IN-PLANE DYNAMIC CRUSHING OF HONEYCOMBS WITH DIFFERENT SIZED REGULAR HEXAGONAL CELLS ARRANGEMENTS

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ABSTRACT

The effect of insertion of a smaller sized regular hexagonal cells' honeycomb, controlled arrangement inside an otherwise uniform cellular structure, in multiple combinations is proposed to study its effect on the densification, energy absorption and deformation mode patterns under dynamic in-plane axial crushing. The detailed finite element studies are performed on a row, column, diagonal and mixed insertion of such class of different sized cells to show the effect of such functional gradient feature as per a selected number of configurations while observed under low to moderate velocities. The manufacturing of such system is explained and deformation plots along with energy absorption are discussed. The results indicate that inclusion of regular hexagonal cells pattern can guide the deformation modes and alter the energy absorption. This phenomenon is different in different configurations; hence providing a way to define the in-plane crushing and energy absorption control.

INTRODUCTION

Metallic based cellular materials, such as honeycombs have been developed and are growing in use as new engineering materials due to their advantages of high relative stiffness, strength and effective energy absorption during accidental impacts while limiting the crushing force [1]. In some applications, such as using a honeycomb block as an energy absorption layer in aircraft against bird or debris collision, the crushing could take place along any direction of the honeycomb. Hence, the in-plane dynamic behaviors of the honeycomb also needs to be known in addition to its out of plane behavior [2]. In quasi-static compression, collapse first takes place at the weakest row or band of cells, which is dominated by the distribution and extent of the initial imperfections, and gradually spreads to stronger areas of the structure [3]. The response to dynamic loadings is very different from the quasi-static one, as the structural and inertial effects will significantly influence the crushing behaviors [4]. Localization bands would initiate at the loading end or the supporting end of the honeycomb block once the impact velocity exceeds a critical value, despite the initial imperfections distribute among the honeycomb. Three different patterns of localization bands in uni-axially impacted honeycombs were identified based on numerical simulations [3]: ''X'' pattern, ''V'' pattern and ''I'' pattern as in Fig 1. When the impact velocity is sufficiently high, the localization band will develop in the ''dynamic localization mode'' (i.e. form an ''I'' pattern) and propagate layer by layer from the impact end to the fixed end.

In this study, a new kind of honeycomb panel as shown in Fig. 2a is proposed which consists of a combination of regular hexagonal cells with a modified small sized row, column or diagonal addition in otherwise uniform honeycomb panel. The addition of the small sized cells arrangement is user dependent and quite easy to be fabricated to control the performance. The said honeycomb panel is numerically crushed at multiple velocities varying from low to moderate, in in-plane directions to observe the change in deformation modes and its ability to define the user command on deformation patterns and energy absorption curves. Numerical simulation methodology is described in Fig. 2b. Multiple configurations are defined to access the applications of such systems starting from a single row, column or diagonal addition to multiple mixed insertions of modified small regular cells additions.

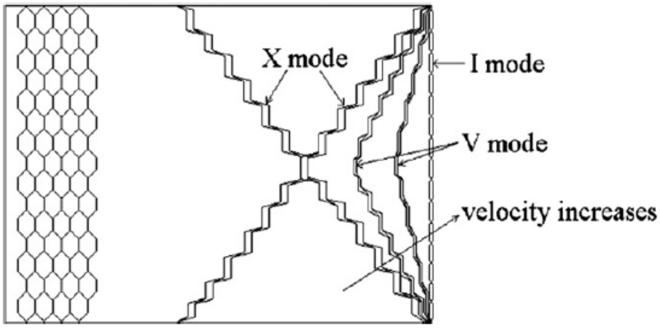
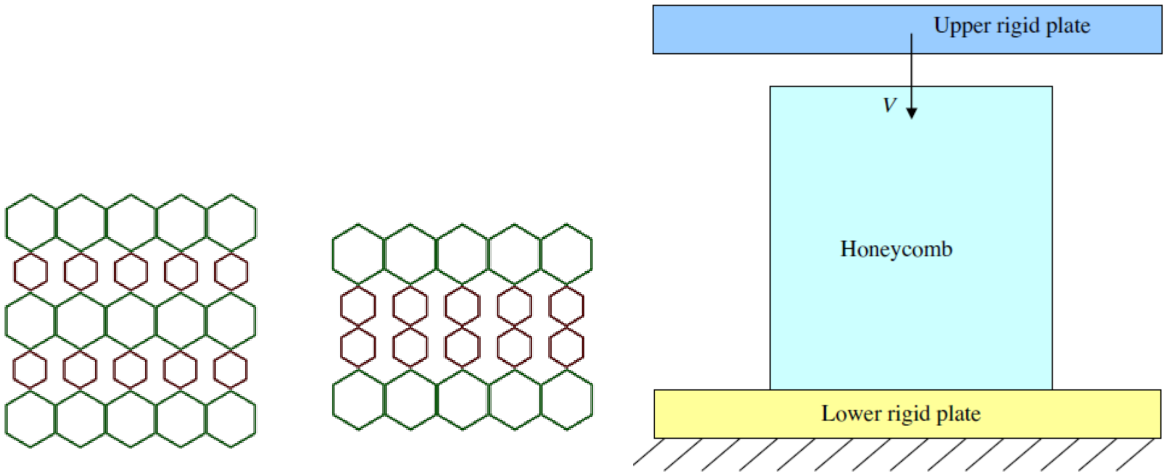


Figure 1: Three type of the deformation modes in uniaxially impacted honeycombs [3]



(a) (b)

Figure 2: (a)Exapmle of arrangements of different sized regular cells in honeycomb (b)Simulation methodology

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