Studies on Temperature Distribution in Various Joint Designs and Design of Horns for Ultrasonic Welding of Thermoplastics

Use of engineering plastics in structural and non-structural applications is rapidly increasing. As the demand for plastics increases so does the requirements for joining of plastics. Of the many techniques that are available for joining of thermoplastics, ultrasonic welding is one of the suitable processes. Polymers are categorized according to their molecular structure as amorphous and semi-crystalline. Ultrasonic welding of these two types of thermoplastics is expected to be different. As heating is confined to the interface area, quality of weld mainly depends on temperature at the interface. So study on temperature distribution during welding is very important to predict the quality of weld. Viscoelastic heating is most critical to ultrasonic welding of thermoplastics because it is the main mechanism by which heat is developed at the interface. Heat developed due to viscoelastic heating depends on applied frequency, square of amplitude and loss modulus. Ultrasonic welding is generally divided into (a) near field welding in which the horn is located within a distance of 6mm from the joint and (b) far field welding where the horn is located at a distance which is more than 6mm from the joint.

There are several other factors that affect the quality of welded parts. The critical variables are joint design, weld time, amplitude, pressure and hold time.

For any application, there are two major factors regarding design: part design and joint design. There are many variations on joint design, but the two major categories are energy director and shear joints. Both promote stress at the bond line to assure that energy is concentrated at the bond line.

In this study, modeling of temperature distribution for various joint designs of thermoplastics as practised by industry is attempted and simulation is done in ANSYS. Model is validated by measurement of temperature during welding.

Studies using Differential Scanning Calorimetry (DSC) and Scanning Electron Microscope (SEM) were carried out on the specimen before and after welding to understand the changes that may take place in the polymers. DSC is a convenient and accurate equipment for performing thermal analysis on a wide variety of materials. The heat flow rate curves are prepared from these experiments. The weld morphologies of amorphous and semi-crystalline polymers were studied for ultrasonic welding using SEM.

Ultrasonic horns are tuned components designed to vibrate in a longitudinal mode at ultrasonic frequencies for thermoplastic welding. Reliable performance of such horns is normally decided by the uniformity of amplitude of vibration at the working surface and the stresses developed during loading condition. This work discusses horn configurations which satisfy these criteria and investigates the design requirements of ultrasonic horns in ultrasonic system. Design requirement includes amplitude required at the tool end and minimal stress distribution throughout the horn while subjected to loading. Mathematical equations are developed for analyzing vibration system to determine the displacement and stresses. Cylindrical, conical and exponential horns are studied. This provides a basis for design of horns. The temperature distribution in the horn is also modeled.

When developing a horn, the designer begins with a concept, and then simulates operation of the resonator in the computer. Based on the result of the simulation, the designer makes decisions on the modification of the model. Modifications are made and the computer simulation is repeated. A large number of iterations may be required to arrive at an optimized solution. In industries horns are modeled in Computer Aided Design (CAD) environment, analysed using Computer Aided Engineering (CAE) tools and manufactured with the help of Computer Aided Manufacturing (CAM). Thus the relevance of solution using ANSYS. The mathematical model for the horn, its solution and solution using ANSYS are presented in the work.