Experimental researches on fracture behavior of semicircular bending PMMA specimens

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Abstract. The fracture resistance behaviors of the semicircular bending (SCB) PMMA specimens with different geometry are experimentally investigated. In order to evaluate the effect of orientation, location and right roll’s distance, a series of SCB experiments are performed on the PMMA specimens with different notch angle and location on the universal mechanical testing machine. Finally, the variation of the fracture load and the load vs. displacement relation are displayed and evaluated respectively.

1. Introduction
Polymethyl methacrylate (PMMA) is widely used in architectural lighting, urban street and aircraft due to their many advantages. Especially in commercial airplane, the cracking becomes one of the main distress modes. In order to enhance the cracking resistance of PMMA, it is significant to investigate the fracture mechanism of PMMA.

The SCB test is practically more attractive than the other tests because of its relatively simple testing configuration, easy specimen preparation, and applicability for mode I and mixed mode fracture. In order to investigate the fracture toughness of PMMA, the semicircular bending (SCB) test is utilized to investigate various fracture modes of PMMA by Aliha et al[1,2]. However, PMMA, whose fracture properties are highly influenced by many geometrical parameters such as crack orientation and location. Combined with CDM to build two-dimensional (2D) microstructural models, Zeng et al[3,4] investigated damage evolution and crack growth of pre-notched asphalt mixture samples. It is noted that PMMA generally exhibits complex strength behavior with different pre-notches[5-7]. Accordingly, an appropriate quantifiable evaluation is very important for describing cracking process.

In this paper, in order to better understand geometrical effect on the resistance of SCB pre-notched PMMA samples, a series of aging experiments are performed to investigate the effects of pre-notches orientation and location on the fracture behavior.

2. Experiments
All of the specimens are located inside a servo hydraulic compressive test machine loaded by displacement control with a constant rate of 0.5 mm/min, and the experimental data are recorded by
the test system automatically. The SCB fracture experimental setup is shown in figure 1. The test environmental temperature is 20°C. Additionally, the thickness and radius of all specimens is 5mm and 50mm uniformly. According to the pre-notched type, two types of specimens are investigated in the fracture experiment.

![Experimental setup.](image)

2.1. SCB Specimen with different pre-notches orientation
In order to evaluate the orientation effects, the first group of PMMA specimens is made of SCB Specimen with different pre-notches orientation. Figure 2 shows the geometry and loading condition of SCB specimens with pre-notches, which are prepared for the three-point bending experiment. A notch with depth of 10 mm and thickness of 0.3mm is machined in each specimen and its root is located at the center of specimen, the distance of supporting is 80mm. The details of this group of specimens are listed in the Table 1.

Table 1. The details of specimen number with different pre-notches orientation.

| Specimen number | Notches orientation α (°) |
|-----------------|---------------------------|
| Alpha-00        | 0°                        |
| Alpha-15        | 15°                       |
| Alpha-30        | 30°                       |
| Alpha-45        | 45°                       |
| Alpha-60        | 60°                       |
| Alpha-75        | 75°                       |

2.2. SCB Specimen with different pre-notches location and right roll’s distance
In order to evaluate the location effects, another group of PMMA specimens is made of SCB Specimen with different pre-notches location. Compared with the first group, the angle of the notch in the second group is fixed at α=0°, with depth and thickness is same. However, the location of the pre-notch L and the distance of right supporting roll are changed, the schematic diagram of this group of specimens are displayed in the figure 3. The numbered lists of the specimens are given in Table 2.

3. Result and discussion

3.1. Effect of pre-notches orientation on SCB test results
The load versus displacement curves for specimens with different pre-notches orientation are plotted in Figure 5. And Figure 6 shows the experimental peak load for notch orientations of 0°, 15°, 30°, 45°, 60° and 75°. It can be seen that with increasing the orientation angle the peak load decreasing monotonously. The specimen with the largest orientation angle has the maximum peak load, and the
displacements corresponding to the peak loads are distributed in the scale between the 0.9mm to 1.4mm. It can be concluded the peak load increased with the angle increased but the displacements corresponding to the peak loads are disordered.

Table 2. The details of specimen number with different pre-notches orientation

| Specimen number | Distance of right supporting roll S₂ (mm) | Notches location L (mm) |
|-----------------|------------------------------------------|------------------------|
| S2-40-L00       | 40                                       | 00                     |
| S2-35-L00       | 35                                       | 00                     |
| S2-30-L00       | 30                                       | 00                     |
| S2-40-L10       | 40                                       | 10                     |
| S2-40-L20       | 40                                       | 20                     |
| S2-40-L30       | 40                                       | 30                     |

Figure 2. Geometry and loading condition of SCB specimen with different pre-notches orientation.

Figure 3. Geometry and loading condition of SCB specimen with different pre-notches location.

3.2. Effect of pre-notches location and right roll’s distance on SCB test results

To study the effects of pre-notches location on fracture behavior of PMMA, the different effects of pre-notches location and supporting roll distances on the load versus the displacement curves are plotted in the Figure 6 and Figure 7. It can be observed those specimens are influenced by both the effects of pre-notch location and supporting roll distance.

In order to analyse the effect of both notch location and supporting roll distance quantitatively, the maximum value of peak load are plotted in the Figure 8 and Figure 9. It is suggested that the higher the notch location is, the larger the peak load is. However, the longer the supporting roll distance is, the smaller the peak load is.
4. Conclusions

This study integrates experimental efforts to investigate the fracture behavior and geometrical effects in the SCB specimens of PMMA. The influences of orientation and location of pre-notch on load-displacement behavior are evaluated. The following conclusions can be concluded:

Figure 4. Experimental load versus displacement curves for PMMA with different pre-notches orientation.

Figure 5. Experimental peak load versus the orientation angle for PMMA.

Figure 6. Experimental load versus displacement curves for PMMA with different pre-notches location.

Figure 7. Experimental load versus displacement curves for PMMA with different right supporting roll distance.

Figure 8. Experimental peak load versus the pre-notch location for PMMA.

Figure 9. Experimental peak load versus the supporting roll distance for PMMA.
(1) Due to the geometrical effect in the experimental results, the peak load of SCB specimen decreases with the pre-notch orientation angle enlarging. 

(2) According to the fracture analyses, both the pre-notch location and supporting roll distance have a significant effect on the peak load and load-displacement behavior. Compared with the peak load, the variation of displacement corresponding to the peak load is negligible.

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