Stress-Relaxation Hardening of Nylon 66 Filaments

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It was observed that an additional increment in stress was necessary to continue deformation in nylon 66 filaments, which had been relaxed, but not unloaded, before fracture. This stress increment consisted of a small permanent increase in stress, in addition to a larger temporary increase in stress to yield. Both the temporary and permanent increments increased as the strain, strain rate, temperature and humidity increased. Similar effects were observed in other polymers, but not in metals or ceramics.

1. Introduction
Stress-relaxation studies on polymers have been carried out by a number of investigators. An extensive compilation of the available data on polymers has been made by Tobolsky [1]. In particular the stress-relaxation behaviour of nylon 66 has been studied by Hammerle and Montgomery [2]. It has been shown that the relaxation is dependent on previous strain, temperature, humidity, relative viscosity and strain rate.

In general, the previous work on polymer systems has been concerned only with the stress-relaxation behaviour. The present paper describes an unusual hardening behaviour in polymers. It was observed that an additional increment in stress was necessary to continue deformation on reloading filaments which have been stress-relaxed with time under load. The effects of strain, strain rate, time of stress-relaxation, humidity, and temperature on this hardening are described.

2. Experimental Procedure
In this investigation monofilaments of 65 denier as-spun and 15 denier machine drawn nylon 66 of normal commercial molecular weight were used. All stress-strain tests were performed on an Instron tensile testing machine at 25°C, 55% relative humidity and a strain rate of 2.0 in/in/min unless otherwise noted. The machine drawn samples were also tested after exposure to boiling water for one minute in the slack (free to relax during boil-off) and taut (held at constant strain during boil-off) conditions.

3. Experimental Results
3.1. Definition of Terms
Fig. 1 illustrates a typical Instron chart of a sample which has been strained to a stress, $\sigma_1$, and a strain, $\epsilon_1$, held at constant strain for a time varying from $t_0$ to $t_1$ during which time stress relaxation occurs, and then restrained. In all cases an increment in stress was necessary to continue deformation after the relaxation under load. The dashed line in fig. 1 is the $\sigma$-$\epsilon$ for a continuous test. We will define $\sigma_R$ as the amount

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Figure 2 The relaxation stress, $\sigma_R$, for samples given the indicated pretreatment as a function of time at a variety of stresses.

Figure 3 Typical stress-strain curves for samples which have been continuously strained to fracture and for samples which have been strained-relaxed and restrained to fracture.