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Condition monitoring of piezoceramic fibers during joining by forming

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Abstract

Nowadays, piezoelectric transducers with sensor or actuator functionality are applied on the surface of components by bonding. New research activities enable a novel process chain for sensor integration in which piezoceramic fibers are integrated directly into the surface of metal sheets using joining by forming. Scope of the paper is to investigate a method for condition monitoring of the piezoceramic fibers during the joining process. Different test samples are prepared and studied by its inherent sensor function in terms of electrical impedance during various loads. As a result, a novel approach is presented for monitoring the preload status during the forming operation and detecting errors by electrical impedance spectroscopy. This method contributes to ensure a high-volume production.

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Keywords: piezoceramic fibers, condition monitoring, impedance spectroscopy, joining by forming

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1. Motivation

Currently, a new approach for the production of structural components with integrated sensor and actuator functionality is pursued. Existing methods of preparation of such active structures are, inter alia, bonding piezoelectric patch transducers on the surface of components. The new approach enables a direct integration of lead-zirconate-titanate (PZT) fibers into the surface of metal sheets with joining by forming [1]. This method offers some new potential application but also leads to new challenges. Due to the elimination of adhesive and other polymer interlayers a better electromechanical coupling of the PZT fibers to the surrounding metal structure is achieved. Possible applications are in the field of structural health monitoring [2] or active vibration control [3]. Moreover, the direct integration offers the potential to produce complex three dimensional curved components, which have structure integrated sensor and actuator functionality [4].

One challenge in the joining process is the provision of a defined and reproducible preload of fibers with the metal sheet, which is necessary to transfer the process to a high-volume production. Without a sufficient preload it may happen that clamping is significantly reduced during operation as an actuator. If the preload is too high, there is the danger that the brittle ceramic breaks during production process and loses its sensor and actuator function.

For that reason, this paper deals with the maximum tolerable load to failure of the fibers during the forming operation. The inherent sensor function of the PZT fibers is employed to measure the change of the electrical impedance of the fibers during various loads. A similar approach has been described in [5]: a piezoceramic ring with a diameter of 44 mm is integrated into an aluminum tube by rotary swaging. By utilizing the direct piezoelectric effect the generated charge has been detected. Based on experimental and simulated results the process design were hedged and a non-destructive integration was ensured. However, in this paper the foundation for fiber condition monitoring during joining process is created with help of an electrical impedance spectroscopy, which is transferable for a high-volume production of piezoceramic/metal composites.

2. State of the art

2.1. Design of piezoceramic/metal composites

Hereafter the newly developed principle for direct integration of piezoceramic fibers by joining by forming is presented in a short version. Initial materials are aluminum sheets (AlMg2 alloy) and PZT fibers. A microstructure is pressed in the aluminum sheet by micro impact extrusion. The structure consists of ten parallel microcavities (0.3 x 0.3 x 10 mm³). Ten PZT fibers (0.26 x 0.27 x 10 mm³) which are interconnected by two collecting electrodes on both ends of the fiber are assembled in the microstructure of the aluminum sheet. The joining parts are illustrated in Fig. 1a. The actual joining process of the fibers with the application of the preload F_{pre} is schematically visualised in Fig. 1b. The upper punch moves down and deforms the webs of the aluminum sheet. The aluminum material flows and the sidewalls of the cavities clamp the PZT-fibers. After this process the fibers and the aluminum sheet are joined form-fitted and friction locked and thus forms a piezoceramic/metal composite. The proof of functionality and the detailed production steps are described in [4].

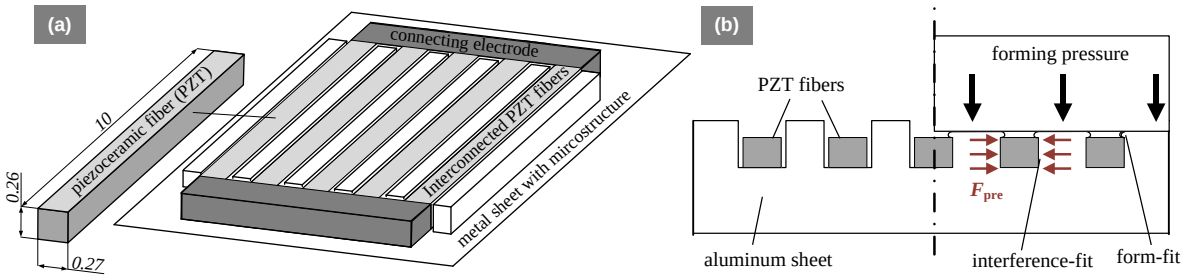

Fig. 1(a) Principle of integration of PZT fibers in microstructured sheet metal; (b) principle of joining process