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Case study

Failure analysis of a motor-car coil spring ☆

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1. Introduction

A motor car coil spring of a rear shock absorber has been ruptured during car operation. The surface of a spring was protected against corrosion with a thick layer of paint on polymer basis. Around the fracture surface, a protective layer was damaged and removed over a length of several centimeters. In this area, spring has long been exposed to corrosion attack and thus surface heavily corroded and winkled (Fig. 1).

The fracture surface of a spring is discontinuous and in major part of it covered with fresh rust. On a minor portion of a fracture surface, a compact, dark brown rust (like on the circumference of the spring) is visible, which was formed substantially (months) before the final rupture of the spring (Fig. 2). From this part of the fracture surface, crack gradually propagated (the "arrest lines" are clearly visible), due to the combination of corrosion attack and cyclic loading during the car operation (Fig. 3), until the length of the crack reached its critical value, and the spring broke instantly (Fig. 4).

Part of the fracture surface, covered with thick, compact and dark rust is the primary crack, which was exposed to corrosion attack for months. Part of the fracture surface (Fig. 5), where a layer of compact surface rust and indentations of rust into the material are clearly visible represents a propagating stage of a fatigue and part of a surface (Fig. 6), which is covered with thin fresh rust (formed in a few days after final rupture) the terminating stage of the fatigue.

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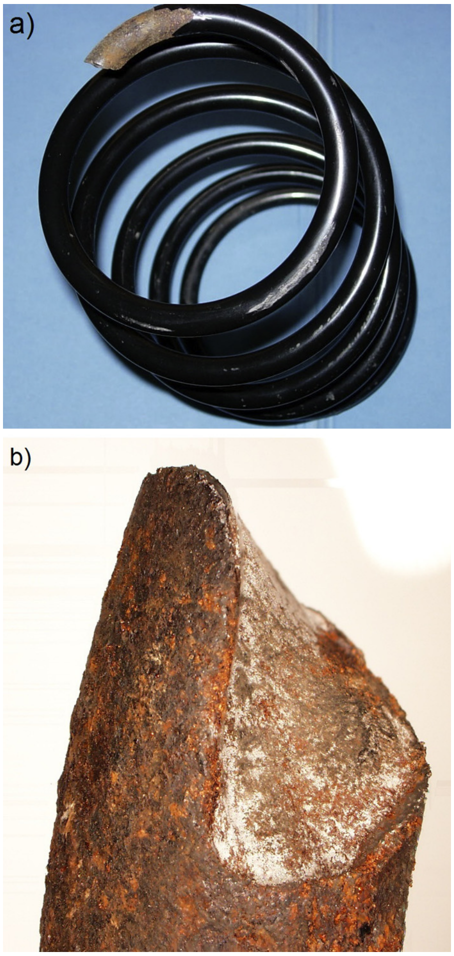

Fig. 1. Damaged motor-car coil surface (a) and corroded fracture surface (b).

2. Failure origin

Rupture of the coil spring is considered as a failure due to corrosion induced fatigue. Corrosion fatigue caused simultaneous action of corrosion, due to damaged protective layer, and cyclic loading [1,2]. From one of the corrosion induced indentations, crack propagated through the material and led to the final rupture of the spring [3].

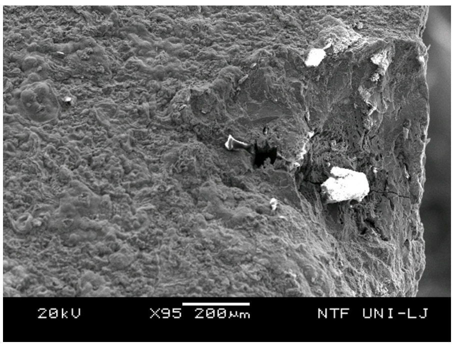

Fig. 2. The fracture initiation surface of a coil spring, covered with corrosion products and secondary cracks.

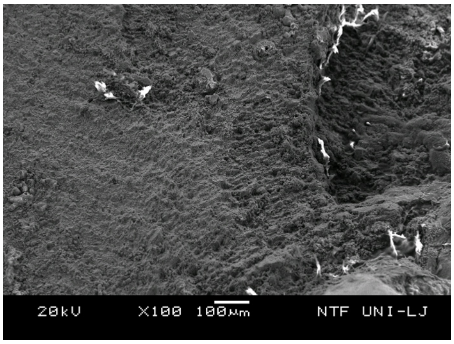

Fig. 3. Part of the fracture surface with a gradual crack propagation (corrosion induced fatigue).

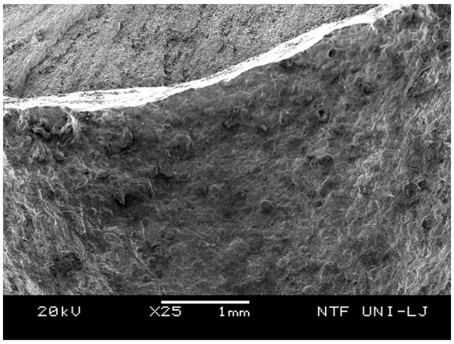

Fig. 4. Upper part of a fracture surface represents a termination stage of a fatigue where spring broke instantly and lower area corroded surface of the spring.

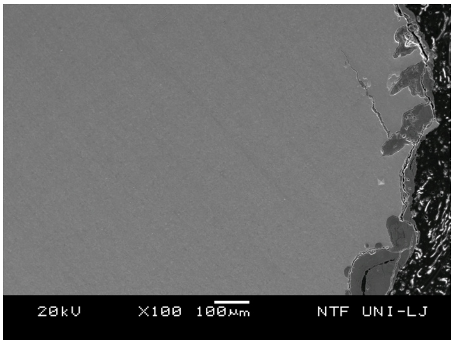

Fig. 5. Axial cross-section through fracture surface. Corrosion products are at the circumference and the fracture surface as in the indentations (secondary cracks).

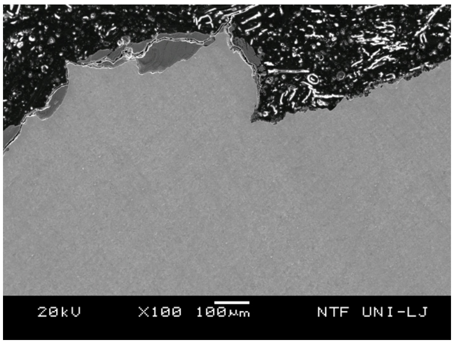

Fig. 6. The micrograph shows the boundary between propagating stage, with visible corrosion products and terminating stage of the fatigue fracture. Opposite side of the primary crack.

Table 1
Chemical composition of the spring steel.

Element	C	Si	Mn	P	S	Cr	Ni	Mo	Al	N
wt.%	0.56	1.39	0.66	0.007	0.006	0.62	0.02	0.01	0.005	0.0056

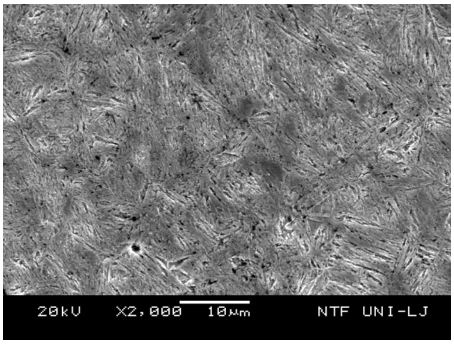

Fig. 7. Martensitic microstructure of the spring.

3. Material of the spring

Spring was made from chromium and silicon alloyed spring steel [4]. The chemical composition is shown in Table 1.

Steel was quenched and tempered to obtain martensitic microstructure with hardness of 520 HV–560 HV (49 HRC–51 HRC). There was found no evidence of any imperfection in the steel, which could be the cause of failure of the spring (Fig. 7).

4. Conclusion

Rupture of the spring results from the corrosion induced fatigue of steel. The main reason that this has occurred was damaged corrosion protection layer (paint) on the surface of the spring, where corrosion attack has started. Simultaneous activity of corrosion and cycling loads caused failure of the spring.

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