Bell Helicopter TEXTRON

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MEMO REPORT

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SUBJECT: RELIABILITY OF THE "WELDCOMPUTER CORPORATION" CONTROL SYSTEM INSTALLED ON RESISTANCE WELD MACHINE #8616

The purpose of this report is to establish that the resistance welding process, as controlled and monitored by WeldComputer's equipment, is sufficiently reliable to allow the substitution of nondestructive evaluation for the currently required destructive testing. This substitution is allowed by Mil-W-6858 *Welding, Resistance: Spot and Seam*, paragraph 4.3.3.3, which states - "The contractor may substitute nondestructive evaluation for routine lot tests upon approval of the procuring activity, provided he can demonstrate that the evaluation system will identify welds complying with strength or size requirements with a 99.5 percent reliability." The 99.5% reliability is equivalent to +/- 3 standard deviations (+/- 3 sigma) and 3 standard deviations equals a process capability index (Cpk) of 1.0. The resistance weld process at Bell Helicopter-Textron is controlled by BPS 4115, which defaults to the latest revision of Mil-W-6858. Pre-cleaning requirements of the various alloys are provided for in BPS 4113.

Resistance welding at BHTI is predominately Class B (per Mil-W-6858) which requires production witness destructive testing as follows a) Preproduction tests - 3 welds for shear strength determination and 3 welds for metallographic examination, b) Every 2 hour interval - 3 welds for shear strength determination, and c) Postproduction tests - 3 welds for shear strength determination. The purpose of these destructive tests is to ensure the welds meet a minimum shear value and metallographic quality.

The computer control system, recently installed on resistance weld machine #8616, can measure (non-destructively) weld nugget expansion, force, and conductivity of each individual spot weld. Nugget expansion measurements were chosen to be monitored because they provide excellent information as to the repeatability of the welding process from weld to weld. Nugget expansion is the growth of the workpiece due to thermal expansion during welding and is measured by a linear encoder attached to the upper arm of the weld machine. It is a useful variable for monitoring weld repeatability because virtually any process variation will cause a change in the nugget expansion response pattern.

The following data will demonstrate the existence of a significant correlation between weld nugget expansion and shear strength. As a result, nugget expansion measurements can be used to predict the spot weld shear strengths. A lower expansion limit will be established that ensures the required minimum average shear strengths are obtained and an upper expansion limit will be established that ensures over-penetration of the weld nugget is prevented.

To establish the *lower and upper limits* (see Figure 7), weld data on nugget expansion and shear strength shown in Table I was collected using two layers of 0.025" alclad 2024 aluminum. Twenty-five observations of nugget expansion and the corresponding shear values were collected for each of 7 different weld schedules. These weld schedules were developed around the production weld schedule (i.e. W/S 001) to provide a large range in shear strength/nugget expansion values.

Data from Table I are plotted in Figure 1 (except for data from Weld Schedule 80% - Over-Heated) which shows the relationship between nugget expansion and shear strength. Nominal values for each level of nugget expansion are connected with a line. The relationship between nugget growth is linear (with 95% statistical confidence) as described in Figure 2. The *lower limit* of this tolerance may be found using the linear model from Figure 2. The confidence bands around the nominal line represent the area within which 99.5% shear values (resulting from this particular material stackup) are expected to fall. If the lower confidence line is projected downward, 235 pounds corresponds to a nugget expansion of 1.9 mils (i.e. 0.0019"). All shear values were above the 235 pound requirement for this particular stackup. The distributions of nugget growth and shear values, independently, are shown in Figures 3 and 4.

The *upper limit* was developed from the distribution of the nugget expansion of an overheated weld schedule (i.e. W/S 80% - Overheated) shown in Figure 6. This schedule produced nuggets whose average penetration was slightly in excess of 80% of the sheet thickness which is the maximum allowed per Mil-W-6858. The actual weld data is shown in Table I, W/S 80%. The lower 3 standard deviation limit of that distribution was 3.4 mils of expansion. This limit was compared with the original W/S 001 nugget expansion data shown in Figure 7. The probability of exceeding the 3.4 mil upper limit is 1.5 out of 1000 welds. This insures the low probability of having an over-penetrated weld.

The distribution of shear values resulting from Weld Schedule 001, the production schedule, is shown in Figure 5. The process capability index (Cpk) is 1.53 which indicates that Weld Schedule 001 can consistently produce spot welds having shear values above the 235 pound minimum requirement.

This analysis indicates that substituting nugget expansion monitoring for destructive testing could result in a productivity improvement while maintaining the quality intent of Mil-W-6858. The weld computer measures the expansion of each nugget and can be programmed with a tolerance on nugget expansion. If a single measurement falls outside this tolerance, the machine will be programmed to halt operations and the operator must locate and correct the problem before resuming production. If (for W/S 001) 1.9 mils is programmed as the minimum acceptable nugget expansion and 3.4 mils is programmed as the maximum acceptable nugget expansion then 99.75% of the spot welds should have a shear strength greater than 235 pounds. At each failure of a nugget expansion outside the 1.9 - 3.4 mils expansion range, welding will be stopped and the problem identified and corrected. Witness specimens will then be welded to verify the success of the corrective action and that acceptable weld nugget expansion is being achieved prior to continuing production.

Upper and lower nugget expansion limits will be assigned to each individual weld schedule based on similar exercises. Because each individual weld's expansion value is monitored by the controller, there would be greater confidence in spot weld quality than with the periodic destructive monitoring required by Mil-W-6858.

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