Improving product quality using design for Six Sigma: an Indian case study

This case study was conducted at Swaraj Division of Mahindra & Mahindra, a 2012 Deming Prize-winning company. It has remained at the top position in the Customer Satisfaction Index (CSI) in the tractor industry for the last three consecutive years. To maintain its CSI position and achieve the organizational vision of improving market share in 2015–2016, one of the key focus areas is to improve product quality by solving chronic issues. The company therefore sponsored an executive from the R&D Division, Deputy General Manager (Design) J.S. Sohal, to attend Six Sigma Black Belt training at the PTU Nalanda School of TQM & Entrepreneurship and equip him with the methodology and advanced tools for building quality into the product at the design stage. He was mentored by the author of this column, who is a Master Black Belt in Six Sigma, to solve the chronic problem of early-hour failures of hitch control valves (field failures occurring between 0–250 hours of tractor running) using define-measure-analyze-design-optimize-verification (DMADOV) methodology. This case demonstrates that if we follow improved methodology rigorously and appropriate quality tools are used, we can reap immense benefit on a recurring basis.

Define phase: selection and definition of problem
Among all failures due to hydraulics in Swaraj tractors, those in hitch control valves are the most common. Six-month data showed that the average in-house rejection rate for hitch control valves was 3.2%, costing the company US$40,000 annually. This high internal rejection was also reflected in external failures. Early failures of tractors are most damaging to customer satisfaction. Warranty costs during early-hour failures are more than 50% of the total warranty amount.

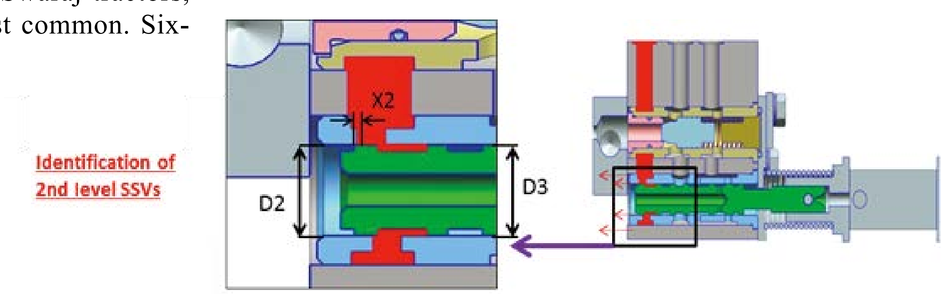
A Six Sigma project team was formed and set the goal of reducing in-house rejections by 50% (from 3.2% to 1.6%) by June 2014, thus contributing $20,000 directly to the bottom line of the company annually. It also estimated that this reduction in internal failures would stop 80% of early failures.

Measure phase: establishing baseline
The team recorded the trend of internal failures as well as failures at the supplier end of control valves for the period 12 February to 13 August. The baseline figure for internal failures was 3.2% expressed as rejections per hundred units (RPH) and that for the supplier end was 9%. Field data showed that there were 332 early field failures attributed to hitch control valve failure during the period among the 72,083 units in the field, i.e., 5,396 parts per million.

Further analysis showed lift dropping is a critical-to-quality parameter of hitch valves. A lift drop of more than 10 mm in 3 minutes is considered as failure of the control valve. From past experience, the team was aware that it occurs because of oil leakage inside the valve.

Analyze phase: identifying key design parameters
The team studied the construction of the control valve to identify defective components. It was concluded that any variation in the design parameters of the three major parts, the spool valve, spool sleeve, and control valve housing, could lead to oil leakage which in turn leads to lift dropping.

The team identified the design parameters, as shown in Figure 1. Thirty control valves were selected randomly and regression analysis between their design parameters (Xs,



Design parameters	Description
X1=D3-D4	Clearance between spool & sleeve
X2=X2$_1$-X2$_2$	Spool overlap X2$_1$=Spool land-to-land distance (spool L/L) X2$_2$=Spool hole-to-hole distance (spool H/H)
X3	Surface finish of sleeve bore
X4	Taper in sleeve bore
X5	Ovality of sleeve bore in lowering zone
X6	Surface finish of sleeve O.D
X7	Taper/ovality in spool
X8	Surface finish of housing bore

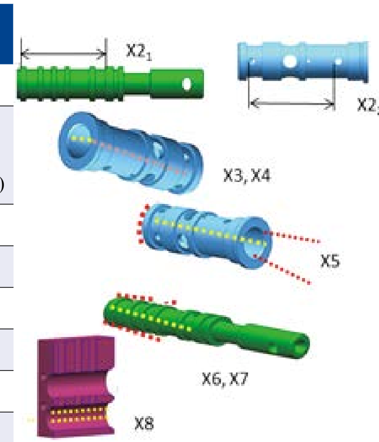


Figure 1. Design parameters of the hitch control valve.

causes) and lift dropping (Y, effect) was performed. It was concluded from the analysis that out of all the design parameters, four, i.e., clearance between spool and sleeve (X1), spool overlap comprising spool land-to-land (L/L) and spool hole-to-hole (H/H) distances ($X2_1$ – $X2_2$), and ovality of the sleeve bore (X5) contributed 90% to the total variation in lift dropping. These design parameters are controlling factors.

Control factor	Level 1 (existing level)	Level 2 (proposed level)
X1 (µm)	10	6
$X2_1$ (mm)	50.5	51.1
$X2_2$ (mm)	50.0	49.8
X5 (µm)	2	4

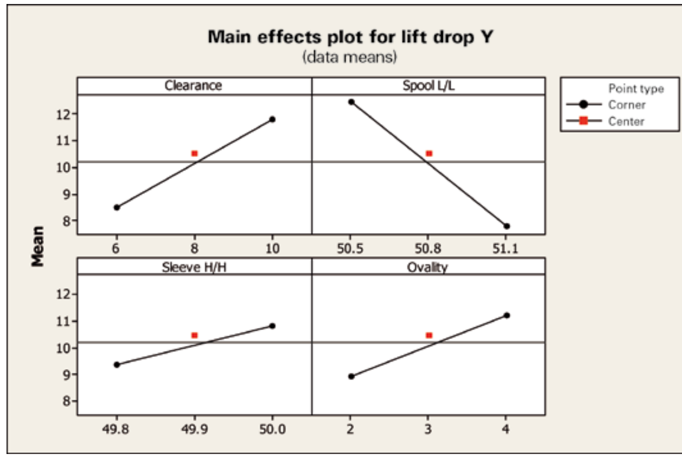


Figure 2. Results of DoE.

Design phase: designing parameters

The Six Sigma team proposed alternative values for these parameters, as shown in Figure 2. Based on full factorial design of experiments (DoE) at two levels, the existing and proposed levels for four parameters, 16 experiments (2^4) were conducted. Four sets of experiments were conducted at median values, i.e., the average of existing and proposed values. Experiments were replicated to capture variations with the same design. At the proposed levels, lift drop was significantly lower, and therefore a design modification was proposed. The results are shown in Figure 2.

Optimization phase: optimizing results

For design optimization, a global solution of all four parameters, i.e., clearance, spool L/L, spool H/H, and ovality, were computed using a response optimizer and contour plots with Minitab software. However, the manufacturability of the parameters at the proposed tolerances was a major challenge. Before rolling out the new design, it was decided to improve the capabilities of the related manufacturing processes such as honing, drilling sleeve cross holes, and heat treatment.

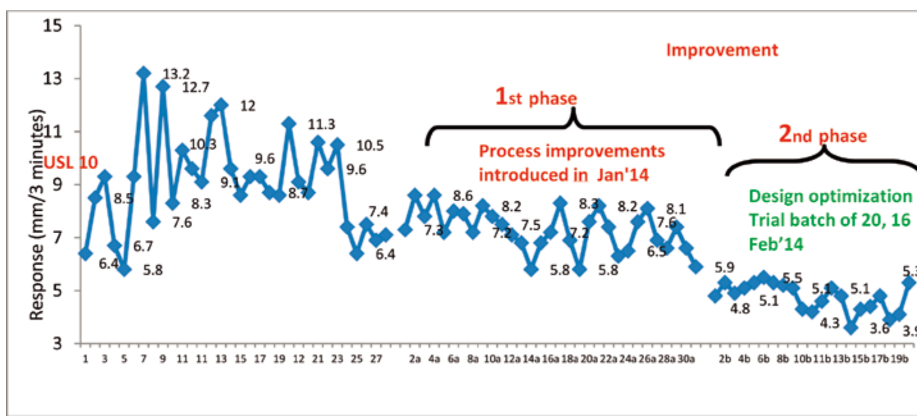


Figure 3. Improvement in lift drop.

Verification phase: results

After implementation of process and design improvements, the magnitude of response (lift drop) and its variations were reduced significantly, as shown in Figure 3.The RPH rate (on the production line) was also reduced significantly, as shown in Figure 4.

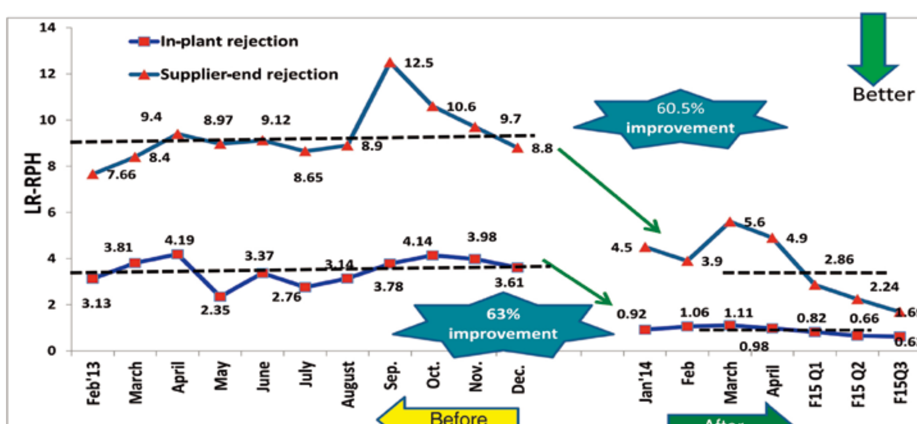


Figure 4. Reduction in the RPH rate before and after manufacturing process redesign.

Benefits

The Swaraj Division reaped the following benefits from applying the DMADOV methodology of Six Sigma to issues in its tractor hitch control valves:

- Rejections at the supplier end were reduced from 9% to less than 4%.

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- The in-plant RPH rate was reduced from 3.2% to 1% by June 2014.
- The average number of reworks/day decreased from 8.75 to 2.87.
- Financial savings to the tune of $30,000 were made due to fewer internal rejections.

Naresh Chawla holds a postgraduate degree in engineering and is an APO-certified Productivity Practitioner with abundant experience in consulting and training in industrial engineering, quality management, and operational excellence. He served as Deputy Director of the NPC, India, for 15 years. Naresh is a Six Sigma Master Black Belt and lean manufacturing consultant with the NPC while spearheading programs on Six Sigma certification and lean manufacturing in various organizations as General Manager (Consultancy and Training) of the PTU Nalanda School of TQM and Entrepreneurship in Mohali, India.