Investigation of induction heating of thermoplastic composites for on-demand debonding in MRO operations.

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Abstract:

A significant value in European aviation is created during aircraft operations and through supporting services, such as maintenance, repair, and overhaul (MRO), which lead to expenditure of approx. € 290mil. per airline. The main task of MRO is to ensure the airworthiness of aircrafts during periodic inspections or line maintenance. Due to the highly competitive nature of this market (expected to rise to € 106bil. by 2029 up from € 75bil. in 2019), reduction of operating costs is a critical goal for airline companies. In this regard, the impact of novel, high-technology MRO methodologies that will enable easy-to-disassembly aircraft component designs for increased repairability, is of critical importance. Induction heating (IH) has emerged as a promising technique for fast and selective heating of adhesively joint systems, enabling on-demand debonding procedures**.** IH delivers high-strength electromagnetic fields to magnetic nanoparticles (MNPs), which as susceptors, resulting in heat generation within nanocomposite materials through hysteresis.

Herein, an investigation of IH capacity of thermoplastic nanocomposites (TPNCs) for on-demand debonding is presented. First, TPNCs consisting of poly-ether-ketone-ketone (PEKK) and 2.5 – 10.0 % wt. iron oxide-based MNPs (Fe_3O_4, $NiFe_2O_4$ and $CoFe_2O_4$) were compounded and their IH capacity was examined as a function of time and frequency of the employed electromagnetic field by RF generator. All samples demonstrated temperature increase proportional to the MNPs concentration, while high concentrations enhanced the maximum achieved temperature, triggering extensive shape deformation, which may facilitate the de-bonding process. Based on the TPNC processability and the initial IH experimental outputs, Fe_3O_4 MNPs at a concentration of 7.5% was selected to for the fabrication of multi-layered components consisting of a) carbon-fiber-reinforced low-melt polyaryletherketone (LM-PAEK & CFs) and b) Fe_3O_4 MNPs-reinforced polyetherketoneketone (PEKK & MNPs). In this configuration, PEKK & Fe_3O_4 was utilized as the intermediate layer between LM-PAEK & CFs layers. Samples were processed in three different sizes to assess the influence of nanocomposite area to the IH capacity of the overall composite structure. In addition, RF process parameters (power, coil-to-nanocomposite are standoff distance) were investigated to conclude to an optimum disassembly process window, while ensuring the structural integrity of the LM-PAEK layers. All samples exhibited temperature increase proportional to the nanocomposite area size and the applied RF generator power. Decrease of standoff distance between the induction coil and the nanocomposite area also enhanced the IH capacity. The combined optimal parameters led to the heating of the PEKK & Fe_3O_4 layer above the glass transition temperature of PEKK (~160 ^oC), thus enabling sample debonding in most of the trials.

The development of innovative TPNC systems with incorporated MNPs holds great promise, as they can be integrated to high-performance components to facilitate easy-to-disassembly operations through IH. The study results, contribute to the optimization of IH processes of TPNCs, by proposing a process window for the fine-tuning of critical process parameters with regards to enhancing de-bonding, while minimizing minimize the risk of accidental overheating of adjacent components.

Keywords: thermoplastic composites; magnetic nanoparticles; induction heating; adhesive joints; debonding; MRO;

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