Annealing polyethylene pipe

David Ryan

Mechanical research engineer Akatherm International BV, Panningen, The Netherlands

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Abstract

Thermal annealing is the process of reheating plastic articles for a certain length of time after they have been formed. It adds an additional step in manufacturing and therefore increases product cost. But there are also important benefits to be gained from this process. This article explains the technical background of annealing and the benefits of using annealed polyethylene pipe.

1. Introduction

Siphonic roof drain installations consist of a plastic pipe hung directly under the roof surface inside in a building. In extrusion of polyethylene pipe the plastic is cooled rapidly using water sprays directly after it leaves the forming die. The sudden drop in temperature freezes the plastic molecules in whatever position they happen to find themselves at that moment. The molecules can be compared to springs that have been stretched and held under tension. This tension or orientation is brought about by the stresses they encounter as they are forced through the opening of the extrusion die. This article explains how the process of annealing produces polyethylene pipe with advantageous properties compared to standard pipe.

2. Theoretical background

Annealing is the process of reheating a formed plastic article in order to remove stresses frozen into the product during manufacture. Just as people like to relax by sitting in the warm sun, plastic molecules will relax if heated to a comfortable temperature. The frozen in tension will be released. For Polyethylene (PE), comfortable means between 80°C and 120°C. Relaxation of the molecules allows them to go back to their natural random state. The random molecules are shown in illustration 1 as the black irregular lines.

In polyethylene there is also a second factor to be considered that is relevant to the annealing process, namely crystallinity. Polyethylene is a semi-crystalline plastic. This means that there are areas of organised molecules, or crystals, (shown in blue) embedded in a matrix of the other randomly arranged molecules.

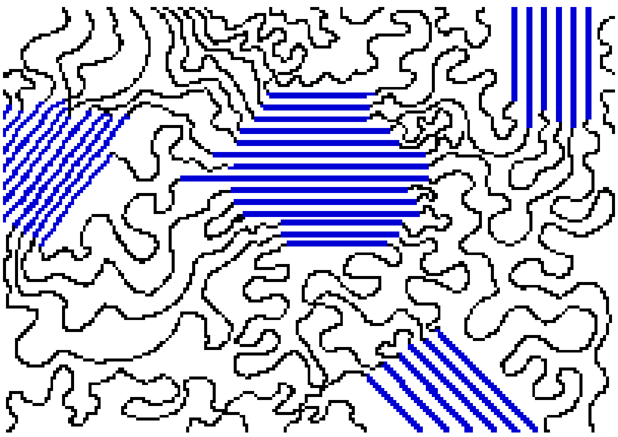

Illustration 1. Polyethylene molecules

These crystals will grow over time until they reach a state of equilibrium. In the hours after pipe extrusion the crystals will grow slowly. The more organised structure of the crystals takes up less space and therefore the plastic product will shrink.

Thermal annealing has then two effects:
1. the random molecules are brought into a less stressed state
2. the crystals can grow and reach their equilibrium state faster due to the higher temperature

We can relate these molecular changes to changes in the physical properties of the pipe, i.e. shrinkage and release of frozen in stresses in the pipe wall.

Relaxation of the residual or frozen in stresses has been associated with improvement of the following properties

- fracture related properties [(1) (2)]
    - o sustained long term strength
    - o slow crack growth characteristics
    - o impact strength
- Tensile yield strength [(1)]
- Quick burst strength [(3)]

The degree of crystallinity affects the shrinkage and deformation of pipe. Pipe which has been annealed exhibits negligible post shrinkage. This means it will not shrink further when in service. Pipe shrinkage can be measured using the standard test method for longitudinal reversion as described in EN-ISO 2505. Tests conducted at Akatherm have confirmed the theory that pipes with a high residual stress also exhibit more longitudinal shrinkage. See illustration 2.

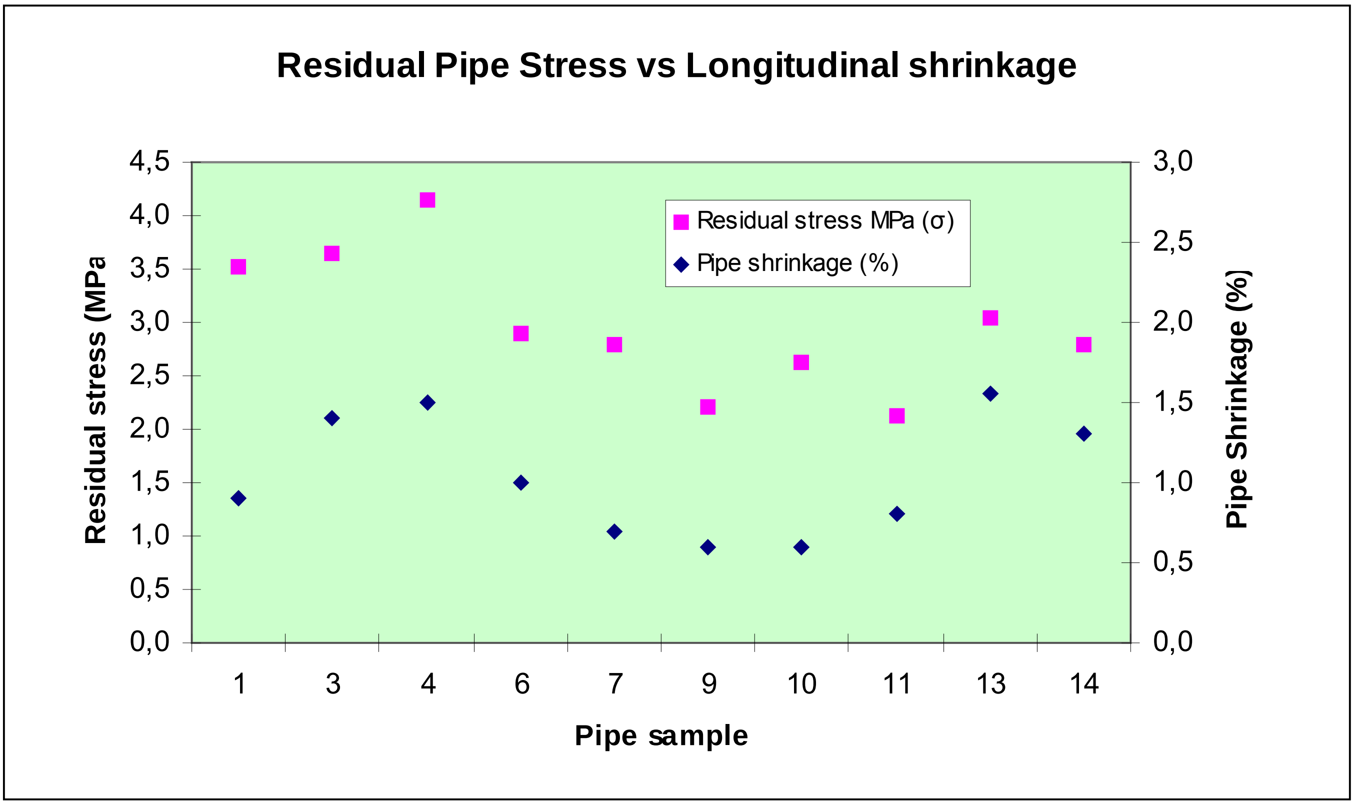

Illustration 2. Residual stress vs longitudinal shrinkage

3. Conclusions

Annealing will:
1. Improve the hydrostatic burst resistance [(5)(6)]
2. Improve the quick burst strength [(1)]
3. Improve the dimensional stability of the pipe in service[(4)]

4. References

(1) Sunwoong Choi, Lawrence J. Broutman , "Residual Stresses in Plastic pipes and Fittings IV. Effect of Annealing on Deformation and Fracture Properties" Polymer (Korea) Vol.21, No.1 pp 93-102 (1997)

(2) Gebler H , "Influence of Processing on Properties of HDPE Pressure Pipes", Kunststoffe, No.2, Feb 1983, p. 73-6

(3) Wolters M , "RAPID CRACK PROPAGATION IN PE PIPES STUDIED BY MODIFIED ROBERTSON TESTS ", Plastics Pipes 6;Proceedings of the Sixth International Conference -Citation- York,March 26-28,1985,p.22.1-22.6

(4) Bhatnagar A;Broutman , "EFFECT OF ANNEALING AND HEAT FUSION ON RESIDUAL STRESSES IN POLYETHYLENE PIPE", L J ANTEC '85;Proceedings of the 43rd Annual Technical Conference -Citation- Washington D.C.,April 29-May 2,1985,p.545-9

(5) Krishnaswamy R K; Lamborn M, "INFLUENCE OF MORPHOLOGY ON THE FAILURE OF POLYETHYLENE PIPES IN HYDROSTATIC PRESSURE TESTSANTEC 2003." Proceedings of the 61st SPE Annual Conference held Nashville, Tn., 4th-8th May 2003 -Citation- Brookfield, Ct., SPE, 2003, Volume 1-Processing Session T19-Trouble Shooting, p.224-8

(6) Krishnaswamy R K; Lamborn M J, "INFLUENCE OF PROCESS HISTORY ON THE DUCTILE FAILURE OF POLYETHYLENE PIPES SUBJECT TO CONTINUOUS HYDROSTATIC PRESSURE", Advances in Polymer Technology-Citation- 24, No.3, Fall 2005, p.226-32