UNIVERSITY OF TWENTE

Internship

at the Royal Grolsch

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Internship for the master program mechanical engineering at the University of Twente. Working in the maintenance department of the packaging division at the Grolsch brewery. Improving efficiency on the non-return bottle filling line.

Contents

1. Introduction

This internship has been performed at the Royal Grolsch. The Royal Grolsch is a brewery in the Netherlands creating the Grolsch beer.

SABMiller

Since march 2008 Grolsch is part of SABMiller plc. SABMiller is a British-South African multinational brewing and beverage company. It is the second largest brewer measured by revenues world-wide. It has more than 69.000 employees in over 80 countries worldwide producing more than 200 beers. Some well-known brands from the SABMiller portfolio are Grolsch, Peroni, Tyskie, Miller and Pilsner Urquell.

Figure 1: SABMiller brands

Grolsch

The Royal Grolsch has been founded in 1615 in Groenlo. By then the place was called Grolle. That is why the beer is called Grolsch, meaning “of Grolle”. The Grolsch brewery is no longer located in Groenlo but in Enschede. The brewery in Enschede is a modern brewery opened in 2004. At the brewery not only the Grolsch beer is produced but more brands from the SABMiller portfolio for the western Europe market. At the Royal Grolsch around 850 employees are working.

The production part of the brewery can be divided in the brewing and the packaging department. This internship takes place at the packaging department.

Packaging department

In the packaging department at Grolsch there are 8 lines for different products. Line 1 fills kegs. Line 2,3,4 and 7 fill glass bottles. Line 8 fills 30cl and 50cl cans. Line 5 fills the so called “magnum” 1,5 liter swingtop bottle. Line 24 mounts the swingtops on the bottles to be used on line 4.

At the majority of the lines operators work in a 3 shift rotation (one week morning, one week afternoon and one week night shift, weekends off). As this internship is performed on line 7, the hierarchy will be described from this perspective.

On the technical department two maintenance planners and two strategic maintenance planners are working. They schedule the daily tasks to be done by the technicians working in day shift. They also are responsible for long time maintenance planning and overhauls.

Every production line is managed by a unit manager. The unit managers are responsible for the daily affairs on one or more lines. The line is manned by a small crew of operators and a shift team leader. furthermore every shift has its own shift technician for troubleshooting in case of breakdowns.

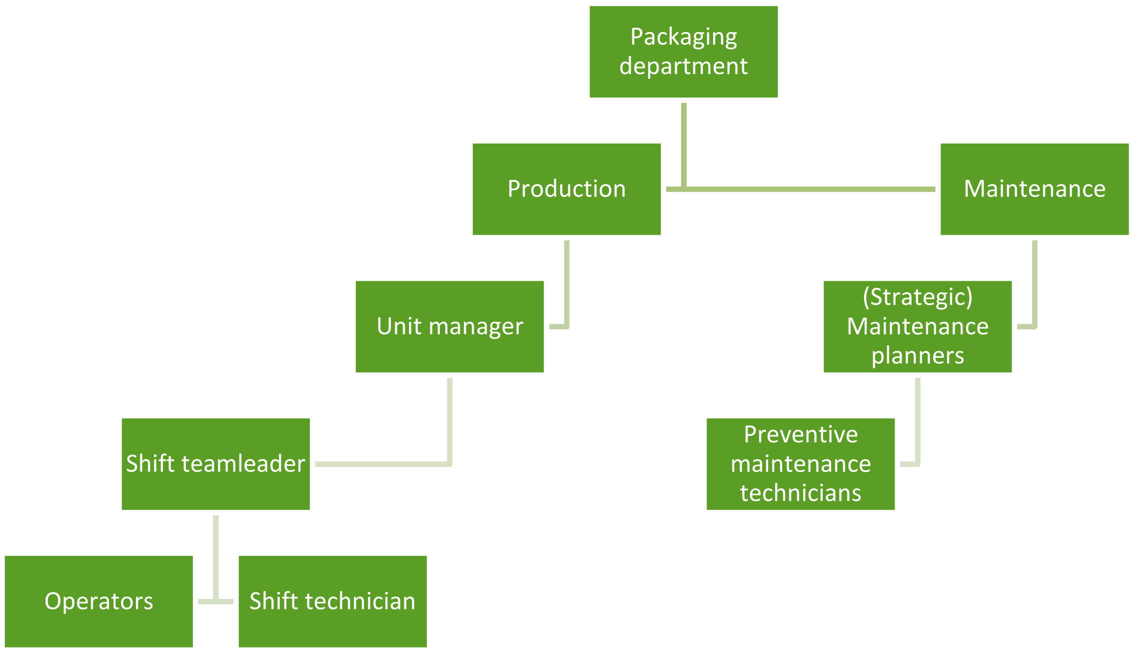


Figure 2: Schematic overview of the packaging department

Line 7

Line 7 is the non-returnable bottle (NRB) line. This means all bottles filled here are not returned to the brewery. Therefore only new bottles are used. All bottles are packaged in a cardboard box or tray and not in the well-known plastic crates.

Line 7 produces 6 days a week, 24 hours a day. The operators work in a 4 shift rotation (they work two mornings, two afternoons and two nights in a row followed by two days off).

Because all non-return bottles are filled on line 7 there is a large variety in products and beer types. This makes the batches of the same product very small and the use of packaging materials very diverse. There is variation in beer, bottle, label, crown, six-pack, cardboard box, tray and pallet-size.

This does not only bring a logistic challenge but also lots of technical difficulties. Each other beer or packaging type requires most of the machines to be adjusted. These adjustments give potential problems when the production lines starts producing.

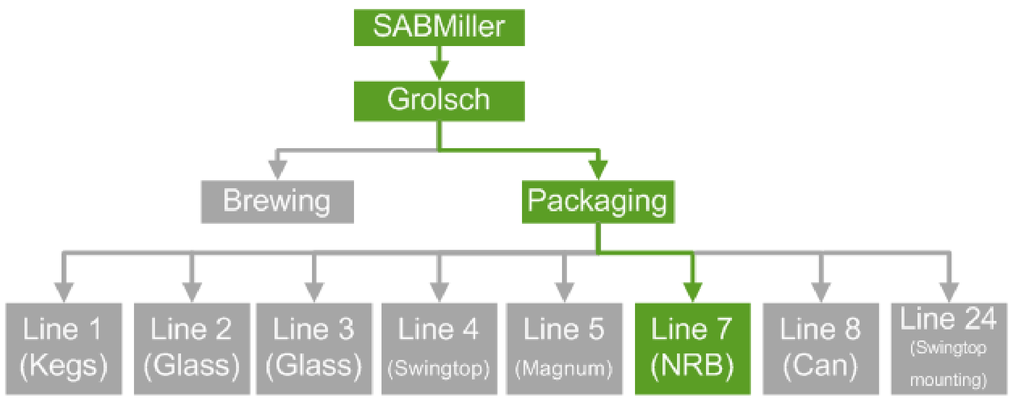


Figure 3: Schematic overview of Grolsch

Overview line 7

In Figure 5 an overview of line 7 is displayed. Following the bottle through the line the equipment shown in Figure 4 can be found. Between these machines there are bottle and/or box conveyors.

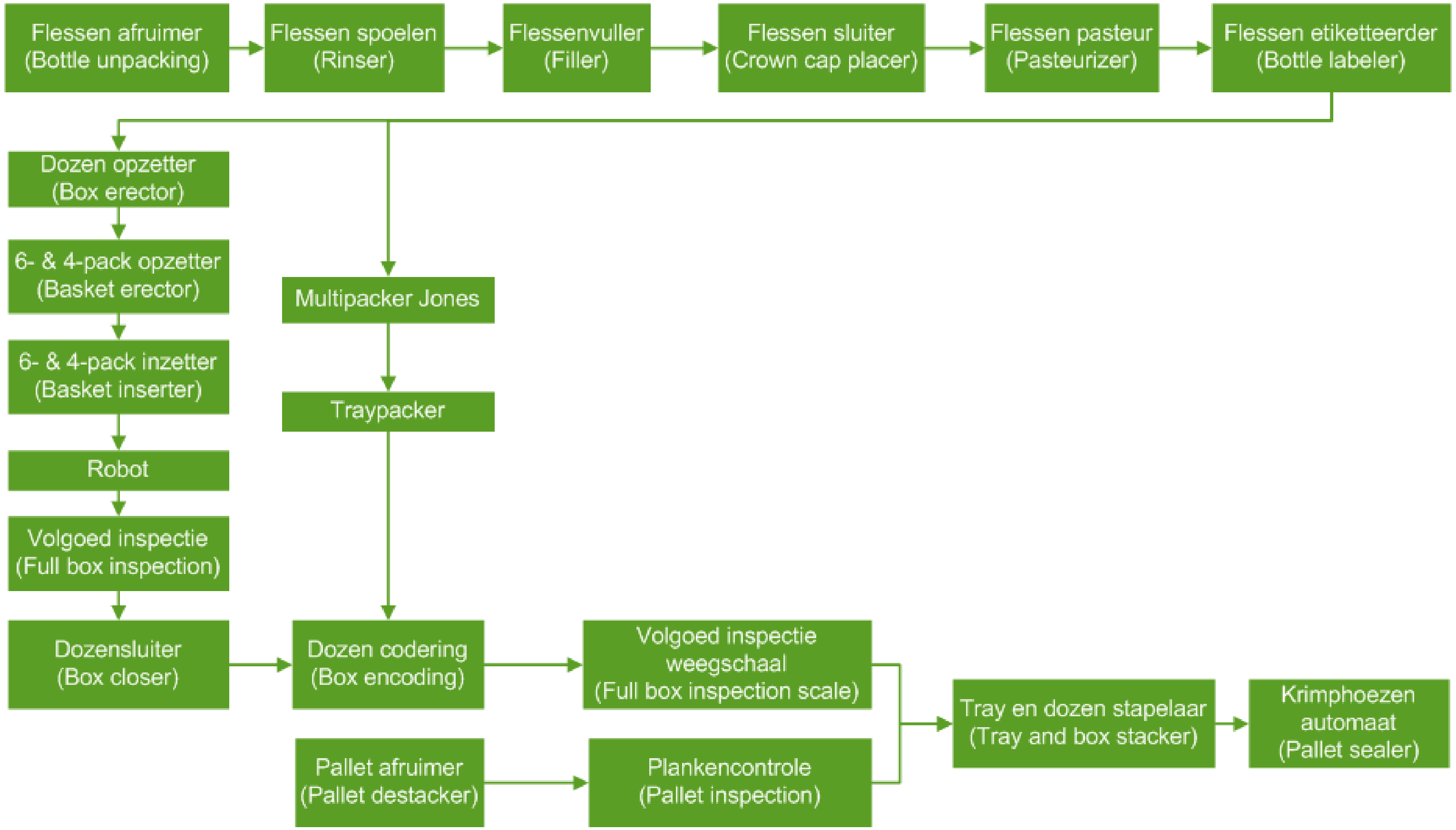


Figure 4: Equipment on line 7

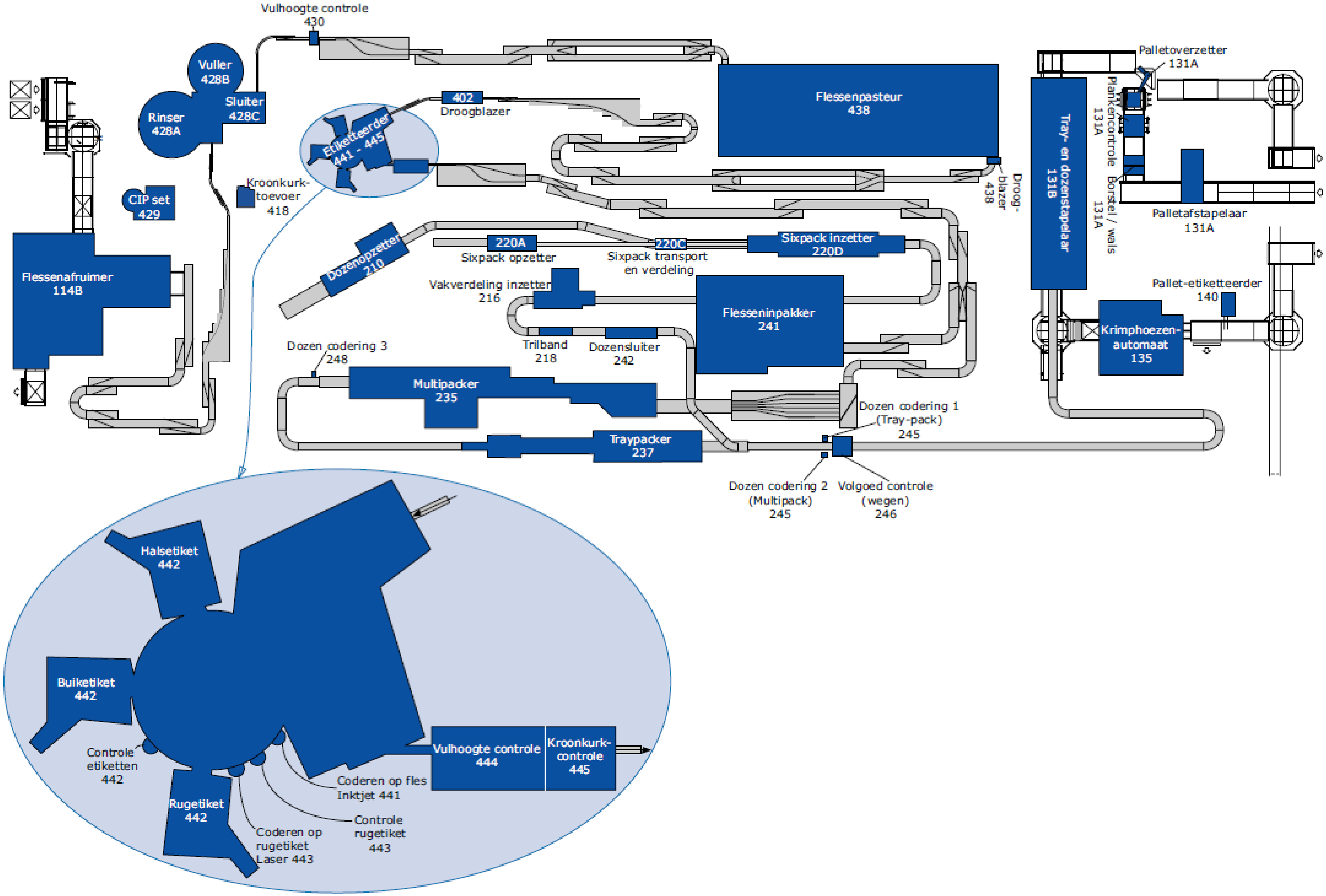


Figure 5: Floor plan of line 7

Assignment

The assignment from this internship is formulated as following:

Perform an analysis on the efficiency losses and other interruptions on the machines on bottling line 7 using the available systems (SAP, DTR). Distinguish interruptions on technical and operational nature.

Create a graph from this en take actions to improve this, based on an underlying business case (solving this improves efficiency with x%, but cost y euro, so payback time is z).

Furthermore review the current maintenance plans using these results and suggest improvements. If useful improvements are found these can be applied on other bottling lines as well.

Analysis of Down Time Registration data

All Down Time Registration data is saved in a so called DTR database. The data is supplied by the operators on the line. Every time the filler is on a hold they write down which machine is causing this and if known some detailed description.

Records are made of every minute the filler is on hold. This machine is the bottleneck in the system, as long as this filler is working there is production. This machine can come to a halt because a problem occurs in the machine itself, but also if a machine upwards or downwards in the line is having a problem. Other factors influencing the productivity of the line can be cleaning, product change, planned maintenance and external factors (supply of packaging, supply of beer, transport of full pallets, utilities, etc.).

In this DTR database not all problems are listed, but only those that cause the filler to stop. For performance measurement only stops of the filler are relevant, because as long as the filler is running bottles are filled. When an operator or mechanic is working on a machine that is not causing the filler to stop (yet) he or she cannot perform his/her standard tasks, possible causing other problems.

ME/FE

From this data so called Machine Efficiency (ME) and Factory Efficiency (FE) numbers are calculated. Targets are set for this performance.

Machine Efficiency is the technical availability of the machines on a line versus the total available production time. This number is measured using filled volume versus theoretical possible volume on that line (hectoliter packed beer). External factors such as cleaning, planned maintenance, product change, etc. are not taken into account. The target for machine efficiency is set on 82%.

Factory Efficiency is the efficiency including all external factors. This is also measured as filled volume versus theoretical possible volume. The factory efficiency target is set on 56%.

Other Key Performance Indicators (KPI's)

Next to ME and FE there are some more key performance indicators. These are amongst others bottle loss, water usage per hectoliter packed beer, energy consumption, etc. It has to be taken into account that an improvement made to improve ME can negatively influence these KPI's. For example as more water is used for lubrication of a conveyor, the water consumption overall increases.

Improving DTR registration

In the DTR database there only is the option to log breakdown (storing) of a machine. It can be very useful to be able to make a distinction in the type of breakdown that occurs. Therefore a new version of the DTR database is created in which it is possible to log the nature of the breakdown. Distinction is made between "technisch technisch (TT)" and "productie technisch (PT)". The first is a breakdown caused by a technical failure like a machine breakdown. The latter is a breakdown caused by another non-technical problem like for example adjusting a machine or placing wrong materials in the machine.

The excel sheet was adjusted including all the visual basic macro's. Also an analysis file was added to monitor the ratio of these malfunctions over time. This file automatically gathers its data from the database and plots it in a graph. The ME is also included in this graph (Figure 6) so one can get an overview which kind of downtime influences the ME the most.

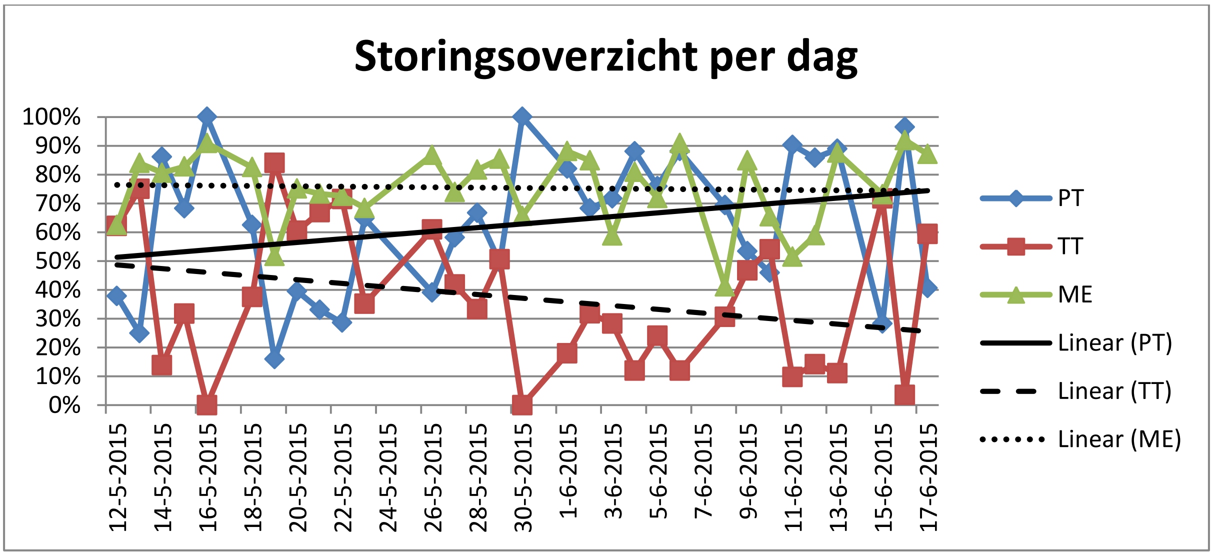


Figure 6: Analysis of types of downtime and ME.

Pareto analysis

In Figure 8 the pareto graph of the downtime of line 7 of book year F15 is displayed (apr-2014 till apr-2015). The first five records make up more than half of the downtime.

For these first five machines individual pareto graphs are made trying to find root causes. As the database contains information on the part of the machine that is causing a problem, an overview can be made. In practice this is not the most useful information as this is not always filled in correctly and some machines only have a few parts listed.

Flessenvuller (bottle filler)

The bottle filler is responsible for most of the downtime (14%, 8323 minutes). This can be partially be explained because this machine is the bottleneck in the line. Every second of downtime of this machine is registered in the DTR database. With other machines this is not the case. Nevertheless this machine is one of the machines that is worth looking at. Together with a team leader, an operator and a shift technician a project team in order to improve this machine is formed. More on this in Project Teams on page 10.

Multipacker

Next in line is the multipacker Jones. This machine is accountable for 11% or 6748 minutes of downtime. This machine unfolds and glues the 12-, 20- and other specific packs (Figure 7). It also places the bottles of beer in the packs and closes them. When using regular cardboard boxes, these steps are done by several different machines (dozenopzetter, robot, dozensluiter). This machine is a machine with lots of problems regarding the set up for a new product. The list of adjustments points is very high and therefore the machine is hard to understand for the operators working with it. Several people are working or have been working on this machine to improve this. Next to this there are many problems with quality of the material used (cardboard). This is not a thing that can be solved on a technical perspective but has to be done by the purchasing department. Therefore this will not be the main focus. Furthermore this machine is not used all the time. Only about 20% of production is done using this machine.

Figure 7: Left: Multipacker 12-pack. Right: Standard 24 cardboard box (robot)

Flesseninpakker (Robot)

The third machine is the “robot”, the robot who places the bottles from the line in the cardboard boxes. This machine also has quite some problems which are confirmed by the numbers (9%, 4th in the pareto graph). Together with a team leader, an operator and a shift technician a project team in order to improve this machine is formed. More on this in Project teams on page 10.

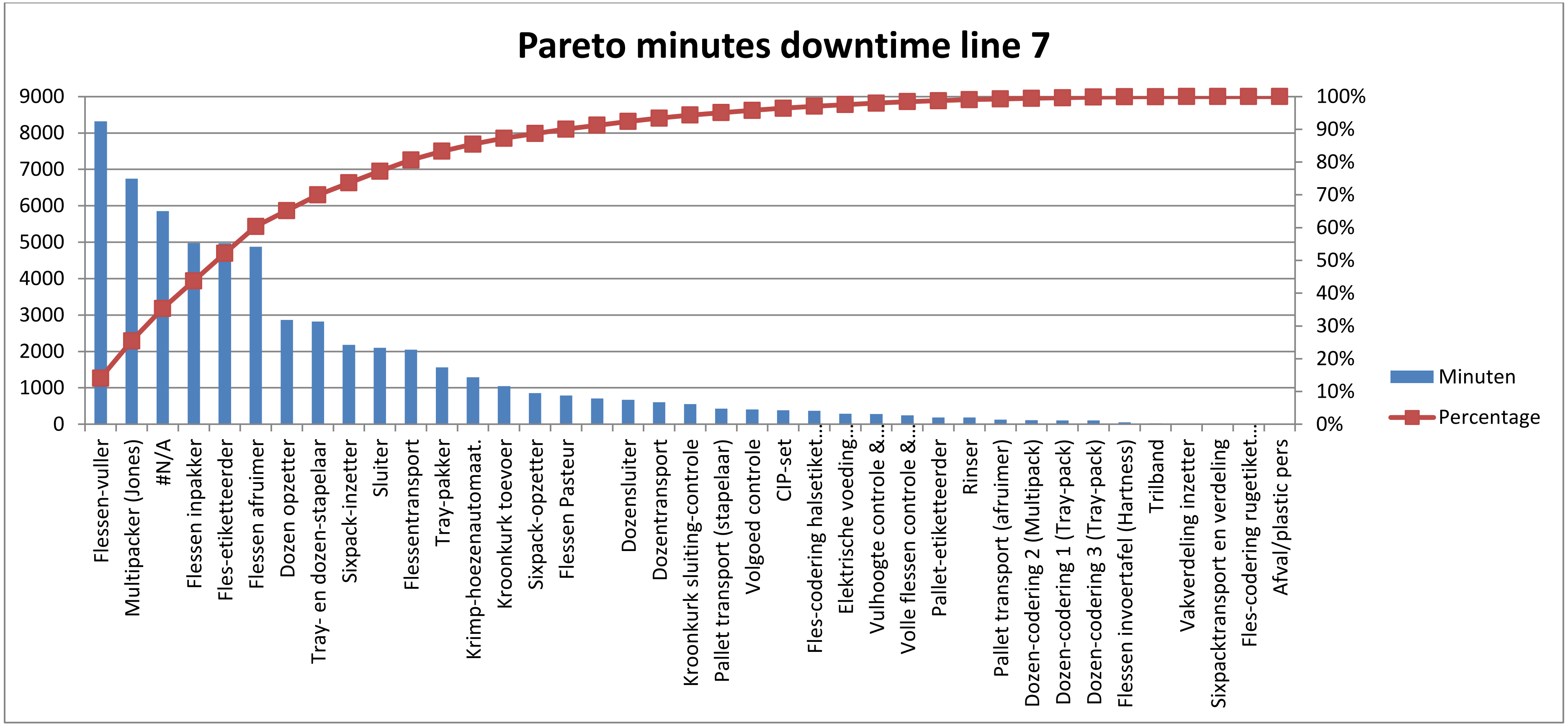


Figure 8: Pareto of the downtime on line 7

Project teams

There are two project teams to improve ME on line 7. Each of these project teams focuses on improving one single machine. Each project team is led by one of the shift team leaders. Also there are one or more operators and a shift mechanic part of the team.

Data analysis

To get a good image of what is causing the downtime on these machines an analysis from the DTR database of the last twelve months is created. For every machine the kind of downtime (part, cause) is manually categorized for every entry in the database. Next an excel tool which can be used to analyze the minutes and number of occurrences per category is created. A selection can be made which time frame is displayed. Using this tool there can be analyzed where the largest problems occur and if they still occur or just happened some time ago and have already been solved. This file is made for both the project teams.

Data vanaf01-04-2014 t/m 26-05-2015				
vanaf:	1-10-2014		gem min per maand	30000
tot:	1-4-2015		gem min per dag	1364
Categorie	Min	Aantal	gemiddeld per storing	ME loss %
Aanvoer dozen	49	9	5	0,03%
Anders	417	25	17	0,23%
Breukglas	51	10	5	0,03%
Inzetter	116	15	8	0,06%
Kop	135	9	15	0,08%
Ombouw / afstellen	254	27	9	0,14%
Omgevallen flessen	554	108	5	0,31%
Onderhoud (achterstallig)	17	2	9	0,01%
Programma	258	18	14	0,14%
Raamwerk	142	23	6	0,08%
Sensoren overig	120	14	9	0,07%
Sixpack in elkaar gedrukt	83	15	6	0,05%
Stopper	200	29	7	0,11%
Tulp	314	31	10	0,18%
Vingers	180	19	9	0,10%
Totaal inpakker	2890	354	8	1,62%

Figure 9: Result of analysis for the "Flesseninpakker" (robot). For the filler a likewise analysis has been made.

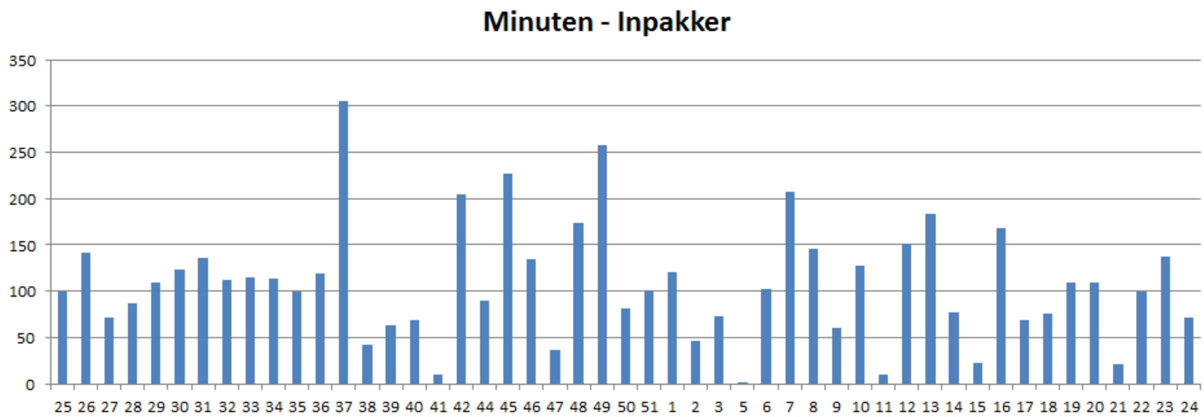


Figure 10: Minutes of downtime for the last year per week

Project team Robot

At the robot there are a number of large disturbances. The first is the tipping over of bottles on the conveyors. These bottles are transported to the feed-in-table of the robot and when a bottle tips over, the machine stops until an operator removes these bottles. Next there are the “tulips” (Figure 14), the cups that clamp the bottles so the robot can lift them.

These tulips sometimes are not functioning anymore and need to be replaced. The third issue is adjustment and fine-tuning after setup for a new product.

Based on the conclusions of the analysis actions are taken. First it is focused on the tipping of bottles. First a video analysis is done to find out where the bottles tip over. Several locations are found. The first position where this occurs is the feed-in-table. Between the conveyor and the feed in table there are sheet metal plates (fingers), see Figure 15 and Figure 16. These fingers are very worn which causes the bottle to wobble and tip over. Before replacing these fingers the operators counted the number of tipped bottles on a list. After changing these fingers they counted again and there was a small improvement. The desired effect however was not achieved as still lots of tipped over bottles are counted.

From the video was found that the bottles also tip over before they enter the robot. This is illustrated in Figure 17. To be able to solve this problem a short study about the theory of bottle conveyors is performed, mostly based on SABMiller internal documentation. More about this can be found in appendix B.

In this study can be read that lubrication is a key factor in solving this problem. The nozzles which spray on the conveyors need to be cleaned and adjusted on a regular basis (

Figure 11,

Figure 12 and

Figure 13). This is performed in a planned maintenance scheme every 26 weeks. In the period in-between it is expected from operators and mechanics to take action if necessary. These actions expected from operators or mechanics are not carried out in practice, causing the nozzles to be in bad shape. The interval of the planned maintenance is adjusted from 26 to 13 weeks. Furthermore all the nozzles checked and replaced if needed to get a good base to start from.

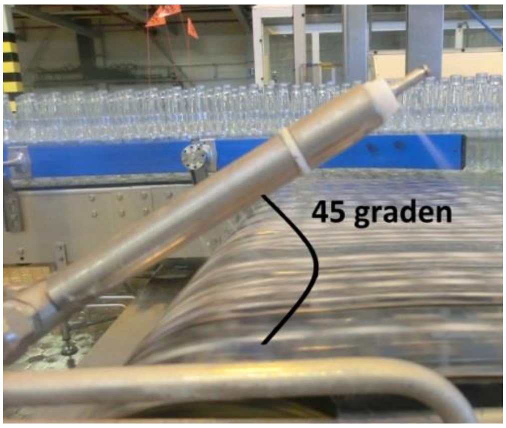


Figure 11: Height if the nozzle needs to be right

Figure 12: The nozzle need to spray the entire width of the conveyor

Figure 13: Dirty inside of a nozzle

Figure 14: Tulips

Operators suggested that the pusher that ejects the declined bottles after inspection was causing the bottles to tip over. They suggested that if it pushed a bottle away the following bottle in line is tipped over. This bottle is then transported to the robot. To take a better look at this recordings with a high-speed camera were made. The results from the video proved that this was not the case.

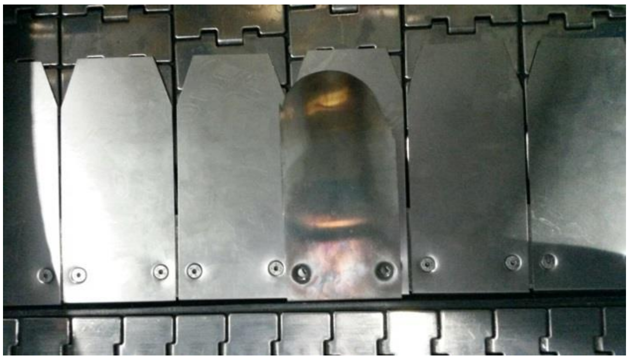


Figure 15: New fingers on the inliner of the “bottle table”. On top lays an old finger.

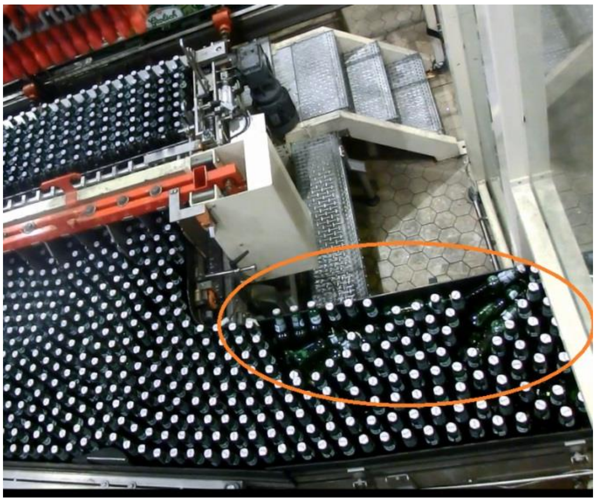


Figure 17: Screenshot of video showing tipped over bottles

Figure 16: Overview of the bottle table, old fingers still present

Figure 18: Shooting video of the robot. The robot head with the (red) tulips can be seen.

To reduce the time needed for adjusting after a setup up for a new product a measurement tool is made for the stopper. This stopper hold the boxes in place while the bottles are placed inside. The position of this stopper determines the position of the box. If this position is off the bottles are placed on the side of the box. For every different box size this stopper has to be adjusted. There is no setting to adjust this stopper, it is more trial and error. To make a first time right setting an adjustment tool with a ruler is made (Figure 19). This tool allows the operator to set the stopper at the correct position the first time.

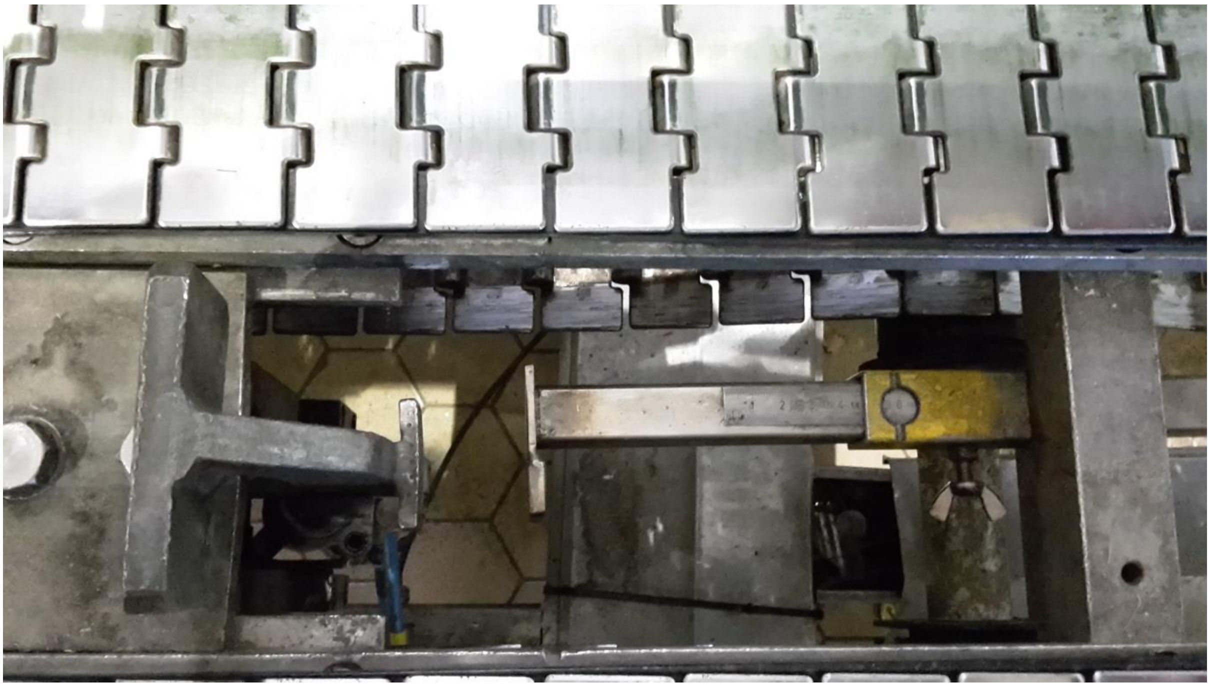


Figure 19: Adjustment tool (right) for the stopper (left)

To reduce the time of problems with the tulips it is investigated what caused the most downtime. It seemed that waiting on a new part was the biggest problem. Next to the machine there is a cabinet with spare parts in which ten spare tulips should be present. It happened quite some times that the cabinet was empty. To make sure there are always new tulips, two containers have been placed in the cabinet. When the first one is empty an operator has to refill this from the central warehouse immediately. The second problem is the use of standard and modified (narrower) tulips. Some operators use the wrong tulip while replacing a broken one. These narrower tulips however can be used in all the different robot heads. Therefore it is decided to modify all available tulips. This can be done at the in-house technical department using a lathe.

Project team Filler

The project filler is a project similar to the project of the robot. This project however is done with another shift team leader, shift technician and operator.

The team leader has set the goal for this project to get 2% ME improvement from the filler. This ME is not the machine specific ME but for the complete line.

To get the right focus points an analysis is made similar to the project robot (Figure 9).

From this analysis is found that the filler was responsible for 5% of the total downtime of the line. To get an improvement of 2% on the entire line we have to solve 40% of the filler specific downtime. A big problem last year has been the High Pressure Injector (HDI). This was a technical malfunction that has already been solved. This leaves us with 4% on the entire line from which we need to solve 2%. This means 50% of the filler specific problems. The top 3 problems, combined accountable for 48% of the downtime (Figure 22), are selected. The first one is the probes (sondes). The second is the filler valves (kranen) and the last is tipped over bottles at the inliner.

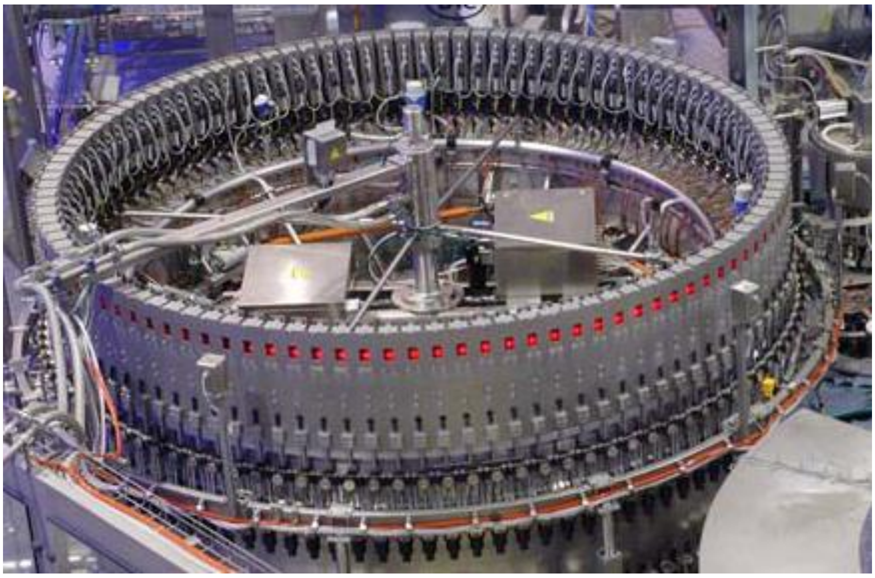


Figure 20: The filler

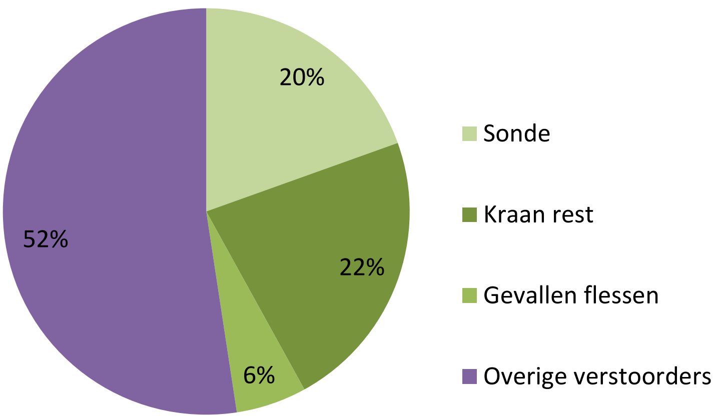


Figure 22: overview downtime root causes of the filler

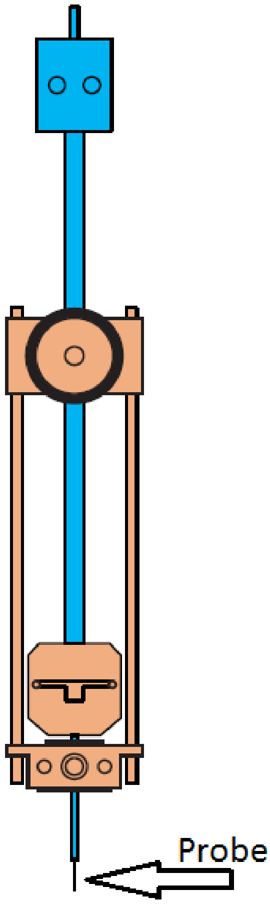


Figure 21: Filler valve

Probes

Probes are small stainless steel pins which go in the neck of the bottle that is being filled (Figure 21). This pin is coated except for the tip. At the top this probe is connected via a connector to a wire. When the tip makes contact with the beer a circuit is closed so the filler knows that the bottle is filled with beer and the filler valve has to close.

These probes tend to get damaged. The coating wears over time. The coating also gets damaged due to unwanted contact with the tube of the filler valve and the bottle. When this coating is damaged the probe is not presenting reliable readings anymore and needs to be replaced. When a probe needs to be replaced during production the filler has to be stopped for about 5 minutes. This is 5 minutes of unwanted downtime.

There is no time to perform a visual check on all probes on a regular basis as they need to be disassembled from the filler valve to be checked. The filler has 108 valves and thus 108 probes. There is however an indication of wear of the probes in the computer system controlling the filler. A new undamaged probe gives a measuring voltage of 5 volt. When the probe makes contact with the beer this pressure drops below a trigger voltage. If the probe wears or gets damaged this base voltage drops. When the measuring voltage is below around 0,75 volt the probes is not functioning well anymore because it is always below its trigger voltage. An operator can check these voltages easily on the control display of the filler.

To prevent getting troubled by damaged probes a preventive action was suggested. A checklist for the operators to check these voltages on a regular basis has been made. Every time the filler is stopped for a beer or bottle change there is time to change out a probe without losing production time. Before the filler stops the operators check all the probe voltages on the display and write down the probes with a voltage lower than 1 volt. These probes has to be checked and if needed changed out during the upcoming stop. When production is resumed they perform a last check to see if the problem is resolved. This list and instruction are displayed on page 20.

Valves

The valves are the parts of the filler that control the flow of beer into the bottle. This is a complex process. This process follows the next steps:

- Bottle enters the machine and is placed on the filler table.
- Bottle is clamped
- Bottle is vacuumed (90% of air removed →98% O_2 removed)
- Bottle is filled with CO_2
- Bottle is vacuumed again (90% of air removed → 99.8% of O_2 removed)
- Bottle is pressurized with CO_2
- Beer valve is opened (beer pressure is lower than CO_2 pressure)
- CO_2 outlet (quick filling) is opened, CO_2 flows out of bottle, beer enters bottle
- CO_2 outlet (quick filling) is closed, slow filling is opened
- Probe detects beer level is at top
- Beer valve is closed
- CO_2 pressure release valve is opened
- Bottle is unclamped and leaves filler

All these steps take place in less than 10 seconds.

The filler valve assembly consists of three main components (Figure 23) :

- Doggyhouse (CO_2 valve block)
- Vulkraan (Beer valve)
- Vacuumhuis (Vacuum valve)

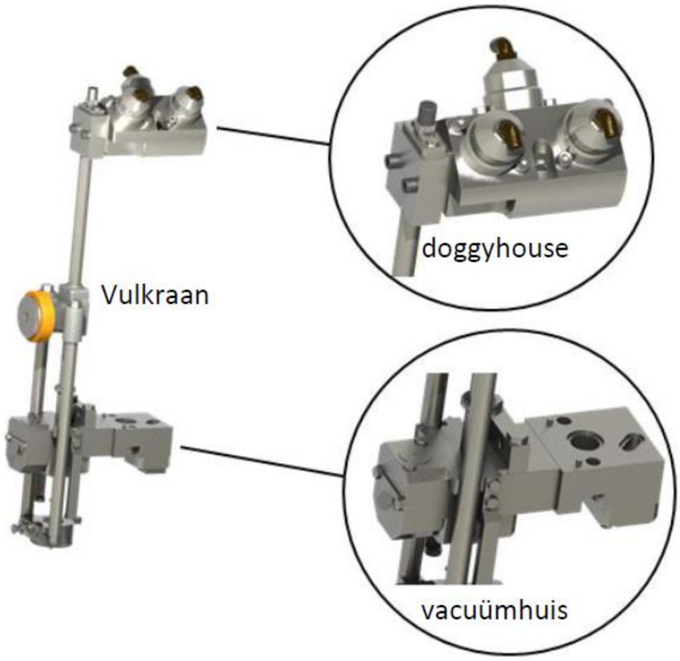


Figure 23: Filler parts

Each of these components can malfunction and can be changed out individually. During production this takes a lot of time. For example changing a doggy house takes 20 minutes. After changing this part the problem is not always resolved because it is hard to judge during production which part is malfunctioning.

An alternative to changing a filler part is to disable this valve in the control system. This means every 10 seconds a bottle is ejected (1 of every 108 bottles). If a production run is not too long it can be wiser to disable this valve and wait until the end of the production batch to replace the part. The times a batch should take before it is wise to change a filler part has been calculated. If the remaining batch is shorter the operator should disable the valve and throw away the empty bottles. These times are calculated based on bottle cost, downtime cost and ME loss.

From this a schedule is generated and placed on the filler:

	zonder CIP	met CIP (MGD)
Sonde schoonmaken	01:00u	22:00
Sonde wisselen	02:30u	23:00
Doggy house	08:45u	29:00u
Vacuumblok	08:45u	29:00u
Lekkende voorkant	07:00u	28:00u
Kraan vervangen	08:45u	29:00u
IR - kaart	10:30u	31:00u
Herion ventielen	15:30u	36:00u
Doggyhouse & kraan & vacuumblok	14:00u	35:00u
Overige activiteit **per minuut** stilstand van de filler	00:20u	21:00u

Figure 24: Decision schedule changing filler parts

A distinction is made between MGD and standard beers. On line 7 not only Grolsch beer is filled but all kind of other beers. The Miller beer is an unpasteurized beer (MGD). Therefore this beer is very critical regarding hygiene. Therefore it is not allowed to change a part during production without running a cleaning program (CIP). This program takes about an hour and thus extends the downtime with an hour.

To create better understanding why this schedule is so important an evaluation of the use of this schedule in the first month is made. Every time a part was changed during production this decision is reviewed. In the first month the operators stopped production 15 times for changing a part. Seven of those were not allowed according to this schedule. In total this generated 316 minutes of unneeded downtime costing €1700,-.

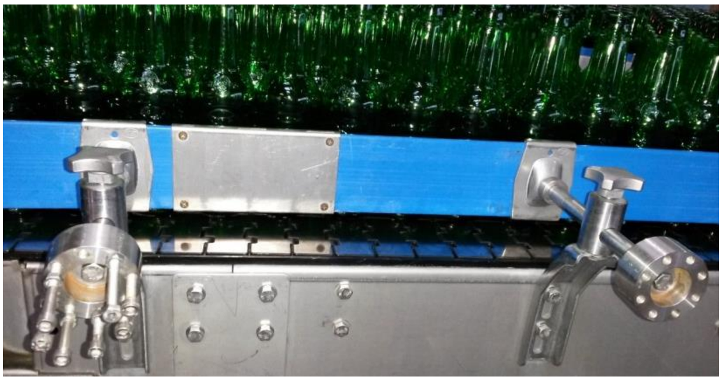
With this schedule unneeded downtime is reduced to a minimum. Off course, it is preferred to have no downtime at all. To accomplish this it is essential that the valves do not malfunction anymore. This is a task that is not achievable within this project. This is a much more complex and longer process involving the maintenance procedure, hygiene of refurbished valves, reviewing quality of the parts itself, monitoring every individual valve, reviewing preventive maintenance periods, contact with the supplier of the filler, etc. For this a specific project team is started involving more people. This will be carried out after project filler.

Tipping over bottles

In this machine bottles tipping over is also a great problem. Using information gathered for the project Robot some improvements are suggested on this as well. This problem has two root causes; lack of lubrication when the filler has been on hold for a while and incorrect adjustment of the side barriers.

When the bottles are lined up from the “afruimer” they are waiting about a half hour before production starts. At this moment the conveyor is on hold and thus not lubricated. This conveyor runs at a very high speed as the bottles are not transported ten next to each other but are lined up individually to enter the filler. When the conveyor then starts the bottles will tip over due to lack on lubrication. To prevent this extra spray nozzles are mounted which spray the bottles on this location with extra soap solution to keep them from tipping over (Figure 26).

The second problem is the adjustment of the side barriers. When the bottles are stacked ten next to each other like in Figure 32 and they need to speed up and get in a single line it is every critical that the side barrier is in the right width. For every different bottle type this barrier needs to be adjusted. A long time ago someone made an adjustment tool on these barriers. These tools are no longer in use. It is decided to take them back in use after making an improvement. The old state of the tools can be seen in Figure 25. The tools are mounted backwards, the right one is even incomplete. The idea behind the tool is that the bolts sticking out of the revolver are of different lengths. Each length is for a different bottle type. The side barrier distance can be measured using this revolver. The distance was measured against a round bar. This bar is flattened to make a clear adjustment point. Furthermore new lengths of the bolts are to be determined. The bolts are then secured using Loctite to prevent them from unwanted adjustments. Finally, every bolt is given a color corresponding with the color of the parts in the filler belonging to this bottle size.



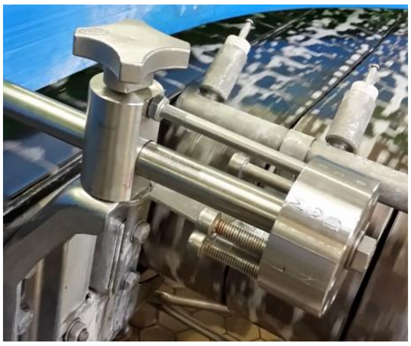


Figure 25: Left: old adjustment tools for the side barrier. Right: current status of adjustment tool

Figure 26: New spray nozzles

Samengevat in 3 stappen:

	Wie?	Wanneer?	Wat?
1	Operator filler	1 kwartier voor vullen laatste flessen voor bier- of fleswissel	Nalopen voltages van alle sondes en voltages lager dan 1.0V noteren op de lijst. Inclusief datum en tijd. Noteer ook datum en tijd als alle voltages in orde zijn.
2	Operator en /of shiftmonteur	Tijdens batchwissel / ombouw	• Vervangen of schoonmaken sondes volgens de lijst • Ondernomen actie afvinken op de lijst. Inclusief datum en tijd.
3	Operator filler	Zodra de lijn weer draait (en er tijd vrij is)	Noteren nieuwe voltages op de lijst.

Controlelijst sondes filler lijn 7

1) Vul voor alle sondes < 1V onderstaande tabel in. (+/- 1 kwartier vóór elke bierwissel of fleswissel) ***<u>Alle sondes OK? Toch datum en tijd noteren!</u>***
2) Vervangen/schoonmaken sondes tijdens stilstand. Noteer wat je gedaan hebt en wanneer.
3) Noteer na opstart de nieuwe voltages van de sondes

1			2			3
Datum & tijd	Sonde nr.	Voltage	Schoongemaakt?	Vervangen?	Datum & tijd	Nieuw voltage

Figure 27: Instruction and checklist for the probes

Results

During this internship some improvements have been done. Also some improvements have been suggested and implemented. As most of the improvements are implemented at the end of the internship or are to be implemented yet there are no numbers yet to confirm an increase in machine efficiency.

The project robot however looks promising. The table below shows the results on the key focus points. As can be seen all the minutes of down time per month are going down which is a good thing. A revision of the robot head is planned for the coming month so the total minutes are expected to get even better.

	F15 half jaar		mei-15		jun-15		difference	
	aver. per month							
	Min	Aantal	Min	Aantal	Min	Aantal	Min	Aantal
Bottle tip over	92	18	100	25	71	11	-7	0
Stopper	33	5	0	0	0	0	-33	-5
Tulip	52	5	11	1	83	8	-6	-1
Total robot	**482**	**59**	**270**	**47**	**605**	**49**	**-44**	**-11**
Green is less = improvement								
Red is more = worse								
170 minutes downtime due to a broken relais which wasn't on a technical drawing.								

The project filler is on hold as the project is to be continued on larger scale in the coming months. The planned technical improvements are not finished. The inspection of the probes is not done very well by the operators. This however is now in hand of the team leaders to make the operators follow through with it. The decision table for maintenance is used quite well. Both team leaders and the unit manager find this very useful. Therefore this will be a permanent improvement. In the future it can be useful to do this kind of analysis for the other lines. This is however a bit more complex due to the use of return bottles.

	F15 half year		may-15		jun-15		difference	
	aver. per month							
	Min	Aantal	Min	Aantal	Min	Aantal	min	aantal
Bottle tip over	40	5	20	2	0	0	-30	-4
Valve	253	5	1302	17	288	6	542	6
Probe	263	19	176	11	30	2	-160	-12
Totaal Filler	**1372**	**7**	**1884**	**46**	**408**	**21**	**-226**	**26**
Green is less = improvement								
Red is more = worse								

The focus points and the results of the project filler can be seen in the table above. As can be seen the number of tipped over bottles is reduced to zero in the last month. There are still problems with the valves, but this project is to be continued. The downtime for probes is much less than before and the total downtime time of the filler in june is far below average.

Conclusion

During this internship several technical and operational improvements are made or suggested. Not all of them show direct results due to lack of finishing or adapting by the operators. The changes that are finished show good results.

The steps taken for the robot are promising. Project filler is showing great results on the probes and the tipping over of bottles. The valves project is continued and therefore results are expected to show in time.

References

Containers conveyors – Speed and Accumulation Calculation and Control Philosophy	A SABMiller internal document
WPO Techniek_filler	A Grolsch internal document

Appendix A: Other small projects

Can end unwrapper line 8

Line 8 is the can line at the Grolsch brewery. As this line is managed by the same unit manager as line 7 quite some information about this line is gathered in the meeting that is attended every morning.

There are extensive problems with a certain machine on this line, the can end unwrapper. This machine removes a paper sleeve from the ends and feeds the ends to the can closer. There were lot of different issues with this machine and even more opinions about the root cause. Therefore an investigation is conducted and an eight page report about the issues with this machine and the history of actions taken in the last two years is written. There is also looked into a possible change of the supplied ends and the packaging of these ends. For this with everyone involved is spoken and all data (SAP, DTR) is analyzed. Facts are separated from fiction and a clear timeline of everything that happened in the last two years is made.

Also, some advice on the steps to take to find a solution to the long lasting problems with this machine has been given. The conclusion from this report was that the root suggested by lots of people could not be confirmed. Therefore it is suggested to start at the root of the problem and start debugging from there. Also consulted the supplier of this equipment is contacted to give the advised actions a flying start.

Sensors line 1

For the keg line an inventory of all the available sensors (pressure, flow, temperature, conductivity) is made. This to have the important ones calibrated. In total there are about 140 sensors. Using the Process and Instrumentation (P&ID) diagrams all the sensors are located and checked for type. Next specifications from the supplier are looked up.

Work instructions full box inspector

For the full box inspector work instruction for the operators are made. In this instruction is explained how to act in case of a problem with the inspection of a certain product. The steps to take in debugging as well as what to report to the technician are included. Using this the technician can take more direct actions in solving the problem and adjusting the program in the machine.

Appendix B: Theoretical background tipping over bottles

There are several causes for a bottle to tip over on a conveyor. These factors are amongst others lubrication, bottle shape and side barrier. To make things more difficult, a combination of all these factors can also be the problem.

Lubrication

Lubrication of the conveyors is an important factor. The conveyors have a stainless steel surface which is lubricated with a soap water solution. This solution is sprayed on the conveyors every 50 seconds by a nozzle. If the conveyor is to rough the bottles will tip over. This roughness will also cause pressure on the bottle as the conveyor is running underneath the bottles as the conveyor is filled. The conveyor is designed in such way that it will not stop directly as the conveyor is filled. This pressure generated on the bottles will cause the bottles to pop up (Figure 31).

Bottle shape

The shape and size of a bottle is another important factor. It can be seen that depending on the type of bottle they tend to tip over more. For example the 50cl bottle has a wider base than the 25cl. Also the ratio base to height is different causing the center of gravity to shift. Therefore the 25cl bottle will tip over easier compared to the 50cl bottle.

The new Grolsch "Apollo" 30cl bottle has another problem. This bottle tends to pop up if the pressure on the conveyor is too high (Figure 31). This is caused by the shape off the bottle. The standard 30cl BNR bottle has a straight side. The Apollo bottle has a relief surface. This causes the bottle to only make a two point contact with the other bottles. Therefore there is less friction between the bottles and they are popped out easier. Furthermore the Apollo bottle is just a bit tapered which also makes it easier to pop up.

Figure 28: Apollo 30cl

Figure 29: BNR 30cl

Figure 30: 50cl

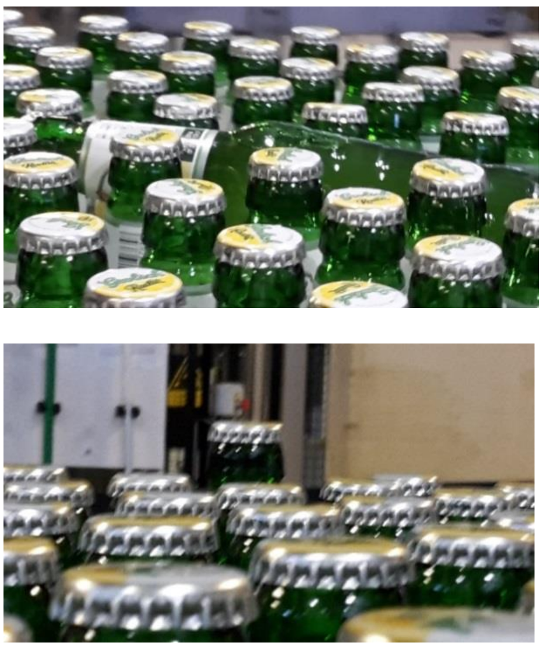


Figure 31: Grolsch Apollo bottles pop up

Side barrier

The size of the conveyor and its side barriers also is an important factor. The side barriers keep the bottles from falling off the side of the conveyor. They also keep the bottles from tipping over and guide the bottles through a bend. The width of the side barriers has to be adjusted to the width of the bottle. In an ideal situation the bottles are placed next to each other as can be seen in Figure 32 under an angle of 30 degrees. On most of the lines in the packaging hall this is not a problem, but as on line 7 a lot of bottle sizes are used it is always a compromise. Not all side barriers can be adjusted every time another bottle is used as this is too much work. Next to this there are areas where the bottles are not following the side barrier. An example can be seen in Figure 33. The bottles are not guided in the part of the barrier in the red circle. This is an area where the bottles are free to tip over. When the bottles are placed as shown in Figure 32 this is not possible as they support each other. Then reason this area is made is to give the conveyor some time to slow down when the conveyor starts to fill up without generating too much pressure on the bottles. If the barrier is adjusted this advantage is removed improving the pressure on the bottles and the chance of them to pop up. The chance of tipping bottles however decreases.

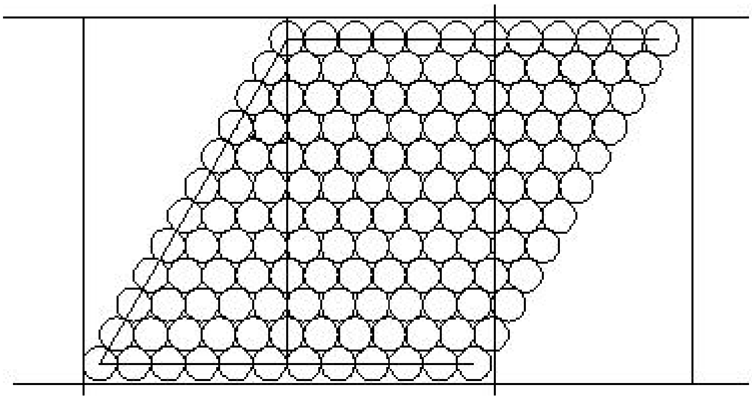


Figure 32: Layout of the bottles between the barriers

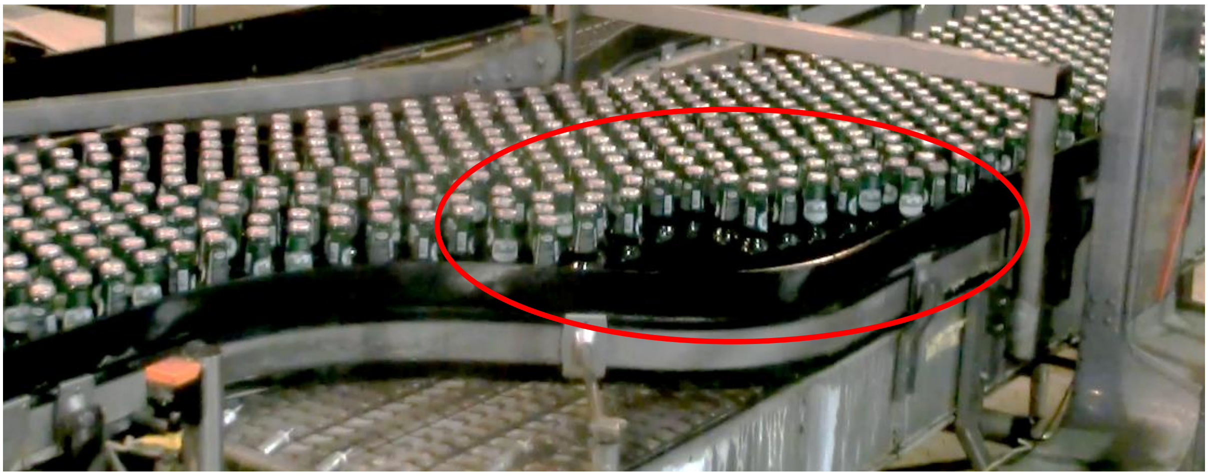


Figure 33: Part of the side barrier where the bottles are not guided

Conveyor speed

A final factor to be taken into account is the conveyor speed. On different parts of a line the bottles move on different speeds. For example the filler fills 40000 bottles an hour. This means that the bottle conveyor moves on an average speed of 11 bottles per second. As a bottle is fed in separately with an distance of approximate 10 centimeter in between and the base width of the bottle is about five centimeter the speed is eleven times 0,15 meter per second is 1,65 meter per second. When they move on the conveyor placed ten next to each other the speeds is ten times as low.

There is a limitation in speed called the limiting velocity. If there is a change of speed exceeding the limiting velocity the bottle will tip over. This velocity is determined by the stability angle of the bottle. This angle is defined as $\tan\alpha = \frac{r}{H}$. Where r is the radius of the bottle footprint and H is the height of the center of gravity of the bottle. (Figure 34)

Using this angle the limiting velocity can be calculated as following: $V = \sqrt{2 \cdot g \cdot r \cdot tan\left(\frac{\alpha}{2}\right)}$.

If a conveyor has a slope this has to be taken into account by compensating the stability angle for this: $V = \sqrt{2 \cdot g \cdot r \cdot tan\left(\frac{\alpha}{2} - \beta\right)}$

As a conveyor slows down or speeds up the center of gravity in a bottle will shift due to the shift of the beer inside and the partially tipping of the bottle. Therefore conveyors need to speed up and slowdown in steps below the limiting velocity.

Containers will tip over if $m \cdot g \cdot \mu \cdot H < m \cdot g \cdot r$ or $\mu < \frac{r}{H}$ during conveyor speed change.

where:
μ=coefficient of fiction between container and conveyor
m=mass of the container
g=gravity coefficient (9,8m/s^2)
r=radius of the container footprint
H=height of center of gravity of the bottle

From this it again can be seen that both lubrication and bottle size are an important factor in tipping over. If the friction coefficient is small enough bottles are far more stable on the conveyors. On a conveyor with a slope however too much lubrication can cause the bottle to slide down.

Many problems occurring due to speed changes on conveyors can be avoided by using lubricants to limit the coefficient of friction below r/H. In the market new materials are available for the conveyor surface. These plastic surfaces have such a low coefficient of friction that lubrication is not needed anymore. At Grolsch all the lines however are equipped with stainless steel bottle conveyors.

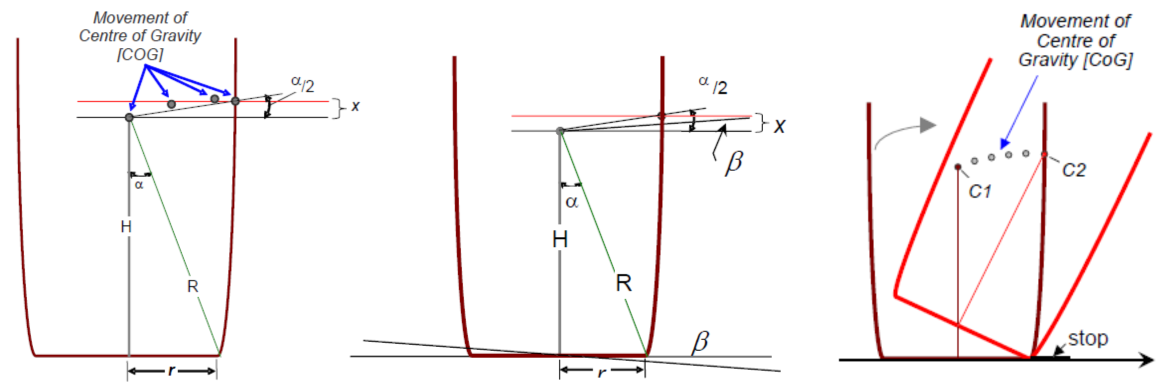


Figure 34