ASSESSMENT OF THE INTERNAL TRANSPORT PROCESS BY POSITIONING SELECTED QUALITY TOOLS ON THE EXAMPLE OF SOLDERING PROCESS

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Abstract: In the article we assessed the in-plant transport on the soldering line. The assessment was based on three-month process observation, registration of non-conformities and a modified PFMEA analysis form. Among the 9 non-compliance groups, the so-called critical inconsistencies for which the reasons for their generation have been determined. Actions have been developed to eliminate the causes of non-compliance, aimed at improving the process and devices of in-house transport. The proposed solutions are implemented in the analyzed organization.

Keywords: transport, FMEA analysis, quality of transport process, logistic.

1. Introduction

Intra-company transport is the area of the company's activity, directly related to production logistics (Gembalska-Kwiecień, 2017; Kruczek et. al., 2016; Łuczak, and Wolniak, 2015; Pacana et al., 2017; Restecka, and Wolniak, 2016; Restecka, and Wolniak, 2017). It applies to the carriage of finished products, products, semi-finished products or raw materials for short distances, which depend on (Skotnicka-Zasadzień, 2012; Skotnicka-Zasadzień, 2014, Skotnicka-Zasadzień, and Masłoń, 2016; Skotnicka-Zasadzień et al., 2017):

- size of the production enterprise,
- its spatial dispersion,
- elements of the production process infrastructure,
- their location.

In special cases, internal transport may include transport between neighbouring production plants, if it results from the production process technology.

The in-house transport, in the literature of the subject, is often referred to as internal, near or industrial transport. It consists of (Rychły-Lipińska, 2008):

- warehouse and storage transport,
- production transport:
- inter-faculty transport,
- intra-departmental transport.

This article will examine the inter-departmental transport occurring between workplaces and placement fields, and at the station itself in the soldering process. Identification of inconsistencies generated in the analysed transport process will be identified, affecting the quality of manufactured elements and downtime in the production process at the discussed department (Sułkowski, and Wolniak, 2018; Szczucka-Lasota, and Wolniak, 2017a; Szczucka-Lasota, and Wolniak, 2017b; Szczucka-Lasota, and Wolniak, 2017b; Wolniak, and Skotnicka-Zasadzień, 2014; Wolniak, and Skotnicka-Zasadzień, 2017; Wolniak, 2018). The measurable effects of the qualitative research will be proposed solutions aimed at improving the analysed cell in the production logistics chain (Gemnalska-Kwiecień, 2017; Pacana et al. 2016; Wolniak et al., 2015). It is expected that the introduction of the proposed changes will contribute to the reduction of the cash outlays incurred in the production of the product. The measure of the analysed costs can be, among others (Rychły-Lipińska, 2008).

- time losses due to changes in the flow of products,
- delays in the performance of subsequent lots,
- amount of scrapped goods damaged during transport.

The modified carried out FMEA analysis (Wolniak, 2011; Wolniak 2013a; Wolniak, 2013b; Wolniak, 2014; Wolniak, 2017a; Wolniak, 2017b; Wolniak, and Burtan, 2009; Wolniak, and Skotnicka, 2011; Wolniak, and Skotnicka-Zasadzień, 2008; Wolniak, and Skotnicka-Zasadzień, 2010) will be based primarily on data obtained from observations of the process, but also on information provided by the management of the unit and employees and recorded data presented in (Doktor, 2018)

2. Subject and scope of research

The activities of the transport system must be integrated with other activities of the enterprise (production, storage and state control, preparation of orders). Therefore, both the flow of materials and information in the process should be recognized as an integral system. The subject of the research is internal transport taking place on the production line of the soldering process, applying thermo-active paste, applying silicone and covering the whole with a cover to protect the printed circuit board. The whole process is carried out in the ESD zone, i.e. in the area preventing electrostatic discharges.

The research was carried out through a three-month observation of the transport process and means of transport, recording disturbances and recording the number of defects and their causes in the analysed process. During the observation period, about 54,000 soldered parts were made on the analysed production line.

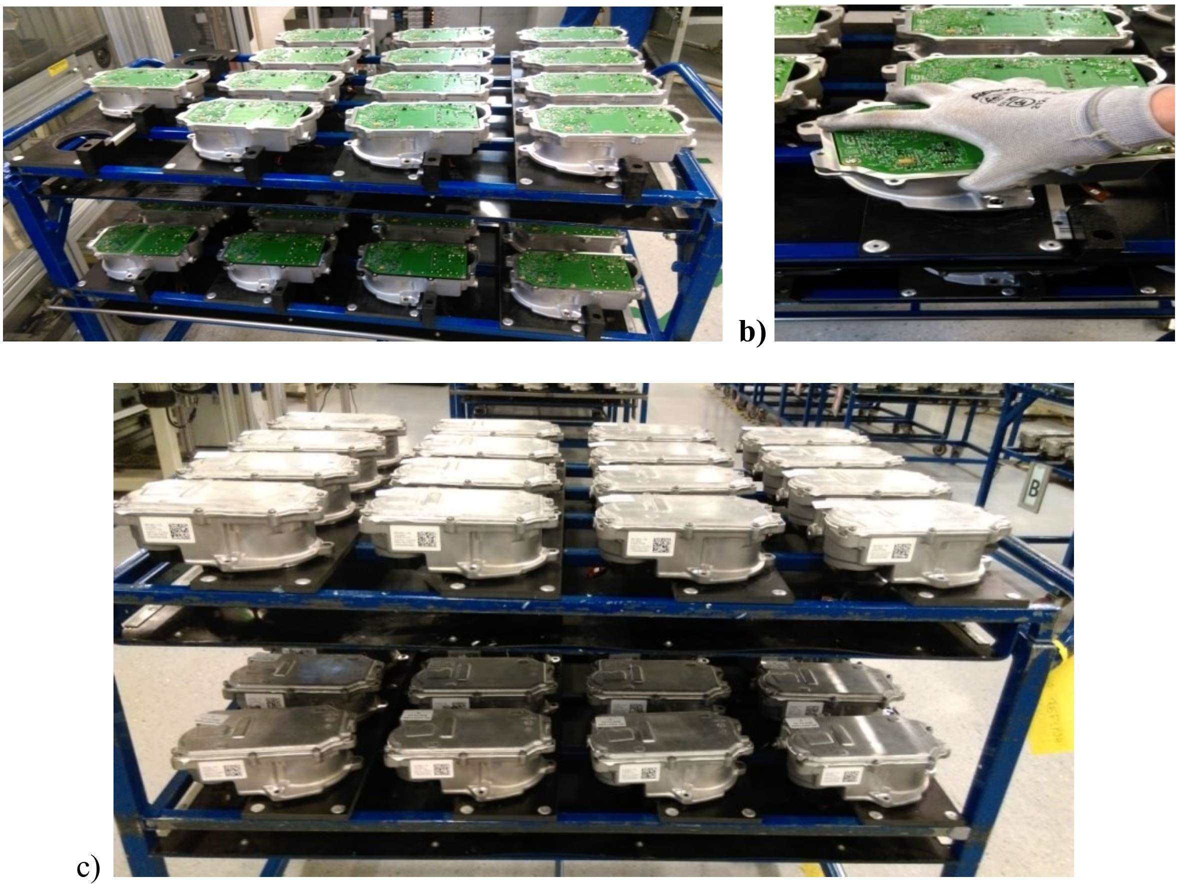
The research identified those elements of the process and means of transport that hinder or slow down the work of operators. The data obtained in the preliminary tests were introduced into the form developed in the Exel. The evaluation of the process was carried out with a modified FMEA analysis, determining the reasons for the nonconformities. As a result of the research team's work, corrective actions aimed at improving the process were proposed.

3. Characteristic of the process

The soldering process of a printed circuit board with the engine via terminals consists of eleven stages and a buffer. There are two twin threads in the ESD zone. The entire zone has been designed so that static electrostatic charges do not transfer to components. There are three operators on the line, which means that four stations require human participation, while the rest is fully automated. The production process on the analysed line includes: transport functions, picking and loading of parts – operation O1; flux dispensing (operation marked O2); heating of terminals (operation O3), soldering (operation O4); verification (operation marked as O5); visual inspection (operation as O6); silicone dosing (O7 operation); dispensing thermo-active paste (operation O8) final inspection and assembly of the cover (operation O9); tightening the cover (operation O10); unloading parts into a buffer (BUFOR).

The process of transporting components to the process and finished products arising on the brazing line is carried out using buffer trolleys (Fig. 1a-b). In addition, manual transport occurs between the soldering line and the testing machine. The remaining transport of the solder line is fully automated.

The analysis of the condition of the existing transport on the soldering line allowed to state that the delivery of parts to the production station is not carried out smoothly. The basic non-conformities include: frequent tacking of the trolleys and the problem of their unhitching by the operators, moving of the parts arranged on the trolley and entering the elements into undeveloped spaces of the trolley.



a) b) c)

Figure 1. Transport trolleys: a) transport of components, b) collection of components, c) transport of finished products on the soldering line. Source: Doktor, 2018.

As a result, some elements protrude beyond the frame of the trolley, which causes their damage when parking the trolleys. In addition, insufficient information flow and occasional pledging of the transport route with other items was found. In the in-house transport on the analysed production line, a total of 9 non-compliance groups were identified, of which the most important were damage to the entire manufactured part, damage to the plug, damage to the pins of the plug, part fall during picking or putting down. In the above-mentioned groups, more than 200 non-compliant elements were identified within three months of observation. It was found that the non-conformities are the result of both carriage transport (in operation O1 and O10), taking parts from buffer trucks (operation O10) as well as incorrect storage of parts on the place of storage (operation O9). For these operations, 46 discrepancies (operation O1), 82 procedural (procedural) failures and 42 damaged parts (O9 operation) were registered respectively and in the last stage of the process (operation O10) 2 non-compliance groups were classified, in which 66 pieces of damaged items transported with a buffer trolley were registered.

All the above mentioned discrepancies result in: stopping the production process (delivered damaged items) or delaying the production process (stoppages in delivery, coupled trolleys, pledged route), breaks at work which may be the reason for delay in delivery for the internal customer. The data has been presented in the table 1.

Table 1.
List of non-compliance in the internal transport process

Transport and collection of parts - operation O1	
Damage of the plug	21
The pins of the plug are damaged	15
Other damages	10
Placing parts on the table - storage place (before testing the element with a testing machine - operation O9)	
Falling parts during storage:	27
Incorrect storage of parts	55
Number of damaged parts, plugs or pins	42
Operation - O10	
Damage to parts on the buffer truck	60
Taking parts from the trolley	6

Source: Own study base on Doktor, 2018.

4. Analysis of the collected data

The most discrepancies at stage O1 appeared in the group: damage to the plug (they constitute 46% of registered non-conformities for O2 operations) and damage to the pins of the plug, which constitutes about 36% of all non-compliant items registered at this stage of production. Both groups of non-conformities account for over 80% of the non-conformities identified in the first stage of the process. For O9 operations, also damage to plugs and pins of the plug was recorded (the number of damaged elements was 42). In addition, procedural incompatibilities regarding the postponement of parts have been identified. Elements are put on top of each other instead of one next to the other. Incorrect postponement causes the parts to slide off, the part engages with one another. The consequence of incorrect parts deposition is its fall from the height, damage to the whole of the element or its part during the pickup by the operator. For the last operation O10, up to 90 percent of non-conformities concerned damage to parts during transport by strollers, and only 10 percent were associated with collecting parts from carts.

In the next stage, a detailed analysis of the above nonconformities was carried out, based on the form based on the FMEA evaluation sheet. The results are presented in Tables 2-4. Each type of non-compliance was given a number, effects were identified, and the reasons for the non-compliance were identified (Table 1). The RPN index was determined by assessing individual values (Z) – significance (R) – risk of occurrence and (W) – detection on a scale of 1-10, where 1 – means low (low) meaning and 10 – very high (table 2).

Table 2.
PMEA analysis - part 1 Designation and effects of non-compliance

Document no. Z-01-2018/LL01	Analysis type: modified PFMEA analysis			
	description/function:		date of development:	
	FMEA analysis to improve the process		17.01.2018	
Line name: Soldering line - the transport process			Comment: RPN=Z*R*W	
The number of the operation:	**Characteristics of the operation:**	**Discrepancy no.**	**Identified non-compliance:**	**Consequences:**
O10	Transport by stroller	NW-01	Damaged parts during transport Slowing down the process through coupled trolleys	Part rejected, scrapped, suspension of the process, loss of secondary functions, loss of support
O9	Using a storage place –	NW-02	Falling parts while pulling out	Part scrapped, minor disturbances, loss of assistance, loss of basic functions, final test error
O9	Using a storage place	NW-03	Incorrect storage of parts	Falls of the parts, probe housing damage, socket damage
O10	Putting the part on the buffer	NW-04	Damage to parts on the buffer	Part rejected, minor disturbances in the later stages of the process, loss of secondary functions, loss of support

Source: own study.

According to the data in Table 2, all nonconformities belong to critical incompatibilities. The RPN indicator calculated for them exceeds the contractual limit of 100 points. This border was accepted in the analysed enterprise. Above it, corrective actions should be taken immediately. The calculated RPN coefficient was 160 points for non-compliance NW-02 to 392 points for non-compliance NW-01 and NW-04.

Table 3.
PMEA analysis – part 2 RPN indicator

Document no. Z-01-2018/LL02	Analysis type: modified PFMEA analysis					
	description / function:			date of development:		
	FMEA analysis to improve the process			17.01.2018		
Line name: Soldering line - the transport process				Comment: RPN=Z*R*W		
Discrepancy no	**[Z]:**	**Causes:**	**[R] :**	**Current process control:**	**[W]:**	**RPN:**
NW-01	8	Rolling out trolleys, protruding plugs outside the trolley, badly designed trolleys, hooking the plugs on the edges	7	According to the standardization sheet	7	392

cont. table 3

NW-02	8	Incorrect method, improper handling of parts, blocking of parts in the pallet	4	According to the standardization sheet	5	160
NW-03	8	Incorrect method, low buffer space, big difference in cycles between the line and the next operation	6	According to the standardization sheet	8	384
NW-04	8	Rolling out trolleys, protruding plugs outside the trolley, badly designed strollers, hooking the plugs on the edges	7	According to the standardization sheet	7	392

Source: own study.

In the case of non-compliance, corrective actions were proposed (Table 3). These activities are discussed in detail in the next chapter.

Table 4.
PMEA analysis – part 3 Corrective actions proposal

Document no. Z-01-2018/LL02	**Analysis type: modified PFMEA analysis**						
	description/function:				**date of development:**		
	FMEA analysis to improve the process				17.01.2018		
Line name: Soldering line - the transport process					**Comment: RPN=Z*R*W**		
Discrepa-ncy no	**Recommend ed actions:**	**Responsib ility:**	**Date of implemen tation:**	**SEV [Z]:**	**OCC [R]:**	**DET [W]:**	**RPN:**
NW-01	Reconstructi on of trucks	Engineer, UR	30.03.201 8	8	During the analysis	7	-
NW-02	Fileing pins on the palette	UR	30.03.201 8	8	During the analysis	5	-
NW-03	Overhang table for putting away parts, adding a second level	UR	30.03.201 8	8	During the analysis	8	-
NW-04	Reconstructi on of trucks	Engineer, UR	30.03.201 8	8	During the analysis	7	-

Source: own study.

5. Corrective actions

For all critical non-conformities, photographic documentation was prepared along with a description of nonconformities and corrective actions were developed. For stage O1, it was found that the main cause of rejection, scrapped parts and suspension of the process is incorrect construction of trucks. Examples of improper installation of separators and faulty construction of trucks are shown in Fig. 2.

Figure 2. Coupled trucks with each other, hooked separators. Source: Doktor, 2018.

The push bogies shoot together, shocks cause the elements to move and most frequently the plugs fall out of the trolley area. In the event of a plug falling between two striking carriages, the part is broken off. An analogous problem was found at step O10 of the process. It consists in the fact that during the deposition of parts for buffer trolleys, plugs emerge beyond the edges of the trolley, which are damaged during the withdrawal of carts, due to the colliding of the carriages against each other. Incorrect construction of trucks is the main cause of damage to the transported elements Fig. 3 and 4. In the case of non-compliance NW-04 (damage to parts on the buffer truck) defects of elements are detected by operators at a later stage of the process, which causes complications, stopping the production process, and increased the amount of scrapped parts.

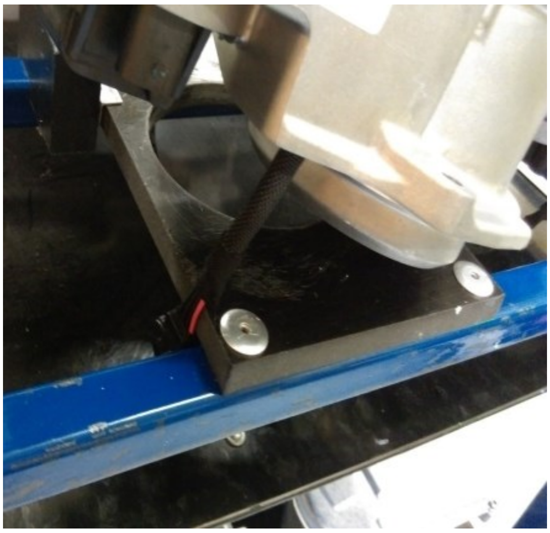
a)  b) 

Figure 3. Plug attached to the edge, protruding parts beyond the edge of the trolley. Source: Doktor, 2018.

Unconformities shown in Figures 3 and 4 also pose a problem when pulling parts out of the carts. The plugs are attached to the edges of the base on which the parts rest. Pulling out the attached parts causes further damage, which in turn increases costs.

To solve the problem (NW-01 and NW-04 – tacking buffer carriages, damaging the plugs on the buffer), separators should be installed on all carts in time. It is important that the separators are placed at the appropriate level, both on the sides and the front of the trolley. The level of separators must be the same for all trucks. In this way, collisions of the carriages, their scraping and breaking off protruding parts of the plugs will be avoided. It should be emphasized that this is a temporary solution. Ultimately, it is proposed to dismantle separators that disrupt free transport and then mark and blind all unnecessary gaps with ESD material. When all the gaps, except those that allow the parts to be put down, are plugged, it will not be possible for the plug to get out of the trolley (thus eliminating problems with plugs protruding through the slots and the problem of hooks hitting the edge of the trolley).

For non-compliance of NW-02 (part failure during collection or postponement), two reasons for its generation were determined during the research. The first one is connected with the material removal, which in addition to the latches is held by stabilizing pins, blocking its download. The operator is often forced to "tear out" part of the pallet, which causes weakening of the handles, causing the parts to fall. The proposed solution is partial filing of stabilizing retainers, so that parts can be downloaded smoothly by the operator. The second reason is too small placental surface (Fig.4). The problem was solved in the same way as in the case of non-compliance NW-03.

Figure 3. Too small placement area – incorrectly placed part (own study). Source: Doktor, 2018.

NW-03: Incorrect parts deposition:

The problem concerns the difference in cycles between the line and the test machine. Therefore, more elements are transported to the storage place than can be tested in the testing process. The average cycle length on the production line is 32 seconds while the cycle time of the testing machine is up to 100 seconds. The difference causes line downtime or, most often, incorrect component deposition on the inter-operation buffer by operators. Currently, the company cannot afford to buy and install an additional testing machine. On the other hand, incorrect placement of parts on the table causes their damage or falling from a height. These parts usually have to be scrapped. The size (width) of the storage table is determined by the free space between the machines. Therefore, it is not possible to set another table.

It was therefore proposed to add a second level to the table, so that instead of 4 pieces, you could put down 8 pieces. This solution will ensure the continuity of the process and prevent the parts from falling. A table with levels will allow placing more of the produced elements, and in addition the width of the storage space will be kept. The solution should reduce the number of downtime. Unfortunately, it will not completely eliminate the cause of the problem related to the time difference resulting from the work of the machines.

6. Conclusion

As a result of the conducted research, critical incompatibilities in internal transport taking place during the soldering process were determined. These discrepancies affect the quality of the soldering process and are the main cause of downtime on the production line, as well as generate costs associated with the scrapping of incompatible components.

For the 11 stages of the manufacturing process on the soldering line, over 220 discrepancies in in-house transport processes were identified during the observation. These discrepancies are generated in O1, O9 and O10 processes. An in-depth analysis of the obtained results made it possible to determine the reasons for the existing critical inconsistencies. RPN indicator designated for these non-conformances is from 160 to 392 points.

The most important causes of non-compliance include:

- reckless design of trucks for parts,
- too big difference in the cycles between the last operation of the process and the testing machine,
- too little space for the inter-operation buffer.

A measurable effect of the conducted research is the implementation of a change to the company regarding the operation O10 of the process – that is, the reconstruction and retrofitting of buffer trolleys. The first prams have already been modernized, however, this stage will take several months due to the number of prams and the lack of stops. The proposed corrective action regarding the reconstruction of the table has also been accepted and implemented.

It should be emphasized that the majority of causes of non-conformity arise from errors that arise during the design of the transport process. In-house transport was considered separately as a process without integration with the production process. This is a serious logistical error committed at the planning stage.

It can be assumed that after the company has implemented all corrective measures, expenses related to the scrapping or dismantling of parts will be reduced to a significant extent. It is therefore stated that the implementation of tasks resulting from the introduction of modifications in the in-house transport process will enable the organization to improve the soldering process and reduce downtime and eliminate the main causes of non-compliance.

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