Overview

The symposium on Fatigue in Mechanically Fastened Composite and Metallic Joints was organized to define the state of the art in durability of mechanically jointed structures.

Mechanically fastened joints are used in many critical engineering structures, including buildings, machinery, power plants, automobiles, and airframes. The joint is the magic part that turns a series of material forms into a structure. The joint between one piece of material and another is often blamed for causing the design to be heavier than desired or for being the point at which fatigue or fracture problems initiate. The study of stress, fatigue, and fracture at joints, then, is of significant interest for the structural designer, as well as those interested in the durability and damage tolerance of the resultant structure.

This volume will serve as a state of the art of joint fatigue. Its usefulness is enhanced by the range of the papers herein, since they run the gamut from basic research to the very applied, from bridge structures to airframes, from adhesive bonding to welding, and from metallic to composite materials. The broad range of the topics covered in this Special Technical Publication makes it an excellent resource for designers, analysts, students, and users of mechanically fastened structures.

The initial paper, by *Speakman*, covers the development of high-performance fasteners in airframe applications. He provides an excellent review of the development of new fasteners and other joining methods for reducing weight and improving fatigue life. The paper is filled with practicality in its approach to improved mechanical fastening systems through methods and fasteners that are "forgiving to the hole." To this author, "forgiving to the hole" means that the fastener system is a practical one in which the hole manufacturing tolerances and the joint materials are taken into account, which results in a mechanical joint that has a large degree of compatibility and, therefore, good fatigue performance. In this wide-ranging paper, Speakman covers fasteners, corrosion, fatigue, fretting, tapered fasteners, sleeved rivets, solid rivets, special nuts, and high-performance bushings and bearings.

The paper by *Champoux and Landy* covers the experimental evidence for structural bushed hole fatigue improvement by using a hole expansion method that includes the simultaneous installation of an interference-fitted bushing. This new bushed hole expansion method is shown to provide a threefold increase in bushed joint fatigue performance while decreasing installation costs, in comparison with the cryogenic shrink-fit installation methods commonly used.

The paper by *Ozelton and Coyle* covers the fatigue improvement of aluminum airframe structures through the use of cold hole expansion by the split-sleeve technique prior to fastener installation. The process of cold hole expansion is being utilized in many applications to improve the fatigue performance of joints. This paper not only covers the fatigue performance of properly cold-expanded fastened joints but also looks into the fatigue improvement of holes with preexisting cracks and also improper reaming during manufacture. The Ozelton and Coyle paper provides excellent evidence of fatigue performance improvements that can be realized.

The paper by *Albrecht and Sahli* covers the fatigue performance of adhesively bonded and bolted highway bridge joints. The paper covers bolted joints, bonded joints, and bolted and adhesively bonded joints in many configurations. These joints are shown to provide increased fatigue performance in typical highway bridge beam splices when compared with conventional joints.

The paper by *Lee* covers the study of load transfer and its effect on fatigue performance in aluminum joints. The Lee paper uses no-load, low-, medium-, and high-load transfer joint specimens to define experimentally the crack initiation and propagation behavior. The results provide an experimental basis for methodology for service life prediction of joints.

The paper by *Yang, Manning, and Rudd* reports on a study of crack growth at fastener holes. The authors have developed statistical evaluations from a very large data base of crack growth at fastened joints for cracks of an extremely small size [less than 2.54 mm (0.10 in.)]. This analytical approach allows excellent predictions of the safety and durability of complex mechanically fastened joints.

The paper by *Nicoletto* covers the application of frozen-stress photoelastic techniques in the stress intensity determination of cracks in open holes and pin-loaded lugs. Pin-loaded lugs are an important branch of mechanically fastened joints, for which the stress distribution is not well characterized. The techniques and measurements presented by Prof. Nicoletto provide considerable insight into stress effects on these joints.

The paper by *Ekvall* covers the fatigue performance of lap joint and butt joint specimens made from recently developed aluminum alloy materials. These fatigue performance results were compared with those of conventional aluminum alloy product forms to assist in the process of defining improvement for the new materials.

Landy, Armen, and Eidinoff address the cold hole expansion repair of cracked fastener holes in structural joints. In this study, residual stress distributions from the cold hole expansion process were analytically developed. The resultant residual stress distributions were then superimposed with applied-load stress intensity factors to give a prediction of crack growth during fatigue exposure following the stop-drill hole repair process. Experimental evidence from mechanically fastened joints supports the prediction of an improvement in fatigue performance. The data indicate that the fatigue life following the cold expansion repair process of cracked joints can exceed the basic as-manufactured fatigue performance.

The paper by *Huth* covers the effect of the fastener in the stress redistribution of a fastened multiple-row joint. Dr. Huth provides compelling experimental evidence of the effect of many primary joint and fastener parameters, including fastener rotation and flexibility, on the predicted load transfer and resultant fatigue performance in the joint and subsequent structure. In this paper, Huth has developed a formula for load transfer within multiple-row joints which includes fastener flexibility. The formula can be used with a variety of fastener systems and joint materials to improve the general predictability of stress and fatigue performance in mechanically fastened joints.

The paper by *Ramkumar and Tossavainen* covers the fatigue performance of composite-to-metal fastened joints. Joint parameters such as the fastener type, stacking sequences and thickness, fastener head type, and joint configuration were investigated to define their effects on fatigue performance. Also studied were the effects of moisture conditioning and load spectrum type.

The paper by *Mallick, Little, and Dunham* describes the fatigue performance of fastened joints where the joint was made from a composite material used in the automotive industry. The composite [continuous fiber sheet molding compound (CFSMC)] joints were prepared with conventional fasteners and subjected to fatigue loading. The authors were able to define several failure modes in the CFSMC fastened joints, including bearing and fretting failures. The variables covered include the bolt clamping pressure, fastener pattern, and specimen width in comparison with the fastener head size.

Mechanically fastened joints have been with us since the first use of assemblies. People have used dowels, rods, screws, pins, keys, glue, bolts, and rivets as mechanical means of fastening. These mechanical fastening methods will be with us for the foreseeable future wherever efficient and inexpensive methods of fastening are required to ensure that a structure will serve the purpose for which it was manufactured.

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