Experimental and Numerical Investigations of Joining by Electromagnetic Forming for Aeronautical Applications

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Abstract. Due to the demanding requirements on cost, weight, and safety for helicopters, a continuous improvement of the manufacturing processes is necessary. Increasing interest in unmanned aircrafts as well as developments in the direction of hybrid-electric propulsion systems are some of the other drivers, which encourage the aircraft industry to permanently look for alternative manufacturing processes for lightweight components to improve cost and weight. The present study investigates the electromagnetic crimping process as an alternative to thermally welded joints with different form-fit elements like grooves, pockets, and knurlings. The electromagnetic joining technology is based on pulsed magnetic fields to reshape components made of electrically conductive materials and it is able to manufacture form-fit or welded joints. First the analytical methods are presented to design a lightweight helicopter's cyclic stick by the electromagnetic joining process based on maximum applied pilot control forces. Furthermore, approaches to calculate the maximum axial and torsional load transfer between the joining partners are given. The results are used in a two dimensional finite-element simulation to determine the process parameters and to optimize the groove design with respect to shear stresses. A good agreement between the numerical results and the experimental investigations is shown. The pull-out force is set as the failure criterion of the connection and the specific joint strength of different groove shapes is compared with the analytical model. Due to the slight increase of the total weight at the presented weight analysis, proposals for design optimization with focus on the joining zone are made. Despite this fact, the cost analysis shows a reduction of production costs. The achieved main goal of the presented study is the proof of feasibility of substituting thermally welded connections with electromagnetically crimped joints made of lightweight components and the proof of the remarkable potential of reducing production costs and time of aeronautic components.

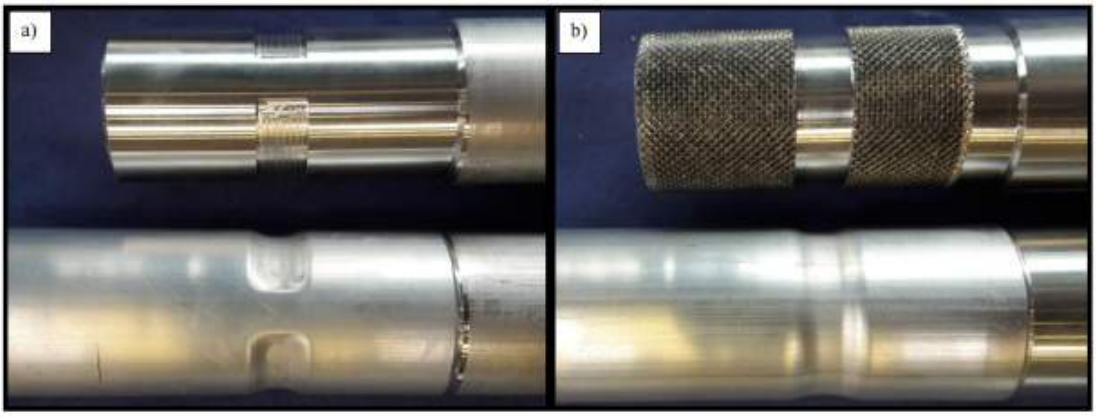

Figure: Components before and after electromagnetic joining operation; a) Spline shaft with two grooves, b) Mandrel with circumferential groove and knurled joining zone