Optimization of Crashworthy Thin Walled Tubular Structures by Localized Heat Treatment Using a Compliant Mechanism Approach

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ABSTRACT

This paper focuses on improvement of the crashworthiness properties of tubular structures using compliant mechanism approach by applying localized heat treatment. Depending on the heat cycle and the thermal treatment methodologies, hardness of the material can be controlled locally. Previous results via localized heat treatment using laser beams on the tubular structures have shown improved energy absorption capabilities and reduced peak force. By such process the material properties can be modified locally to achieve desired value of hardness. However the present approach limits to axial loading and uniform tubular structure. Progressive buckling is achieved when subjected to an axial impact however in practice the tubes can have geometric imperfection and are subjected to oblique impact for which Euler buckling / Global Bending is observed. Our design methodology extends the use of localized heat treatment on tubular structure using compliant mechanisms. The design methodology relies on the ability of a compliant mechanism to transfer displacement and/or force from an input to desired output port locations. The suitable output port locations are utilized to enforce desired buckle zones, mitigating the natural Euler-type buckling effect. The objective is to find the distribution of the value of hardness over the entire tubular structure to achieve progressive buckling while improving the energy absorption and limiting the peak force. This distribution of the value of hardness can be achieved by heat treating the tubular structures locally. A nonlinear explicit finite element code LS-DYNA is used to simulate tubular structures under crash loading. Biologically inspired hybrid cellular automaton (HCA) method is used to drive the design process. This paper illustrates the use of this design methodology on uniform tubes and on S-Rail which are widely used in the industry.