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DETROIT RESEARCH INSTITUTE
P.O. BOX 36504 • GROSSE POINTE, MICHIGAN 48236 • (313) 886-7976

LEONARD G. JOHNSON
EDITOR

WANG H. YEE
DIRECTOR

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TAGUCHI ON-LINE RELIABILITY
(DEFFECTS PER MEASURED PIECE)

ABSTRACT

INSTEAD OF CLASSICAL APPROACH TO THE CONFORMANCE OF A PRODUCT TO BLUEPRINT LOWER AND UPPER SPECIFICATION LIMITS (I.E., GO OR NO-GO CLASSIFICATIONS), THE TAGUCHI METHODS OF EVALUATION ASSIGNS EVERY ITEM WHICH IS OFF THE CENTRAL TARGET OF A SPECIFICATION INTERVAL A WEIGHTED DEFECT NUMBER PROPORTIONAL TO THE SQUARE OF ITS DEVIATION FROM THE CENTRAL TARGET. IN THIS WAY AN ITEM WHICH IS EXACTLY AT EITHER END POINT OF THE SPECIFICATION INTERVAL IS ASSIGNED 1 DEFECT POINT. FURTHERMORE, ANY ITEM INSIDE THE SPECIFICATION INTERVAL IS ASSIGNED A FRACTIONAL DEFECT INDEX EQUAL TO THE SQUARE OF THE FRACTION OF THE SEMI-INTERVAL FROM THE CENTRAL TARGET TO THE ITEM'S ACTUAL MEASURED VALUE. ALSO, ANY ITEM OUTSIDE THE SPECIFICATION LIMITS WOULD BE ASSIGNED MORE THAN 1 DEFECT POINT, DEPENDING ON HOW FAR OUTSIDE THE LIMITS IT FALLS.

THIS PAPER DISCUSSES THE IMPLICATIONS OF SUCH TAGUCHI EVALUATIONS (DEFECTS PER MEASURED ITEM), AND HOW THEY LEAD TO A MORE DISCRIMINATING CRITERION FOR PRODUCT UNIFORMITY AND REDUCES LOSSES MAKING FOR IMPROVED PROFITABILITY.

THE TAGUCHI LOSS PARABOLA

LET US SUPPOSE WE ARE DEALING WITH A PRODUCT FOR WHICH A CERTAIN MEASUREMENT (SAY, LENGTH) IS REQUIRED TO BE WITHIN A BLUEPRINT SPECIFICATION INTERVAL BETWEEN L (THE LOWER LIMIT) AND U (THE UPPER LIMIT), AS SHOWN IN FIGURE 1.

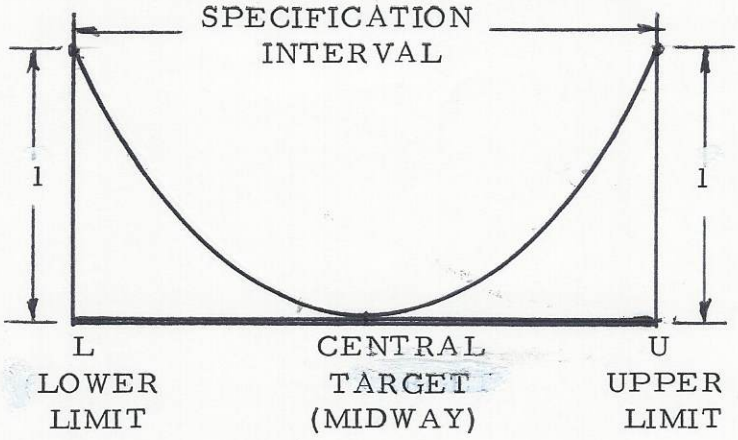

FIGURE 1

THE TAGUCHI APPROACH IS TO CONSTRUCT A PARABOLA WITH VERTEX AT THE CENTRAL TARGET AND WITH UNIT HEIGHTS AT BOTH L AND U . THIS PARABOLA WILL THEN HAVE THE FORMULA

$$Y = [2X - (L + U)/(U - L)]^2$$

IN PARTICULAR, AT $X = \frac{1}{2}(L + U)$, THIS GIVES $Y = 0$ DEFECTS.

AT $X = L$ OR $X = U$, THE FORMULA GIVES $Y = 1$ DEFECT .

A NUMERICAL EXAMPLE OF A TAGUCHI DEFECT INDEX

SUPPOSE A PART'S LENGTH IS REQUIRED BY BLUEPRINT TO FALL BETWEEN 4.990 INCHES AND 5.010 INCHES WITH CENTRAL TARGET AT 5.0000 INCHES. (SEE FIG.2).

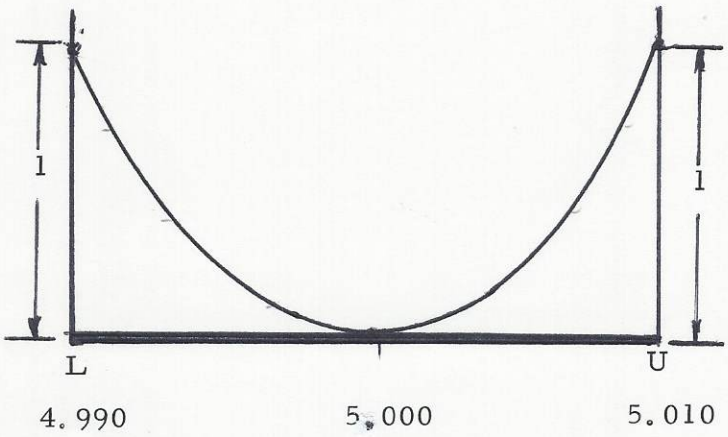

FIGURE 2

SUPPOSE 12 SPECIMENS ARE MEASURED WITH THE FOLLOWING RESULTS (IN INCHES):

EXAMPLE 1

X = 4.995 , 5.008 , 5.001 , 5.005 , 4.991 , 4.993 ,

5.009 , 5.011 , 5.012 , 5.002 , 4.999 , 4.994 .

WE ASSIGN DEFECT INDICES ACCORDING TO THE TAGUCHI PARABOLA HAVING THE FORMULA

$$Y = ((2X - 10)/.02)^2 \quad .$$

ACCORDING TO THIS FORMULA, THE 12 MEASURED VALUES WILL HAVE DEFECT INDICES AS SHOWN ON THE NEXT PAGE .

X	DEFECT INDEX
4.995	.25
5.008	.64
5.001	.01
5.005	.25
4.991	.81
4.993	.49
5.009	.81
5.011	1.21
5.012	1.44
5.002	.04
4.999	.01
4.994	.36

(SUM = 6.32 = ΣY) (ΣY^2 = 5.756)

AVE. DEFECT INDEX PER MEASURED ITEM = 6.32/12 = .52667 = $MEAN_1$

STD. DEVIATION OF DEFECT INDEX = $1/12\sqrt{\ 12(5.756) - (6.32)^2}$ = .44977

STD. ERROR OF AVE. DEFECT INDEX = $.44977/\sqrt{12}$ = .12984 = $SIGMA_{MEAN1}$

THE TAGUCHI IMPROVEMENT CRITERION

SUPPOSE THAT IN THE PREVIOUS EXAMPLE 1 WE MAKE AN ADJUSTMENT TO REDUCE THE DEVIATION FROM THE CENTRAL TARGET AND MEASURE ANOTHER 12 ITEMS AFTER THE ADJUSTMENT, WITH THE FOLLOWING RESULTS :

EXAMPLE 2

X = 5.001, 5.003, 4.999, 4.998, 5.000, 5.004,
4.999, 4.998, 5.002, 5.005, 4.996, 4.995.

NOW THE SUM OF THE DEFECT INDICES BECOMES

$$\Sigma Y = .01 + .09 + .01 + .04 + 0 + .16 + .01 + .04 + .04 + .25 + .16 + .25 = 1.06$$

HENCE , THE AVE. DEFECT INDEX PER MEASURED ITEM IS NOW

$$MEAN_2 = 1.06/12 = .08833$$

THE NEW STD. DEVIATION OF DEFECT INDICES IS

$$SIGMA_2 = 1/12 \sqrt{12\ \Sigma Y^2 - (\Sigma Y)^2} = .08933$$

THE NEW STD. ERROR OF THE AVE. DEFECT INDEX IS

$$SIGMA_{MEAN2} = .08933/\sqrt{12} = .02579$$

THE SIGNIFICANCE OF THIS IMPROVEMENT IS DETERMINED BY THE SO CALLED T-SCORE TO COINCIDENCE

$$\hat{t} = (MEAN1 - MEAN2)/(SIGMA_{MEAN1} + SIGMA_{MEAN2})$$

$$= (.52667 - .08833)/(.12984 + .02579) = 2.817$$

CONFIDENCE OF IMPROVEMENT = $1/[1 + e^{-1.8138(3.984)}] = .999+$

[NORMAL AREA TO Z-SCORE OF $t\sqrt{2} = 3.984$]

THUS, WE ARE OVER 99.9 % CONFIDENT OF AN IMPROVEMENT .

DOLLAR LOSS COMPARISONS

SUPPOSE ANY ITEM WHICH IS AT AN END POINT OF THE SPECIFICATION INTERVAL CAUSES A LOSS OF $100 FOR THE EXAMPLES JUST CONSIDERED.

THEN THE AVERAGE TAGUCHI LOSS PER MEASURED ITEM BECOMES

FOR EXAMPLE 1 : .52667 x 100 = $52.67

FOR EXAMPLE 2 : .08833 x 100 = $ 8.83

DIFFERENCE = AVE. SAVINGS PER ITEM SOLD = $43.84

STD. ERROR IN AVE. SAVINGS PER ITEM SOLD

$$= 100\sqrt{SIGMA^2_{MEAN1} + SIGMA^2_{MEAN2}}$$

$$= 100\ (1.3238) = \$13.24$$

HENCE , THE AVE. SAVINGS PER ITEM SOLD IS SURE TO BE WITHIN THE INTERVAL $43.84 ± 3 ($13.24) OR $43.84 ± $39.72 .

CONCLUSION

IT CAN BE SEEN THAT THE TAGUCHI LOSS PARABOLA ALLOWS US TO MAKE A SYSTEMATIC COMPARISON OF IMPROVEMENTS BOTH WITH RESPECT TO UNIFORMITY OF OUR PRODUCT , AS WELL AS WITH RESPECT TO DOLLAR LOSSES .