Influence of Thermosetting and Drying on Shrinkage, Tenacity, and Elongation of Acrylic Fibers

A. I. STOYANOV, *Economic Combine NEFTOCHIM, Plant BULANA, Burgas, Bulgaria*

Synopsis

A study is carried out to investigate the effect of heat treatment (thermosetting and drying) on shrinkage, tenacity and elongation of acrylic fibers with different degrees of drawing. The effectiveness of the heat treatment depends on orientation of the fibers. It is shown that the thermosetting influences the elongation of the fibers after drying.

INTRODUCTION

Acrylic fibers contain water as a result of drawing in boiling water. In order to stabilize the acrylic fibers, the water is removed by heat. It is also necessary to eliminate tension which may have developed after coagulation. The relaxation of tension is possible only at sufficient molecular mobility. Thermosetting is usually conducted in the presence of steam at 100°C.

The drying process and its influence on fiber properties has been the subject of many investigations.[1-6] The shrinkage which occurs during drying has also been studied.[2,6,7]

This paper reports the results of our investigation on the influence of thermosetting and drying on shrinkage and tensile properties of acrylic fibers with different degrees of drawing.

EXPERIMENTAL

The polymer used in this work was a copolymer of 93% acrylonitrile, 6% methyl methacrylate, and 1% sodium vinylsulfonate (CH_2=CH—SO_3Na). The experimental samples were prepared by coagulation, washing, stretching, thermosetting, and drying at conditions shown in Table I.

The thermosetting was carried out under steam. The thermosetting and drying were carried out at free relaxation. Samples were taken after thermosetting and after drying. The samples after thermosetting were dried at 25°C and a relative humidity of 65%. The percent shrinkage of the fibers was measured after each heat treatment. The residual shrinkage was measured after boiling the fibers in water for 15 min.

Measurements of tensile properties were made by using a Fafegraf.

RESULTS AND DISCUSSION

The shrinkage decreases with increasing draw ratio to 3×–4×, regardless of the kind of heat treatment (Fig. 1). Thermosetting produces greater shrinkage compared with drying. This may be explained as follows: during thermosetting

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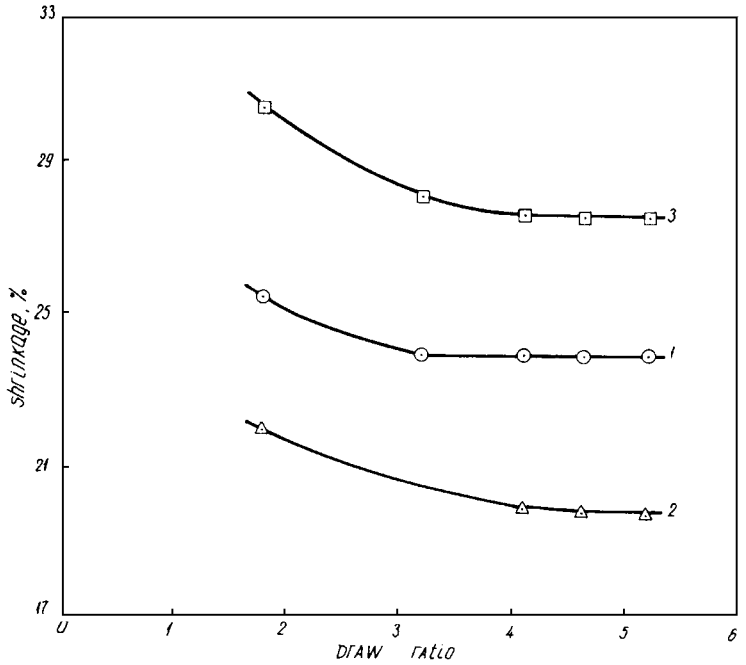

Fig. 1. Shrinkage as function of draw ratio at different heat treatments: (1) after thermosetting; (2) after drying at 120–125°C; (3) after thermosetting and drying at 120–125°C.

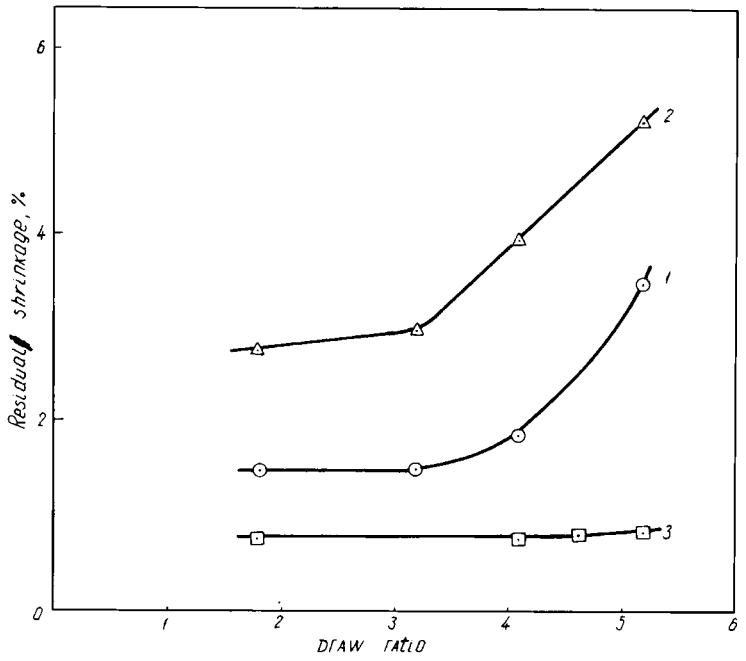

Fig. 2. Residual shrinkage as function of draw ratio at different heat treatments: (1) after thermosetting; (2) after drying at 120–125°C; (3) after thermosetting and drying at 120–125°C.

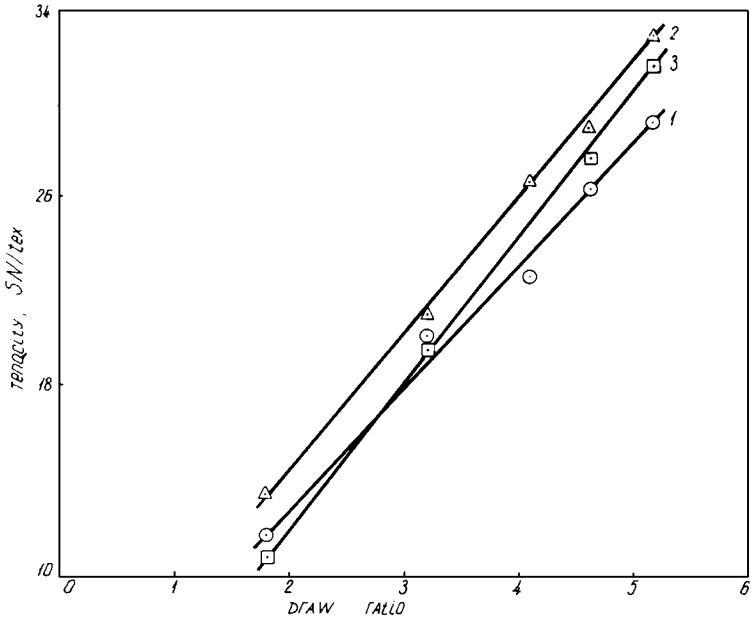

Fig. 3. Effect of draw ratio on tenacity of fibers at different heat treatments: (1) after thermosetting, (2) after drying at 120–125°C; (3) after thermosetting and drying at 120–125°C.

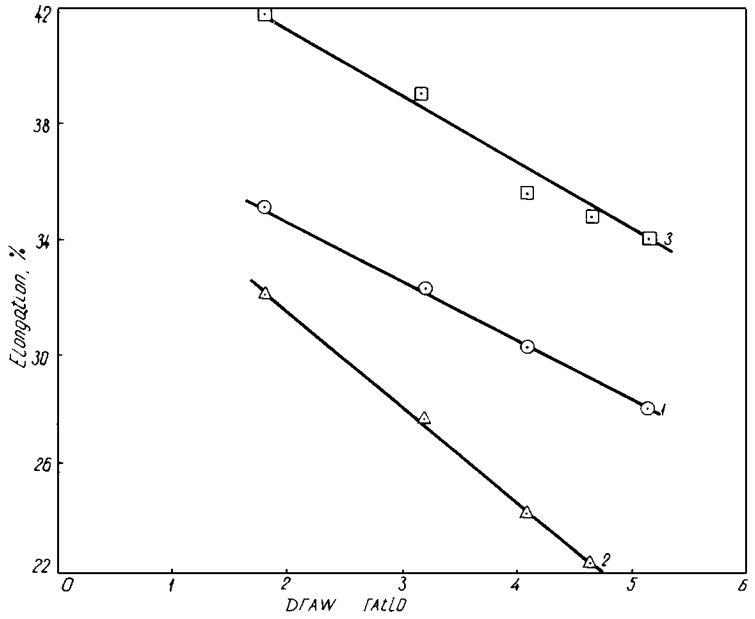

Fig. 4. Effect of draw ratio on elongation of fibers at different heat treatments: (1) after thermosetting; (2) after drying at 120–125°C; (3) after thermosetting and drying at 120–125°C.

TABLE I
Sample Preparation Conditions

Dope solids	25%
Coagulation bath, composition (water:dimethylformamide)	50%:50%
Coagulation bath temperature	30°C
Drawing water bath temperature	98–99°C
Draw ratio	1.8×–5.2×
Thermosetting temperature	100°C
Thermosetting time	8 min
Drying temperature	120–125°C

water molecules increase segmental mobility and the fibers become free of tension. This process results in a return of molecules to a conformation (helical) with a higher entropy. The high temperature and the presence of water increase the mobility of the supermolecular structure, resulting in significant axial shrinkage.

The drying is carried out at a higher temperature simultaneously with retraction of the molecular chains. Re-formation of the network coherently with elimination of voids occurs. These changes, reported by Bell and Dumbleton,[6,7] lead to consolidation of the structure. This fact and the plasticizing action of water molecules explains the difference in shrinkage after thermosetting and drying.

The increase in orientation of the fibers decreases the effectiveness of the heat treatment. It is natural because the ability of the molecules to return to a helical conformation is less. The residual shrinkage of fibers increase as a function of draw ratio 3×–4× (Fig. 2). However, when the fibers are thermosetting and drying at 120–125°C, the residual shrinkage is the least and compactness of structure is the best.

When the fibers undergo double heat treatment (thermosetting and drying), they possess the best ultimate tensile properties (Figs. 3 and 4). The elongation of the fibers at different draw ratios depend on the conditions for heat treatment (Fig. 4).

CONCLUSIONS

The influence of thermosetting and drying on the shrinkage, tenacity, and elongation of acrylic fibers was discussed. When the fibers undergo double heat treatment (thermosetting and drying), the main part of the shrinkage occurs during thermosetting. Elimination of tension in thermosetting increases the elongation and compactness of the fibers after drying.

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