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Total Microscopy of a Tire

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Every aspect of an automotive passenger tire can be probed by some sort of microbeam instrument and Figure 1 identifies the aspects that are common to today's wire belted radial passenger tires. The salient features of each aspect are discussed with respect to the microscopical information obtainable from the area, how this information impacts on understanding tire performance, and the microscopical activity used to extract the information.

Tread Surfaces **1** –The type of abrasion patterns generated on tread surfaces during tire operation reflect the mechanism of tread wear [1]. Three possible mechanisms for tread wear have been identified: random cutting and tearing, pattern abrasion, and roll formation. A confirmation of the prevailing mechanism reflects the tire usage history. In some instances it may be important to know the direction of rotation of the tire and this also can be learned from abrasion patterns. Methods used are optical microscopy (OM) and scanning electron microscopy (SEM) on tread surfaces, SEM on cross sections cut normal to tread surfaces, and transmission electron microscopy (TEM) of ultrathin sections cut normal to tread surfaces [2].

Tread Wear Debris Particles **2** - The internal morphology of tread wear debris particles can provide additional evidence for establishing the mechanism of tread wear since the roll formation mechanism can be easily verified by OM examination of microtomed sections. Energy dispersive spectroscopy (EDS) fingerprints of the rubber compounds in the roll add to this evidence [2].

Bulk Rubber Compounds **3** - The degree of carbon black dispersion in tire compounds is one of several indicators that directly affect tire performance. The referee method for evaluating this is by quantitative OM on microtomed sections [3]. This method also provides critical information of tire durability, i.e. assessment of cement lines, splices, junctions, flow patterns and/or bulk grain effects. Morphological changes in bulk compounds caused by tire operation dynamics can be monitored by OM, SEM, and EDS [4], [5]. Investigations that reveal the bonding interaction between rubber and carbon black are conducted by straining ultrathin sections up to 300% prior to TEM examination [6].

Steel Wire Cable Belts Under the Tread **4** – Vulcanization pressure and cable twist patterns affect the depth of penetration of rubber into cable void spaces. Trapped air that promotes wire corrosion must be avoided. These aspects can be seen by OM and SEM. The complex adhesive system of rubber to brass plated steel wires is reflected by several metal oxide and metal sulfide layers that form the bond between the rubber and metal. SEM/EDS on surfaces and TEM selectedarea electron diffraction (SAED) on ultrathin sections provides critical information [7].

Steel Wire Belt Cut Ends **5** – This is a critical region that needs constant monitoring of adhesion between rubber and cut ends and is best done by OM and SEM. Thisis also the area of "belt edge separation" which may be a principle failure mode in some catastrophic events. The shape of individual cut wire filaments must be such that they do not act as stress raisers. OM and/or SEM can also reveal polishing of the cut ends that occurs as failures progress.

Textile Cord **6 –** Adequate adhesion requires optimum penetration of adhesive dip into cord interstices and this can be evaluated by OM, SEM on single step systems. For multiple dip adhesive systems the distribution of adhesives is best done by TEM on ultrathin sections [9].

Ply Turnup Ends **7** - Penetration of rubber into cut cord ends and the absence of porosity are diagnostics of cure pressure and can be observed best by SEM.

Bead Area **8** - Compaction of rubber into and around bead wires and the absence of trapped air are essentials for proper bead integrity and easily observed by OM and SEM.

Other Surfaces **9** - Molding processes can be evaluated by checking for: insufficient mold filling; presence of blemishes; existence of mold flow problems; and "health" of sidewall vents. OM and SEM/EDS methods are effective here.

The total microscopy of a tire must include the microscopy of failures. All techniques useful for the above aspects 1 through 9 can be applied to investigations of failure incidents. A necessary adjunct is that of applying intentional damage to the structure to see what morphological changes can be useful for diagnostic purposes. This would include the microscopy of punctures, road hazards, abuse, and other assaults common or uncommon to tires.

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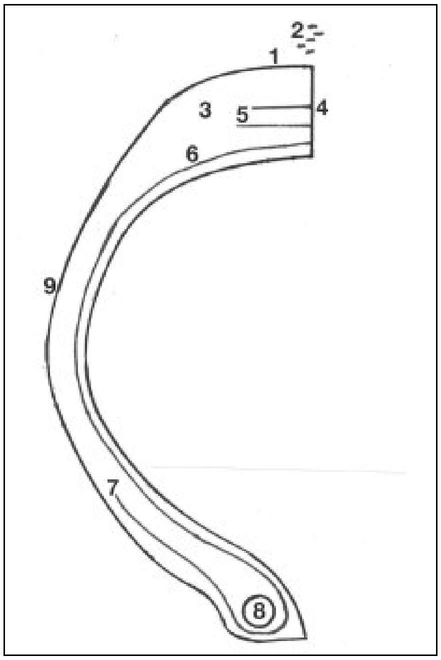

FI G. 1. Generic Tire

1. Tread Surface
2. Tread Wear Debris
3. Bulk Rubber Compound
4. Steel Belt Plies
5. Steel Belt Cut Ends
6. Carcass Ply
7. Carcass Ply Turnup Ends
8. Bead Package
9. Other Surfaces

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