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# On Creep Test Loading for Soft Polymers

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## Synopsis

The dead-weight loading speed in the creep test for soft polymers was investigated. The optimum dead-weight loading speed can be determined so as to assure instantaneous elastic deformation and, at the same time, also avoid dynamic effects. It is found that small dynamic effects are inevitable for soft polymers such as polypropylene even at optimum speed. The experimentally determined optimum dead-weight loading speed for polypropylene was 300 mm/min for 30 kg dead-weight at 16°C.

## INTRODUCTION

In performing the creep test, it is generally accepted that the dead-weight application on a creep specimen must be done in such a manner that it is to be done so slowly as not to give rise to dynamic effects and also so quickly as not to produce any creep strain during the dead-weight application. Soft polymers, in contrast to metals, are sensitive to creep even at room temperature due to their predominant viscous element, so that slower dead-weight loading causes more creep deformation in the specimens. In this respect, dead-weight loading speed must be high enough to eliminate the undesirable creep deformation. However, too high a loading speed induces dynamic effects, resulting in the live load problem which produces an additional dynamic component, and this must be avoided.

Consequently, it is necessary to determine the optimum deadweight loading speed which does not produce any creep deformation and, at the same time, also does not induce any dynamical effect, in advance of creep tests for soft polymers.

In the present paper, the authors investigate experimentally the optimum dead-weight loading speed for polypropylene.

## EXPERIMENTAL

### Testing Apparatus

Two types of tensile testers were used. One was the IM-100 Tensile Tester, manufactured by Shimadzu Seisakusho Ltd., Japan, having a

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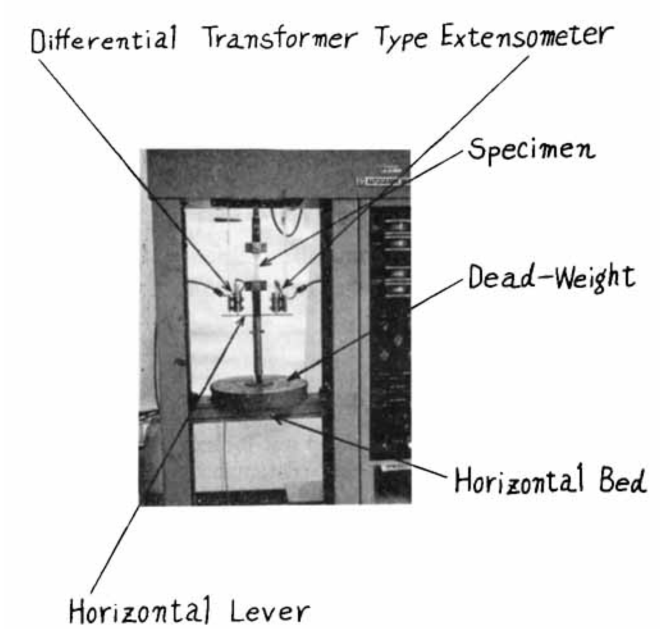


Fig. 1. IM-100 Tensile Tester and specimen fitted with extensometers and dead weight

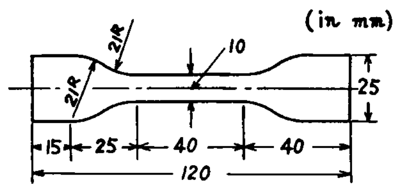


Fig. 2. Test specimen.

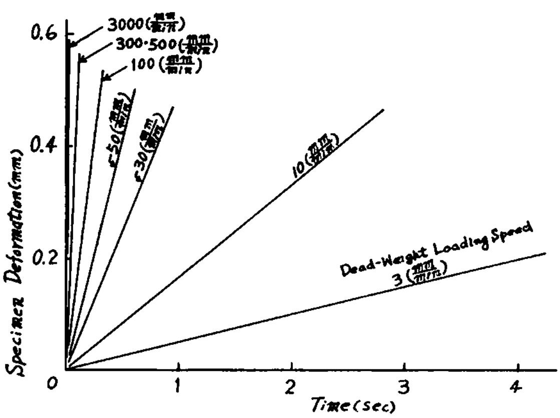


Fig. 3. Experimental results of specimen deformation as a function of time at various dead-weight loading speeds.

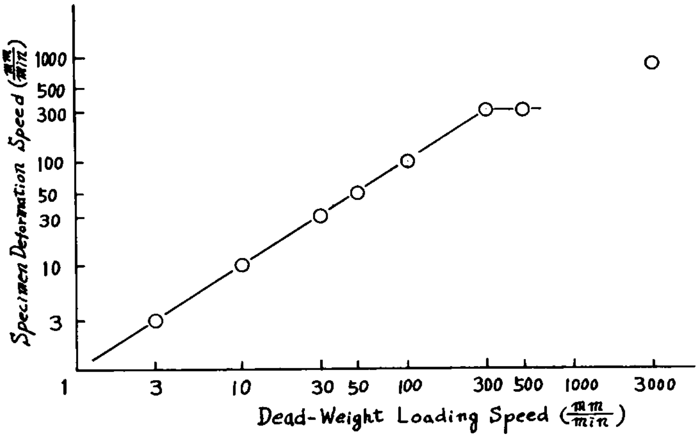


Fig. 4. Experimental results of specimen deformation speed vs. dead-weight loading speed.

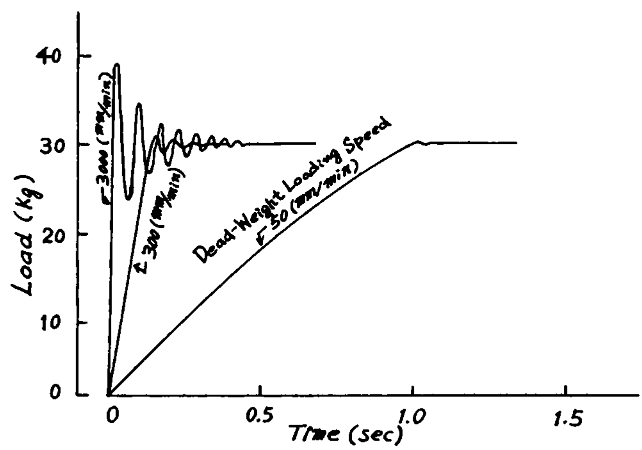


Fig. 5. Experimental results of load as a function of time at various dead-weight loading speeds.

maximum capacity of 100 kg tension, as shown in Figure 1. The other was the UTM-5 Tensile Tester, manufactured by Toyo Measuring Instruments Co., Ltd., Japan, having a maximum capacity of 500 kg tension, which was designed for high-speed tension loading up to 6 m/sec. The vertical elongation of a specimen due to the applied dead-weight loading was measured by a differential transformer-type extensometer, as shown in Figure 1, whose data were recorded on the electromagnetic oscillograph EMO-1 Photocorder, manufactured by Yokogawa Electric Works, Ltd., Japan. The dead-weight was 30 kg (including attachment and a horizontal lever for measuring purposes), equivalent to 1.5 kg/mm$^2$ in stress, and was applied through lowering the horizontal bed on which the dead-weight was loaded so as to apply the creep load gradually, as shown in Figure 1. The crosshead speed itself is the very dead-weight loading speed at the same time, since the horizontal bed runs vertically at the cross-head speed. The load during loading was measured by load cells.

### Specimens

The test specimen, shown in Figure 2, was stamped out of virgin state polypropylene sheet, Chisso Polypro-1011, measuring about 1000 mm × 1000 mm × 2 mm, manufactured by Chisso Corporation, Japan. The distance between jaws for gripping was 60 mm.

## EXPERIMENTAL RESULTS AND DISCUSSION

Experimental results at 16°C with 30 kg dead weight are shown in Figures 3 to 5. In the figures, the specimen deformation is the average value of two rigidly suspended extensometer readings as shown in Figure 1, and the dead-weight loading speed is the cross-head speed.

In order to eliminate any creep deformation generation in the specimen during dead-weight loading, the very loading has to be applied so that the instantaneous elastic deformation is not prevented. When this condition is realized, the specimen deformation speed remains unchanged at any dead-weight loading speed higher than this critical value, since the instantaneous elastic deformation due to the dead-weight application is constant, except where the dynamic phenomenon is concerned. From Figures 3 and 4, the critical dead-weight loading speed was found to be 300 mm/min, since the specimen deformation speeds at 300 and 500 mm/minute dead-weight loading speed were the same. The specimen deformation speed corresponding to the dead-weight loading speed of 3000 mm/min increased to 800 mm/min, which showed the dynamic contribution. Consequently, the optimum dead-weight loading speed is higher than 300 mm/min but must be below 3000 mm/min.

However, other experimental data are shown in Figure 5. In Figure 5, the change of load during the dead-weight loading was measured by the load-cell using the resistance wire strain gauge as a function of time. It is easily observed that the creep phenomenon appears for slow dead-weight loading at 50 mm/min, because the curve obtained up to a load of 30 kg is nonlinear. On the other hand, a linear relation is maintained up to 30 kg load for both 300 and 3000 mm/min dead-weight loading speed, which assures no creep. However, obvious dynamic effects are seen for a deadweight loading speed of 3000 mm/min, showing a conspicuous dynamic jump in load followed by subsequent damping due to internal friction. Even at the critical dead-weight loading speed of 300 mm/min a slight dynamic jump in load is perceived. That is, small dynamic effects are inevitable for soft polymers such as polypropylene, inasmuch as the dead-weight loading speed assures instantaneous elastic deformation. Therefore, the optimum value to be employed is 300 mm/min.

The performance of such investigation is recommended in order to determine the optimum dead-weight loading speed, at the prescribed load and temperature, in advance of a creep test for soft polymers. The same must be considered in cases of creep loading for metals at high temperatures.

## CONCLUSIONS

The optimum dead-weight loading speed for creep test that assures instantaneous elastic deformation and also avoids dynamic effects was experimentally investigated for soft polymers. It was found that small dynamic effects are inevitable for soft polymers even at optimum dead-weight loading speed. The optimum value obtained for polypropylene at 16°C is 300 mm/min with a 30-kg load.

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