STUDIES ON
RESIDUAL STRESSES DUE TO GRINDING

By

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TO MY WIFE,

MRS. SETHULAKSHMI NAIR

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CERTIFICATE

This is to certify that the thesis entitled 'STUDIES ON RESIDUAL STRESSES DUE TO GRINDING' being submitted by Mr. R. Ravindran Nair to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy in Mechanical Engineering is a record of bona fide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis which, to our knowledge, has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

A review of the literature has been presented covering the analytical and experimental investigations concerning residual stresses induced in the workpiece by the grinding process, and the need for comprehensive analytical approaches for the prediction of residual stresses due to grinding has been indicated.

An analytical model has been proposed for the determination of residual stresses due to surface grinding taking into account the microstructural transformations in addition to thermal and mechanical load. The model considers the grinding process to be equivalent to the case of a moving force and a moving heat source, both distributed over the contact area between the wheel and workpiece.

The model employs the finite element method based on the elasto-viscoplastic approach to determine the elastic-plastic state of stress within the workpiece due to grinding. The finite element program developed as a part of this thesis was validated at different stages of its development by solving appropriate examples. The validity of modelling of microstructural transformations for residual-stress analysis was checked by solving the quenching problem, where residual-stress distributions measured on quenched samples showed good agreement with those predicted by the analytical model taking transformations into account.

The main feature of the program developed is its ability to take account of the effects of the microstructural transformations, the strain-hardening behaviour of the material, and the variation of the mechanical and thermal properties with temperature.

The analytical model uses an iterative procedure for the step-by-step movement of the temperature field and the mechanical forces to simulate the movement of the grinding wheel over the workpiece. The transient-stress distributions within the workpiece during grinding have been computed, leading to the residual stresses. Computation has been carried out for different values of the intensity and speed of movement of the heat source, representing a range of grinding conditions.

The relative contributions of the mechanical, thermal, and transformational effects to the final residual-stress pattern in the workpiece have been determined with the help of the analytical model and it has been shown that the mechanical force in grinding has only a relatively small contribution compared to that of the thermal load. The microstructural transformations in mild steel due to grinding have been shown to increase the surface tensile stresses, to produce an additional hump in the residual-stress pattern near the surface, and to decrease the depth of the tensile layer.

The residual-stress distributions in a number of mild steel specimens surface-ground under different conditions have been measured employing a bending-deflection technique based on continuous layer removal, suitable for beam specimens. The experimental results obtained were compared with those of the analytical model.

The analytical and experimental investigations enable inferences to be drawn in terms of the influence of process and material parameters on the residual-stress distributions induced in the workpiece due to grinding.

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