Study of IQS & Improvement in Harvester Combine IQS Score by TQM Approach: A Case Study of Harvester Combine SWARAJ – 8100 Model

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Abstract— IQS stands for Initial Quality Study. It is the evaluation of the product by customer's point of view when final product comes after manufacturing & is ready for dispatch. In IQS, all defects are recorded aggregate wise & overall IQS Score is generated. This is called Demerit score whenever it is discussed about improvement in IQS. TQM approach is followed for IQS score improvement in Harvester combine. Swaraj Division, Plant -2, Mahindra & Mahindra Limited manufactures Tractors, Harvester combine & Forklift. This plant has a capacity to produce 500 Harvester Combines per year. IQS is done on tractor & Harvester combine. Forklift excludes from IQS. Tractor & Harvester combine have IQS score if 106 & 3406 respectively. So, harvester combine was selected for improvement as it has high score as compared to tractor. In this work, using TQM methodology, data was collected from IQS. Major defects were identified by Pareto analysis in three aggregates i.e. HPU, Supplies & Design. Cause & Effect analysis was done for major defects to find out probable causes. Possible causes were identified from probable causes using technical skills, knowledge and experience. Possible causes were tested hypothetically by actual measurements and analysis. Corrective action plans were made for the valid causes. After observing and analyzing results, correction procedures were standardized and implemented. Overall IQS score of HC from major 14 defects of three aggregates were identified from Pareto analysis, reduced from 2119 to 1109, having 48% improvement. HPU score of major 5 defects identified from Pareto analysis, reduced from 1016 to 700, having 31% improvement. Similarly, Supplies and Design score reduced from 753 to 409 having 46% improvement and from 350 to 0, by eliminating all 4 defects respectively.

Index Terms— Applying TQM Methodology for Improvement in IQS Score, Demerit Score of a Product for Defects, Initial Quality Study (IQS), Pareto Analysis, Root Cause Analysis, Testing Hypothesis & Implementation of Corrective Action Plan.Testing Results.

1. INTRODCUTION

IQS stands for Initial Quality Study. It is the evaluation of the product by customer's point of view, taking performance as well as appearance into consideration. Let us take an example of a car, which is bought by the customer, if its performance like mileage, acceleration & power etc. will not be up to the desired level, customer will not be satisfied even if it has an excellent appearance. Similarly, if the car has an excellent performance, but its appearance is not up to the desired level, than also customer will not be satisfied. Both factors play important role for customer satisfaction & increased sale of the product.

IQS score is also called demerit score as it is evaluated by the sum up of individual score of all defects. Auditor randomly selects product from stock yard which is complete in all aspects and is ready to dispatch to the dealer. He notes down all defects one by one, keeping in view component, category, aggregate, grade and score on an IQS summary sheet. In IQS, there are four steps Selection, Evaluation, Projection & Continuous Improvement.

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TQM stands for Total Quality management. TQM is defined as a continuous effort by the management as well as employees of a particular organization to ensure long term customer loyalty and customer satisfaction. In last step in IQS i.e. continuous improvement, TQM approach is followed. Pareto graphs, Cause & Effect diagram, testing hypothesis, Corrective action plan's implementation & measuring results are the steps used in this methodology.

In this research, in first phase, it is necessary to study the IQS methodology so that we can understand how IQS score is evaluated. In second phase, TQM methodology is used to improve the IQS score. These two phases are explained below.

2. STUDY OF IQS

There are two types of audit done in IQS to identify defects i.e. Dynamic audit & Static audit. In dynamic audit, those parameters are tested in which Harvester combine has to run like in actual field performance. Dynamic audit includes Roller testing which consists of leakage, noise, vibration & system malfunctioning detection & Road testing which consists of checking functions of brakes, clutch, gear box, steering, engine and sub assemblies etc. Static audit includes shower testing, sheet metal, paint, toe-in & hydraulic checking etc. in which Harvester combine is stationary. While performing these two audits, all defect observed are noted in IQS summary sheet. These defects are further summarized component wise, cate-

gory wise, aggregate wise, cases wise, grading wise & scoring wise. In IQS of Harvester combine, all defects were divided into three aggregates i.e. HPU (Harvester production unit, Supplies & Design) depending on the source of defect generation. The sum of defects score of a particular aggregate is the sum of that aggregate. The sum of all three aggregates score is the overall IQS score of Harvester combine. To understand IQS procedure, Flow diagrams are shown below

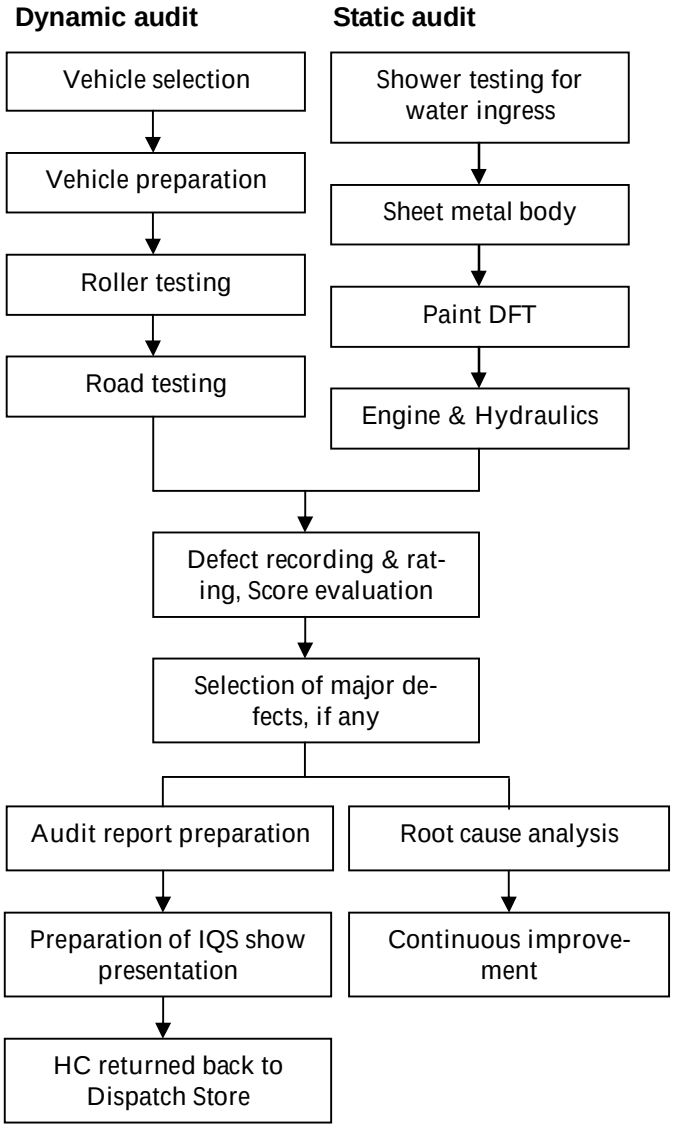

Fig. 1 Flow Diagram for IQS

IQS has standard criteria for grading & scoring of defects as shown in Fig. 2 & Fig. 3 respectively. Each defect is graded as per its criticality, location and weightage. Grading is helpful in scoring a defect. There are 10 grades i.e. G1 to G10. G1 has highest whereas G10 has minimum scoring. Monitoring range of Harvester combine was G5 to G6.

GRADE	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
					Monitoring range					
DESCRIPTION	Must be improved					Need	Continuous improvement			
Probability of customer complaint (%)	100	100	100	50	10	1	0	0	0	0
Noticeable by trained auditor (%)	100	100	100	100	100	100	50	10	5	0

Fig. 2 IQS Grade Evaluation Criteria

GRADE	Steering	Engine	Transmission	Hydraulics	Electric	Leakages	Brakes	Exterior	Sheet metal	Paint
Grade 1	800	800	800	800	800	400	800	400	400	400
Grade 2	400	400	400	400	400	200	400	200	200	200
Grade 3	200	200	200	200	200	100	200	100	100	100
Grade 4	100	100	100	100	100	50	100	50	50	50
Grade 5	50	50	50	50	50	10	50	10	10	10
Grade 6	10	10	10	10	10	1	10	1	1	1
Grade 7	0	0	0	0	0	0	0	0	0	0
Grade 8	0	0	0	0	0	0	0	0	0	0
Grade 9	0	0	0	0	0	0	0	0	0	0
Grade 10	0	0	0	0	0	0	0	0	0	0

Fig. 3 IQS Scoring Criteria

The score developed through this procedure represents the overall quality of Harvester combine. This demerit score has to be reduced to show improvement.

3. IMPROVEMENT IN IQS SCORE BY TQM METHODOLOGY

As already mentioned, TQM – Total Quality Management approach is very effective in overall quality improvement of a product or service. Initially, it was implemented in manufacturing sector but later, it was also implemented on service sector. In this research, various TQM tools have been applied to improve quality of Harvester combine by reducing IQS score through focusing on major identified defects.

At the start of this research, when data was collected, overall IQS score of Harvester combine observed was 3406. It is shown by Fig. 4. This score was sum of the score of three aggregates i.e. HPU, Supplies & Design having 1684, 1057 & 665 score respectively. It is shown by Pie chart in Fig. 5

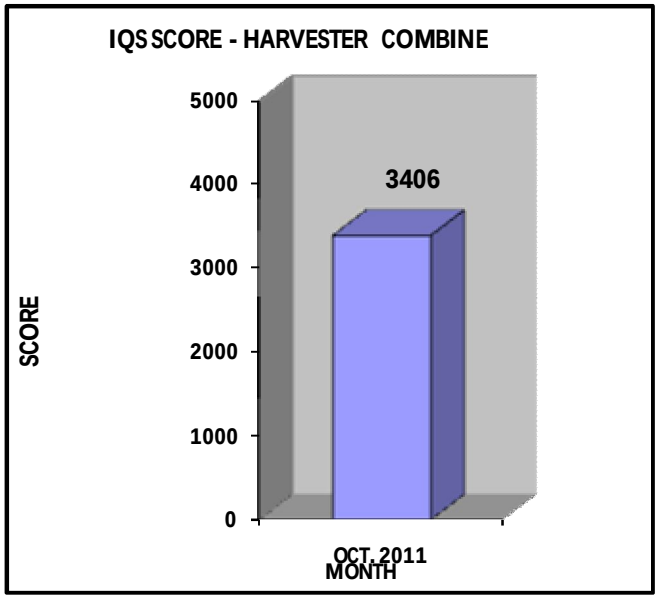

Fig. 4 IQS Score – Overall

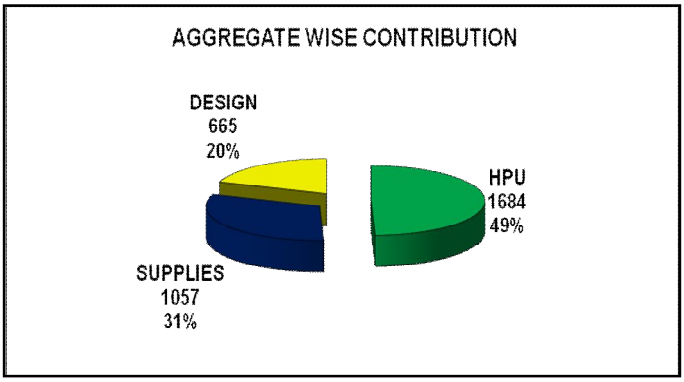

Fig. 5 IQS Aggregate wise Score

Further, Pareto graph was made from individual score of each aggregate. Major defects were identified from these aggregates.

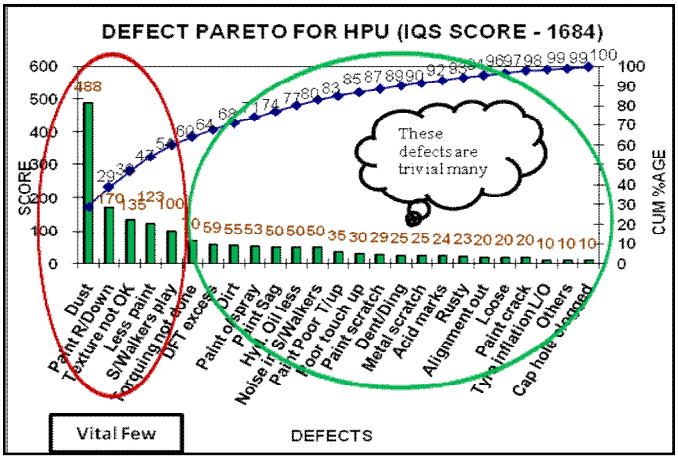

Fig. 6 Defect Pareto for HPU

Inference: Top five HPU defects were Dust (Score-488, 29%), Paint rundown (Score -147, 10%), Texture not ok (Score – 135, 8%), Less paint (Score – 123, 7%) and Straw walkers play (Score – 100, 6%). These five defects cover 60% score of total HPU defects and selected for further analysis.

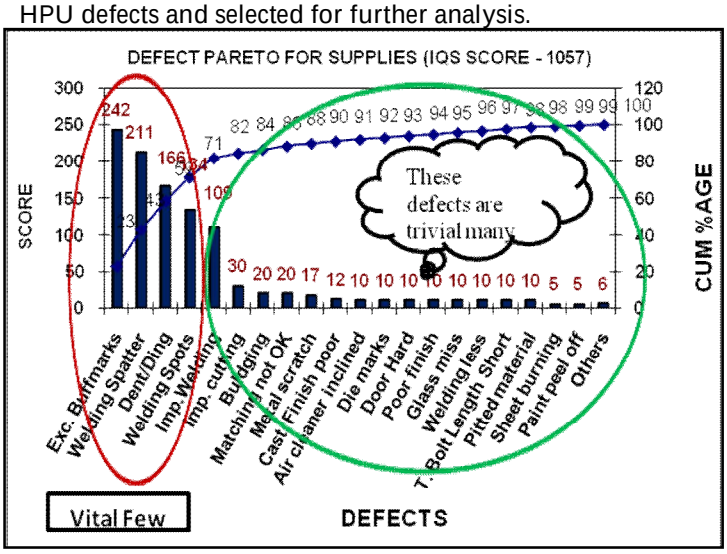

Fig. 7 Defect Pareto for Supplies

Inference: Top four Supplies defects were Excessive buff marks (Score – 242, 23%), welding spatters (Score – 211, 20%), dents / ding (Score – 166, 16%) and welding spots (Score – 134, 12%), These five defects cover 71% score of total Supplies defects and selected for further analysis.

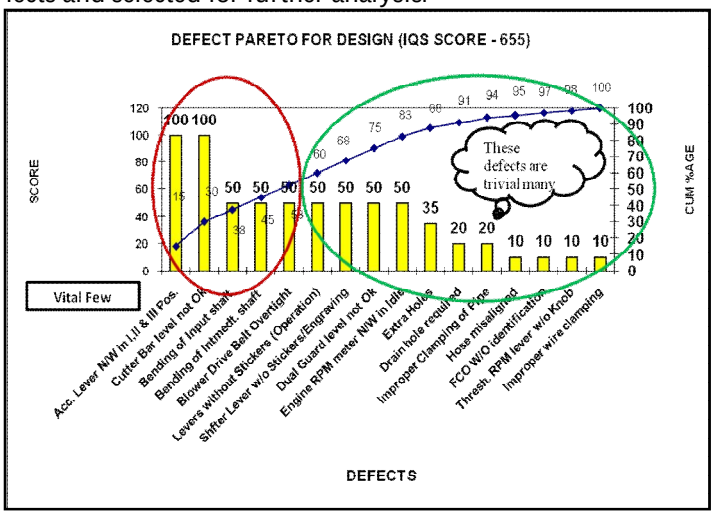

Fig. 8 Defect Pareto for Design

Inference: Top five Design defects were Accelerator lever not working in I, II & III position (Score – 100, 15%), cutter bar level not ok (Score – 100, 15%), bending of input shaft (Score – 50, 8%), bending of intermediate shaft (Score – 50, 7%) and blower shaft over tight (Score – 50, 7%).

Cause & Effect diagrams of major identified defects were made for Root cause analysis.Each C & E diagrams has been divided into four factors i.e. Man, Machine, Method & Material. Every suggested cause of defect has been put to a particular factor from above mentioned. These causes are called probable causes suggested during brainstorming session between the team members. Revised C & E diagrams were made after deleting invalid possible causes after discussion between technical, skilled & experienced members of the team. Some of C & E diagrams of selected 14 defects are shown below:

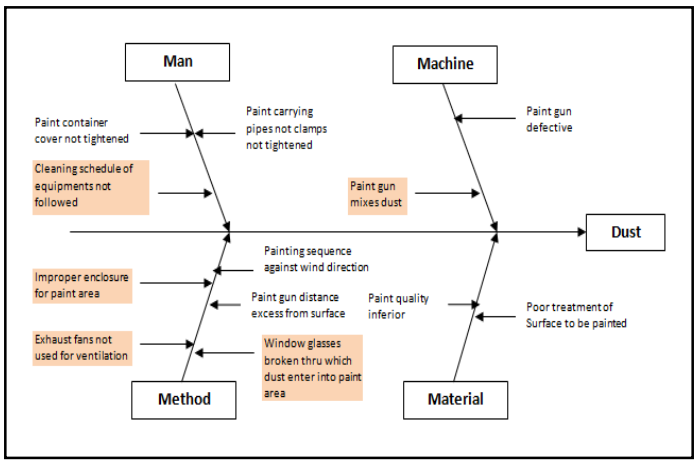

Fig. 9 Cause & Effect diagram – Dust (HPU)

Inference: Paint gun mixes dust, improper enclosure of paint area, exhaust fans for ventilation not working, window glasses broken through which dust entered into paint area & cleaning schedule of paint equipments not implemented & followed were valid causes for Dust in paint.

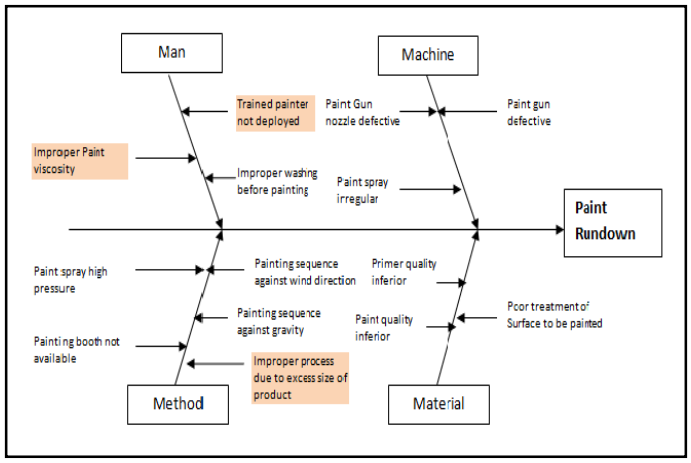

Fig. 10 Cause & Effect diagram – Paint rundown (HPU)

Inference: Improper paint viscosity, trained painters not deployed & improper process of painting due to excess size of product were valid causes for paint rundown.

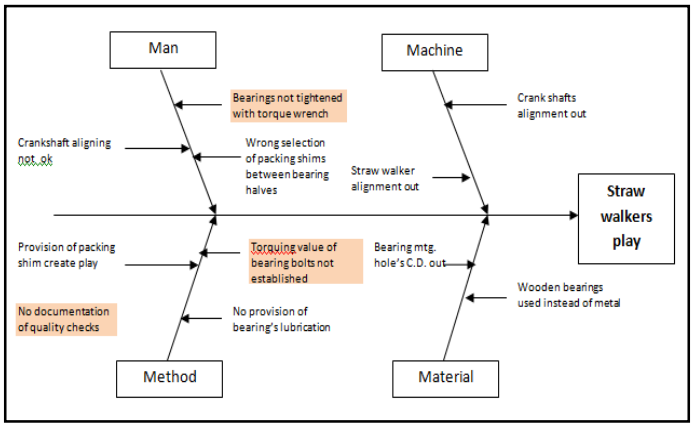

Fig. 11 Cause & Effect diagram – Straw walker's play (HPU)

Inference: Straw walker's bearings not tightened with torque wrench due to non establishment of torque value & no quality check reports were valid causes for straw walker's play.

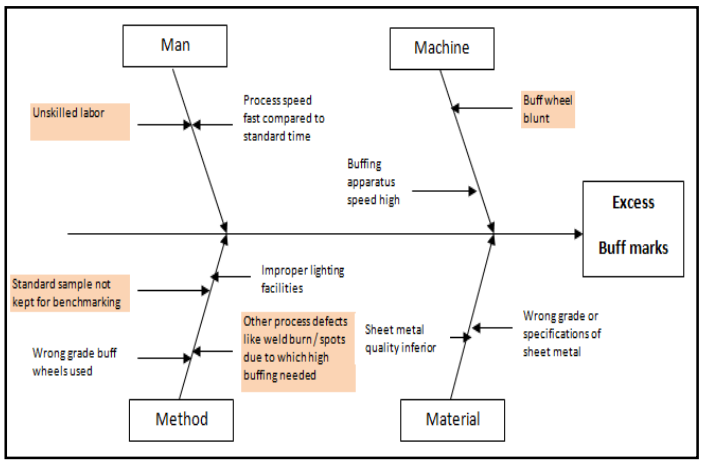

Fig. 12 Cause & Effect diagram–Excess buff marks (Supplies)

Inference: Unskilled labor, buff wheel blunt, standard sample for benchmarking at supplier end & excess welding bead were valid causes for excess buff marks.

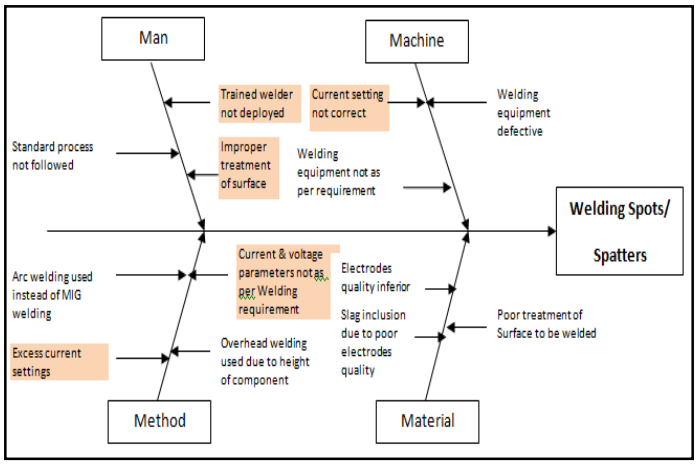

Fig. 13 Cause & Effect diagram – Welding spots/spatters (Supplies)

Inference: Trained welder not deployed, Improper dressing of surface & current setting not correct were valid causes for welding spots / spatters.

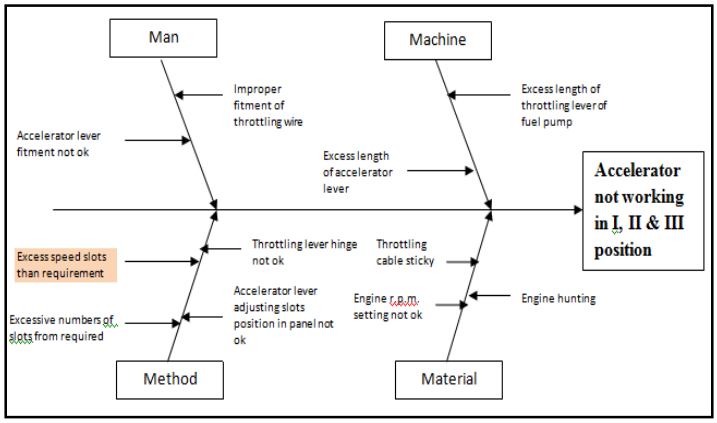

Fig. 14 Cause & Effect diagram – Accelerator not working in I, II & III position (Design)

Inference: Excess slots than requirement i.e. only three slots were sufficient for speed variation Harvester combine as it is operated in fields or on roads. Moreover, it has hi-lo gear also

by which three speeds can be operated in six speeds by engaging hi-lo gear.

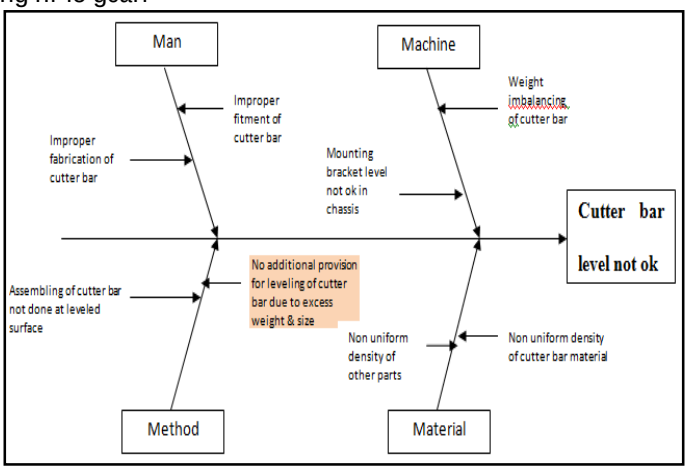

Fig. 15 Cause & Effect diagram – Cutter bar level not ok (Design)

Inference: Due to excess width i.e. 4.2 meters & heavy weight i.e. 1000 kg; it was difficult for alignment of LHS & RHS of cutter bar between 20 mm.

After root cause analysis of 14 defects, it was observed that most of the defects were due to improper procedures or methods. It can also be verified by C & E diagrams of defects, in which most of the valid causes are lying on method factor. Corrective action plans were developed for three aggregates. These corrected procedures and method were implemented.

Table 1: HPU – Improvement action plan

S. NO	DEFECTS	COMPONENT	1ST IQS SCORE	VALID CAUSES	OLD PROCEDURE	SOLUTIONS TO BE IMPLEMENTED	CFT	6TH IQS SCORE
1	Dust	Side shields	150	1. Improper Enclosure 2. Gun mixes dust 3. Window glasses broken 4. Exhaust fan not used 5. Cleaning schedule not followed	1. Partition is flexible (i.e. Tarpal) which torn after sometime & dust enter into paint 2. Old gun used. 3. Broken glasses not replaced 4. Exhaust fan not working. 5. Cleaning schedule not followed.	1. Solid partition is to be made (i.e. fiber sheet) 2. Electrostatic paint Gun implemented instead of ordinary Paint Gun 3. Broken window glasses replaced. 4. Exhaust fan at floor level installed to drive off dust of floor. 5. Cleaning schedule for partition, roof, walls & floor made & implemented with check sheet to be duly signed by worker.	1 ME 2 MAINT 3 QUALITY	120
		Rear cover	80					70
		Chassis	50					45
		Cutter bar	50					45
		Grain tank	40					34
		Platform	25					20
		Feeder casing	25					20
		Others	68					88
		TOTAL	488					442
2	Paint rundown	Chassis	42	1. Primer Viscosity 2. Excess Size 3. Unskilled manpower deployed	1. Primer viscosity not maintained 2. Excess height 3 Training not given to new manpower	1. Primer viscosity controlled as per chart. 2. Painter height made adjustable with elevator 3. Training provided to unskilled manpower.	1. PROD. 2. R&D 3. HR	12
		Feeder casing	31					2
		Cutter bar	29					12
		Platform	22					4
		Side shields	20					5
		Others	26					46
		TOTAL	170					81
3	Straw walkers play	Chassis	100	1.Torquing not done for tightening bearings 2. No documentation of quality checks	1. Torque wrench not used 2. torque value not established 3. Travel card not implemented	1. Torque wrench for tightening added in SOP 2. Torquing value established by H&D. 3. Travel card implemented.	1. R&D 2. QUALITY	0
		TOTAL	100					0
GRAND TOTAL			1016					700

Inference: In table 1, action plan is shown & it becomes clearer that what were the valid causes, old methods, corrective methods, implemented by which team & the results of these methods after implementation, of a particular defect. Here only 3 defects were shown as it was difficult to show all five defects in this research paper. Similarly, Supplies & Design action plans are also shown in table 2 & 3 respectively.

In HPU defects, there were mainly three departments' involvement i.e. Production, Quality & Ind. Engg. Supplies defects were looked after by Buy, Vendor Development Cell & Quality. Design defects have to be solved by R&D, Quality & Buy.

Table 2: Supplies – Improvement action plan

S. NO	DEFECTS	COMPONENT	1ST IQS SCORE	VALID CAUSES	OLD PROCEDURE	SOLUTIONS TO BE IMPLEMENTED	CFT	6TH IQS SCORE
1	Excessive buff marks	Side shields	111	1. Unskilled manpower. 2.Poor welding equipments 3. Poor Buffing equipments. 4. Standard sample for benchmarking	1. Daily wage labor was used. 2. No managerial help there for technical input. 3. Blunt buff wheel due to long use without replacement 4. Slow speed & vibrations in equipments.	1. Qualified Supervisor appointment made mandatory. 2. Supplier Visits added & schedule made to give technical inputs to suppliers 3. Buff wheel change time established & displayed 4. Standard sample of buffed component kept for reference at supplier.	1. BUY 2. VDC 3 QUALITY	90
		Rear cover	68					0
		Grain tank	30					26
		Cutter bar	20					30
		Others	13					21
		TOTAL	242					167
2	Welding spatters	Cutter bar	85	1. Skill, excess arc length 2. Poor surface preparation. 3. improper current settings	1. Untrained welder employed. 2. Surface to be welded not well prepared. 3. Welding equipment current settings not maintained.	1. Skilled workers identified & employed. 2. Rust & dust cleaned with emery paper. 3. Standard settings done on equipments & standard current values chart displayed on equipments.	1 ME 2 QUALITY 3. SUPPLIES 4. VDC	34
		Chassis	57					43
		Grain tank	20					0
		Platform	17					0
		Feeder casing	8					14
		Others	24					4
		TOTAL	211					95
3	Welding spots	Feeder Casing	81	1. Excessive current 2. Sheet thickness less	1. Excess current in spot welding leads to spots 2. Sheet thickness less to be spot welded	1. Standard settings done on equipments & standard current values chart displayed on equipments. 2. Sheet thickness given in design not followed by supplier, required sheets implemented	1. QE 2. VDC 3. R&D 4. SUPPLIES	0
		Grain Tank	37					0
		Platform	13					9
		Others	3					92
		TOTAL	134					101
GRAND TOTAL			753					409

Table 3: Design – Improvement action plan

S. NO.	DEFECTS	COMPO-NENT	1ST IQS SCORE	PROBABLE CAUSE	OLD PROCEDURE	SOLUTIONS TO BE IMPLEMENTED	CFT	6TH IQS SCORE
1	Acc. Lever N/W in I, II & III Pos.	Platform	100	Excess speed slots made during design	Out of 5 slots, 4th & 5th slots were effective due to short accelerator range and step speed not reqd. in HC.	Instead of 5 slots; only 3 slots provided, 2 eliminated. 3 speed slots are excess for HC due to slow moving operation in fields	1 QUALITY 2 R&D 3 MKTG. 4. BUY	0
2	Cutter Bar level not ok	Cutter Bar	100	No additional provision for leveling of cutter bar instead of weight & size	LHS & RHS of cutter bar have always a difference in height. As RHS has all drive systems, so this is kept high. Max. Difference of 20 mm is kept. But here due to large length of cutter bar (4.2 meters), it is difficult to maintain it.	Packing shims implemented between cutter bar mounting brackets & feeder casing where cutter bar rests.	1 QUALITY 2 R&D 3 BUY 4 PROD.	0
3	Bending of Input shaft during hi-lo gears	Chassis	50	Support for shafts not provided instead of over hang	Due to overhang of both shafts out of chassis, shafts bends towards each other driven by belt under dynamic thrust.	Footstep bearing provided to the drive shaft at the end by which their bending restricted	1 QUALITY 2 R&D 3 BUY 4 PROD.	0
4	Bending of intermediate shaft during hi-lo gears	Chassis	50	Support for shafts not provided instead of over hang	Due to overhang of both shafts out of chassis, shafts bends towards each other driven by belt under dynamic thrust.	Footstep bearing provided to the drive shaft at the end by which their bending restricted	1 QUALITY 2 R&D 3 BUY 4 PROD.	0
5	Blower Drive Belt over tight	Chassis	50	Wrong size of belt	Belt C-61 used which is undersize, replacing in field frequently due to rapid wear	Belt C-60, slightly large in size replaced with old one. This belt also used in field by users.	1 QUALITY 2 R&D 3 BUY 4 PROD.	0
GRAND TOTAL			350					0

4. RESULTS

In TQM methodology, improvements are proved with results, which should be measurable. In this research, IQS score is measurable to show improvements. Here, various graphs show the results which are discussed one by one.

First of all 14 major defects of three aggregates are shown graphically. IQS score is a demerit score thus Improvement trend will be there, if score line will decline or slopes downwards in the graph.

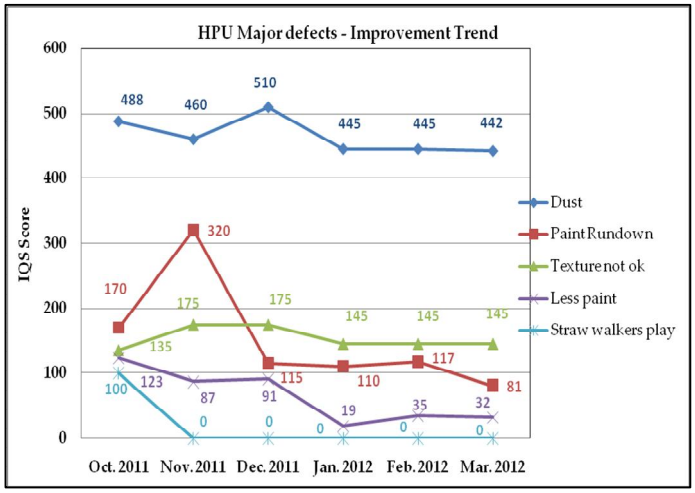

Fig. 16 HPU Defects – Improvement trend

Inference: Paint rundown, less paint & Straw walker's play defects have downward trend proving improvement, while Dust & Texture not ok didn't improved significantly due to traditional paint facility and scarcity of trained painter.

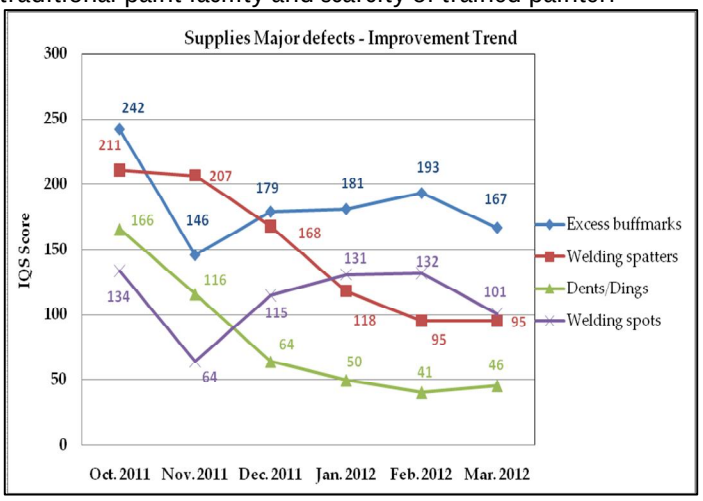

Fig. 17 Supplies Defects – Improvement trend

Inference: Excess buff marks, welding spatters & dents/dings defects have downward trend proving improvement, while welding spots didn't improved significantly due to improper welding practices & lack of trained labor at supplier end.

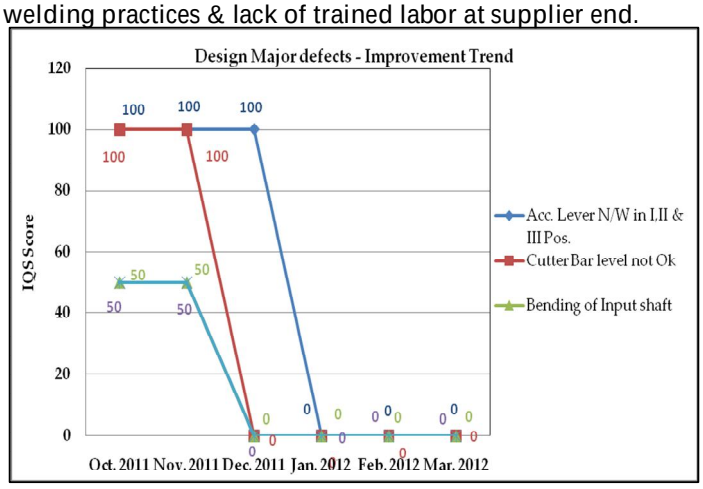

Fig. 18 Design Defects – Improvement trend

Inference: All design defects were eliminated showing drastic improvement. It was due to the acceptability of need for product development by company.

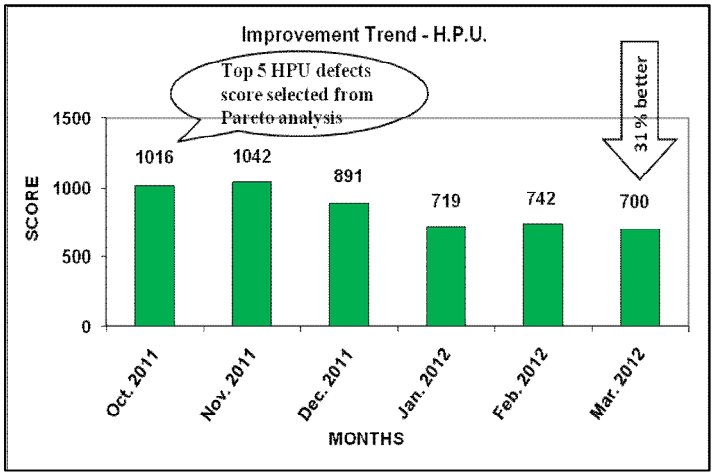

Fig. 19 HPU IQS Score – Improvement trend

Inference: IQS score of 5 HPU major defects was reduced from 1016 to 700, securing 31% improvement.

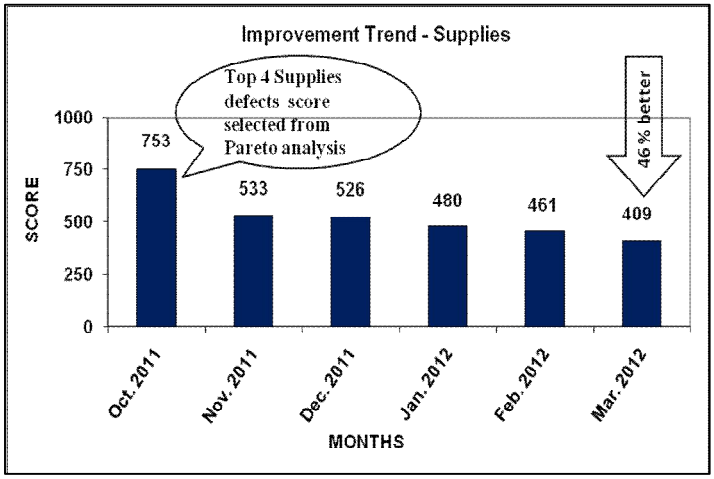

Fig. 20 Supplies IQS Score – Improvement trend

Inference: IQS score of 4 Supplies major defects was reduced from 753 to 409, securing 46% improvement.

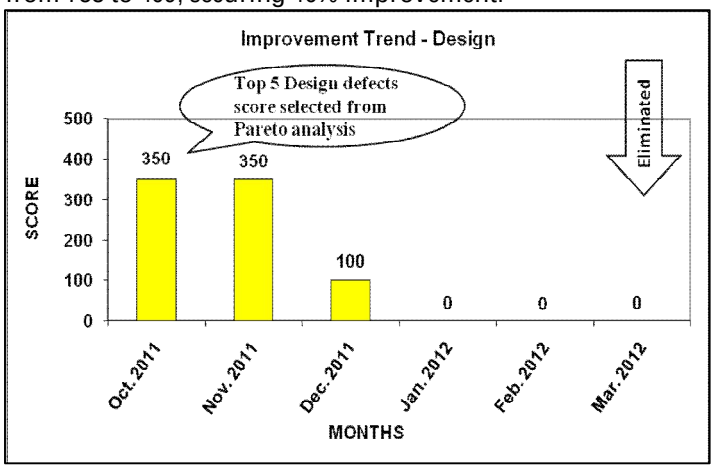

Fig. 21 Design IQS Score – Improvement trend

Inference: IQS score of 5 Design major defects was reduced

from 350 to 0, eliminating all 5 defects.

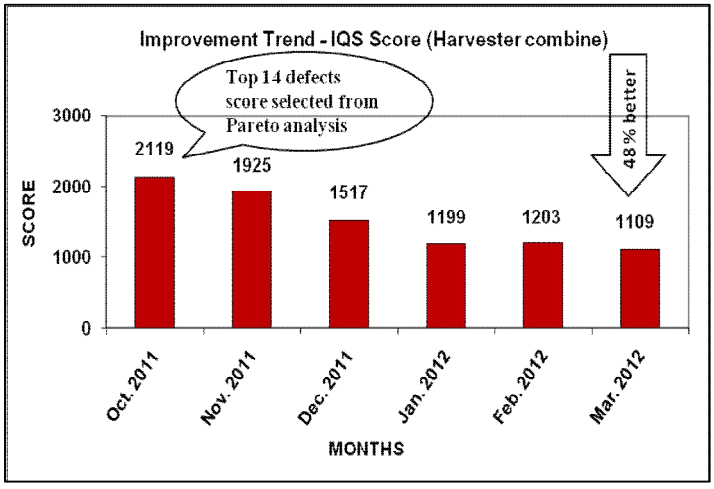

Fig. 22 Overall IQS Score – Improvement trend

Inference: Overall IQS score of 14 major defects was reduced from 2119 to 1109, securing 48% improvement.

5. DISCUSSION

I. Dust defect reduced from 488 to 442 score having 9.5% improvement. Dust defect didn't improve much, in spite of all possible solutions due to incomplete enclosure of paint area. Dust was entering above the fiber partition where as in a paint booth, if provided, there is a controlled atmosphere.

II. Paint rundown defect reduced from 170 to 81 score having 52% improvement. It was due to the training provided to the new/semi skilled painter, paint viscosity control and introduction of elevator for painting at elevated position of HC.

III. Texture not ok defect increased from 135 to 145 score having - 7.5% improvement. All solutions implemented except required paint drying time. It was due to high dispatch pressure and lack of open space for paint drying. HC was stored under shed area where sunlight couldn't come and moisture disturbs the texture of paint.

IV. Less paint defect reduced from 123 to 32 score having 74% improvement. Due to identical color of paint and primer i.e. cream, the painter had difficulty to identify paint layer on primer, improper masking system caused area left unpainted and unskilled manpower were major issues for this defect

V. Straw walkers play defect reduced from 100 to 0 score having 100% improvements. In assembly during analysis, it was observed that there was no documentation of critical quality checks due to which workmen don't have fear for penalties against loose work. Travel History card was developed and implemented on each HC so that workman can be traced out due to which problems appear at any stage or in field.

VI. Excess buff marks defect reduced from 242 to 167 score having 31% improvements. High current settings during welding lead to thick bead weld. It was dressed by blunt buffing wheel which was not replaced after its standard time. Due to this, buff marks appear on welding portion. Standard sample for reference also kept at supplier end. Training of manpower, supplier visit and technical supervisor ensured at supplier end.

VII. Welding spatters defect reduced from 211 to score 95 having 55% improvement. Excess are length during welding by untrained welder, poor surface preparation before welding and dress up after welding and improper current settings were major causes of this defect.

VIII. Dents/Dings defect reduced from 166 to 46 score having 72% improvements. Poor handling, improper bins, no capping provisions for aesthetic area of components and poor transportation were the major causes of this defect. Safety caps and cover of thermocol implemented on sheet metal components.

IX. Welding spots defect reduced from 134 to 101 score having 25% improvements. This defect has same reasons as of welding spatters in addition, sheet metal having less thickness used by supplier than required.

X. Accelerator not working in I, II & III position defect reduced from 100 to 0 score having 100% improvement. There were five slots in panel for various speeds of HC. Engine supplied by Ashok Leyland which is supplied to various HC manufacturers, having limited throttling as specific requirement of HC. It runs in fields with low speed and on road with full speed. So, two slots were deleted in panel. Now, only three slots provided for speed adjustment

XI. Cutter bar level not ok defect reduced from 100 to 0 score having 100% improvement. Cutter bar having 4.2 meters length and 1000 kg weight is being fitted on HC at two brackets. Due to this, it was very difficult to level it within required limits i.e. L.H.S should be only 20 mm up from R.H.S. Packing shims implemented between cutter bar and its mounting brackets of various thickness to level it.

XII. Bending of Input shaft defect reduced from 50 to 0 score having 100% improvement. Due to overhang of input shaft from chassis and heavy pulley mounting on it, during high speed, shaft bend up to 6 to 10 mm. various field failure reported of input shaft due to this reason. Foot step bearing implemented at end on input shaft to restrict the bending.

XIII. Bending of intermediate shaft defect reduced from 50 to 0 score having 100% improvement. This defect was linked with bending of input shaft as same belt rotates the both shafts.

XIV. Blower shaft over tight defect reduced from 50 to 0 score having 100% improvement. C-60 belt implemented which is exactly fit on this pulley instead of C-61. Previous belt was over tight even after disengaging tension pulley from it.

6. CONCLUSION

In this research, it has been observed that the overall quality of a product can be improved by TQM approach. This work concludes following outcomes.

I. Overall IQS score of HC from top fourteen defects of three aggregates, identified by Pareto analysis, reduced from 2119 to 1109 score having 48% improvement.

II. HPU score of top five defects identified by Pareto analysis, reduced from 1016 to 700 score having 31% improvement. Similarly, Supplies and Design score reduced from 753 to 409 score having 46% improvement and from 350 to 0 score eliminating all 4 defects respectively.

III. Conventional & manual paint process for HC and its size were main factors for HPU defects in IQS.

IV. Inadequate infrastructure, equipments, unskilled manpower and lack of managerial expertise at supplier end were the main factors for Supplies defects in IQS.

V. It has been observed from cause & effect diagrams that most of the causes lie in man and method categories. This verifies the requirement of improvements in these categories as explained in above two points.

VII. All defects, except dust & texture not ok in HPU and excess buff marks & welding spots have positive improvement trend.

IX. By using TQM methodology, focusing on few large contributing defects was done to gain major improvements. This way major part of a problem was eliminated by minimum efforts.

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