

A PHOTOELASTIC INVESTIGATION OF RESIDUAL STRESSES IN CIRCULAR RODS OF TRANSPARENT POLYMERS

By
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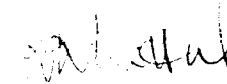


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CERTIFICATE

This is to certify that the thesis entitled "A PHOTOELASTIC INVESTIGATION OF RESIDUAL STRESSES IN CIRCULAR RODS OF TRANSPARENT POLYMERS" being submitted by Mr. Vibhu Rashmi to the Indian Institute of Technology, Delhi (India) for the award of the Degree of Doctor of Philosophy in Applied Mechanics Department, is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the standard fulfilling the requirements for the Doctor of Philosophy Degree. The research report and the results presented in this thesis have not been submitted in part or full to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

Residual stresses are generally present in solid polymers and they arise as a result of temperature gradients during solidification. Most of the methods to measure these stresses are destructive. In this thesis a non-destructive technique is established and applied to circular rods of various sizes of polymethyl methacrylate (PMMA). In order to measure residual stresses in long rods or to compare the birefringence patterns near the ends and away from the ends, a large field diffused light polariscope was designed and fabricated with a provision for scanning the birefringence levels across any diameter. The second requirement of this technique is a fluid of matching refractive index which should not be chemically reactive with the material of the rod under consideration. Several combinations of fluids were tried to select a proper immersion fluid.

The theoretical basis of the technique used is described in detail. It is shown that the total birefringence across any chord is dependent only on the axial stress in a long rod (assuming plane strain conditions) provided the stress state is an equilibrium state. In this technique, it is also possible to assess the birefringence due to causes which are not thermomechanical in nature, e.g. birefringence due to molecular orientations, etc.

The theoretical analysis results in an integral equation of Abel's type. Although the solution of this equation is known, yet it is very more convenient and physically more intuitive to use a numerical procedure for the solution.

The numerical procedure used in this investigation consists of replacing the rod with a number of concentric rings and then progressively calculating the values of axial stress from one ring to another, starting from the outer surface. This procedure is verified by considering a parabolic distribution of residual stresses in a circular rod.

As mentioned above, the influence of birefringence caused by molecular orientations is also investigated using the birefringence curve. This effect is found negligible, as expected, in glass rods.

After establishing the technique for the determination of residual stresses and evaluating the magnitude of molecular orientation, the effects of various thermal treatments on residual stresses in PMMA rods are studied. Various heating and cooling programmes were considered for this purpose and in each programme the distribution of residual stresses across the diameter of rod was obtained. For PMMA rods in 'as extruded state' as well as for all thermal treatments, it is seen that there is a compressive stress in the outer region of the rod and tensile in the interior. The magnitude

of the stresses depends on the particular thermal treatment. It is also shown that the level of molecular orientation varied, depending on the thermal history.

The residual stress distribution was also obtained by using a well-known destructive technique, i.e., the layer removal technique for circular rods, and the results are compared with the present photoelastic method. For the layer removal technique it is shown that the time interval between two successive removals is very important and an accurate determination of the state of residual stresses by layer removal technique requires not only high precision but can take several days. In contrast, the present method is very efficient, simple and accurate.

The present photoelastic technique also enables one to determine the radial and hoop components of residual stresses. The difference of these two components can also be measured by a direct photoelastic analysis of a slice cut from the end of the rod. The results of both these methods have also been compared and the influence of the slice thickness on the stress difference measured by the "slice method" established.

As applications of the non-destructive photoelastic technique established in this work, two phenomena of interest are considered : (1) the relaxation of quenching stresses with time, and (2) re-distribution of residual stresses during layer removal technique. Since any destructive method will

itself interfere with the phenomenon under consideration, the non-destructive method is ideal.

Thus, in conclusion, it may be stated that a non-destructive technique has been established which is accurate and efficient and thus can also be used as a suitable quality control method for monitoring stresses produced in processing of transparent polymers, besides being a useful research tool for the study of various aspects of residual stresses in these materials.

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