C2 Cause of Failure of a Bungee Cord

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During tensioning of the cords in a reverse bungee machine in preparation for a launch, one cord suddenly snapped. The damaged cord was alleged to be within its life span. The question arose whether someone had tampered with the cord, resulting in its premature failure. Investigators submitted the following exhibits for laboratory examinations: the two lengths of the damaged cord, the corresponding unbroken cord on the other side of the carriage, a newly bound cord (control sample), and a control sample of black elastic ribbon.

Construction of cord: The bungee cord had a white hard plastic bobbin at each of its two attachment ends. The bungee cord consisted of a bundle of many black elastic ribbons bound by similar black elastic bands stretched spirally over the thick bundle. The spiral bindings criss- crossed in opposite directions of twist (clockwise and anti-clockwise), holding tightly together the bundle of ribbons. The ends of the spiral bindings were knotted together. The broad ribbons were made of black elastic strands joined side-by-side lengthwise. The elastic material was made of vulcanised carbon black-filled cis-polyisoprene (natural rubber) with some silicone oil coating. The cord was protected by a blue cloth sleeve (sheath), woven from a blend of polyamide (nylon) fibres and polyether urethane fibres (lycra-like). This highly elastic flexible material provided a protective sleeve that “hugged” the black elastic cord but was able to accommodate the longitudinal stretching and radial expansion of the cord.

Questioned damaged cord: The two lengths of cords with the bobbins weighed 40.3 kg. The two lengths of broken cord were 7.31 m, and 3.13 m long, respectively. The ends of the black elastic strands in them were of varying lengths, indicating they were not cut but had torn under tension. The number of strands in the cord was approximately 4,268.

Damages on the blue sleeve: Some areas of the blue sleeve had thinned out due to stretching, abrasion and wear-and-tear. Throughout its length, the blue sleeve had circular dirt marks and thinned bands around the circumference of the cord, corresponding to the bindings around the cord. The sleeve was double-stitched along its length; some seams had burst. The sleeve was found to be torn and burst due to the elastic strands enclosed within in it pulling back (rebounding) when the cord snapped. Beneath the blue sleeve were many lumps due to loops of black elastic strands forming between the spiral bindings. However, there was no evidence on the blue sleeve of cuts by a sharp cutting object or instrument.

Damages on the black elastic cord: The damaged ends of the two lengths of cord had many broken ends of varying lengths; some long and some short, in a tangle. The spiral black elastic bindings were not damaged. Many of the exposed ribbons had split length-wise into separate individual strands. SEM examination revealed cracks on the surfaces of many strands, and fracture at the ends due to tension, with evidence of elongation past breaking point. The damages indicate that the sudden break in the cord and release of the load immediately caused the stretched strands to spring back, gathering as loops between the spiral bindings. This led to a sudden radial expansion or increase in diameter, which burst the blue sleeve in certain areas. Removal of the blue sleeve revealed numerous black rubber strands in the cord with broken ends, and loops of strands between the spiral bindings. Removal of the spiral bindings to expose the interior of the bundle revealed about 875 broken strands in one 0.5-metre section.

Cord on the other side of the carriage: It was 9.30 m long and had a diameter ranging from 26.7 cm to 30.0 cm. Grey stains and thinned- out areas were found on the blue sleeve, and some parts of the seams had burst. Lumps could be felt beneath the sleeve. Numerous black rubber strands in the cord had broken ends, and numerous loops of strands between the spiral bindings. Removal of the criss-crossing spiral bindings in a 0.5-metre section revealed about 300 broken strands in a 0.5-metre section.

Test damages: Test damages were created on control elastic strands by stretching until breakage, cutting with a utility knife (box-cutter) with and without tension in the strands, and cutting with a pair of scissors with and without tension in the strands. The ends of the test damages were compared with those of the questioned cord.

Conclusions: The black elastic strands of the bungee cord and its blue sleeve were not cut by a sharp

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cutting instrument or object. The damages were consistent with failure and fracture of the bundle of rubber strands in the cord due to ageing, tension (stretching) and fatigue. Environmental factors can affect both the short- and long-term fatigue behaviour of rubber. Detrimental factors include: elevated temperatures, oxidative ageing by oxygen and ozone, other chemical attacks, ultraviolet light and sunlight, and repeated mechanical stresses. Fatigue life is also affected by the presence of unintentional uncontrolled flaws introduced at any stage of the manufacturing process of rubber.

Bungee Cord, Elastomer, Fracture

