Implementation of Total Productive Maintenance on Haldex Assembly Line

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DEDICATION

We dedicate this thesis to our lovely parents.

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ABSTRACT

The core of this thesis is doing a study on assembly line of automatic brake adjusters at Haldex Brake Products AB and coming up with suggestions to implement total productive maintenance on the assembly line.

Companies around the world spend a lot of money on buying new equipments to increase production but a little is done to get hundred percent output from the machine for which it is designed for. Small losses in time or small deviations from designed capability are taken as normal machine behavior. But now because of increased competency levels and demand of quality products at lower costs, buying latest equipment is not a solution unless it is fully utilized. Total Productive Maintenance (TPM) is a plan which concentrates on total involvement of everyone from top management to all employees to implement a comprehensive maintenance program for all equipment throughout its life. This plan results in maximum effectiveness of equipment, tidier, neat and clean work place and morally boosted employees.

The initial study carried out on assembly line indicated some very obvious lapses in the system. Overall Equipment Effectiveness (OEE) was measured but not in a very effective manner. In this report a new model for measuring OEE is presented with emphasis on each of the three factors separately so that the actual problems should get immediate focus during the group meetings. Automatic and manual inputs are presented separately with a defined list of outputs. For recording quality problems, a quality analysis sheet is presented. A stepwise TPM implementation plan is derived for line with time schedule. Importance of management commitment is discussed. The pilot team building process is discussed as it is a basic step for TPM plan. Pilot team should be motivated enough to lead from the front. The necessary training should be provided to the pilot team. Training module is also presented in the thesis. An autonomous maintenance plan is also derived with checklists to strengthen TPM implementation. Each of the seven steps of autonomous maintenance are described with a list of daily and weekly checks of the equipments and whole assembly line. At the end of the report the work instructions for work station 6 operator and the outman are written as an example.

Keywords: Total productive maintenance, Overall equipment effectiveness, 5S, Autonomous maintenance, Preventive maintenance.

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1 INTRODUCTION

The companies throughout the world are trying to improve their profit without increasing the sale price of their products. This can only be done by minimizing the manufacturing cost of the products by increasing the productivity and reducing losses during production. Automation has played a great role in increasing productivity but it fails if the equipment is not maintained properly.

The motivation of this particular thesis project was derived from the company, Haldex Brake Products, ambitions to adopt the best set of practices in lean production. The company has started its journey towards lean, by identifying the core values of the entire business. The tools defined to support the business to focus on core values also include implementation of Total Productive Maintenance in the manufacturing units.

Total Productive Maintenance (TPM) is a maintenance program which involves a newly defined concept for maintaining production plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction.

1.1 Background of TPM

TPM originated from Japan as equipment management strategy designed to support the total quality management strategy. In middle of 19th century, Japanese realized that companies cannot produce a consistent quality product with poorly-maintained equipment. It began in 1950s and focused primarily on preventive maintenance. As new equipment was installed the focus was on implementing the preventive maintenance recommendations by the equipment manufacturer. A high value was placed on equipment that operated at designed specifications with no breakdowns. During 1960s, TPM focused on productive maintenance, recognizing the importance of reliability, maintenance and economic efficiency in plant design. Then in 1970s TPM evolved as a strategy focused on achieving preventive maintenance efficiency through a comprehensive system based on respect for individuals and total employee participation. It was at this time the word Total was added to productive maintenance (Tokutaro Suzuki. 1994).

Seiichi Nakajima is regarded as father of TPM by many writers and professionals. He pioneered the approach in Japan and exerted a major influence over the economic progress made by Japanese manufacturers from the late 1970's. Today the international focus on TPM is intensifying. The interest is expressed to support a company's full utilization of its assets.

1.2 Company Presentation

Haldex is an innovator in vehicle technology supplying proprietary systems and components for commercial vehicles incorporating trucks and trailers, cars and industrial vehicles, worldwide. Haldex has it's headquarter in Stockholm, Sweden, and is listed on the Stockholm Stock Exchange. Haldex has a yearly turnover of 8 bn SEK and employs 6,100 people worldwide.

1.3 Products

Haldex offers a broad product range, including: ABS and EBS systems, compressors, air dryers, regulating valves, brake actuators, automatic and manual brake adjusters, disc brakes and friction material.

A uniquely wide range of services is available from Haldex. These include expert consultancy for braking and suspension development, brake calculations, type approvals and application engineering. The aim is accurate specification for manufacturers and low cost of ownership for the operator.

The Group currently has 23 production facilities in Brazil, China, Germany, Great Britain, Hungary, India, Mexico, Sweden and the USA. And Landskrona is one of them.

In Landskrona, there are three Operating Units with a total number of employees of 800.

1. Foundation Brake
    - Automatic Brake Adjusters
    - Disc Brakes
    - Lining Wear Sensors
2. Traction
    - Four Wheel Drive Systems
3. Alfdex
    - Crank Case Gas Cleaning – Joint Venture with Alfa Laval

We worked in Automatic Brake Adjuster section in its final assembly area.

There are four assembly lines in the section namely: Wermtec 1, Wermtec 2, KK line and Manual line. We had the task of TPM implementation on Wermtec 1 only.

1.3.1 Purpose of Automatic brake adjusters

The Haldex Automatic Brake Adjuster (ABA) maintains the optimum lining to drum clearance. This ensures the shortest stopping distance possible for a safer, more reliable vehicle. Without ABAs the brakes would require four to five manual brake adjustments a year to maintain acceptable brake performance.

1.3.2 Working of ABA

The Haldex Adjuster is a clearance sensing brake adjuster that senses the lining to drum clearance and adjusts, if necessary, on the release of the brake.

The Haldex ABA helps ensure maximum brake performance with minimal maintenance. Backed by the longest warranty in the industry, they actually pay for themselves through increased service life.

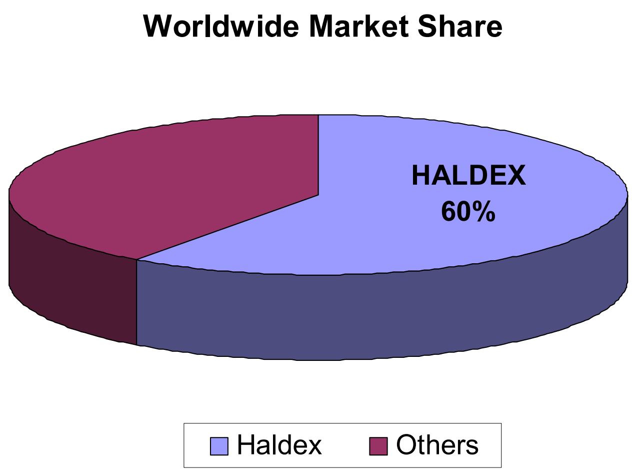

Fig 1.1 Haldex ABA worldwide market share

1.3.3 Working of SABA

The new Haldex SABA is the latest innovation in brake adjustment. The unique SABA Self-Setting Control arm design allows the control arm to be placed in any position, this virtually eliminates any installation errors.

Fig 1.2 S-ABA

Fig 1.3 ABA

1.4 Why TPM for Haldex assembly lines?

The assembly lines of brake adjusters were achieving about 67% production rate consistently. The goal was to improve it to 75%. We are calling it as production rate and not OEE number because for OEE measurement, a very trustable data is required for the time, speed and quality losses and current system for losses measurement was not good enough. For focused improvement one must know that in which particular area he needs more and quick attention. Only a trustable categorized data can depict such an area.

Concept of autonomous maintenance is important for improving equipment reliability. It was much needed to be adopted in Haldex assembly lines. As a pillar of TPM, autonomous maintenance plan is also worked out in our work.

1.5 Goal

The goal of the work was to study and analyze the assembly line WermTec1, and also to suggest the ways to implement Total Productive Maintenance for maximizing equipment effectiveness. It was divided into following parts:

- The losses during the production were to be pointed out and categorized into six big losses of OEE and giving suggestions to decrease the losses.
- Developing a model for trustable data collecting model, depicting the losses categorically for statistical analysis.
- Developing of a training module for TPM teams.
- Developing of Autonomous maintenance plan.

1.6 Scope

The project gives details about a time based stepwise implementation plan of TPM on assembly line Werm Tec1. The necessary training material for operators according to their level of education is also presented. A data collection model for statistical analysis of losses is also proposed.

The online data collection mode only gives time losses automatically, while the material losses are recorded manually.

2 METHODOLOGY

To categorize each loss into six big losses defined in Overall Equipment Effectiveness scale, for better clarification of problems and then suggesting improvements in problematic areas using trainings, 5S and autonomous maintenance plan. Training of the operators involved to improve their skills and better understanding of problems. And also involvement of operators in routine maintenance tasks.

2.1 Overall Equipment Effectiveness

The OEE measure is a unique Key Performance Indicator which provides a holistic view of asset utilisation. It drives an organisation to examine all aspects of asset performance in order to ensure we are obtaining the maximum benefit from a piece of equipment that is already bought and paid for.

OEE is simple and practical. It takes the most common and important sources of manufacturing productivity loss, places them into three primary categories and distills them into metrics that provide an excellent gauge for measuring where you are - and how you can improve!

OEE is frequently used as a key metric in TPM (Total Productive Maintenance) and Lean Manufacturing programs and gives a consistent way to measure the effectiveness of TPM and other initiatives by providing an overall framework for measuring production efficiency.

The first application of OEE can be traced to the late 1960's when it was used by Seiichi Nakajima at Nippon Denso as a key metric in TPM (Total Productive Maintenance). According to Nakajima S. 1989, "TPM is a plant improvement methodology, which enables continuous and rapid improvement of the manufacturing process through the use of employee involvement, employee empowerment and closed-loop measurement of results."

2.2 Six Big Losses

2.2.1 Downtime losses

1. Unexpected breakdowns

2. Machine setup and adjustments

2.2.2 Speed losses

3. Idling and minor stoppages

4. Reduced speed

2.2.3 Quality losses

5. Process defects

6. Scrap and rework

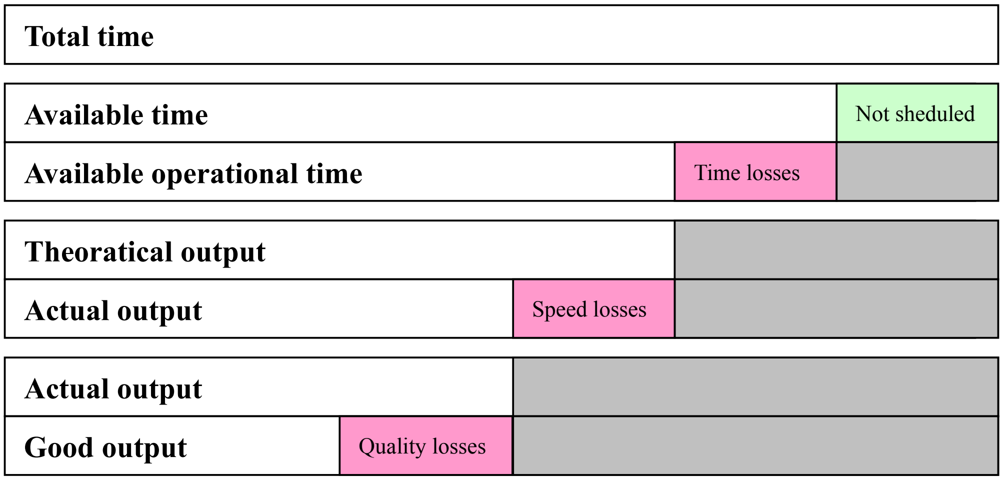

Fig 2.1 Overall Equipment Effectiveness diagram

2.3 5S

5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. Implementation of this method "cleans up" and organizes the workplace basically in its existing configuration, and it is typically the first lean method which organizations implement.

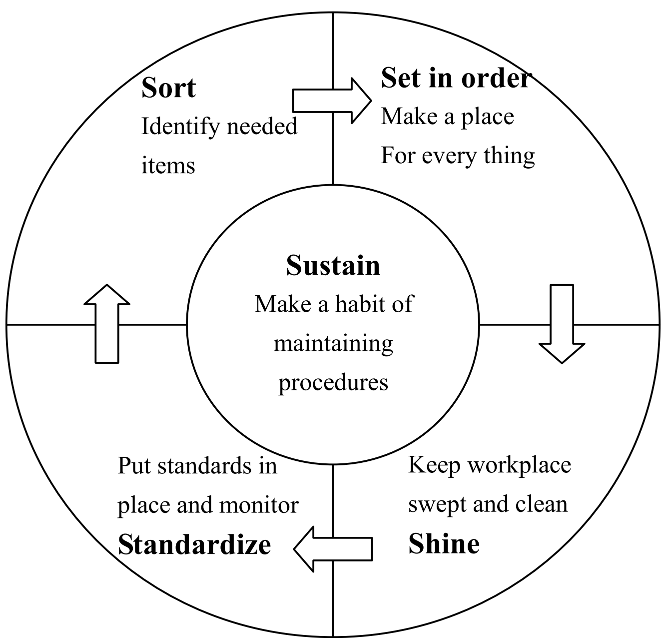

Fig 2.2 5S philosophy

- Seiri - *Sort* - the first step in making things cleaned up and organized
- Seiton - *Set In Orde*r - organize, identify and arrange everything in a work area
- Seoso - *Shine* - regular cleaning and maintenance
- Seiketsu- *Standardize* - make it easy to maintain - simplify and standardize
- Shitsuke -*Sustain* -maintaining what has been accomplished

The 5S pillars, provide a methodology for organizing, cleaning, developing, and sustaining a productive work environment. In the daily work of a company, routines that maintain organization and orderliness are essential to a smooth and efficient flow of activities. This lean method encourages workers to improve their working conditions and helps them to learn to reduce waste, unplanned downtime, and in-process inventory.

A typical 5S implementation would result in significant reductions in the square footage of space needed for existing operations. It also would result in the organization of tools and materials into labeled and color coded storage locations, as well as "kits" that contain just what is needed to perform a task.

3 DATA COLLECTION AND ANALYSIS

3.1 Process flow chart for ABA and SABA

There are three main components in brake adjusters: Housing, Worm Wheel and Worm Screw.

1. Housings; are imported from Spain in particular batches and machined in the machining area to get required dimensions. Then these are heat treated and then sent to paint house. From paint house the painted batches are set on the wrecks in the super market and specific batch is taken from there to assembly line when required. There is Kanban used between paint shop, heat treatment and machining.
2. Worm Wheels; are bought in castings and are then machined into many different models according to the requirement. The worm wheels are sent outside of the factory to a contractor for heat treatment. After that these are treated for surface smoothness in the plant. Then the wheels are placed in wrecks in super market and are carried to the assembly line when required. There is Kanban system between super market and surface smoothing section.
3. Worm Screws; are bought in shapes of rods and are cut and machined into two desired models. These are also sent to contractor for heat treatment. These are then carried to the assembly area where there is a marked place for both the models. And from there these are carried to the line when required.

The rest of the parts are either preassembled first and put on the wrecks in supermarket or directly from main store to wrecks and then are carried to assembly lines when required.

3.2 Current Value Stream Map of assembly line

A current state VSM was made to find the bottle neck. So cycle times for each manual and automatic stations were calculated. For cycle times, mean of 40 readings was taken for each operation. Station 3b was observed to be having the maximum operation time and hence was the pace maker. But it shifted to manual station 4 some times when the Adjuster arm has more then 3 bushings and if there is no extra operator.

Production plans are made on every week on shift wise planning. The assembly line receives the plans daily and the material is brought to the line as per plan.

One critical observation made during current state mapping showed that the work on different work stations is not balanced. This creates a lot of troubles in implementing single piece flow. So a study should be done on line balancing as well.

3.3 Cycle time calculations

Ten readings were taken from each of the four shifts and the mean was considered as the average cycle time for each of manual and automatic work stations. Stop watch was used for recording times.

3.4 Root cause analysis table

A root cause analysis table was made to investigate the reasons of production time losses and their duration. Four problems were categorized having different reasons.

1. Equipment Problems; included problems with the conveyer and the machines 3b, 4b, 5c, 6a, 6b, 6c and any other machine.
2. Part Problems; included passing and re-passing of defective parts.
3. Operator busy in other tasks; included fixing defective parts, bringing parts to be assembled to their respective work station, removal of filled boxes from WS 6 and bringing empty ones when the out man is no in sight.
4. Operator idle time; means the operator being idle for a time more than the cycle time of the pace maker or the part is waiting to be processed but there is no operator. This is very normal for a minute or two when the operators change their positions which they have to after every 90 minutes.

The study was carried out in all four shifts for two continuous hours in each. Two persons standing on either side of the line with the stop watches noted down whenever there was a stop on any station lasting more than the process cycle time. The tables were filled and the results were presented on bar graphs which showed a regular trend in each shift. In every shift 'no operator' emerged as the biggest problem, both in frequency and also the duration. Overall trend was the following graph;

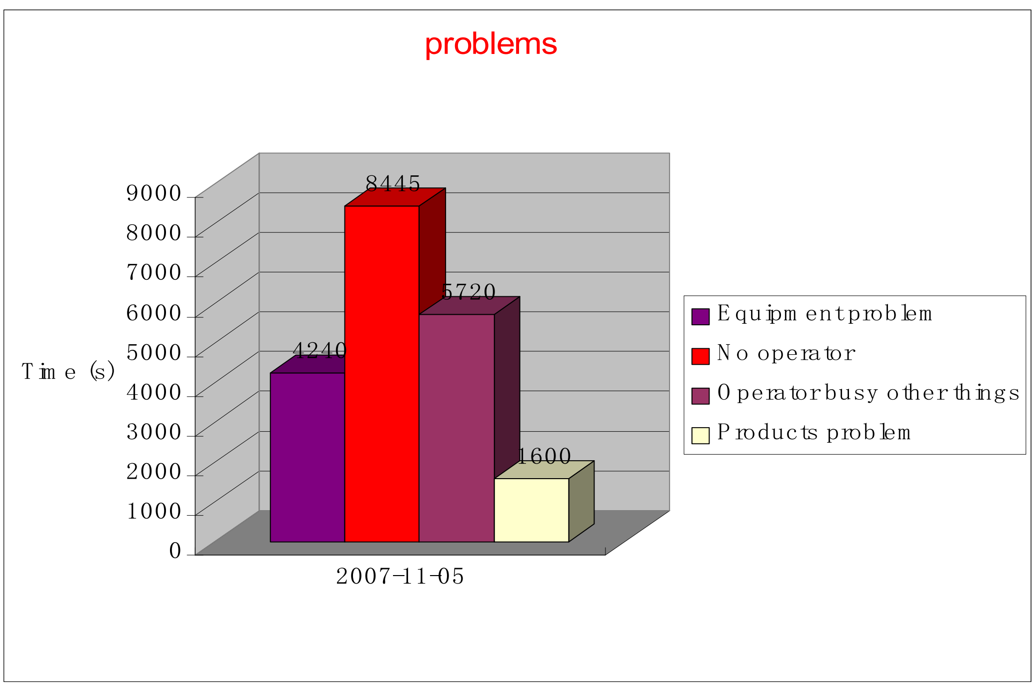

Fig 3.1 Problem trends

From the study of root cause analysis, it was clear that small stops are the most time wasting. And among those the stops due to the operators were the most. One notable thing is that when such stops happened, these were not documented or noted although such stops were the biggest reason for time loss. Operators were not much trained to get bothered about such losses. So, on the basis of such facts we decided to work on two different pillars for our project.

One was the stepwise implementation plan for Total Productive Maintenance including the training module and the second pillar was to work on a data collection model to record such stops for statistical analysis of problems.

4 PROPOSED IMPLEMENTATION PLAN FOR TPM

The implementation of TPM was necessary to increase the sense of ownership of equipment among the operators and developing their interest in work. The goal of increasing production can be achieved by active participation of operators.

A 10 step implementation plan was written.

4.1 Step 1: Announcement of TPM and top management commitment

Make all the employees aware of the change of shifting towards the new culture of TPM. Upper management commitment is the key to start with. By commitment we mean the sacrifice of short term goals in pursue of long term goals. The management must be ready to spare operators for trainings and meetings when required. The management must also be ready to invest in buying necessary equipments and accessories if required.

According to Moran and Avergun (1997), change is top-down and bottom-up. It must be top-down to provide vision and create structure; and it must be bottom-up to encourage participation and generate support. Ultimately, leading change is a shared responsibility of everyone in an organization, from top to bottom. To bring in changes, the managers have to prepare themselves to the changes before asking their employees to adopt the changes. Top management must be able to create an environment that effectively reduces or eliminate the fear for change. The management also must provide their employees with proper tools, techniques and other facilities to allow people to synthesize the new concepts, and align them to the new way of working. Firms must have top management support, understanding and commitment to embark on the TPM program as it involves a cultural change that cannot happen overnight. Hoffman and Mehra (1999) in their study described that the all four scholars; Deming, Juran, Crosby and Garvin, link top management involvement and commitment to both productivity and quality improvement programs.

The responsibility of the top management is to actively promote motivation, ability and favorable work environment (Nakajima, 1989). Of these three keys, motivation and ability will be the responsibility of the workers and that the creation of favorable work environment will be the responsibility of the management.

It would be good sign of commitment and involvement from upper management, if one of the top level managers, like Vice President, present at the TPM launching ceremony.

4.2 Step 2: Pilot Team building and meeting plan

This step needs a lot of care from management who build teams, as team is a group of people who are jointly responsible for achieving a shared goal. If one member fails then it can hinder the achievement of the collective goal. Even if the members fulfill their individual roles but they don't work in a cooperative manner, then they may not fulfill their potential or achieve as much as they could. Moreover the pilot team will work like a model for the rest of the teams to join so the members selected should be highly motivated to learn and implement new ideas, ready to adopt changes in working practices and should be made clear about the goal. Share with them that the company is beginning a very important event. Also tell them that TPM will allow them to make their work easier, safer and more efficient. Tell them that in the new system, the most important thing is their opinions, points of view and active participation, and that those who decide to participate will receive training that will allow them to have a bigger decision making role. After sharing this information with them, ask them if it would interest them to have the opportunity to participate. Only if their response is affirmative, consider inviting them to the pilot group training.

On the assembly line WermTec 1, a total of eight operators work. Six of them work on the 6 work stations, one is a reliever (each operator has a fifteen minutes break after every ninety minutes of work) and one is outman whose duties involve feeding of housings, worm wheels, worm screws and cover plates to their responding work stations. Outman is also responsible for preparation of worm wheels. These eight persons are directly reporting to a team leader who also in charge of three other assembly lines.

So the pilot team can consist of eight persons for the line, one team leader of their shift, the production manager and maintenance manager. The production manager and maintenance manager should be present at meetings. So the team comes out as:

8 operators

1 team leader

1 maintenance person

Production Manager

Maintenance Manager

This group will to promote and sustain TPM activities. In the beginning, weekly 1 hour meeting of the group should be organized for 1 month, after a successful start, the meeting can be held fortnightly, to assess the progress.

4.3 Step 3: Launch a formal training program for selected team

According to Jeffrey K. Liker (2004) “Teams do not do value added work, Individuals do. The teams coordinate the work, motivate and learn from each other. The teams suggest innovative ideas. Nevertheless, for the most part, it is more efficient for the individuals to do the actual detailed work necessary to produce a product”.

So the individual excellence and the team effectiveness should be balanced. For individual excellence, a training program should be held for in depth understanding of technical knowledge and a broad range of skills.

Nakajima (1989) mentioned that, to carry out the TPM activities, a company needs persons with strong maintenance and equipment-related skills. This is because one of the important goals of TPM is to raise workers’ skill levels and this only can be done if there is thorough and continuous training.

The training program should include the basic knowledge of following:

- What is TPM?

  A brief description about total productive maintenance, its advantages and challenges to adopt it, implementation plan and how to measure TPM, should be given.
- Knowledge about OEE

  As being the true measure of TPM, operators should understand that what is overall equipment effectiveness and how is it calculated.
- Knowledge about 5S

  What are different 5S and how they are implemented systematically to improve productivity, quality and safety?
- Categorization of losses into six big losses of OEE

  It is extremely important that the operators should know the losses categorically so that they can take care of each one of them.
- Knowledge about VSM (takt time and bottle neck)

  The current state value stream map should be shown to tell operators about the bottleneck and cycle times at each station so that they can work accordingly. The importance to know the exact takt time should be delivered to the operators.
- Knowledge about optimization of WIP (work in process)
- Basic training for preventive maintenance

  "Cleaning is maintaining". Everyday cleaning of equipment means everyday monitoring of equipment. It works like condition monitoring. Whenever there is a need for an equipment to be maintained is very easy to find before breakdown.

4.4 Step 4: Establish basic TPM policies and quantifiable goals

During the meetings the group should analyze the existing conditions and set goals which are specific, measurable, realistic and time based.

In early weeks the improvements should be assessed on the basis of trustable data. Ideas from the team members should be taken on further improvements and discussed to come up with some goals for the next meeting.

4.5 Step 5: Outline a detailed master deployment plan

After 3 months of start of pilot team, the team should develop a detailed master plan for both WT1 and WT2. The group should also derive a preliminary TPM implementation plan for KK line and the manual line, if possible. The plan should take care of following things:

1. Revised training requirements for operators.
2. Revised preventive maintenance plan for WermTec 1 and preliminary preventive maintenance plans for the rest of lines.
3. Need for new technology or equipment.

4.6 Step 6: TPM training (for one month) and Kick-off

According to the recommendations of pilot team, new teams should be formed for each line and their training should be started. After a month of training the official Kick off for TPM implementation for every line should take place with a small ceremony to emphasize its importance. This ceremony must involve people from higher management.

The training should include: basic knowledge about equipment for operators, it can be internal training held by maintenance persons. After basic training of employees, kick-off with the plan chalked out in step 5 by making TPM teams on every line.

4.7 Step 7: Improvement effectiveness of each piece of equipment

The teams should have weekly meeting in the beginning to analyze each piece of equipment separately on the basis of collected data and make recommendations for necessary improvements to be analyzed again at next meeting. The meeting should work according to PDCA cycle: which is Plan, Do, Check and Act.

4.8 Step 8:Develop an autonomous maintenance program for operators

After 1 month of kick-off the teams should be able to make autonomous maintenance[1] plan for their lines which includes routine cleaning and inspection that will help stabilize machine conditions.

4.9 Step 9: Develop a preventive maintenance plan

After 3 months of kick-off, review the preventive maintenance plan for every equipment and change it accordingly.

4.10 Step 10: Follow ups and Continuous improvement

Refine measurement process, carry out scoping study, gap analysis and accountabilities, periodically. Align short, medium and long-term goals under a single change agenda/master plan.

[1] Autonomous maintenance plan is derived in chapter 5 with daily and weekly checklist of each work station but it should be reviewed by the groups for necessary changes.

5 AUTONOMOUS MAINTENANCE

Tokutaro Suzuki (1994) writes as:

TPM improves corporate business results and creates pleasant and productive workplace by changing the way people think about and work with equipment throughout the company. Autonomous maintenance (maintenance performed by production department) is one of the most important basic building blocks of TPM program.

Autonomous maintenance is an important TPM Pillar which emphasizes the importance of the machine operator.

Historically, maintenance has been done by dedicated, highly skilled employees. But machine operators are around the equipment all of the time, and should be the first to identify oil/grease and air leaks and vibrations because of lose nuts and bolts.

5.1 What operators can do?

So the operators should work closely together with the maintenance people, and they can do this in 3 ways:

1. They can alert maintenance people

2. They can provide excellent information

3. They can perform routine maintenance

Autonomous Maintenance is a critical first step of TPM, and operators must be trained to close the gap between them and the maintenance staff, making it easier for both to work as one team.

5.2 Steps for AM implementation

Seven steps are implemented to progressively increase operator’s knowledge, participation and responsibility for their equipment. The steps start with the initial cleaning proceeding towards full self management. Steps 1 to 3 place priority on abolishing environments that cause accelerated deterioration, reversing deterioration and establishing and maintaining basic equipment conditions. The goals of these steps are to get operators interested in their equipment and help them shake off their self image as mere button pushers or switch flickers. In steps 4 and 5, operators are taught about inspection procedures. The goals of these steps are to reduce failures and develop operators who thoroughly understand their equipment. Last two steps are designed to upgrade autonomous maintenance and improvement activities by standardizing systems and methods. The ultimate goal of these steps is a robust organization and culture in which every workplace is full of self management.

1. Performing an initial cleaning and inspection

   We have developed a list of daily and weekly inspection and cleaning for each work station and the whole line as well, with the help of maintenance persons. Eliminate dust and dirt from the main body of the equipment. Expose irregularities such as minor defects, inaccessible places and contamination sources. Eliminate unnecessary and seldom used items and simplify the equipment.

2. Establishing countermeasures for the causes and effects of dirt and dust

TPM (Autonomous maintenance)

Red Tag (Maintenance)

Equipment Number ____________________

Date found ____________________

Found by ____________________

Date ____________________

Description of problem

____

____

____

Attach this tag to the equipment

Fig 5.1 Tag for marking equipment abnormality

TPM (Autonomous maintenance)

White Tag

Equipment Number ____________________

Date found ____________________

Found by ____________________

Date ____________________

Description of problem

____

____

____

____

Attach this tag to the equipment

Fig 5.2 Tag for marking abnormality

The key part in this step is not to clean for the sake of cleaning, but clean to inspect. As the team begins to clean they will identify defects. It can be wear and tear in equipment, lose or lost nuts and bolts due to vibrations, lubricant leakages or dirt and dust on machine parts which hide the parts to be inspected. The causes of such defects or problems should be found and countermeasures should be taken. The defects can be divided into two different categories, the first kind of defects are those which can be corrected by the operators themselves, while the second kind of defects are those which can only be corrected by maintenance. According to Tokutaro Suzuki (1994), using tag cards can be a good idea for such purposes.

Tag the location of each abnormality as it is spotted, using a card that shows when it was found, who found it and nature of the problem. This enables everyone to see what is going on and share in the activities. Use white tags for problems that operators can handle and red tags for ones that the maintenance department will handle. Tagging takes problems out of individual autonomous maintenance circles and involves everyone.

3. Establishing cleaning and routine maintenance standards (checklist)

   The list made by us should be reviewed by the TPM team and new cleaning and maintenance standards should be set which should include countermeasures for root causes of defects and cleaning routine of dusty parts. Formulate work standards that help in maintaining cleaning, lubrication and tightening levels with minimal time and effort.

4. Conducting a "standards and inspection" training

   The training should emphasize on standards of inspection for example the visual inspection of major parts, modification of equipment to aid inspection, finding and fixing minor defects. Inspection manuals should be developed and followed for the training.

5. Carrying out an autonomous equipment inspection

   Cleaning, lubrication and inspection standards should be practiced to maintain optimal equipment conditions. A review of equipment and human factor should be carried out to fix problems.

6. Organization and standardization of the workplace

   Improve work effectiveness, product quality and safety through work place organization and housekeeping. Set and practice control standards for raw material, WIP, tools and spare parts.

7. Continuous improvement of policies, standards and equipment

   Pinpoint the weaknesses in equipment and give suggestions in meetings to improve them to simplify the operations and increase reliability.

5.3 Benefits of AM

Autonomous maintenance will give the following main benefits:

1. The operators experience a sense of pride and ownership of their machines.
2. Machines and work areas are safer and easier to work around.
3. Breakdowns, defects and other losses are reduced.

5.4 AM list for checks

5.4.1 Daily checklist for each work station

Daily maintenance list:

Station 1:

1. Clean the sensor.

Station 2:

1. Check the torque.
2. Clean the corner between station 2 and station 3 daily (specially the green belt)

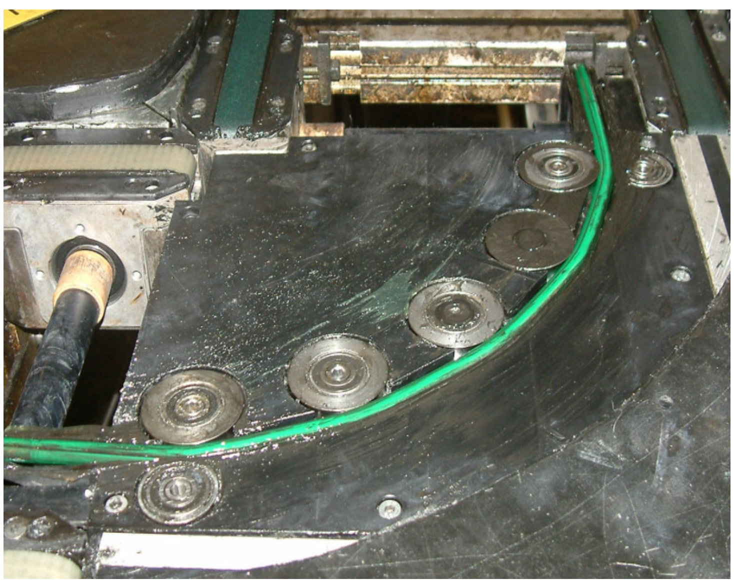

Fig 5.3 Corner between station 2 and 3

Station 3:

1. Clean the standing plate up and down; ensure that there are no screws, nipples etc.
2. Clean the under face of model check.
3. Clean the cylinder in station 3B, ensure there is no grease.

Fig 5.4 Clean the cylinder

4. Keep the rails of the conveyer clean, especially under 3B.

Fig 5.5 Keep the conveyer and under clean

5. Check the hydraulic oil, no air bubbles.

Station 4:

1. Keep the 4A turning system clean.

2. Check the spring in the hammer (for rivet).
3. Check the spring press bar.
4. Clean the table in the serial number press machine.

Station 5:

1. Clean the under face of model check.
2. Clean the grease machine head, and use hand to feel, if it is ok or not.
3. Check is the main grease machine, leaking or not?
4. Clean the sensor on the bush pressing handle.
5. Clean the corner of between 5 and 6 daily, especially the green belt.

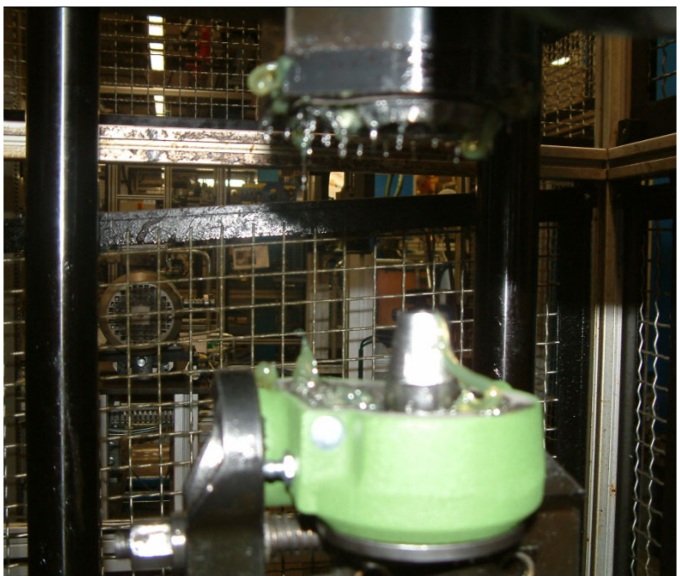

Fig 5.6 Grease machine head

Station 6:

1. Clean the under face of model check.
2. Keep the rails of the conveyer clean, especially the screw machine and final testing machine.

5.4.2 Daily checklist for whole line

1. Check the sensors, keep all of them clean.
2. Check all the screws are tight.
3. Check leakages.
4. Check the leakage of lubrication.
5. Keep all the buttons clean.

Fig 5.7 Keep buttons clean

5.4.3 Weekly check list for work stations

Station 5:

1. Check the bit of the screw machine, if it is ok or not?
2. Clean the around of the screw box, ensure that there are no screws on the table.
3. Take the nose out and clean it.
4. Clean the track of the feeder pot.
5. Check the white pipe, ensure that is not bended.

Station 6:

1. Take the nose out and clean it.
2. Clean the track of the feeder pot.
3. Check the blue pipe, ensure that is not bended.

5.4.4 Weekly checklist for whole line

1. Keep all the line clean.
2. Keep all the pallets clean.
3. Check all the alarm.
4. Check the hydraulic oil level.

6 PROPOSED MODEL FOR DATA COLLECTION

Establishing a data collection model should be seen as a fundamental step at the start of any improvement activity. The statistical analysis of a data collection process is compulsory for the project teams to efficiently and accurately measure and establish a baseline of current performance and also quantifying later improvements. The reason behind a lot of failed improvement projects is the lack of accurate and timely information.

6.1 Problems with current data collection system

6.1.1 Problems with small stops data recording

When we did a study for root cause analysis, we noticed that there are a lot of small stops which are never recorded. And normally the stops were repeating on the same equipments due to same reason again and again. These small interruptions were wasting the most of the production time but the management did not exactly know those because there was no data collection system which could show the frequency or duration of such stops.

6.1.2 Problems with breakdown data recording

Also we got the data for breakdowns for which Haldex uses the system Tekla. After going through that data, we came to the conclusion that the data was not trustable at all because it was totally manual and dependent on operators. Apparently the operators were not using Tekla properly because they were not trained enough to use that. This data was very important not only for OEE but also for maintenance department for budgeting.

6.1.3 Problems with quality control data recording

Losses in quality are the most critical for any process. So to reduce the losses in quality, the root causes leading to bad quality should be taken care of. Trustable data is necessary for the analysis and improvement. The concept of single time pass was not followed and it was quite normal to re pass a part through a machine for more than one time before taking that to the fixing station. There was record keeping for the number of parts scraped but there was no record keeping for the problems or defects which led for the part to be scrapped. Also the parts which were not ok in first attempt but were ok after rework were not documented.

6.2 Summary of problems

We can summarize the above discussion by pointing out the main problems which need to be solved:

1. Tekla and the assembly line were not directly connected. Tekla was 100 percent dependent on workers i.e. operators and technicians.

   Currently it works as follows:

Whenever there is a breakdown, the operator responsible at that station logs in the system Tekla and presses a command which tells the system that the line has stopped and technician is called to fix the problem. The system records that time as the start of down time. The technician arrives, fixes the problem and logs in the system and writes the description of the problem occurred and whatever he did to solve that or if he replaced some parts. After that when the line is again started the operator is supposed to log in again and tell the system that the line has started. Then the system knows the total downtime of the line due to breakdown.

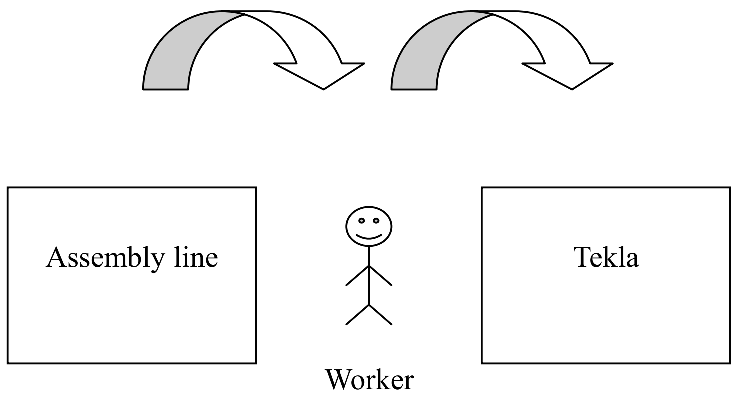

Fig 6.1 Current use of Tekla

But the last step from operator was always missing. Also many times the technician was too busy to log in as he had to rush to some other machine. This led to a breakdown data which was extremely unreliable. For example according to Tekla, there were only 12 breakdowns in the whole month of September and the number of breakdowns is 5 in October on wermtec1. While this number is 23 in the month of May.

So the three time manual input was required for one breakdown.

2. The plan for production line is to step up the OEE from 66% to 75% but it seems like an ambition only unless the different losses are categorized. When the different loss causes are known then they can be worked out. The improvement work should start from the biggest one. According to our study, small interruptions were the biggest contributors to the time losses. These small losses were not registered and hence required an automatic registration. The equipment's operational status is required in order to obtain a complete picture of shorter, reoccurring stoppages. Short, frequent interruptions, which may sometimes be interpreted as a part of the machine's normal behavior, amount to a big loss in production time in the end.

6.3 Solutions for data collection system

6.3.1 Online data collection

Reliable data is an essential support for continues improvement. The equipment and different manual steps of assembly should be monitored closely. Online data should be recorded and analyzed statistically after certain time periods.

The two main above mentioned problems must be solved and we have laid down a simple data collection model for this purpose.

The system Tekla is made more efficient by reduction of manual data entry dependency and its role is extended by connecting the critical equipment and manual stations with it. The model generates following statistics automatically:

- Line status in real time
- Each machine's operational status in real time
- Breakdown times (number of occurrences and durations)
- Small stop times (number of occurrences and durations)
- Disruptions
- Produced parts
- Losses

We define these terms as:

1. Every machine on the line has light signals which are green when the machine is running without any problem. But whenever there is a technical problem the red light glows. That signal of red light can be taken and used in the system.
2. Breakdowns and small stops can be differentiated in two manners. One way is the duration. A break point time can be set for example if a stop is less than three minutes, it is recorded as small stop and if it is more than three minutes then recorded as breakdown. The second manner can be like if the problem is fixed by he operator himself/herself and technician was not called, this can be regarded as small stop. Otherwise if the technician is called then it falls in breakdown category.
3. Small stops are not only connected to equipment but also to the manual work stations. Presently on the conveyer, a pallet comes to a work station and stops by a stopper. Operator, after finishing his/her job presses a green button to release the part. That green button signal is taken and used in the system but with two presses, one when the pallet arrives and the other when it is released. Cycle time for each work station is defined and if the time interval between two presses exceeds the cycle time then it is recorded as either small stop or disruption.
4. Disruptions are closely related to small stops. The pace maker of the line is machine 3b which takes 27 seconds for its process. Other machines and manual stations have smaller cycle times some of them have even 10 seconds. So if such a machine or work station with 10 seconds cycle time stops, it can afford stop for 17 seconds

without affecting the production output. These kind of small stops are called disruptions.

Cycle time of station + stop time < 27 seconds (cycle time of pace maker)

Disruptions also need to be recorded to analyze the small problems faced by any machine or operator.

5. The number of parts produced per hour or per shift.
6. Time losses are presented and compared for different stations.

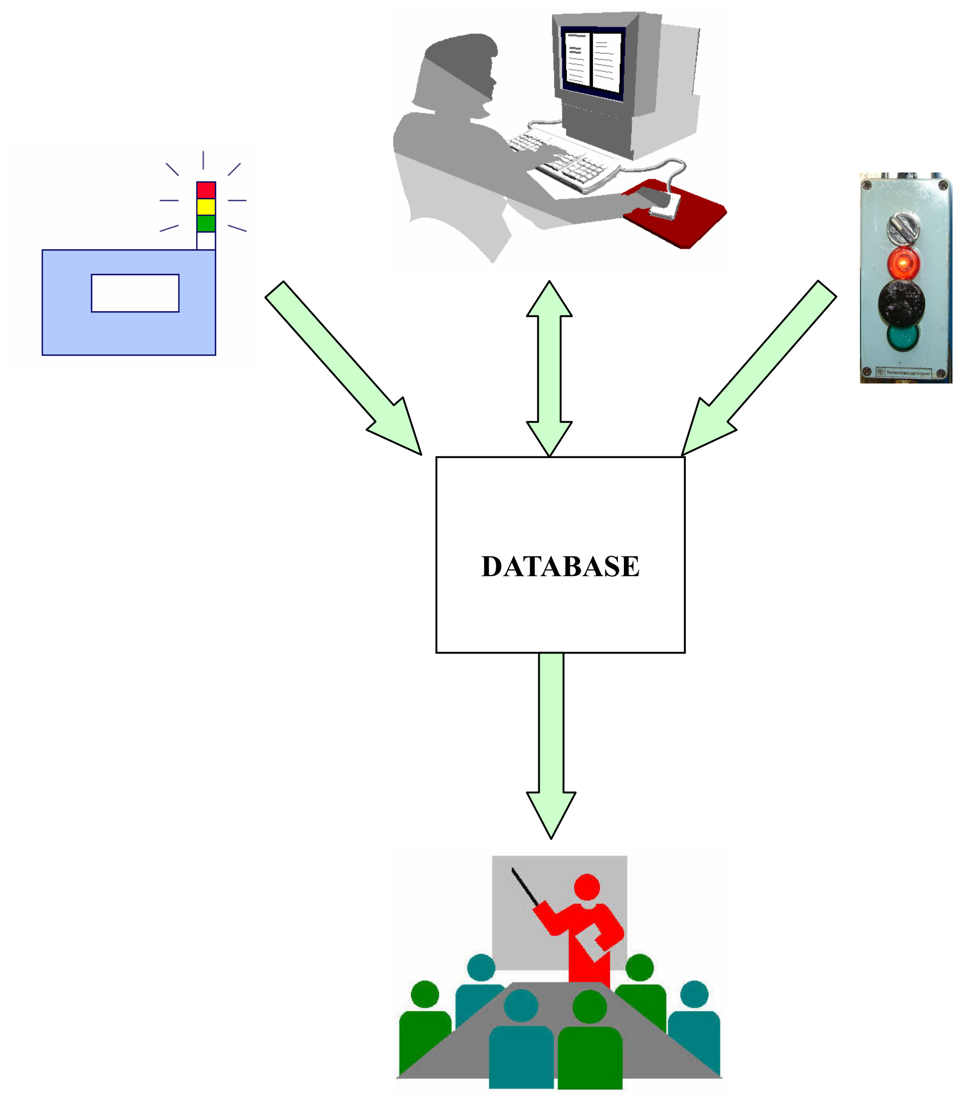

Fig 6.2 Data collection model showing direct machine signal input, manual input from computer and input from pressing of button by operator. The status of line can be seen on the computer system. The results from the database should be presented in group meetings.

Following manual input is also needed for complete reports:

- Breakdown cause and remedial action taken
- Material loss
- Change of batch

1. In the case of a breakdown, the technician has to enter a report showing the cause of breakdown, the action taken, number of working hours and parts changed if any.
2. The model does not take direct inputs from material loss. So if there is any material to be scraped, it should go through a manual procedure defined in Quality problem data recording.
3. Whenever there is a change in batch, it has to be entered in the system to trace out if there is a problem with any particular station when a particular batch is being produced.

6.3.1.1 Limitation of model

This model does not record the quality losses in the form of material loss or scrapped. There is a manual procedure for the quality problems consisting of a quality analysis sheet(Appendix A) which is originally developed by Mr. Anders who is in charge of six sigma projects in Haldex.

Only duration and frequency of stoppage time of equipment is directly recorded but the reasons of stoppage have to be added manually for some machines.

Difference in skill level of operators can also limit the use of the model.

6.3.2 Quality problems data recording

Quality problems are recorded manually. Each part which is to be scrapped has to go through a quality analysis sheet for defective parts. Whenever there is a problem with some part, it is taken to the manual line by the out man who fixes the problem. He has to fill the sheet and sign it.

The operator on the line should fill the week, shift, serial number, part number and possible cause of failure of the part and sign the sheet.

While the out man should take that part to manual line and check if the problem can be solved without dismantling of part. And if it has to be dismantled at repair bench and some sub part has to be replaced, it should be noted down and also should be noted that if the defected part can be reused or scraped. Note batch number and part number. Remove the stub card and put together with defected item in a bag and then in the "repair box" if it can be reused, otherwise put the part in scrap box.

This sheet must be filled whenever there is a problem with the part which can not be fixed by the operator in first attempt. Kept in record and analyzed during meetings.

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Appendix A Quality analysis sheet for defective parts

week____ shift ____

Wermtec Line 1

B/N ___________

P/N___________

Possible cause of failure

Sign

Manual Line (test if the brake adjuster is ok)

- ☐ OK
- ☐ NOT OK

  If not ok, dismantle and investigate possible cause of failure at the repair bench.

Repair bench (Dismantle, change and tick defected item)

Tick defected item

- ☐ House
- ☐ Worm shaft
- ☐ Worm wheel
- ☐ One-way clutch
- ☐ Bearing
- ☐ Other (mention)

Note (if defected item is scraped or reused):

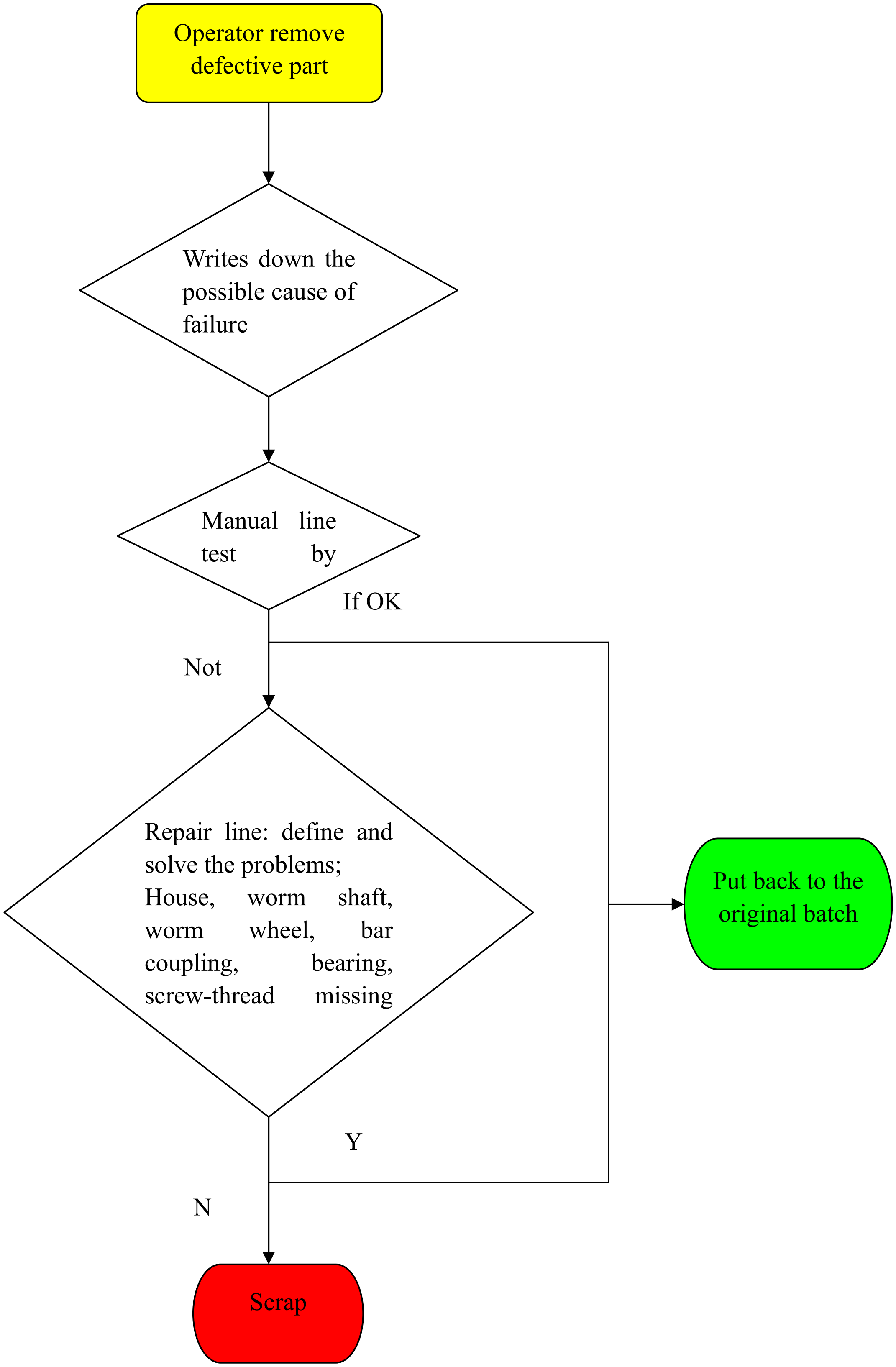
Sign

Note B/N and P/N below. Remove the stub card and put together with defected item in a bag and then in the “repair box” if it can be reused, otherwise put the part in scrap box.

S/N ___________

P/N ___________

Appendix B Defective part flow chart



Appendix C Work Instructions for WS 6 operator and Outman

Why are effective work instructions important?
Work instruction is the most basic tool used in this line to help the employee follow a sequence of steps. Inadequate work instructions could result in returned product, loss of materials, decreased OEE etc. Work instructions can have a major impact on any management system effectiveness. If instructions are difficult to follow, the operator will make errors in implementing the steps. Optimizing operating instructions can definitely lead to a better quality and quantity of the products.

Definition of work instruction:
Work instruction is a detailed sequence of steps that an operator needs to follow each time when he/she perform a task. The purpose of a work instruction is to organize steps in a logical format so that an operator can easily follow it independently.

WS 6 instructions:

1) Take the house from the pallet.
2) Send the pallet to WS1 by pressing green button.
3) Assemble pin if necessary.
4) Clean the house, check the stamp (G) on back lock.
5) Check control instructions "9800608" 1.1—1.8.
6) If it is a new batch, then, check control instruction "9800608" from 1.1—2.6 for first three parts and from fourth part, back to the fifth step.
7) Place the brake adjuster in the pallet according to the packing instruction No.20001640 or 20033440.
8) When the batch is finished, sign the pink sheet.
9) If 6A stops, then, operator should screw manually and if the problem occurs frequently, call the maintenance to fix the problem.
10) If 6B has a problem, call the maintenance at once, and return the cover arm manually while waiting for the maintenance person comes.
11) If the part is defective and can't be fixed at WS6, fill the nonconformance report and place the part in the trolley.

Out man instructions:

1) Get the order in a file.
2) Bring housings to WS1 and cover plate to WS5.
3) Prepare worm wheels with rings and transport to WS1, number of worm wheels should be equal to Number of housings.
4) Move the empty boxes in WS1 to special packing area.
5) Move the final products to the packing place and prepare the empty box for WS6, after finishing of the batch, enter information in computer database.
6) Move empty worm screw boxes from empty box area to machine hall and bring filled

boxes to filled boxes area.

7) Repair the defective parts placed at any station.
8) Fix the nipple which in WS1 and control (8---10N/m) it 5/shift, fill and sign the log note.
9) Control the house 3/shift on master testing machine, fill and sign the compare measurement file.