Title	Temperature and strain rate dependent fracture of an SBR vulcanizate
Sub Title	
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Publisher	慶応義塾大学藤原記念工学部
Publication year	1969
Jtitle	Proceedings of the Fujihara Memorial Faculty of Engineering Keio University (慶応義塾大学藤原記念工学部研究報告). Vol.22, No.91 (1969.) ,p.185(37)- 186(38)
JaLC DOI	
Abstract	
Notes	Summaries of Doctoral Theses
Genre	Departmental Bulletin Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001004-00220091-0037

Temperature and Strain Rate Dependent Fracture of an SBR Vulcanizate

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In recent years many viscoelastic materials such as SBR vulcanizate have come to common use in industrial fields. Accordingly, more basic information of their fracture strength has been required. The studies up to now on the fracture mechanisms of these materials, however, have been treated from the view point of molecular structure. Furthermore, very few works have been conducted on a large extent of temperature and strain rate ranges.

In this thesis, the author intended to investigate the fracture processes and mechanisms of an SBR vulcanizate phenomenologically from the view point of their temperature and strain rate dependency. The author suggested that a fracture phenomenon should be discussed not only from final fracture strength but also from deformation and growth process of the defects leading to the final fracture.

It has generally been recognized that many of the amorphous polymer show a linear viscoelasticity in the rather small range of deformation i.e., 10-30%, and the time and temperature superposition technique is valid for the mechanical behavior of the material in this experiment. The technique is also hold for the ultimate strain and rupture stress under the constant strain rate test. From this, the ultimate strain and rupture stress is given by the only one smooth master curve in the large extent of reduced strain rate. In addition, the following results were obtained from the investigation of this master curve: The maximum value exists on the ultimate strain. The ultimate strain and rupture stress have the time temperature shift factor, that is, the dependency of the ultimate properties of this material on temperature and strain rate is given by unique relation. And then, this shift factor is given by the Arrhenius' equation which has different activation energy at high and low temperature ranges. The temperature of intersecting point of these two Arrhenius' equation is close to the temperature which gives the maximum rupture strain mentioned above. Moreover, it would be concluded from the discussions of the results that the different governing factor exists in the fracture process of specimen under constant strain rate at the high and low temperature ranges. It is pointed out that the sensitivity of the mechanical behavior and of defect at large deformation should be considered separately.

The stress relaxation curve under the large deformation reaches the stress of the rubbery state after the considerably long duration. This stress relaxation phe-

nomenon shows strong dependency not only on temperature and strain rate but also on the restriction due to the strain, and this dependency would have the same effect on the stress relaxation curve. From these considerations, the author proposed the new superposed curve between the stress and strain near the rupture point in order to attain the general understanding of the mechanical behavior of the rubbery material at large deformation. It is also shown that this curve coinsides well with the inverse Langevin function which has been used for non-linear rubbery elasticity. The time-temperature shift factor for the stress relaxation under a large deformation is confirmed to be the same as that of the rupture strength, and it is found that the rupture phenomenon of SBR is almost governed by the deformation process itself.

Cut growth process and the relationship between cut depth and strength were obtained from the extension of the strip specimen with an artificial cut. It could be found from this result that the cut growth process of the rubbery material is governed by the strain at high temperature and by the stress at low temperature near the neighbourhood of the cut root. Furthermore, there may exist a Griffith's like criterion between the cut depth and rupture strength.

The filler effect on the matrix strength at high and low temperature was also discussed on the consideration that the addition of filler has the effect of increasing of macroscopic viscosity resistance and of the structural inhomogeneity. It may be concluded from this result that the increase of macroscopic resistance of viscosity due to carbon black is explained by the parallel shift of time axis, and increase of the structural inhomogeneity is possible to be explained by the decrease of the rupture strength in the low temperature range. In addition, it is found that the effect of reinforcement by the addition of carbon black may be interpreted as the apparant phenomenon produced from the parallel shift of the time axis accompanied by the increase of the resistance of macroscopic viscosity.