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Numerical simulation and experimental testing of a Le Mans prototype steering column

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Abstract

Race vehicles depend mainly on passive safety systems, such as the steel collapsible steering column investigated in this report. There is no existing literature that investigates alternate impact testing methods that meet the Fédération Internationale de l'Automobile (FIA) requirements. In this study, the steering columns were statically crushed to determine the effect of residual stresses. The steering columns were observed to collapse on themselves, as the top surface deformed, the 90° bends unfolded, and the 50° bends folded further on the side supports. The reduced residual stresses in the 90° bends after stress relief annealing, resulted in a strengthening effect and therefore a larger bending moment was required to unfold the bend. The residual stresses did not greatly affect the overall strength and energy absorption characteristics of the steering column, because the deformation of the 90° bends only contributed a small percentage towards the energy absorption ability of the steering column. In conclusion, zero residual stresses in cold bent steel plates are desired if the plate is being unfolded as the steering column collapses, however residual stresses can be useful if the plate is being bent further. The quasi-static approximation has been reported to be suitable if the impact mass is much larger than the impact structure. The quasi-static approximation was used to calculate the acceleration-time history of each tested specimen from the static compression tests. Numerical simulation of the steering column impact test illustrated that the impact mass and steering column experienced a series of high frequency collisions. This phenomenon was due to the momentum transfer between the impact mass and steering column, i.e. the steering column locally accelerated away from the impact mass, it then slowed down as the energy was absorbed which allowed the impact mass to again collide with the steering column. The numerical simulation and experimental results showed good correlation after having been digitally filtered using a low pass digital filter with a cutoff frequency of 1000 Hz as per Le Mans regulations. The quasi-static approximation was found to give excellent agreement with the digitally filtered results, however due to its nature it could not replicate the high speed oscillatory behaviour. In conclusion, the steering column under investigation was found to be inertia sensitive, and the quasi-static approximation may only be used to evaluate the energy absorption characteristics of the steering column on its own according to the FIA requirements.