Modeling on Debonding Dynamics of Pressure Sensitive Adhesives

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粘着テープやポストイット、絆創膏のような製品の粘着力を評価する方法の一つとして、「プローブタックテスト」という試験が行なわれている。これは、粘着剤を固体表面上で薄く広げた状態で先が平坦なプローブを一定時間一定圧力で粘着剤に接触させた後、一定速度で引き上げることで「応力－歪み曲線」を評価する試験である。このとき、粘着剤は非平衡状態の下での大変形を起こすため、粘着剤内部に空孔ができる「キャビテーション」や粘着剤が糸を曳く「フィブリル化」が見られ、それに伴い応力－歪み曲線は複雑な形状をとることが知られている。
本研究では、粘弾性の変形やキャビテーションを取り入れた連続体モデルを開発することで、応力－歪み曲線の形状やキャビテーション挙動の再現を試みた。

1 Introduction

Pressure Sensitive Adhesives (PSA) is applied in various areas such as office use, packing, medicine, etc. They are required to stick on a variety of surfaces under low pressure and short time bonding conditions, which is called tack property. One of the evaluation methods is probe tack testing, where a flat-ended cylindrical probe is indented in the adhesive film and subsequently removed at a constant speed, and its stress-strain curves are measured [1]. Recent investigations on debonding process of PSA have shown that it is accompanied with the formation of cavities, and then creation of fibrils before rupture of PSA is done. Many experimental studies have been made to elucidate mechanisms for cavitation/fibrillation process and the stress-strain curve shape [2], but final conclusions have not been reached yet. Moreover, fewer theoretical or numerical studies on debonding dynamics of PSA have been done. We developed a continuum mechanical model including the material deformation and the cavitation dynamics, and studied the relationship between cavitation behavior and the stress-strain curve shape.

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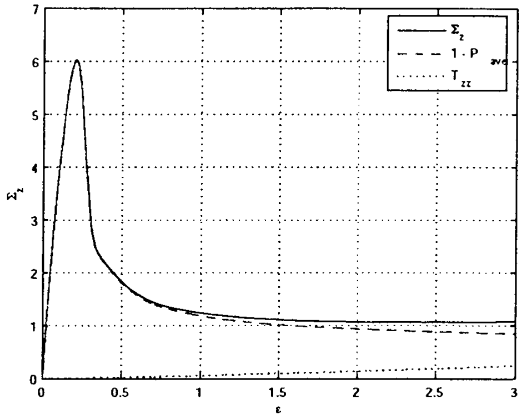

Figure 1: Simulation results for the stress-strain curve and contributions from each factor (Σ_z (solid line), Π_{zz} (dashed line) and $1-\bar{P}$ (dotted line))

2 Simulation Results

The debonding stress σ_z is calculated by

$$\sigma_z = \bar{\tau_{zz}} + (p_0 - \bar{p}), \tag{1}$$

where $\bar{\tau_{zz}}$ is the average zz component of the stress tensor, p_0 is the atmospheric pressure and $\bar{p}$ is the average internal pressure. As shown in Figure 1, the stress-strain curve can be explained by the rapid increase and drop of the negative pressure ($1-\bar{P} = (p_0 - \bar{p})/p_0$, dashed line) at the early stage, and the slow pressure relaxation plus uni-axial viscoelastic stress ($\bar{Pi_{zz}} = \bar{\tau_{zz}}/p_0$, dotted line) at the late stage.

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