STUDY OF POSSIBILITIES OF JOINT APPLICATION OF PARETO ANALYSIS AND RISK ANALYSIS DURING CORRECTIVE ACTIONS

Volodymyr Haievskyi
PhD
Department of Welding Production
National Technical University of Ukraine
«Igor Sikorsky Kyiv Polytechnic Institute»
37 Peremohy ave., Kyiv, Ukraine, 03056
v.gaevskiy@kpi.ua

Abstract: Continuous improvement in the quality management system is based on corrective action. Corrective actions require the identification of priority defects that require priority elimination of the causes of occurrence. The traditional method of prioritization can be considered a Pareto chart, built by the number of identified inconsistencies. This technique makes it possible to prioritize the most frequently detected defects. However, defects that are rare can significantly outweigh those that are often encountered in their consequences. The defect risk is a complex indicator that simultaneously takes into account both the number of detected defects and their impact. Failure Mode and Effects Analysis (FMEA) can be used to quantify risk. This technique allows to determine the risk priority number (RPN), taking into account the number of detected defects (*O*), the consequences of the appearance of a defect (*S*) and the possibility of timely detection of a defect or cause before the onset of undesirable consequences (*D*). The priority number of risks numerically characterizes the risks of a defect and can be used as a criterion for determining priority defects. Based on the values of the priority number of risks, a Pareto chart can be built and defects that form 80 % of the risk area can be identified. These defects require urgent corrective action. According to the data taken from production, it is shown that the Pareto analysis by the priority number of risks gives results that differ from the analysis by the number of identified inconsistencies. Application of the proposed approach will allow introducing risk-oriented methods into the procedures for carrying out corrective actions. This will make it possible to direct the resources of the enterprise to eliminate the causes of defects that are actually detected and can have the most significant consequences for consumers of products.
Keywords: corrective actions, Pareto chart, continuous improvement, FMEA, quality management, risks.

1. Introduction

Corrective actions allow to eliminate the causes of identified defects and are a mandatory process of the quality management system [1]. The effective implementation of corrective actions allows to organize continuous improvement of production processes.

To prioritize corrective actions, the Pareto chart is widely used by the number of detected defects [2–4]. With this approach, the priority is given to the defects that are detected most often. However, this approach does not account for differences in the impact of defects. Meanwhile, defects, which are rare, can lead to dire consequences. This deficiency can be eliminated by using the risk of a defect as a criterion for prioritizing corrective actions. The risk takes into account the possibility of occurrence and the effect of a defect [5]. Failure Mode and Effects Analysis (FMEA) [6, 7] can be used for quantitative risk assessment. The value of the risk priority number (RPN) found by the FMEA method can be used for risk-oriented Pareto analysis and identification of priority defects.

The aim of research is to determine the possibilities of the combined application of Pareto analysis and risk analysis to determine priority defects in corrective actions. This will allow taking into account not only the number of detected defects, but also their impact. To achieve this aim, one should compare the results of applying the Pareto chart by the number of defects and the priority number of risks.

2. Methods

The study compared the ability to identify defects requiring priority corrective action using two prioritization techniques. The methodology is considered as the basic one, which involves the direct use of the Pareto chart by the number of identified inconsistencies [8]. As an alternative, it is proposed at the first stage to determine the priority number of risks for each defect according to the number of detected inconsistencies. At the second stage, carry out a Pareto analysis for the priority number of risks.

3. Results

The research was carried out according to the data obtained in the welding industry. Welding coordination standards require taking into account all defects and taking corrective actions [9]. Using the Pareto chart, the priority areas for improving the welding process in the production of welded seeder frames are identified by the number of defects detected during the month. Within a month, in accordance with the quality control plans adopted during the production, 12,523 welds were inspected connecting the frame elements made from the rolled corner. **Table 1** shows the number of defects found during quality control. A total of 129 defects were identified. The relative and accumulated shares for each defect have been determined.

According to the data (**Table 1**), a Pareto chart is constructed by the number of detected defects (**Fig. 1**).

To determine the priority area for improvement, an ABC analysis of the Pareto chart is carried out and the defects that form the area A of the chart are determined. These defects require urgent corrective action. The zone contains defects with an accumulated share not exceeding 80 %. According to the Table 1 and Fig. 1, zone A is formed by pores, splashes and sagging. Therefore, for these defects, the reasons for their occurrence, actions aimed at preventing these causes (corrective actions) must be determined. However, the priority areas for improvement are based on frequency, without considering the risks associated with the occurrence of a defect.

The risks associated with the occurrence of defects can be identified using the Potential Failure Modes and Effects Analysis (FMEA) methodology. In this case, for each defect, the values of *S* –severity, consequences of occurrence, *O* – occurrence, *D* – detection must be determined. **Table 2** shows the values of *S* and *O* found from the data [10, 11].

Table 1
Defects identified when checking 12523 welds

No.	Defect	Number of detected	Share, %	Accumulated share, %
1	Pores	53	41	41
2	Spatter	29	23	64
3	Overlap	20	16	80
4	Thickness	12	9	89
5	Incomplete	8	6	95
6	Cracks	4	3	98
7	Undercut	3	2	100

All defects are detected by operators after the completion of the welding process using measuring instruments. Thus, for all defects the detection rank *D* (detection) is 6 points [10]. **Table 3** shows the results of calculating RPN – the risk priority number based on reference data.

According to the **Table 3**, a Pareto chart is plotted for the risk priority number (RPN) of the occurrence of discrepancy (**Fig. 2**).

According to the results of A-B-C analysis of the Pareto chart (**Fig. 2**), the first-priority corrective actions require defects that form zone A: cracks, incomplete, thickness, spatter.

Table 2
Initial data for FMEA analysis

No.	Defect	Consequences for the functionality of the weld	Consequences for the consumer	*S*, ball	Frequency on 1000	*O*, ball
1	Pores	Weakening the section of the weld by up to 5 %	No noticeable consequences	1	4	6
2	Spatter	Appearance	Appearance problems (50 % of consumers)	3	2	5
3	Overlap	Potential sources of pitting corrosion	Appearance problems (25 % of consumers)	2	2	5
4	Thickness	Weakening the section of the welded seam by up to 10 %	The products are limitedly workable	5	1	4
5	Incomplete	Weakening the section of the welded seam by up to 20 %	Products are operational with reduced efficiency	7	0.6	3
6	Cracks	Stress concentrator	The products are not functional. Loss of main function	8	0.3	3
7	Undercut	Weakening of the welded seam section by up to 20 %.	Products are operational with reduced efficiency	7	0.2	2

Table 3
Data for building a Pareto chart for the priority number of risks (RPN)

No.	Defect	*S*, ball	*O*, ball	*D*, ball	RPN, ball	Share, %	Accumulated share, %
1	Cracks	8	3	6	144	22	22
2	Incomplete	7	3	6	126	19	41
3	Thickness	5	4	6	120	18	59
4	Spatter	3	5	6	90	14	73
5	Undercut	7	2	6	84	13	86
6	Overlap	2	5	6	60	9	95
7	Pores	1	6	6	36	5	100

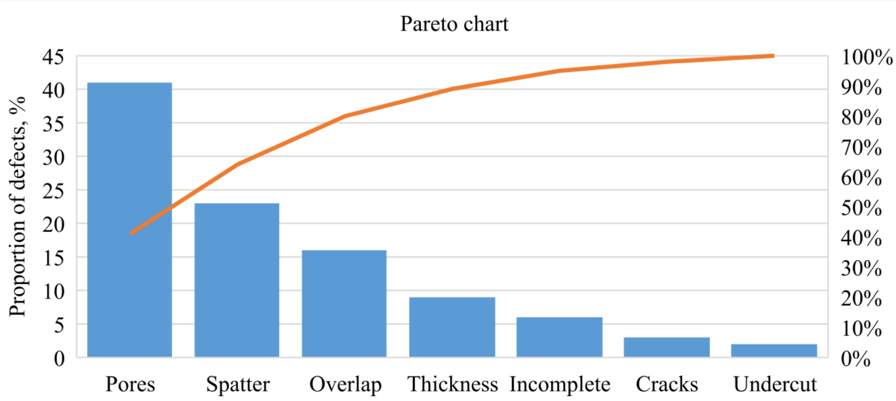

Fig. 1. Pareto chart by the number of defects

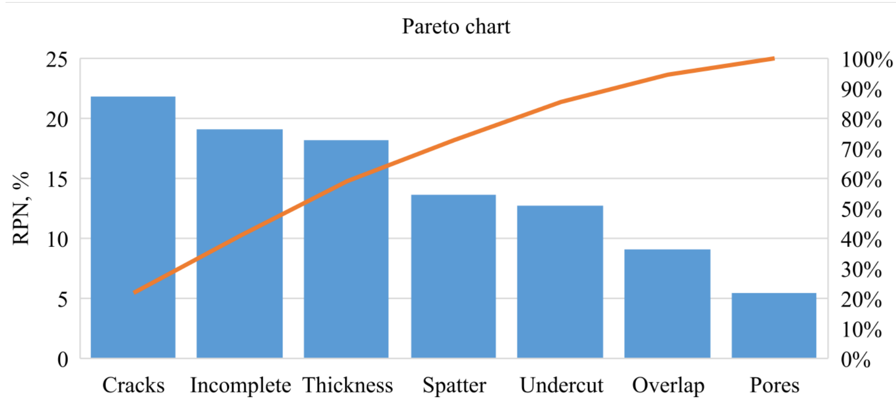

Fig. 2. Pareto chart by risk priority number (RPN)

4. Discussion of results

The Pareto analysis of the number of defects (Fig. 1) shows that corrective actions should be implemented in relation to pores, splashes and sagging. Pareto's analysis of the priority number of risks identified as priority defects: cracks, incomplete, thickness, spatter. The lists are the same only for spatter. Differences in the lists are determined by the indicator by which the Pareto analysis is carried out. At the same time, the list obtained according to the priority number of risks is preferable.

The combined application of Pareto analysis and risk analysis can be recommended as a risk-oriented approach to identifying nonconformities that require priority corrective actions.

5. Conclusions

The use of the Pareto chart for the number of defects and the priority number of risks when identifying defects requiring priority corrective actions gives different results. Pareto analysis for the number of defects identified three priority defects, and the combined application of Pareto analysis and risk analysis identified four defects. Only one defect coincided in the two groups. The combined use of Pareto analysis and risk analysis allows to simultaneously take into account the number of detected defects and their impact. At the same time, corrective actions direct the organization's resources to reduce the risks of defectiveness and increase customer satisfaction.

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