MTSU & Industry Collaboration to Solve Welding Quality Problem Using DOE

David W. Gore, PE[1]; and Donald R. Langston, Graduate Student[2]
[1]Engineering Technology & Industrial Studies Dept., [2]Nissan North America

ABSTRACT

TITLE:
University and Industry Collaboration to Solve Welding Quality Problem Using Design of Experiments

BACKGROUND:
A local automotive seat supplier experienced a major quality problem in the fabrication of the metal seat frame used in the manufacture of the front bucket seats of automobiles.

OBJECTIVE:
Design a set of experiments to determine the effects of weld current, tip force, and weld time on the weld "break-away"

METHODS:
Run experiments using the Design of Experiments (DOE) methodology.

RESULTS:
DOE was successful and defects were eliminated.

CONCLUSIONS:
By collaborating with industry personnel at all levels, the student team was able to model the process successfully and provide setup boundaries for the operation of the welder.

BACKGROUND

This presentation covers the details of the Design of Experiments portion of a SIX SIGMA project that was successfully completed thanks to the collaborative efforts of both the industry and the university personnel.

The tier one automotive supplier has a welding station that welds four nuts to each seat pan.
The four nuts that are welded to the seat pan are not welded consistently in the welding operation.
The nut welding operation was producing defective welds that averaged six (6) defects per week.
"Zero defects" is the requirement for this important weld.
MTSU was contacted for performing a SIX SIGMA project to determine the cause and solution.

Seat pan – showing location of the 4 weld nuts

OBJECTIVE

Perform a SIX SIGMA study to determine the root causes of the problem and to work with company engineering and operations personnel to implement the countermeasures needed to eliminate the weld defects (minimum break-away torque of 400 inch-pounds).

METHODS

Perform Design of Experiments as part of the SIX SIGMA project.

- Run experiment using software provided by Stat-Ease Corporation. Design-Ease ® software
- Full factorial DOE model – 2 levels with 5 factors.
  2^5 tests are necessary, plus 4 more to check linearity: 36 total seat pans.
- Check model for insignificant factors and re-run as necessary.
  [Final model was a 2-level, full factorial, 3 factor model with power transformation to improve linearity].

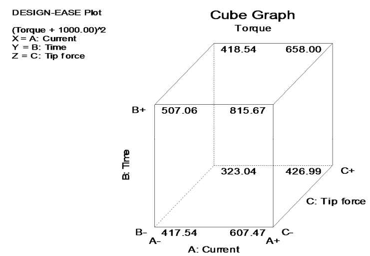
DOE Test Data – 2-level, 3 factor Model (with power transformation)

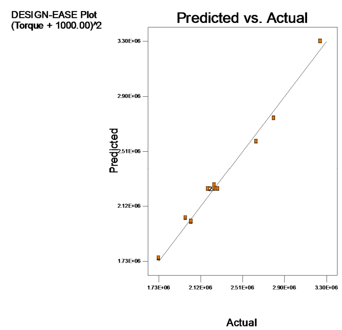
Test	Current (Amps)	Time (Cycles)	Tip Force (psi)	Output torque (in-lb)
1	10,000	4.0	35.0	425
2	15,000	4.0	35.0	625
3	10,000	30.0	35.0	500
4	15,000	30.0	35.0	800
5	10,000	4.0	70.0	315
6	15,000	4.0	70.0	407
7	10,000	30.0	70.0	426
8	15,000	30.0	70.0	675
9	12,500	17.0	52.5	480
10	12,500	17.0	52.5	500
11	12,500	17.0	52.5	511
12	12,500	17.0	52.5	500

ANOVA for DOE Model (99% Confidence Level)

Source	F Value	Prob>F	Comment
Model	94.35	<0.0001	significant
Current (A)	224.92	<0.0001	significant
Time (B)	124.22	0.0001	significant
Tip force (C)	85.11	0.0003	significant
AB interaction	26.59	0.0036	significant
AC interaction	10.9	0.0214	Not significant
Curvature	6.33	0.0534	Not significant
Residual	N/A	N/A	random
Lack of fit	4.91	0.1133	Not significant

RESULTS

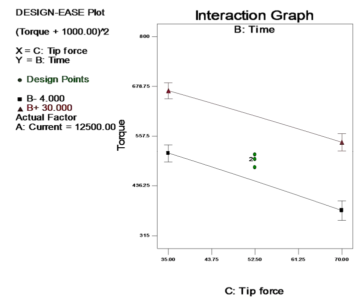




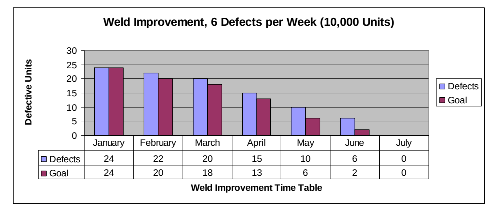
Final Model Equation in Terms of Actual Factors:

(Torque + 1000.00)^2 = +6.40252E+005 +158.78376 * Current -24612.00000 * Time +9099.00000 * Tip force +3.468179 (Current * Time) 1.64979(Current * Tip force)

RESULTS



Defect Reduction



CONCLUSIONS

The Tip Force variable directly affects output torque and is a significant contributor to weld strength. Surprisingly, the output torques improved as the tip pressure was reduced (just opposite to what the team thought intuitively). In fact, the present setting of 70 pounds per square inch pressure is a primary contributor to low torque failures particularly at the low weld current settings that are often run. It is recommended that this pressure should be lowered to a value based on the desired throughput time and welder amperage desired as follows:

- To obtain the lowest weld time of 4 cycles (1/60th of a second per cycle), set the tip force to 35 psi (one-half the original setting) and weld current to 12,100 amps. The DOE model predicts within 99% confidence that the lowest individual torque reading will be 400 inch-pounds (higher than the 365 inch-pound low limit specification) with a population mean reading of 500 inch-pounds.
- For lower weld current and a more typical setting of weld time of 10 cycles, set the weld current to 11,350 amps at the 35 psi tip force recommended above to achieve the same torque output values.
- For a weld that will not break loose until the surrounding metal fatigues, the weld current should be set at 15,000 amps, with tip pressure at 35 psi and weld time at 30 cycles. If this outcome is desired, another set of trial parts should be run to confirm good weld nut quality (i.e. no weld slag or nut deformation).