

DESIGN OF ON-LINE INSPECTION METHODOLOGY FOR REDUCTION OF COST OF INTERNAL FAILURE - A CASE STUDY IN SHEET METAL INDUSTRY

Kane P.V. and Deshpande V.S.

Department of Industrial Engineering, Shri Ramdeobaba Kamla Nehru Engineering College, Nagpur, Maharashtra, India. prasad_kane@yahoo.com, kanepv@rknce.edu, vsdeshpande1@yahoo.co.in, deshpandevs@rknce.edu

Abstract: Industries can endure the superiority over competitors by obtaining proper tradeoff between the quality and cost. One of the alternatives is to reduce the cost of quality. A small-scale unit (SS) in central India engaged in sheet metal working operations has been identified as a potential area for reduction in quality cost. The cost of internal failure has critically analyzed and reduced by eliminating its prominent causes. The critical and frequently occurring defects are targeted for identification at the respective stages of manufacturing process. Accordingly gauges are designed for identification of location error and camber. Inspection by online gauge was incorporated between the straightening decoiler machine and first cropping operation. Since the further processing of defectives is eliminated the cost of internal failures is reduced by about 40%.

Keywords: Quality Cost, Sheet Metal Industry, Gauge Design, On-Line Inspection.

1. INTRODUCTION

Globalization and liberalization has lead to cutthroat competition and all manufacturing units are compelled to cautiously use single rupee for sustaining in this competitive environment while adhering to the highest quality levels. All quality management consultants have selected quality cost program that addresses both the issues of quality and cost. (Campanella, 2003)

Quality cost is one of the performance measures for accessing quality levels achieved. Its estimation can reveal the scope of improvement to be made in the process (Juran J.M. & Gryna Frank M. 1980). Evaluation of cost of poor quality in industry is a first step to assess the quality level achieved. This begins adaptation of quality improvement techniques. Management gets convinced to implement the quality cost program as it expresses the things in monetary terms, which is suitable to understand (Evan, 1997).

A small scale unit (SSU), a certified vendor of Furniture Manufacturing Industry situated in central India is engaged in sheet metal working operations. The SSU has been identified as a potential area for reduction in quality cost. It was observed that the SSU was following the conventional inspection methods. Hence efforts are made here to access cost of internal failures, identify the defects contributing major portion of the cost of internal failure, and designing online and offline inspection gauges as per the process requirement.

2. EXISTING MANUFACTURING PROCESS

The SSU is engaged in the regular manufacturing of Vertical Channels, Top Outer Beam, Top Inner beam, Base Outer Beam and Base Inner Beam that are the components required for assembly of Partition System. Top Beam Inner and Outer are as shown in fig 1. It also manufactures the modular kitchenware using same machinery and raw material as per orders. The raw material for these components is a CrCa (SAE 1008 coil) steel strip of 1.2 mm thickness. Various press-working

operations are performed on mechanical presses of 63 tonnes, 40 tonnes. Final operation involving bending is carried out on 100 tonnes hydraulic bending machine. The coil is straightened by passing through straightening de-coiler machine.

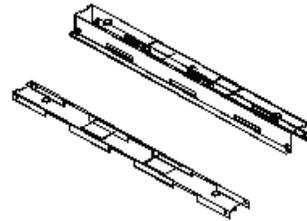
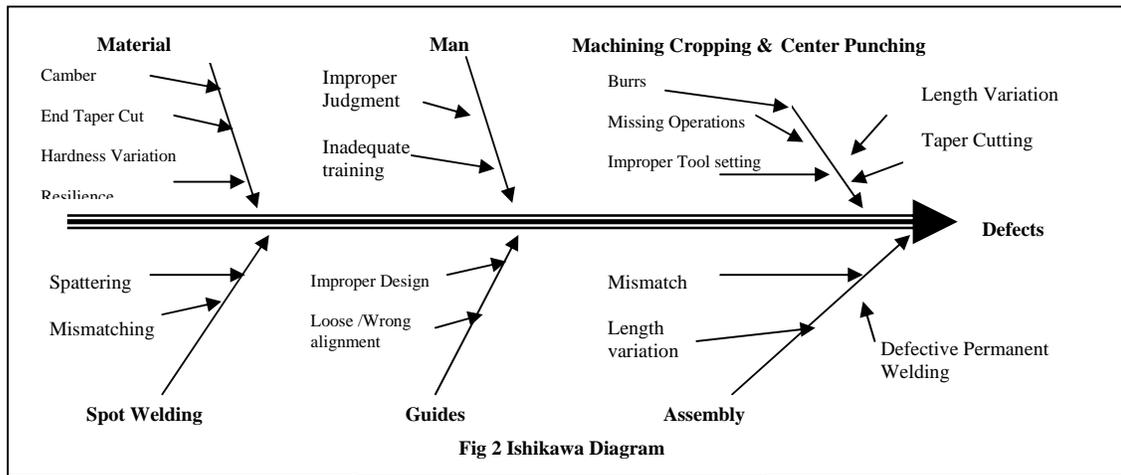


Fig 1 Top Beam (Outer and Inner)

Punching, blanking and cutting operations are performed using various dies. The layout inspection is carried out for the identification of the defect location variation. Job is set on surface plate with the help of angle plates and V block and measurements are done by using vernier height gauge. Job set up time for layout inspection is quite high. It substantially increases inspection time as well as tedious in nature. The GO and NOGO type of the gauges are used after the last operation i.e. bending to identify width variation and carried out for few sample components.

These components are supplied to the Furniture Manufacturing Unit where various assembly operations such as seam welding and spot welding are performed using special purpose machines. The defect like camber i.e. width variation above the tolerance limit gets surfaced out in these last operations of assembly. When the component found defective at the last operations, cost of all other processes gets accumulated on it. It leads to Levy of penalty to the small-scale unit.



3. IDENTIFICATION OF SCOPE OF WORK

A discussion with the industry personnel has revealed that as quality and time schedules are not adhered to the specifications, customer levies penalty. Identification of defects at assembly stage is the significant parameter for this aspect. Hence internal failures and the associated cost are severely affecting the performance targets and delivery schedules. To improve performance the company has decided to implement a quality cost program.

4. FORMULATION OF THE PROBLEM

The Ishikawa diagram as shown in the fig. 2 identifies the prominent causes and defects associated in the process (Ishikawa K 1982). The major defects leading to rejection and rework are width variation above tolerance level in the strip i.e. camber, location error, center punching problem, burrs and stopper liners wear due to which symmetry is not maintained.

5.0 METHODOLOGY

The methodology will comprise of estimation of cost of internal failures, development of approach for the reduction of internal failure cost and implementation of the suggested approach.

5.1. Evaluation of Internal Failure Cost

The cost of poor quality is evaluated by identifying the various parameters associated with cost of internal failures i.e. Scrap, Rework, Scrap and rework supplies and re-inspection.

5.2. Suggested Approach for Reduction of Internal Failure cost

Use of inspection techniques at intermediate stages of manufacturing can lead to reduced cost of internal failure. The cost of further processing on defective does not get accumulated and the problem gets identified before assembly. Gauges need to be designed for reduction in frequency of the layout inspection. Similarly

online inspection methodology needs to be devised for identification of camber defect.

5.3. Implementation of Suggested Approach

In the quality cost program, the cost of internal failure is initially targeted and the relevant data was collected from the SSU. Record of five months was studied and then various defects in various operations were identified. The online inspection device and offline inspection device were designed and proposed for the identification defect contributing to major share of the total internal failure cost. The total savings estimated is evaluated based on identification of defective in initial stages.

6. DATA COLLECTION AND ANALYSIS

Data was collected from the records for process costing, scrap and rework. Data have been organized to estimate cost of internal failures for five months period. Sample data collection sheet for the period of one month is shown in the table 1. Table 2 shows cost of internal failure for the span of five months. The external failure cost is the fine imposed by the customer due to failure at the assembly stage and delivery schedules.

7. DESIGN OF GAUGES FOR IN-PROCESS INSPECTION

The critical and frequently occurring defects are targeted for identification at the respective stages of manufacturing process. Accordingly gauges are designed for identification of location error and camber. Inspection by online gauge was incorporated between the straightening decoiler machine and first cropping operation. The online gauge identifies the portion of raw strip having width variation more than 0.04 mm and gives the signal to sort out the component after cropping itself. It saves the time and cost due to further processing. The various components of the online inspection are shown in the figure 3. The main components of the system are the 1) Gauge sensing variation in width i.e. Camber, ii) LVDT to which the displacement from the gauge is transferred and iii) Feedback control unit with the

Table 1: Estimation of Internal Failure Cost (Monthly)

Sr. No	Particulars		Frequency					Total Cost					
			TBO /CB	TB I	BB O	BBI	VC	TBO /CB	TBI	BBO	BBI	VC	Total Cost
	Name of the Components (TBO- Top Beam Outer, ...)												
	Total Production		16200	4800	4800	4800	9600	353880	62136	99504	54672	272851.2	843043.2
	Process	Defects											
1	Cropping	Camber	52	35	21	5	12	1277.9	453.07	435.33	56.95	341.06	2564.31
		Length Variation	5	8	2	3	7	122.87	103.56	41.46	34.17	198.95	501.01
		Operators Mistake	7	9	8	9	7	172.02	116.50	165.84	102.51	198.95	755.83
2	Central Piercing	Location Variation	12	14	19	20	0	294.90	181.23	393.87	227.8	0	1097.8
		Operators Mistake	4	3	2	2	0	98.30	38.835	41.46	22.78	0	201.37
3	Bending Operation	Angle Variation	3	0	1	0	0	73.72	0	20.73	0	0	94.455
		Operators Mistake	9	5	6	9	3	221.17	64.72	124.38	102.51	85.266	598.05
Total Cost for all components												5812.85	

Table 2: Cost of Internal Failure

Sr. No	Month	Cost of Internal Failures
01	January	5889
02	February	5309
03	March	6311
04	April	5723
05	May	5812

help of which operator on machine gets signal to sort out the defective. The consideration while designing the various components and their working is as follows.

7.1.1 Sensing Unit of Inspection Gauge

Sensing unit designed to sense the width variations consist of base plate with slot, fixed block, movable block, fork and roller assembly where rollers are holding the running strip.

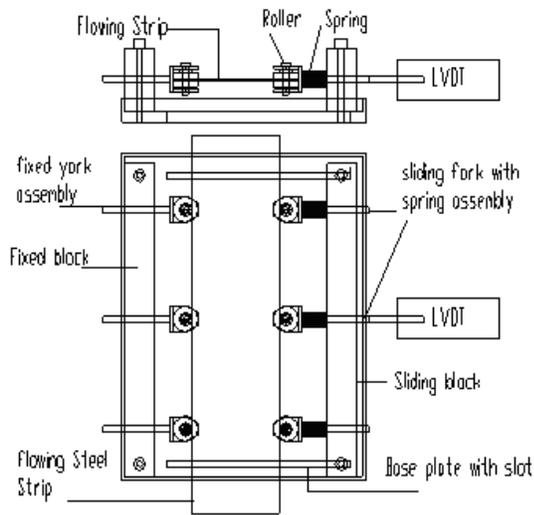


Fig 3 Online Inspection gauge

Different parts like TBO, TBI etc have different strip width and hence the gauge needs to be designed in a way that it can be used for inspection of all types of component. The movable block on the base plate is made to slide in a slot and can be fixed at the desired

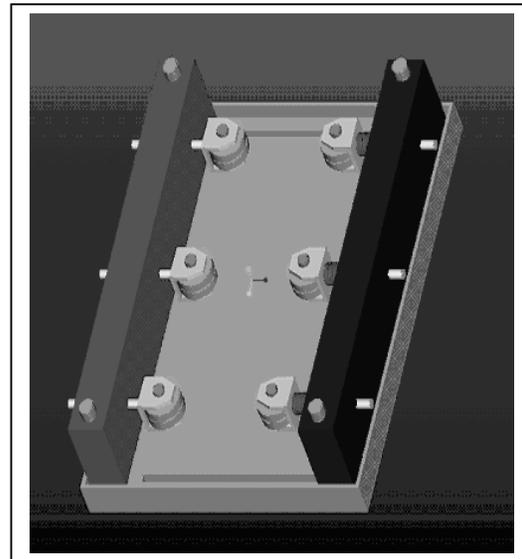


Fig 4 Solid Model of Sensing Unit of Online Inspection Gauge

location from the fixed block The fixed block is mounted at edge of base plate as shown in the figure.3

Rollers position, holding strip on fixed block acts as a reference. Six identical roller and fork subassemblies are used and are mounted in the fixed as well as movable block. The roller and fork assembly consists of rollers, bush, fork and a nut with a locking pin arrangement. The exploded view of the subassembly is shown in fig 5. Roller revolves about the axis of pin hold in the fork as the strip flows after straightening through decoiler. The subassembly is mounted and fixed in fix block while the subassembly in a movable block is mounted in such a way that it can slide in the block. Helical Spring is provided between the fork and the block to hold the strip. For different components strip width varies and gauge need to be set. Depending on the width of the strip, movable block need to be fixed in such a way that spring gets compressed and holds the strip. Once standard dimension is set between the rollers then the movable block remains fixed on base plate, while fork and roller subassembly can slide from its mean position in both directions depending upon the variation of width on either direction compared to the standard dimension.

Out of the six-fork rollers assembly only one central subassembly senses the camber. Others are to hold and support the strip to flow. Online inspection can be possible as spring force holds the strip while it can slide on the grooves provided on the revolving rollers. The weight and the forces on the rollers due to flow of the coil gets distributed on all six rollers. Supporting rollers also take care of vibrations if any so that the central rollers fork subassembly senses the displacement without incorporating any error. The solid model of the inspection-sensing unit is shown in fig 4. The displacement of central fork after setting the gauge is transferred to the LVDT.

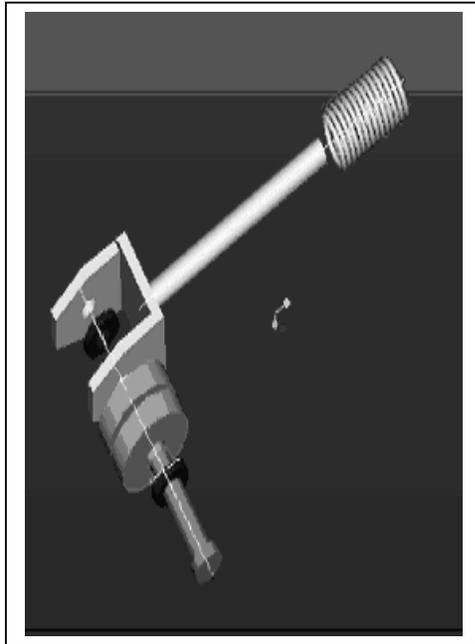


Fig 5 Exploded view of roller & fork Subassembly

7.1.2 LVDT

LVDT an acronym for Linear Variable Differential Transformer, a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal. LVDT linear position sensors are readily available that can measure movements as small as a few micron to several mm and also capable of measuring positions up to ± 0.5 m. (Doebelin Ernest, 2004) With accuracy suiting to the inspection gauge standard model of LVDT is selected.

7.1.3 Control Unit:

As the process of press working is manual. The output of LVDT for the set tolerance level gives alarm for the portion of strip having width variation more than set tolerances. Thus the feedback is given to the operator to sort out the defective component at the first stage itself.

7.2 Offline Gauges

Apart from the camber one more problem identified was location error. The die needs to be set properly to overcome the problem. To identify the problem, layout inspection need to be carried out with the help of V-block, angle plates and vernier height gauge. The inspection method was tedious. To overcome the problem, location gauges are designed so that the location error can be easily detected. In this operator has to just put the strip on gauge after central piercing. If there is an error, then it will not fit the gauge and immediately die can be set again.

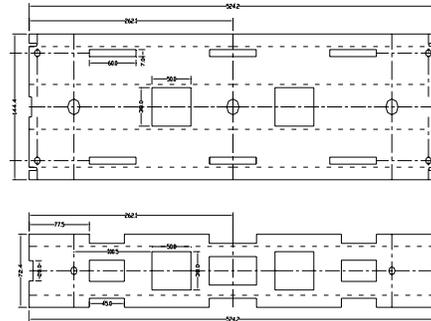


Fig 6 Top Beam Outer and Inner after Cropping and Central Piercing

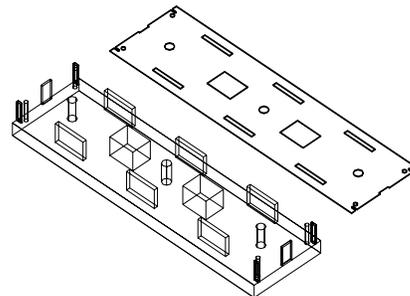


Fig 7 Location Gauge

8. EVALUATION OF REDUCTION IN INTERNAL FAILURE COST.

The reduction in the internal failure cost is evaluated by analyzing the process cost of each operation involved in the process. Process cost of each machine is evaluated as process cost per stroke which is having two components i.e. variable cost & fixed cost. Variable cost comprises raw material cost, energy cost, labour cost, maintenance cost, machine depreciation cost & tooling cost. Fixed cost comprises salary of supervision, accountants, calibration of instruments, overheads like transportation, facilities to workers, taxes etc. The cost of energy per stroke can be evaluated by calculating the energy consumption of each machine and cost associated with each stroke of the particular machine. Hence, at first cost per KW of consumption need to be evaluated. It is found out by evaluating the fixed charges per KW and Variable charges per KW. Considering the total connected load of the company, fixed charges are evaluated. Similarly variable charges have been

evaluated considering the charges per unit, fuel adjustent charges and transmission losses as per the rates decided by the electricity board. The total cost per KW found to be Rs 7.485 considering the KVA ratings of each machine. Based on the these charges and KVA ratings of each machine energy cost pe stroke have been evaluated considering 75% loading factor. The charges per stroke are as shown in table 8.1

Table 3 Energy cost per stroke

Sr. No.	Machine	Rs/Stroke
1	Decoiler (2.25KVA)	0.13
2	63 tonnes Press (3.75 KVA)	
3.	40 tonnes press (3.75 KVA)	0.10
4	100 tonnes press (3.75 KVA)	0.10
5	20 tonnes press (2.625 KA)	0.065

Similarly labour charges per stroke have been evaluated

Table 4 Labour cost per stroke

Sr. No.	Machine	Rs/Stroke
1	Decoiler	0.13
2	63 tonnes Press	
3.	40 tonnes press	0.11
4	100 tonnes press	0.11
5	20 tonnes press	0.16

Considering the other cost associated with the supporting functions like maintenance, calibration, tooling , factory and other overheads the fixed cost per compoent found to be Rs 1.95. The details of the cost reduction for component top beam outer is as follows.

Sr. No.	Defcts identified	Cost incurred upto process without online inspection	Cost incurred withn online inspection
1	Camber	3.80	2.21
2	Location error	3.80	2.40

9. CONCLUSION

The cost of internal failures leads to the reduction by 40% by identifying the defective components at appropriate stage in manufacturing process and eliminating the further processing of defectives. Thus beginning of the quality cost program is a proactive step for obtaining productive gain.

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