WIRE ELECTRIC-DISCHARGE MACHINING AND OTHER FABRICATION TECHNIQUES

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INTRODUCTION

The new concept of wind tunnel testing in a cryogenic environment, combined with requirements for smaller scale and higher accuracy models utilizing new materials, has created fabrication problems. New methods and techniques need to be investigated. Methods to be discussed will include wire electric-discharge machining (EDM), extrude honing, and a surface measurement device. These methods and procedures were used to fabricate a two-dimensional wing for cryogenic wind tunnel testing.

ELECTRIC-DISCHARGE MACHINING BY WIRE

Electric-discharge cutting is done with a moving wire electrode. The cut track is controlled by means of a punched-tape program and the cutting feed is regulated according to the progress of the work. Electric-discharge machining involves no contact with the work piece, and no mechanical force is exerted. With the electro-thermal removal of material, the hardness of the electrically conductive work piece is unimportant. Deionized water is used as a dielectric to flush the particles away from the work piece.

Wire EDM cutting rates can be in excess of 5 sq. in. per hour in tool steel. A cutting tolerance of ± 0.0001 in. can be held, producing an excellent surface finish for easy hand finishing or other methods. In some cases the wire EDM can replace the conventional EDM, eliminating the requirement of fabricating expensive electrodes.

EXTRUDE HONE

Extrude hone is a process for honing finish-machined surfaces by the extrusion of an abrasive material (silly putty), which is forced through a restrictive fixture. The material will pass by the part and polish the surface to the required finish. This method is a very fast process and can be used on model components. A 10-to-1 ratio of surface finish can be realized; i.e., if you have a 40-rms finish you can expect a 4-rms finish. Special equipment is required to perform this operation.

Extrude hone also has a new concept in surface finish measurement. Instead of moving a fragile stylus across the surface to be measured, a rugged sensor is pressed against it. The sensor probe measures electrical capacitance between the sensor pad and the work piece to determine average roughness over the area covered by the sensor. The environment is not important. The equipment is inexpensive to purchase.

MODEL FABRICATION

The following methods and procedures were used to fabricate a two-dimensional cryogenic wind tunnel model. The material used was NITRONIC 40 in the annealed condition. The part was also thermal-cycled by immersing it in LN2 before and during the fabrication process.

A computer-controlled wire electric-discharge cutter (0.16 brass wire) was used to machine the airfoil shape. An EDM tool was used to cut the internal pockets and instrumentation routing. The electrode material for roughing slots and pockets was graphite EDM #1, which is 100 percent graphite. Electrode material used for finishing slots and pockets was graphite EDM C-3, which is graphite and copper. Settings were 65 V at 3 A.

The model was fabricated in two pieces, with the split line basically on the center line of the airfoil shape except on the leading edge, where the part line was 0.270 in. aft of the leading edge on the bottom side. The internal surfaces were finish cut using the wire cutting methods. The two pieces were then hand fitted together to a zero gap. The top and bottom pieces were mechanically fastened together using screws and pins. The trailing edge was cemented together using EC-2216 cement. The outer contour was cut 0.040 in. full using the EDM wire, and was checked on the Zeiss coordinate measuring tool for warpage or bow in the contour. At this time there was approximately a 0.015-in. bow. This was caused by a static charge created between the wire electrode and the work piece, and was not a problem during the roughing operations.

The model was then disassembled and the internal machining was accomplished using the conventional vertical electrical-discharge machine tool. The model was reassembled and wire cut to finish dimensions by using skim cuts of approximately 0.010 in. until the surface was within 0.010 in. full. Final cuts were made in 0.002-in. increments.

There were some problems with the trailing edge lifting due to the cement failing in some areas. This could have been due to material stress, or to not enough cement. The Zeiss check of the contour was very close to the lofted shape, as close as 0.001 in. The outer surface was hand finished to a 4-rms finish, and was then covered with aluminum tape, both for protection and to provide a surface to start the drill. The orifice holes were laid out on the aluminum tape and drilled using a small precision drill press. Type N jobber drills (0.014 in. diameter) were used. Some of the orifice holes near the leading edge were counter-bored from the inside surface using the EDM tool due to the extreme angle required. The rest of the orifice holes were counter-bored using conventional methods. Pressure tubes were installed using Hysol 9309.

CONCLUDING REMARKS

Total wire EDM time for this model was 486 hours. The wire EDM tool ran automatically 24 hours a day until each phase was complete. The time taken to fabricate this model is estimated to be less than that required for the numerically controlled mill method. The surface finish is better than a numerically controlled finish and requires much less time to hand finish. The time spent hand finishing this model was 1-1/2 days. Hysol EA-934 with NITRONIC powder added was used to fill the attachment holes.

Our experience at this time has shown that the wire EDM method can be used to fabricate a wind tunnel model that will satisfy the critical requirements of a cryogenic environment.