Research Summary

Jan K. Spelt
Department of Mechanical and Industrial Engineering
University of Toronto

1. Structural Adhesive Joining

Our research focused on developing methods to predict the performance of structural adhesives, principally those used in automotive applications. Specifically, we have developed methods to allow for the prediction of:

- Adhesive joint fracture loads
- Fatigue crack growth
- Long-term durability
- Creep crack growth under sustained loads

2. Microelectronics Packaging

The mechanical failure of microelectronics devices can result from cracking and creep within solder joints and the circuit boards themselves. The loads on circuit boards and solder joints can result from inertial effects (vibration, impact), thermal strain, and component misalignment during manufacture. Fibre-optic assemblies may be subject to distortions caused by the creep of the adhesives used in various connections. Our research has developed ways to predict:

- Fracture within solder joints
- Crack growth due to thermal fatigue (cyclic temperature changes)
- Solder creep over a wide range of temperatures
- Solder joint fracture due to cracking of the printed circuit board
- Fracture of epoxy underfill adhesives
- Creep of fibre-optic adhesives

3. Abrasive Jet Micro-machining

We have conducted research into three manufacturing processes that utilize erosion to machine metals, ceramics and plastics. The objective was to understand the mechanics of how the erosive machining occurs and to predict material removal as a function of the process parameters. Our research has focused on micro-machining using:

- Abrasive high-pressure water-jets
- Low-pressure abrasive slurry jets
- Abrasive air-jets

4. Vibratory Finishing

Vibratory surface finishing is a versatile process that is capable of cleaning, deburring, polishing, burnishing and hardening a wide range of materials. Our research has examined the mechanics of the erosion processes that occur within the flowing bed of vibrationally-fluidized granular particles. The objective has been to predict the role of process parameters in determining the outcome of the process. These experiments and modeling have investigated:

- Impact forces and velocities throughout a tub and bowl finisher
- Granular media flow velocities and patterns

- Erosion rates and roughness outcomes in aluminum alloys and ceramics

5. Surface Thermodynamics

This research focused on the determination of solid surface tension, including its measurement and its interpretation.

6. Blast Cleaning

Somewhat related to our work in abrasive-jet micromachining, we have investigated the use of solid particle streams to remove aircraft coatings and remove deposits from the surfaces of gas turbine components.

7. Paper and Wood-Fibre Based Materials

This research spanned many length scales, from fibre-wetting distortion in paper to the creep of wood-fibre composites and the breaking strength of the connections in wooden truss structures.

8. Zebra Mussel Biofouling

The principal focus of this work was the measurement of adhesive strength and its dependence on surface chemistry, and in particular the role of copper ions in preventing adhesion. It built on our background in adhesives and surface thermodynamics.

9. Heat Transfer and Fluid Mechanics

Heat transfer to flowing granular materials was an early topic of interest that led to the research in vibratory surface finishing. The measurement of shear-stress in a wall jet was used in the research on zebra mussel adhesion. Most recently, we have investigated the size-based separation of particles due to inertial flow fields in helical microfluidic channels manufactured using abrasive air-jet micromachining.