

(様式)

## 論文内容の要旨

氏名 MITSOMWANG PUSIT  
ミットソムワン プーシット

In the converting industry of sheet materials, cutting processes for three kinds of sheets such as ductile resin, fragile plastic and fiber-based paper are frequently considered. However, since the mechanical properties of these sheets are fairly complicated, compared to ductile metals, fundamental characterization of cutting processes for each sheet is highly necessary for obtaining successful cuts. Thus, in this research work, the author aims to investigate and analyze effects of tool conditions on cutting characteristics of sheet materials subjected to straight shearing tool indentation. Three kinds of sheets were investigated: a 0.5 mm thickness of polycarbonate (PC), a 1.0 mm thickness of acrylic (AC) and a 0.45 mm thickness of white-coated paperboard. As cutting manner, wedge indentation cutting and punch/die shearing which are widely used in the converting industry were considered. Here, the former cutting method was investigated only on the PC worksheet, while the latter was carried out on all the three sheets.

First, concerning the wedge indentation cutting of the PC worksheet, to reveal effects of underlay stiffness on the wedged profile of the worksheet was primary objective. Experimental results of the wedging revealed that the Young's modulus, the out-of-plane bending rigidity, the stiffness in the thickness direction of the flexible underlay remarkably affected the cutting processability and the profile feature of the wedged edge. Apart from the experimental work, a two-dimensional finite element method (FEM) analysis for the indentation was carried out. It was revealed that the effect of underlay stiffness  $kr$  on the profile feature of the wedged worksheet was slightly different when  $kr$  was varied by varying Young's modulus and thickness of the underlay. Through the experimental and FEM results, a suitable range of  $kr$  for generating a preferable wedged profile of the worksheet was recommended.

Second, for the punch/die shearing of the PC worksheet, the cutting characteristics including the cutting load resistance, cracking pattern and final sheared profile of the worksheet was investigated and analyzed with respect to mechanical conditions such as the punch/die clearance, cutting velocity and cutting tool configuration. From experimental results, the clearance of 2 ~ 10% of the worksheet thickness seems to be a suitable range for obtaining a smart sheared edged of the PC worksheet. By varying the cutting velocity  $V = 0.05 \sim 1.0 \text{ mm}\cdot\text{s}^{-1}$ , the cutting load resistance was slightly varied, but such variation did not almost affect the final sheared profile of the worksheet. In addition, a two-dimensional FEM analysis of the PC shearing was performed based on a developed constitutive equation (material model). A state of stresses near the punch and die corners was investigated in order to discuss about a critical stress level for the propagation

of initiated primary cracks near the cutting tool corners.

Next, the punch/die shearing of the fragile acrylic worksheet was conducted. As experimental conditions, the clearance was varied to be negative (overlapped) and positive gaps. Also, the cutting velocity was altered ranging from  $V = 0.025$  to  $0.5 \text{ mm}\cdot\text{s}^{-1}$ . From side-view deformation photographs of the AC worksheet taken during shearing, complicated cracking patterns were observed, and they were recognized with respect to the varied mechanical conditions. From the feature of the final sheared edge, the application of the negative clearance appeared to be preferable to a smart cut of the fragile acrylic worksheet. Moreover, in order to further discuss about cracking on the upper and lower surfaces of the worksheet, a two-dimensional FEM shearing model was developed and simulated. The simulation result of stress distribution on the worksheet surfaces at the sheared zone were investigated, compared with crack initiation position detected in the experiment and discussed.

Finally, the white-coated paperboard was subjected to the punch/die shearing, and its cutting characteristics were experimentally studied. In the shearing test, negative, zero and positive clearances were applied for cutting off the paperboard worksheet. After cutting, final sheared edges of the paperboard were examine using a scanning electron microscope (SEM). Through SEM images taken at the sheared edges, the generation of whisker-like dust was found to be dramatically suppressed under the negative punch/die clearance condition. To furthermore discuss about the generation of the dust, a material flow analysis at the sheared zone was conducted using an image-based analysis. From the analyzed material flow during shearing for each clearance case, the suppression mechanism of the whisker-like was explained. In addition, it was confirmed that the application of the negative punch/die gap was effective for suppressing the generation of the dust in various cutting directions.