample surface.



**MD-Mol**  
Dark Field illumination, sample after MD-Mol stage



**Cord with fretting.** Bright field illumination. Damage on cord filaments, fretting corrosion products in cable.



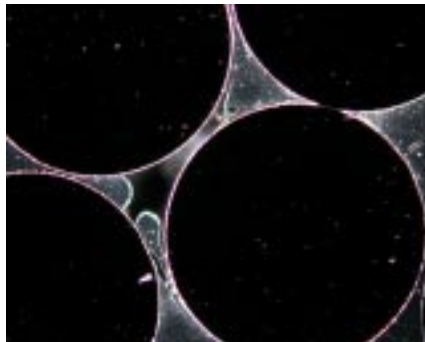
**MD-Chem.** Dark Field illumination, sample after final polishing stage



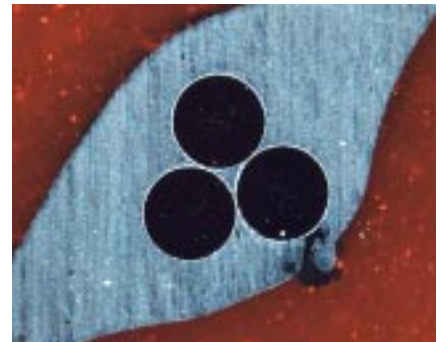
**Cord 1a.** Same picture as MD-Chem, but Bright field illumination, notice that the visibility of the rubber penetration is not as good as in the Dark Field image.



**Grinding.** Dark Field illumination, sample after grinding



**Detail.** Dark Field illumination, detail showing inferior rubber penetration in the cable cord.



**Caldofix with pigment.** Dark Field illumination, better contrast for photography due to red pigment in the Caldofix resin.



**MD-Largo.** Dark Field illumination, sample after MD-Largo stage

### Optical Microscopy

Depending on the cable cord section characteristic to be analyzed, the optical microscope is operated under different modes. For cable cord construction and rubber penetration in the cord, the samples are investigated under Dark Field illumination. In this mode, the ca-

ble sections are black, the rubber is light grey, air gaps in the cable which are filled with resin show the resin color, air gaps that are not filled (due to complex closed cable constructions) show up as black spots. The detection of fretting and corrosion phenomena needs normal Bright Field (reflected light) illumination. The cable sections are white, the rubber is dark grey and the corrosion products vary between orange-red (rust) to several grey levels.

### Conclusion

A method is developed to evaluate the critical interaction of steel cord cables and the rubber compound. The main bottle-neck in preparing a steel/rubber composite product is the grinding and polishing of the soft rubber phase.

The developed method provides a tool to prevent any damage of the rubber and possible pollution of the air gaps. This is done by controlling the pressure loads in combination with a correct choice of the polishing cloth.

The proposed metallographic sample preparation procedure facilitates a high-quality microscopic investigation. Since the optical microscopy photos of the cable sections are the only tool to evaluate the cable/rubber interaction, this reliable and reproducible metallographic preparation method of the samples is fundamental.