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STUDY FOR ZERO BREAKDOWNS AND PRODUCTIVITY INCREASE

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Abstract: *Ensuring a rational production structure and design should be a priority for anyone starting a manufacturing architecture. This action can take place in two different periods of time: when designing the manufacturing architecture or when the manufacturing architecture is functional depending on products range, manufacturing technologies, production or labour organization. The main focus of this paper is to optimise an assembly manufacturing architecture with the purpose of productivity increase. The optimisation process is carried out on a vertical refrigerators assembly line from ARCTIC Company. Our case study is based on identifying and eliminating mechanical breakdowns that occur in the assembly line and negatively influence the productivity rates. Another important factor we have to take into consideration is that all sub-components manufacturing architectures must be levelled as their productivity rates generate the assembly line productivity. Prior to optimisation process the entire system was monitored for several months as to determine the location, number and duration of breakdowns. A number of solutions were proposed, implemented and validated in order to reduce the breakdowns number and to achieve the main goal, assembly line productivity increase.*

Key words: *optimisation, assembly line, mechanical breakdowns, productivity, cycle time, redesign.*

1. INTRODUCTION

Regardless of the method in which the improvement of production structure and design is carried out there is a standard set of rules to be taken into account for achievement of this objective: increase the production volume of the manufacturing architecture main activity by reducing time in auxiliary activities; ensuring that production capacity is well balanced between all company subunits; organising the company production into a continuous technologic flow by following the shortest routes available [1].

All these improving methods will positively influence a number of the company indicators, the most important being:

- volume and cost of internal transport activities;
- number, type, size, location and cost of company deposits;
- number of personnel and payroll related to administrative department;
- production cycle time of company products, the work in progress stocks size and working equipment speed, etc.

Improving the production structure and design must take into account the continuous improvement of all these indicators, both when designing the manufacturing architecture and during functioning period.

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2. PRELIMINARY ASSEMBLY LINE DESCRIPTION

The subject of this paper is a study case based on a vertical refrigerators assembly line [2]. As the global market is constantly changing and vertical freezers demand is growing, the company is forced to implement certain changes in the assembly process organization to increase the number of devices. All improved aspects aim mainly to customer satisfaction and increased profit.

Figure 2 presents the layout and assembly line path that a product must follow from pre-assembly area to packaging and storage unit. For each workstation there are a number of processes that must be performed within a certain time interval.

Fig. 1. General overview of assembly line.

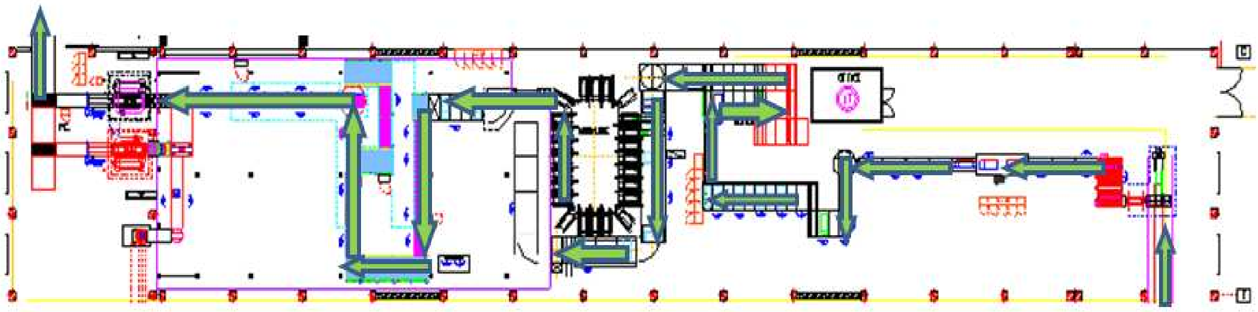

Fig. 2. Assembly line layout and product path.

The first approach of the optimization process was to reduce the assembly line tact from 50 seconds to 28 seconds [2]. The company work schedule is divided into 3 work shifts of 8 hours each (28 800 seconds). During each work shift workers are entitled to three breaks: 2 breaks of 10 minutes for resting (1 200 seconds) and a 30 minutes break for lunch (1 800 seconds).

By removing the break time, we can calculate the work time interval (1):

$$W_T = W_{ST} - B,$$

$$W_T = 28\,800 - 3000 = 25\,800\,[\text{sec}]\,. \qquad (1)$$

Also we noticed a difference between the operators efficiency in the work time. To correct it we introduced a fatigue factor (2):

$$F_F = 0.85\,. \qquad (2)$$

The real work time interval (3) is now calculated using this equation:

$$RW_T = W_T \cdot F_F\,,$$

$$RW_T = 25\,800 \cdot 0.85 = 21\,930\,[\text{sec}]\,. \qquad (3)$$

We already know the assembly line tact (4) is 50 seconds:

$$T_T = 50\,\text{sec}\,. \qquad (4)$$

Based on the input data gathered we can calculate the number of products (5) assembled in one work shift:

$$N_P = \frac{RW_T}{T_T}\,,$$

$$N_P = \frac{21930}{50} = 438\,\text{products}\,. \qquad (5)$$

The calculated productivity corresponds to the assembled products number reported by the company. The optimisation process is based on productivity increase demanded by the company. Our goal is to increase productivity by decreasing assembly line tact at 28 seconds. The estimated number of products (6) after optimisation will be:

$$N_P = \frac{21930}{28} = 783\,\text{products}\,. \qquad (6)$$

By lowering assembly line tact the number of devices manufactured during a work shift will be 783.

For lowering the manufacturing cycle time some actions can be taken into consideration:

- removal of some processes that give non added value to the finished product;
- in order to eliminate flow concentrators in some work stations, more operators can be added;
- the distance between two consecutive operators can be increased;
- the transfer time can be lowered;
- the conveyor belts can be repositioned in a straight line.

The second approach is based on reducing the number of defects that may occur on the assembly line, thus increasing the mean time between failures [3, 4].

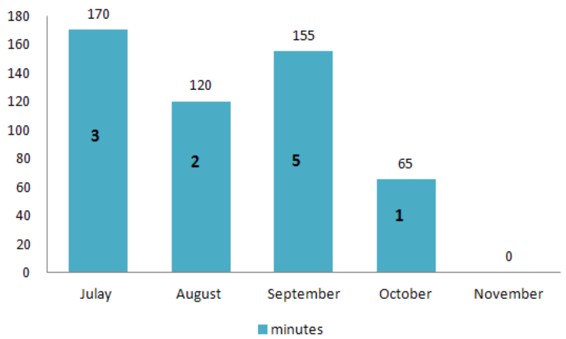

Fig. 3. Electrical defects.

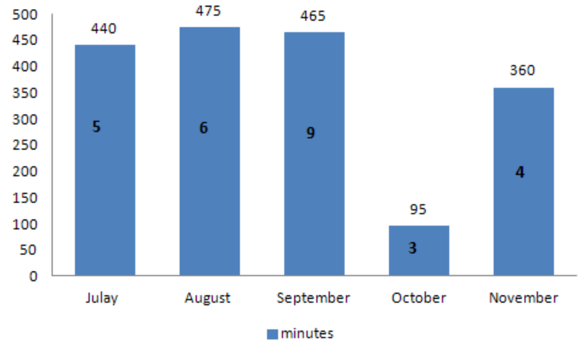

Fig. 4. Mechanical defects.

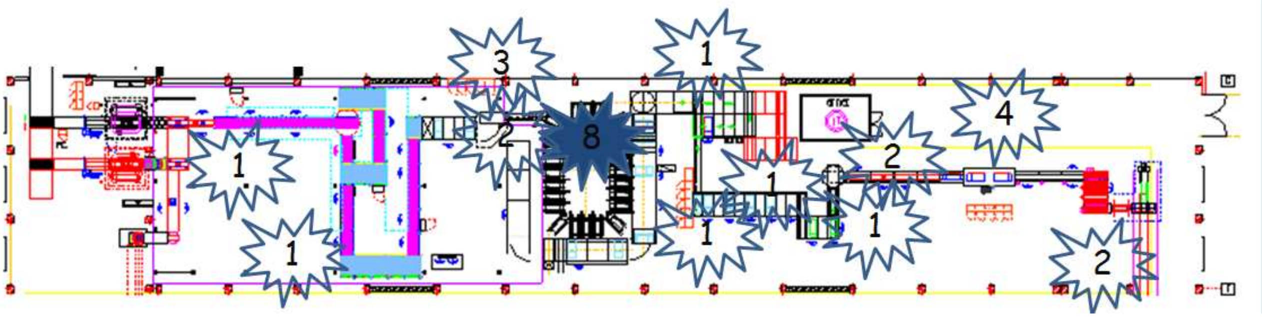

Fig. 5. Mechanical blockages map.

3. SOLUTIONS & RESULTS FOR REDUCING BREAKDOWNS NUMBER

There are two types of defects that can be identified on the assembly line [5]:

- Mechanic defects.
- Electric defects.

The manufacturing architecture was monitored for a period of five months to have better knowledge over the defects rate. We concluded that during monitored time a total of 11 electrical faults and 27 mechanical failures were recorded. Moreover graphic representations reveal that for 510 minutes the assembly process was interrupted due to electrical faults and 1 835 minutes because of mechanical causes.

Figures 3 and 4 reveal the number of defects encountered during a month, the period of time in which the architecture was analysed. For each month we also specified the necessary mean time to repair those defects.

Since mechanical faults are about 3.6 times more likely to appear that electric ones, we conclude that our priority is to remove the causes of mechanical jams.

First we identify where mechanical blockages occur during those five months of monitoring.

For a better understanding of the preliminary architecture we draw a map pointing out the mechanical failures.

Figure 5 describes in detail the entire assembly line emphasizing the points where mechanical failures were recorded. We could identify mechanical failures located at:

- Conveyor belts.
- Transfer systems.
- Elevators.

Most mechanical blockages are recorded in the aria designated to vacuum refrigerators. Due to this conclusion the vacuum area will be analyzed to determine the causes leading to mechanical failures. After we establish what determines this failures we will try to implement some solutions aimed to diminish or eliminate interruptions in the assembly process.

In Fig. 6 it is given a detail of the area subjected to analyze, laying out both the carousel position in the vacuum area as well as the operator position.

The operator's position plays an important role in finding a solution to improve the vacuum process as its placement directly influences the motion direction of the carousel.

After a close examination of the vacuum carousel we could establish that half of the 8 mechanical blockages registered are due to the vacuum trolley.

The mean time to repair for a single breakdown of the trolley is 240 minutes, which means that for all 4 faults identified the total repair time takes 960 minutes.

Analyzing these values the next step will be to come up with solutions to remove defects from vacuum trolley.

Vacuum carousel has 24 trolleys and the cycle time is 15 minutes.

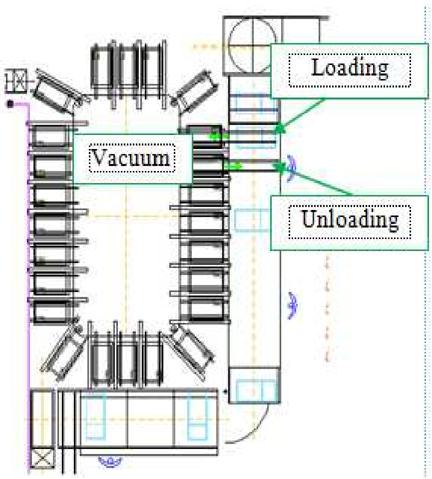

Fig. 6. Vacuum carousel.

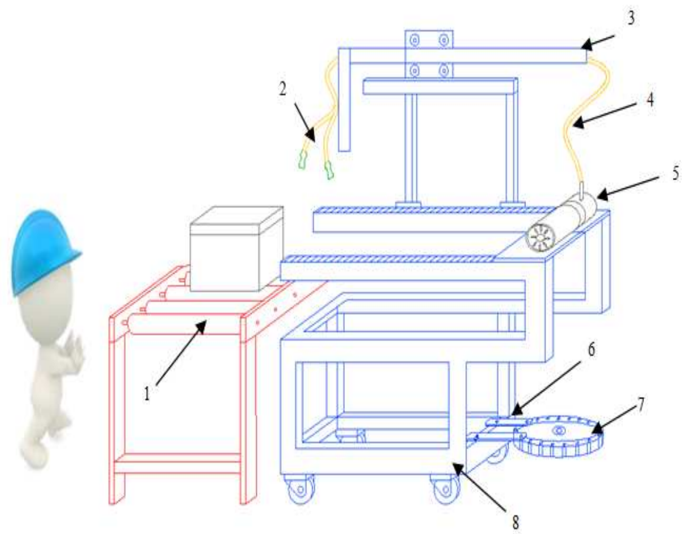

Fig. 7. Vacuum trolley detail.

To better understand the causes leading to mechanical failures Fig. 7 represents a detail of the vacuum trolley along with all the elements that may influence the faults. These elements are:
1 –roller conveyor;
2 – vacuum couplings;
3 – hose port support arm;
4 – vacuum hose;
5 – vacuum pump;
6 – clips with spherical nut;
7 – drive chain and pinion;
8 – trolley frame.

We were able to identify four reasons that can be responsible for mechanical failures. These are:

- Damage of the guidance system.
- Breaking of the guiding arm.
- Breaking of drive chain.
- Breaking clips with spherical nut.

The main cause of the recorded breakdowns is damaging to the guidance system. Damage of the guidance system is due to breaking of the hose port support arm.

Before we can find a solution to stop the hose from tearing we must understand which is its role in the vacuum process and how does this process function. Vacuum hose with the two couplings is hooked to the belt when the trolley enters / exits for loading / unloading products.

In order to restart work on the assembly line the company came up with an intervention protocol. Scheduled maintenance operations are:

- Re-establish trolley in position.
- Coupling / replacement of the broken chain.
- Replace damaged guidance rollers.
- Manual rotation of the vacuum carousel with checking of the trolley stability.
- Start operating.

Manual rotation of the vacuum carousel is performed with the help of two additional operators located inside the carousel.

Since we were able to locate the vacuum hose as a more exact cause for the breakdowns we detailed the process in which refrigerators are coupled to the vacuum pump (Fig. 8). Vacuum hose length reaches 7 400 mm.

Having studied in detail the vacuum process we can divide it in three major categories:

1 – product loading;
2 – product unloading;
3 – vacuum carousel moving.

The necessary steps for performing the vacuum operation are:

1.1 – position the vacuum hose in loading area;
1.2 – connect rapid couplings;
1.3 – elevate loading chain;
1.4 – move product and position vacuum hose in station;
1.5 – lower loading chain;
2.1 – elevate unloading chain;
2.2 – exit product and position vacuum hose from station
2.3 – lower unloading chain
2.4 – disconnect rapid couplings
2.5 – retract the vacuum hose
2.6 – confirm unloading

Loading and unloading products are always consecutive operations.

As a result of the vacuum process analyzes a solution to prevent rupture of vacuum hose is to redesign the vacuum trolley.

As can be seen in Fig. 7 the operator is located outside the vacuum trolley. The human factor is very important in the optimisation process.

The ergonomic structure of the hose port support arm is designed to automatically provide the operator the two couplings which he must attach to refrigerators.

The devices will be placed in the vacuum carousel. After that the devices will be reintroduced into the circuit to be charged with refrigerant agent and tested for functionality.

To eliminate the support arm of the hose the operator must be positioned inside the vacuum carousel. This solution leads to a partial redesign of the vacuum trolley.

In Fig. 9 we draw a sketch of the proposed solution. Along with the operator new position the location of the vacuum engine was also modified. Vacuum hose is attached to the vacuum trolley using clips.

The vacuum hose is brought up in front of the operator and fixed at a convenient height and reach position.

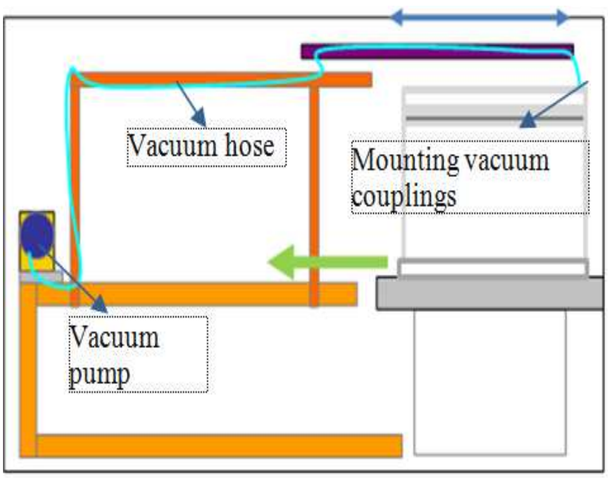

Fig. 8. Detail of the vacuum area.

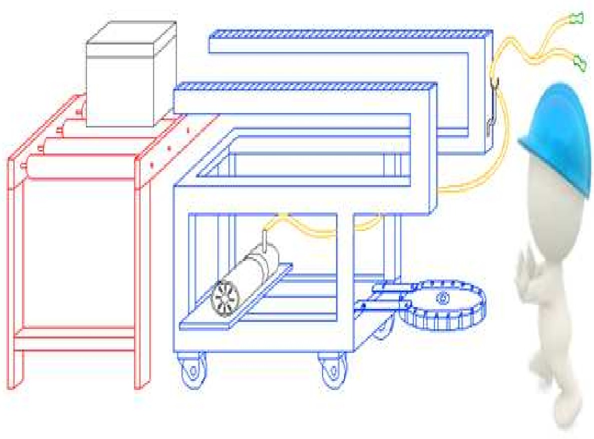

Fig. 9. Vacuum trolley new design.

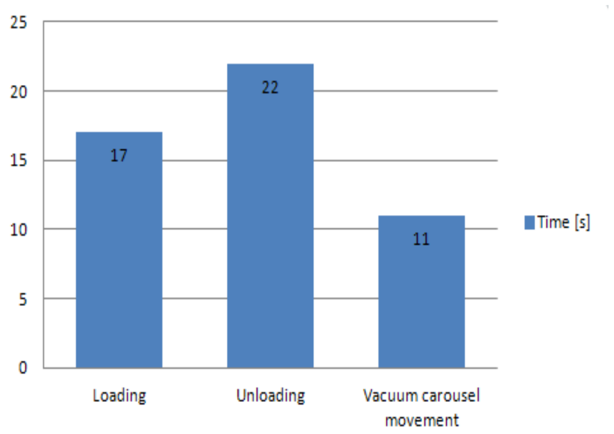

Fig. 10. Devices loading / unloading time values before optimisation.

During loading or unloading devices the vacuum hose with the two couplings are moving along the trolley.

If this solution is accepted the operator will have permanent access to the couplings, without any restrictions in performing during this operation.

Another advantage is the shortening of the vacuum, hose length from 7 400 mm to 2 199 mm. In this case if the vacuum hose should be replaced due to wear or tear there will be approximately 3.3 times less material used.

Besides the interruptions occurred due to faults in the carousel vacuum, another problem are the time values necessary for loading and unloading the devices on the vacuum platform (Fig. 10).

The proposed solution makes possible loading and unloading devices in the same time.

In the process of refrigerators loading / unloading we identified the operations that require a great amount of time to be performed.

Each of the above mentioned operation takes six seconds to finalize: transferring the device in vacuum unit, positioning the vacuum hose in station for loading phase, removing the device from the vacuum unit and the vacuum hose from unloading phase.

As the device unload can be validated only after the withdrawal of the vacuum hose from the station, the rapid coupling disconnect also takes 6 seconds.

The proposed solution for this matter is for loading / unloading operations to take place simultaneously.

The vacuum process operations were reorganised. The device unloading is done in the following order:

1. Rapid coupling disconnect
2. Unload chain elevate
3. Position device in vacuum area
4. Exhaust chain lowering

The device loading requires the next steps:

1. Loading chain elevate
2. Position device in vacuum area
3. Exhaust loading chain
4. Rapid coupling connect
5. Carousel movement

Device transfer in vacuum station in loading and unloading phase is done in the same time, thus reducing to half the necessary time.

Also there is no need to validate the unloading as it is performed in the same time as the loading.

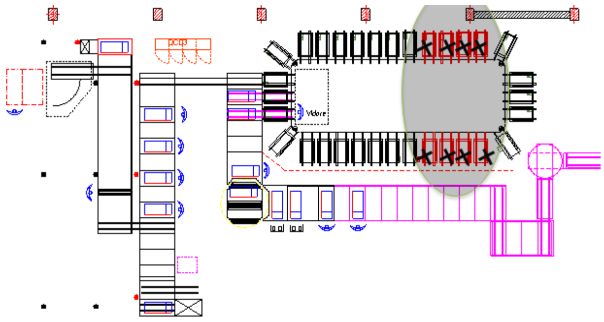

Fig. 11. New layout of vacuum aria.

The changes mentioned above have lowered the time value for the perform operations from 50 seconds to 24 seconds.

After optimisation process the vacuum time exceeds the loading and unloading time.

The carousel has 24 vacuum pumps. For a vacuum cycle of 900 seconds the line tact is 37.5 seconds.

We can continue the optimisation process, but, since it is not possible to speed up the refrigerators vacuum process, the solution was to introduce new vacuum pumps.

However, there are some constrains that need to be taken into account:

- Vacuum pumps number must be even.
- Area designed for this process is limited.

So although it will be necessary to introduce a number of 12 to 14 vacuum pumps to reach 24 seconds tact, due to the limited space of their location, a number of 8 pumps were introduced.

Thus the new tact for vacuum station is 28 seconds. The solution found leads to a new layout of the vacuum area. The placement of the vacuum units and work stations in the neighbourhood must be reconsidered (Fig. 11).

The solutions implemented on the refrigerators vacuum aria can also work for the functional test aria of the same assembly lines (Fig. 12).

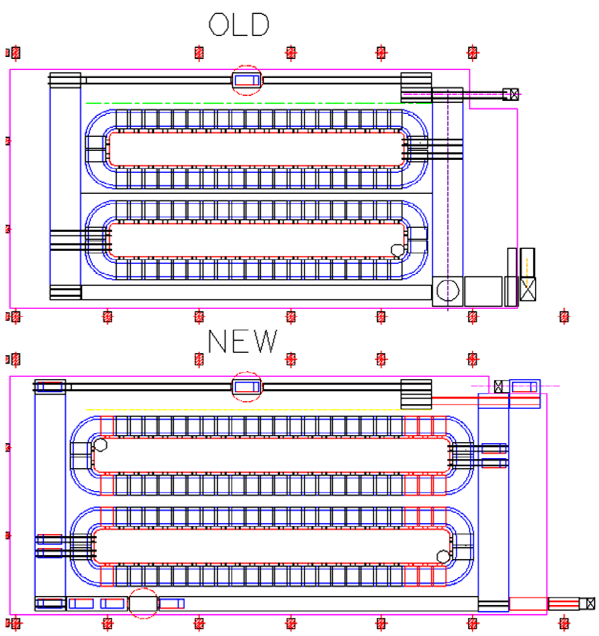

Fig. 12. Proposal for functional test aria new layout.

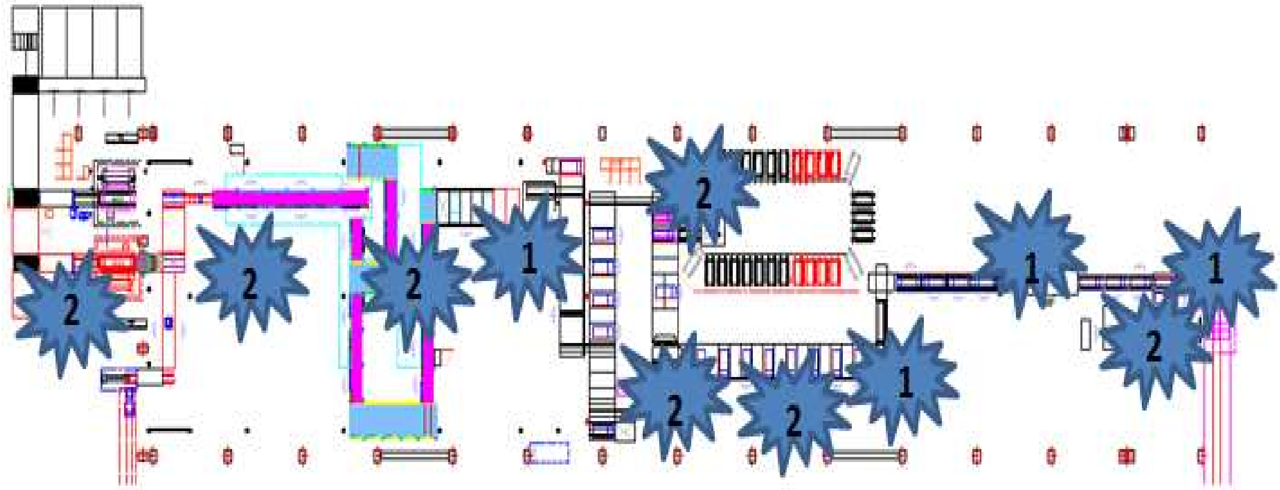

Fig. 13. Breakdowns map after optimisation.

4. CONCLUSIONS

Due to construction, physical and moral wear the vacuum hose support guide ruptures and causes damage to the vacuum trolley.

The solution found was to eliminate the support arm by redesigning the vacuum trolley.

In order to redesign the trolley we followed these next steps:

- Change the sketch.
- Change instructions and specifications.
- Archiving new project.

By making these changes we managed to reduce to half the refrigerators necessary loading and unloading time during vacuum process.

To validate the results of optimisation process the assembly line was re-monitored and mechanical breakdowns recounted (Fig. 13).

The assemble line was again monitored for five consecutive months. In Fig.e 14 we presented the number of mechanic blocks recorded in each month and their duration.

For the entire line a number of 18 mechanical failures were recorded, representing half the recorded number before the optimisation process.

By eliminating half of the mechanical breakdowns the company gain 590 minutes work time.

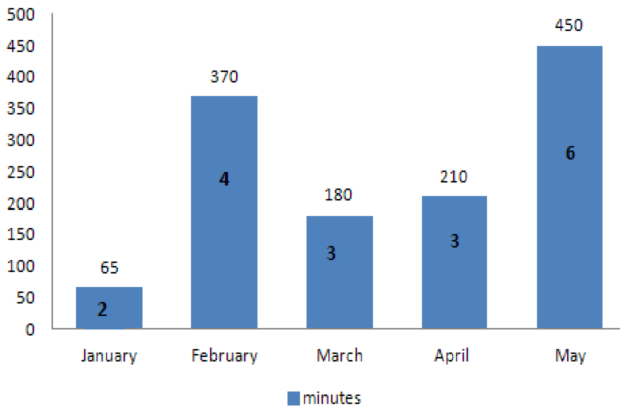

Fig. 14. Mechanical breakdowns after optimisation process.

During the optimisation process a number of solutions meant to improve the assembly process were carried out:

- A new layout was implemented.
- The number of units in the vacuum and functionality test area was increased.
- The increased speed of loading/unloading refrigerators in the carousels leads to reduced assembly time, which means higher productivity rate.

The solutions adopted have resulted in lower mechanical defects both in the vacuum and functionality test area of the assembly line, thus the overall target, the productivity gain was reached.

REFERENCES

[1] I. C. Dobre, I. Simion & F. Chiscop (2012). *Determination and elimination the material flux concentrator for an assembly line - case study*, Academic Journal of Manufacturing Engineering, Vol. 10, No. 4/2012, pg. 24-29, ISSN 1583-7904, CNCSIS “Clasa B”, 3rd International Conference on Computing and Solutions in Manufacturing Engineering, CoSME 12, Transilvania University of Brasov, 25-26 October 2012

[2] www.arctic.ro

[3] F. Shin, R. Menassa, B. Ram, A. Gupta & X. Yu (2004). *A decision tool for assembly line breakdown action*, Proceedings of the 2004 Winter Simulation Conference, editors R .G. Ingalls, M. D. Rossetti, J. S. Smith, and B. A. Peters, pp. 1122-1127

[4] C. Liao, and W. Chen (2003). *Scheduling under machine breakdown in a continuous process industry*, Computers & Operations Research 31

[5] T. Ilar; J. Powell & A. Kaplan (2008). *Simulation of Production Lines -the Importance of Breakdown Statistics and the Effect of Machine Position*, International Journal of Simulation Modelling – IJSIMM, Volum 7, Number 4, 2008, ISSN 1726-4529, December 2008, pag. 176 – 185

[6] U. Ghani, R. Monfared & R. Harrison (2012). *Machine utilisation and breakdown modelling for measuring productivity using virtual engineering simulation modelling*, Proceedings of the 10th International Conference on Manufacturing Research ICMR 2012, Volume I, ISBN 9781905866601, September 11-13, 2012, Birmingham U.K.