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 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                                      |                              | 3              | 2       | 5       |
| 3   | Overlap      | Potential sources of pitting corrosion          | Appearance problems (50 % 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                             |                              | 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. 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.

References

1. Zimon, D. (2016). Influence of Quality Management System on Improving Processes in Small and Medium-Sized Organizations. Quality - Access to Success, 17 (150), 61–64. Available at: https://www.researchgate.net/publication/298072272_Influence_of_quality_management_system_on_improving_processes_in_small_and_medium-sized_organizations

2. Awai, Y. M., Singh, A. P., Amedie, W. Y. (2013). Quality improvement using statistical process control tools in glass bottles manufacturing company. International Journal for Quality Research, 7(1), 107–126. Available at: http://www.ijqr.net/journal/v7-n1/8.pdf

3. Pereira, A. M. H., Silva, M. R., Domingues, M. A. G., Sá, J. C. (2019). Lean Six Sigma Approach to Improve the Production Process in the Mould Industry: a Case Study. Quality Innovation Prosperity, 23 (3), 103. doi: https://doi.org/10.12776/qip.v23i3.1334

4. Chakrabortty, R. K., Biswas, T. K., Ahmed, I. (2013). Reducing process variability by using DMAIC model: a case study in Bangladesh. International Journal for Quality Research, 7 (1), 127–140. Available at: http://www.ijqr.net/journal/v7-n1/9.pdf

5. Popova, L., Yashina, M., Babynina, L., Ryzhakova, A., Yefremova, N., Andreev, A. (2019). The quality management development based on risk-based thinking approach according to ISO 9001. Quality - Access to Success, 20 (170), 58–63. Available at: https://www.researchgate.net/publication/333249424_The_quality_management_development_based_on_risk-based_thinking_approach_according_to_ISO_9001

6. Banduka, N., Veža, I., Bilić, B. (2016). An integrated lean approach to Process Failure Mode and Effect Analysis (PFMEA): A case study from automotive industry. Advances in Production Engineering & Management, 11 (4), 355–365. doi: https://doi.org/10.14743/apem2016.4.233

7. Gayevsky, V. O., Prokhorenko, V. M., Chvertko, Ye. P., Akhmetbekov, M. T. (2016). Restriction of Risks of Failure to Meet Requirements to Porosity of Weld Joints. Trudy Universiteta, 1, 45–48. Available at: http://www.kstu.kz/tu/2016/trudy_universiteta_1.pdf

8. Chen, Y.-S., Chong, P. P., Tong, M. Y. (1994). Mathematical and computer modelling of the Pareto principle. Mathematical and Computer Modelling, 19 (9), 61–80. doi: https://doi.org/10.1016/0895-7177(94)90041-8

9. Haievskyi, O., Kvasnytskyi, V., Haievskyi, V., Zvorykin, C. (2020). Analysis of the influence of the systemic welding coordination on the quality level of joints. Eastern-European Journal of Enterprise Technologies, 5 (1 (107)), 98–109. doi: https://doi.org/10.1587/1729-4061.2020.204364

10. Analiz vidov i posledstviy potentsial’nyh otkazov. FMEA. Ssylochnoe rukovodstvo (2009). Nizhniy Novgorod: OOO SMTS «Prioritet», 148.

11. Zmievskiy, V. I. (2010). Primenenie metoda FMEA dlya obespecheniya kachestva svarkh konstruktsiy. Svarochnoe proizvodstvo, 9, 41–45.

© The Author(s) 2020
This is an open access article under the CC BY license
(http://creativecommons.org/licenses/by/4.0).