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Research Article

INTEGRATED AHP-FMEA RISK ASSESSMENT METHOD TO STAINLESS TANK PRODUCTION PROCESS

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ABSTRACT
This study aims to evaluate the hazards of the stainless tank production process in a company by using the Integrated Analytic Hierarchy Process (AHP) and Failure Mode and Effect Analysis (FMEA) methods. First, the hazards in the stainless tank production process were identified. Identified hazards were assessed with the FMEA method to calculate Risk Priority Number (RPN) for each hazard. The same hazards were then weighted by using the AHP method. Finally, AHP and FMEA are integrated to achieve a more objective result by using two subjective methods. According to the integrated method results, risks have been prioritized and an objective ranking has been established for action plans.

Keywords: *Analytic Hierarchy Process, Failure Mode and Effect Analysis, Risk Priority Number, Stainless Tank*

1. INTRODUCTION

Work accidents can be defined as unexpected events, often causing deaths, injuries, loss to machines and equipment, or stopping production for a certain period, which can often be counterworked if essential measures are taken. Occupational safety is defined as by creating healthy and safe working conditions in the work environment; minimizing work-related accidents and occupational diseases and thus increasing productivity by counterwork material and moral losses (Kurt, 1993; Ceylan, 2000).

Accidents at work in the world and Turkey have become a significant problem. Even though occupational accidents are a common issue of all countries; it can be reduced to a specific extent by taking essential measures. Countries failing to take these measures are more affected by accidents (http://europa.eu.int/comm/eurostat;http://laborsta.ilo.org)

The most important conclusion of occupational accidents is the death, injury or disability of the employees. Besides, serious material losses are another important conclusion of occupational accidents. Even though it is a very serious improvement on the floor in occupational health and safety issues in Turkey, this should be done on the subject is also irrefragable that much is true. In recent years, the number of accidents per employee decreases. However, when the accident statistics of the last six years are analyzed, it is seen that there are 75840 occupational accidents per year in our country and 1103 employees lost their lives in these accidents. Besides, the material loss brought to our country by these accidents is estimated to be around 45 billion TL / year (Ceylan and Gül, 2015)

The most important aim of our country's National Occupational Health and Safety policy is to reduce the frequency of occupational accidents. (Ceylan and Başhelvacı, 2011; Korkmaz and Avsallı, 2012). To achieve this goal, other than avoiding hazards, various studies should be performed to identify and evaluate risks in advance and to eliminate or minimize these risks.

The danger is defined as a situation that can cause great harm or extinction. The purpose of hazard identification is to identify the problems and levels that may arise from the workplace environment. Risk is the likelihood of a specific and unwanted event (danger) occurring within a certain period. The control of risks is to evaluate the measures to be taken within a certain hierarchy for each risk. Control and evaluation should be done to determine the priority order of the work to be performed. The goal in the control hierarchy should always be to eliminate danger and minimize the risk. Risk Assessment is the process of estimating the magnitude of risks arising from hazards in any system and deciding whether these risks are acceptable, taking into account the adequacy of existing controls. (Ceylan and Başhelvacı, 2011).

Song et al. (2007) applied the FMEA technique to quantitatively analyze the importance of each activity in terms of structural assembly and safety of steelworks. Dey (2010), aims to develop an integrated framework for managing project risks by analyzing risk at a project, work package, and activity levels and developing reactions in this study. As a result of this study, AHP is an existing approach to achieve concurrency in controversial decisions. Wessiani and Sarwako (2015), applies fuzzy FMEA in his method taking into account the limitation of traditional FMEA in assessing the risk score by expert judgment, and these reform risks are classified according to RPFNs. Li and Zeng (2016) aim at the supplier selection method by applying failure modes and effect analysis (FMEA) to evaluate the risks in the decree process. In the literature, FMEA and AHP methods are encountered in different sectors and applications.

As seen in the literature, there are many studies where FMEA and AHP methods are applied. In this study, two subjective methods are integrated to make a more objective evaluation of the scores obtained by applying FMEA and AHP methods.

In this study, 17 risks were identified by observing the stainless tank production process in the factory. After identifying potential risks, the risk-threat table was first established. Risk Priority Scores (RPN) of risks were calculated using the FMEA method. Risks were also evaluated by the Analytical Hierarchical Process (AHP) method to calculate weights (w_i) of hazards. Finally, the two methods were combined and the importance of the risks identified. In this way, it is aimed to reach a more objective result from two different subjective evaluations.

2. MATERIALS AND METHODS

2.1. Materials

This study was conducted in a company operating in the field of manufacturing and engineering that produces stainless tanks in Turkey.

Stainless tanks are mainly used in the food industry, industrial plants, hotels, and hotels to obtain potable water. Some design conditions must be determined before the stainless tank is manufactured. Depending on the criteria such as chemical properties, pressure, and temperature of the fluid to be stored in, they can be manufactured with or without walled stainless steel quality.

The stainless tank production process starts with CNC cutting. Rectangular metal sheets are cut by CNC machine to required measures. Then metal sheets are twisted by wreath machine to the desired shape. After CNC cutting, small protrusions are formed on the surface. These protrusions are eliminated during the grinding phase. Then, start to weld opening. One of the methods of steel joining is the application made to make the welding process more effective. After these processes are performed, tapping is performed to connect the two metals without requiring filling material. In the welding process, the end parts of the stainless tank after twisting are joined here and the main profile is formed. Finally, the stainless tank is washed together with special chemicals and it is made resistant to rust in the passivation process.

2.2. Methods

2.2.1. Analytical hierarchy process (AHP)

AHP method originally developed by Thomas Saaty as a Multi-Criteria Decision Making (MCDM) method (Saaty, 1980). AHP can be described as a decision making and making method used in case the decision

hierarchy can be described and gives percentage dispersion of decision points in terms of the factors affecting the decision. The steps to be taken to solve a decision-making problem related to AHP are as follows; First of all decision-making problem is identified. Then the inter-factor comparison matrix is formed by using Table 1. After that percentage of factors are determined. Finally, consistency in factor benchmarks is measured (Sivrikaya and Ünal, 2018).

Table 1. AHP Comparison Table (Saaty, 1980)

Rating	Description
1	"Equal importance"
3	"Moderate importance of one over another"
5	"Strong importance of one over another"
7	"Very strong importance of one over another"
9	"Extreme importance of one over another"
2, 4, 6, 8	"Intermediate values"

2.2.2. Failure mode and effects analysis (FMEA)

FMEA is a conventional reliability and safety analysis technique that has indulged wide implementation of distinct products over several decades (Goddard, 2000).

In general, possible errors are identified in the FMEA technique; the causes of each feasible error are identified, their effect on the customer is assessed, the controls that are applied are reviewed, regulative actions are committed and their application is monitored. Three parameters help determine error priorities. These are the effect of severity (S), error probability (P) and detectability (D).

In its most general form, the method can be summed up in five main steps. First of all the method is started with early studies. Then, suitable error types, causes, effects, and current controls are used to identify the error. Risk Priority Numbers are calculated by determining the effect of severity (S), probability (P), detectability (D). Risk Priority Numbers are calculated by multiplying the effect of severity (S), error probability (P) and detectability (D). After that, sorting according to the risk priority number and determining the errors and actions to be taken. Finally, the determined activities are implemented and the new risk priority number is calculated (Yılmaz, 2000; Aran, 2006). Severity, probability and detectability values are presented in Tables 2,3 and 4 respectively. After calculation of the RPN score, hazards are evaluated according to Table 5.

Table 2. Severity Table (Xu et. al, 2002)

Effect	Effect of Severity (S)	Degree
Warning	The potential error that can cause catastrophe	10
Warning	Failure of warning and failure, which can lead to high damage and mass deaths	9
Too High	Failure of warning and failure, which can lead to high damage and mass deaths	8
High	It causes complete damage to the equipment and has the effect of death, poisoning, 3rd-degree burn, acute fatal disease, etc.	7
Middle	Affecting the performance of the system, causing loss of limb and organ, severe injury, cancer, etc.	6
Low	Fracture, permanent minor disability, 2nd-degree burns, brain concussion, etc.	5
Very Low	Error causing short-term discomfort with minor injuries such as being injured, minor cuts and abrasions, crushes, etc.	4
Small	Error slowing down system operation	3
Very Small	Error slowing down system operation	2
No	No effect	1

Table 3. Probability Table (Xu et. al, 2002)

Effect	Error Probability		Degree
Too high: Unavoidable Error	More than 1/2	50,00%	10
	1/3	33,33%	9
High: Error Repeatedly	1/8	12,50%	8
	1/20	5,00%	7
Moderate: Occasional Error	1/80	1,25%	6
	1/200	0,50%	5
	1/2.000	0,05%	4
Low: Relatively Few Errors	1/15.000	0,006%	3
	1/15.0000	0,0006%	2
Few: Unlikely Error	Lower than 1/1.500.000	-	1

Table 4. Detectability Table (Xu et. al, 2002)

Effect	Effect of Detectability (D)	Degree
Unnoticeable	It is not possible to discover the cause of the potential error	10
Very little	It is too far to discover the cause of the potential error	9
Little	It is far to discover the cause of the potential error	8
Very low	Low potential to detect the cause of the potential error	7

Low	The cause of the potential error is too low to discover	6
Middle	The cause of the potential error can be discovered the medium	5
High Average	The high average for discovering the cause of the potential error	4
High	High potential to detect the cause of the potential error	3
Very High	The cause of the potential error is too high to be discovered	2
Almost Certain	It is almost certain that the cause of the potential error can be discovered.	1

Table 5. RPN Scale (Xu et. al, 2002)

RPN	FMEA-Measure
RPN < 40	No need to take precautions
40 ≤ RPN ≤ 100	It is useful to take precautions
100 < RPN	Precautions must be taken

3. RESULTS AND DISCUSSIONS

In this part, the hazards that can be encountered in the stainless tank production process of a company serving in the complete design, manufacturing, engineering and assembly works of the industrial plants have been determined with observations and expert opinions. Obtained hazard definitions are presented in Table 6.

Table 6. Hazard Definitions

Hazard No#	Definition of Hazard
1	Oxygen cylinders used in the factory are close to the welding machine and the spiral machine, which can cause an explosion.
2	The tubes may explode as the worker uses electronic cigarettes near oxygen cylinders.
3	Due to the overhead crane on the CNC machine, the operator can be hit and injured by careless handling.
4	Workers may have an occupational accident as they are tired and careless due to their busy working tempo.
5	Since the remaining parts are put very close to the machine after cutting on the CNC machine, the operator and workers can get caught in the parts and fall and be injured.
6	As a result of insufficient lighting in the production area of the factory, workers may have accidents and injuries.
7	Due to the length of the cables of some hand tools used, the parts may fall and workers may be injured.
8	Due to broken parts of the wooden support where some heavy metal parts are placed, the parts may fall and cause injury.
9	As the rope used for lifting and transporting heavy parts is worn out, the part may fall during lifting or transportation and cause injury or death.
10	The operator may be injured if the filter on the CNC machine falls.
11	Since the dust pot does not have a lid, overfilled metal parts can be injured by the employees passing by the ladle.
12	Workers may fall and get injured due to loosening in some parts of the metal step around the twisting machine
13	As workers enter the tank during welding, it may result in death if the employee or the tank falls.
14	Workers may be injured as a result of broken hand tools.
15	Employees may fall and get injured due to the inadequate metal step which is used for welding or entering the tank.
16	Failure to perform regular morning checks of the trucks may damage the vehicle.
17	Accidents can occur due to the narrow internal road.

The hazards identified during the stainless tank production process were evaluated by the FMEA method. During the assessment, the effect of severity, the probability of error and the probability of detectability were taken into consideration. Table 2, Table 3 and Table 4 were used for each component. After determining the required values, RPN was calculated for each hazard. As a result of the RPN calculation, the hazards are ranked according to their RPN score and presented in Table 7.

Table 7. FMEA Application Results

Hazard No #	RPN Score	Priority	Interpretation
16	240	1	Precautions must be taken
13	216	2	Precautions must be taken
4	162	3	Precautions must be taken
14	140	4	Precautions must be taken
3	70	5	It is useful to take precautions
15	60	6	It is useful to take precautions
5	48	7	It is useful to take precautions
10	45	8	It is useful to take precautions
6	40	9	It is useful to take precautions
17	30	10	No need to take precautions

1	27	11	No need to take precautions
9	25	12	No need to take precautions
12	24	13	No need to take precautions
8	21	14	No need to take precautions
11	20	15	No need to take precautions
2	18	16	No need to take precautions
7	9	17	No need to take precautions

According to this ranking, Hazard #16 has the highest RPN score and Hazard #13, Hazard #4, Hazard #14 is calculated as the top risks as well while Hazard #9 has the lowest RPN score.

As the second application step of the study hazards is identified in the stainless tank production process has been prioritized by using the AHP method. A CR (Consistency Ratio) of less than 0.10 indicates that the comparisons made by the decision-maker are consistent. As a result of the dual evaluation of the hazards which are in the stainless tank production process, the weight score for each hazard is calculated and presented in Table 8. Table 1 was used for this evaluation.

Table 8. AHP Application Results

Hazard No #	Wi	Priority Order
13	0,1931	1
12	0,1599	2
8	0,1298	3
9	0,1140	4
15	0,0821	5
1	0,0634	6
16	0,0499	7
2	0,0470	8
5	0,0314	9
3	0,0283	10
6	0,0235	11
11	0,0188	12
17	0,0168	13
7	0,0128	14
4	0,0116	15
14	0,0093	16
10	0,0074	17

According to these weights, the hazards are prioritized within themselves. This order of priority is given in Table 8. According to these results, while Hazard #13 has the highest weight, Hazard #10 has the lowest weight. When both results are compared, differences in prioritization occur. For instance, the top 5 hazards which have the highest RPN value are different from the top 5 hazards which have the highest weight.

The values given when determining the RPN and Weight score of hazards may vary according to the opinion of the expert performing the risk analysis. If the expert is indecisive, or if he or she evaluates even one parameter differently when analyzing by another expert, the risk score or weight may be calculated differently. As a result of different calculations, a hazard that needs to be taken into the action plans can be ignored.

Even though measurements in FMEA and comparisons in AHP are performed by the same expert team in the company; results vary from each other which illustrates the subjectivity of the methods which confuses about which hazard should be taken into consideration. Hence, a combination of these two methods has been performed to decrease the subjectivity level, to prevent the negative effects of these subjective evaluations and a more objective result has been tried to be obtained. As a result of AHP-FMEA integration, RPN * *Wi* scores of risks in the stainless tank production process were determined and presented in Table 9.

Table 9. Integrated AHP-FMEA Application Results

Hazard No #	Wi*RPN	Priority Order
13	***41,7260***	***1***
16	***11,9821***	***2***
15	***4,9297***	***3***
12	***3,8383***	***4***
9	***2,8518***	***5***
8	2,7260	6
3	1,9817	7
4	1,8919	8
1	1,7122	9
5	1,5092	10
14	1,3135	11
6	0,9424	12
2	0,8472	13
7	0,1160	14
17	0,5062	15
11	0,3765	16
10	0,3358	17

When hazards are prioritized according to integrated AHP - FMEA risk assessment results, Pareto analysis has been applied to the results to identify which hazards should be taken into action plans primarily. The Pareto chart for integrated results is presented in Figure 1. According to the results, the company needs to focus on Hazard #13, Hazard #16, Hazard #15, Hazard #12, Hazard #9 because of the 80-20 rule of Pareto.

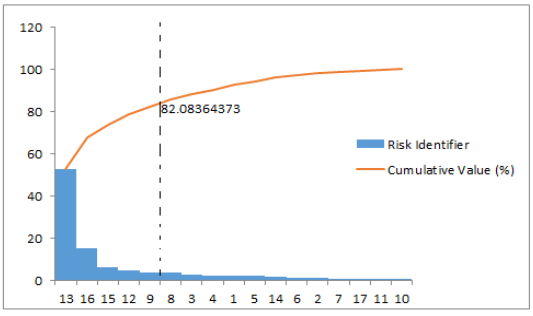


Figure 1. Pareto Chart for Integrated Results

4. CONCLUSION

The use of risk assessment methods performed in companies within the framework of Occupational Health and Safety differs in sectors. The differences between the results of the methods; In risk analyzes performed at decision points where experts are inadequate or hesitant when applying the methods, the results of incorrect prioritization of hazards and incorrect classification of related hazards appear.

In this study, an integrated risk assessment method for the stainless tank production process is performed. FMEA, AHP, and AHP-FMEA integration methods are applied and results are compared for the selected process. In this study, first, 17 hazards were identified in the stainless tank production process. To assess these risks, the FMEA method was applied. The severity, probability, and detectability of the risk were considered when FMEA was implemented. The Risk Priority Number (RPN) was calculated for each risk after FMEA was administered. Then the risks were weighted by applying AHP. The AHP-FMEA integration method was applied to avoid differences in the aforementioned results and to obtain more objective results.

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