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DEVELOPMENT OF A TEST DEVICE (FIXTURE) FOR DETERMINING THE PULL-OUT FORCE OF SWAGED BALL TERMINATIONS ON CONTROL CABLES

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1. Introduction

The mechanical integrity of swaged ball terminations on control cables is a critical factor in the safety and reliability of aerospace, automotive, and industrial actuation systems [1,2]. While analytical models can estimate strength for idealized geometries, real terminations involve complex interactions between the ball, wire strands, and the mating seat defined by military and industry specifications [1,2]. The conditional-realistic ("pull-out") test reproduces the actual seating of the termination to directly measure maximum extraction force (F_{fail}) and to identify prevailing failure modes under service-representative constraints [3,4]. This approach captures combined effects of shear, localized indentation, and potential cable slippage, producing data suitable for design verification and quality assurance [3–5].

The present study outlines the experimental setup, testing procedure, and evaluation methodology for determining pull-out strength, aiming to establish reliable performance benchmarks for swaged ball cable terminations [4,5].

2. Materials and Methodology

The tensile testing is conducted using a Shimadzu AGS-X 10 kN universal electro-mechanical testing machine [6]. The test fixture is designed to be mounted on the testing frame using standard interface elements. The lower section of the fixture is configured avoid inducing stress concentrations and would provide a gradual load release. This prevents damage to the cable, in line with the requirement that the specimen remain serviceable after testing. The significant influence on reducing the tensile force at the end of the cable in a drum-based tensile testing setup of both the number of wraps and the friction coefficient [7]. It can be shown that the load decreases exponentially with increasing wrap count and friction, effectively distributing stress along the contact surface (Fig. 1). Testing equipment manufacturer offers a dedicated fixture for strand testing and one of its clamping halves was utilized for securing the cable during the tests (Fig. 2).

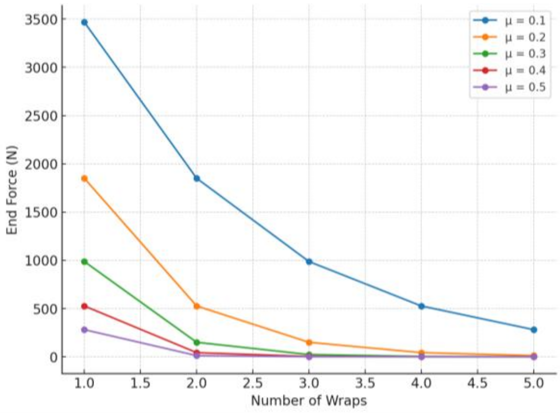
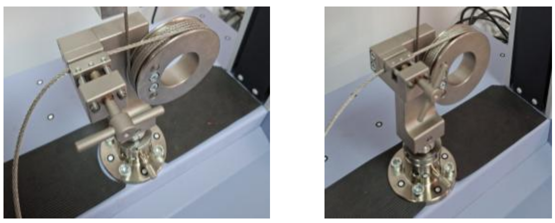


Fig. 1. Force in cable vs Number of wraps for different friction coefficients.



(a) (b)

Fig. 2. Cable placement in lower fixture: (a) 3 ¾ wraps, (b) 4 ¾ wraps.

The upper section of the fixture is designed to apply a concentrated load to the ball termination, enabling the shearing of the ball from the cable. The ball seat is manufactured to replicate service conditions as closely as possible, with a geometry that accurately reproduces the assembly into which the cable end is installed (Fig. 3).

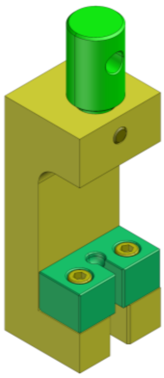


Fig. 3. Pull-out fixture (real-seat method).

3. Results

The testing is performed in two cases. First, for each production batch, the ultimate tensile load that the termination can sustain is determined under a crosshead displacement rate of 1 mm/min (Fig. 4). Subsequently, each cable is subjected to a proof load test at 2 kN, applied at a crosshead speed of 3 mm/min, held for 10 seconds, and then released (Fig. 5).

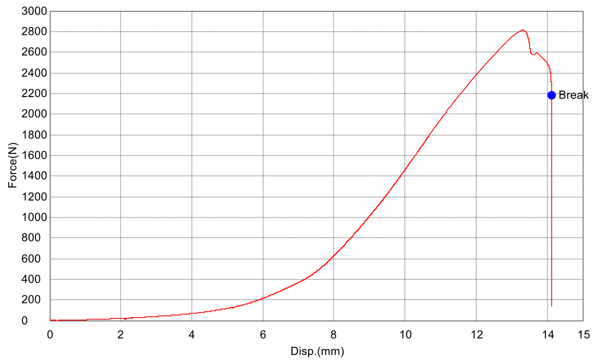


Fig. 4. Ultimate tensile load.

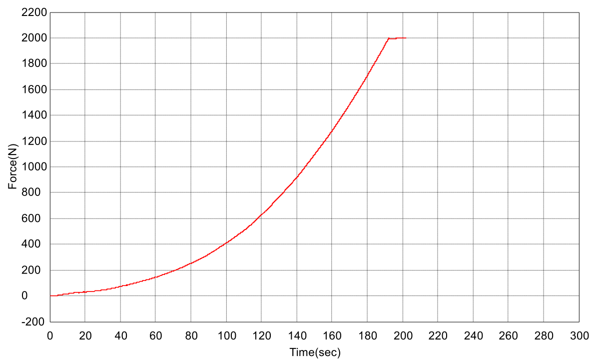


Fig. 5. Proof load test at 2 kN.

4. Conclusions

The developed pull-out test fixture, designed to replicate service conditions of swaged ball terminations on control cables, was experimentally validated through testing on over 100 cable specimens. The results confirmed the fixture's robustness, repeatability, and capability to accurately determine both ultimate tensile strength and proof load performance. This fixture is a significant and practical tool for quality control, certification testing, and research applications in aerospace, automotive, and industrial cable systems.

Acknowledgments

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