IMPLEMENTATION OF "MATRIX DATA CODE" MARKING ON GEAR KITS

Combination of "clear text and matrix code" marking on pinion and crown wheel

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PREFACE

I want to thank Zlate Dimkovski for all the support, inspiration and all the good tips with which he has contributed at Halmstad University. Thank you to the staff at University of Halmstad who took the time to explain the different topics that made me understand the importance of an engineering approach.

I would also like to thank the company Meritor HVS AB, which allowed me to do my thesis at their place and counted me as one of their own. Thank you to those employees who helped when it was necessary. I especially want to thank Milenko Kvrgic and Oscar Ekelund for always giving me answers to my questions and guiding me forward.

With this work I hope that the marking of pinion and crown wheel is facilitated for Meritor and that it will come in handy when they continue with the selection of metal products. Hopefully, the material can also come to care for others who are interested in marking of metal products to be hardened and phosphated.
ABSTRACT

This thesis has been performed in cooperation with the company Meritor HVS AB in order to implement a matrix data codes marked on gear kits for reducing potential human error when inputting the information inside the company's business system. A sustainable marking is the basis for product traceability to follow a product's way from the raw material to finished product so that they can be traced throughout their life cycle. To investigate the current technology, two different marking and reading methods were tested: a laser and dot peen method. It has been found that the dot peen method was more suitable for Meritor to mark the wheel because the marks were clearer and could be read both with the naked eye and scanner. Conversely, the contrast of the mark created by the laser method was not as readable as the dotted marks and there has been a larger risk to be mechanically removed because of its thin thickness. As a result, the matrix data code made by dot peen method has been fully implemented in the pinion’s and crown wheel’s production in Meritor.
## NOMENCLATURE

<table>
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<th>Words/Symbols</th>
<th>Explanation</th>
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<tr>
<td>Pallet flag</td>
<td>A sheet with permanent information on pallets’ content.</td>
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<tr>
<td>Hardening</td>
<td>Implies that the steel mechanical properties are improved by heating the steel in the furnace.</td>
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<td>Case hardening</td>
<td>The parts are heated to obtain a hard surface. The hardening depth is normally between 0, 2-1,5 mm and controlled by the temperature and holding time in the oven. Results in a hard surface and a soft core.</td>
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<tr>
<td>DPM</td>
<td>Direct-part marking.</td>
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<tr>
<td>Business systems</td>
<td>Computer systems information about the company's product and production stored in it.</td>
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<td>Gear kit</td>
<td>A kit consists of some gears and other details that transmit motion force.</td>
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<td>Patching</td>
<td>A machining process in which two surfaces are rubbed with an abrasive between them.</td>
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<tr>
<td>Hard turning</td>
<td>Smooth turning / adjusting after the hardening process.</td>
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<tr>
<td>Phosphating</td>
<td>Phosphating gives the surface a thin layer of phosphates as corrosion protection and with better tribological properties.</td>
</tr>
<tr>
<td>Annealing</td>
<td>Heat the material to be sufficiently tough for processing.</td>
</tr>
<tr>
<td>Tribology</td>
<td>The science and engineering of interacting surfaces in relative motion.[20]</td>
</tr>
<tr>
<td>Pin stamping</td>
<td>The mechanized process that makes marking on product. It is available on different materials. Dot peen marking system.</td>
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<tr>
<td>Customer Value</td>
<td>The value of the benefits a customer can get out of a specific product or service. [17]</td>
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<tr>
<td>Blasting</td>
<td>Particles are inflated by a strong stream towards a surface to clean or reshape the surface.</td>
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1 INTRODUCTION

The purpose of this project is to examine the relevant methods of marking and reading of the marked data on the pinion and crown wheel which are mounted in gear kit for heavy vehicles. Marking shall be durable and readable after hardening and phosphating process. Reading of the marked data on designated details is done by using the scanner to eliminate any human errors. This scanner reads the marked information in the form of clear text and matrix codes and transfers the scanned information to the company business systems.

1.1 The Company

Meritor is a leading global supplier, see figure 1.1 [1], of drive train, mobility, braking and aftermarket solutions for commercial vehicle and industrial markets. With more than a 100-year legacy of providing innovative products that offer superior performance, efficiency and reliability, the company serves commercial truck, trailer, defense, specialty and aftermarket customers around the world. [2]
The factory in Lindesberg, see figure 1.2, was previously owned by Volvo Trucks and sold at the turn of 1998-99 to Meritor Automotive Inc., which after a merger with Arvin in 2000 was part of ArvinMeritor Group until March 2011 when the name Meritor withdrawn. In Lindesberg manufactured front and rear axles for heavy vehicles. Most of the production is delivered to Volvo Trucks’ different assembly plants.

![Lindesberg's factory](image)

**Figure 1.2, Meritor, Lindesberg's company, aerial photo (2014) [1]**

### 1.1.1 Facts about the Lindesberg's factory

- **Company name:** Meritor HVS AB
- **Staff (October 10, 2014)**
  - Officials: 86
  - Officials - hired: 3
  - Production Staff: 838
  - Total: 927
- **Buildings**
  - Total building area: 55,000 sq.m.
  - Capacity of 130,000 rear axles and gears / year
  - 105,000 front axles / year
- **Sales:** SEK 2.8 billion in 2013. [1]
1.1.2 Meritor’s products in Lindesberg’s factory

The differential (see figure 1.3) is a type of gear shift, which divides a drive torque in two or more axles. The shafts may rotate at different speeds so that the sums of the angular velocities are constant. The differential gear splits the driving elements in two or more axes so that each of them can rotate at different speeds at a constant angular velocity. This compensates the distance to the vehicle’s inner and outer wheels when the vehicle turns.

A differential is a particular type of simple planetary gear train that has the property that the angular velocity of its carrier is the average of the angular velocities of its sun and annular gears. [3]

A rear axle connects the rear wheels in four-wheeled motor vehicles. A rear axle need not necessarily have the shape of a shaft but can be constructed in many different ways. A vehicle with more than two axles (see figure 1.4) can have multiple rear axles, they are referred to as front and rear axle.

In a rear axle assembly, engine power enters the drive pinion gear from the drive shaft assembly and differential pinion yoke/flange. The drive pinion gear, which is in mesh with the ring gear (crown wheel), causes the ring gear to turn. The interaction of the ring and drive pinion gears turns the power flow at a 90° angle. [4]
The drive pinion gear is a hardened-steel gear with an integral shaft. It is machined to mesh with and rotate the ring gear. The end of the shaft opposite the gear has external splines that fit the internal splines of the differential pinion yoke/flange. The gear is supported by two tapered roller bearings, called pinion bearings. [4]
Figure 1.6 below shows the components manufactured by Meritor in Lindesberg.

1.1.3 Company’s vision and mission

Vision
To be the recognized leader in providing advanced drive train, mobility, braking and aftermarket solutions for the global commercial vehicle and industrial markets. [2]

Mission
- We anticipate our customers’ needs by developing innovative products that provide superior performance, energy efficiency and reliability.
- We provide a leading portfolio of differentiated services supporting our customers’ products throughout their lifecycle.
- We distinguish ourselves through our ability to consistently deliver on our commitments while maximizing value for our shareholders, customers, and employees. [2]

Improve vehicle stability, ride and handling is a constant focus for Meritor. With nearly a century of advanced technology and product innovation experience, we deliver products that give our customers a competitive advantage. Meritor provides unrivaled expertise in lightweight, yet economical, suspension solutions that add real value to the end user automotive experience. We help our customers
optimize overall vehicle performance to meet, and often exceed, design characteristics and specifications laid down by the original. For suspension system that moves you ahead of the competition, expect Meritor. [2].

In order to gain a competitive advantage against the rest of the market, Meritor is working constantly in cross-functional improvement teams in collaboration with the client to achieve the best possible results. Examples of improvements are:

- Creating sustainable profitability
- Introducing new ways of working to become more competitive
- Production development
- Staff with the right skills
- Streamline production flow by eliminating any human errors

Meritor is equipped with the latest technology in production, assembly and associated equipment to meet the high demands of the automotive industry in terms of quality, tolerances and design.

1.2 Background

It is becoming increasingly important in industry to select the correct marking technique among original equipment manufacturers to track products over their entire life cycle. The goal is to find a method that the company can use for a fast, durable and economical way to mark their products with good quality. The marking should be read by using a scanner. The reader reads and transfers the selection to the business system.

1.2.1 Aim of the study

Implement the marking of gear kits which is the heart of a central gear. The marking contains identification and attribute data. At the start of production (soft turning) the data is marked on the pinion and crown wheel. Patching is a process where crown wheel is paired with a pinion. The process allows individual customized interfaces for those mentioned details in the gear kit. Patch data is saved and follow the product (gear kit) to the assembly. The company marks their products with dot peen technology at the beginning of the process, but the problem is that the marking is not readable after hardening and phosphating processes for this reason when the operator enters the numbers from the marking in the business system; there is great risk of human error. By improving the quality of marking and reading the marking by using a reader, human error is
eliminated and assemblers can get the right product.

1.2.2 The project

To do flawlessly in the assembly, pinion and crown wheel (see figure 1.7) should be marked with matrix data code that will be read later in the installation process and provide the right data to the assemblers. Pinion and crown wheel as in patching process are rubbed together, compelled and mounted in the same gear kit.

![Conventional differential, Pinion and crown wheel](image)

Figure 1.7, Conventional differential, Pinion and crown wheel (2015) [5]

1.2.3 Problem definition

It is becoming increasingly important in industry to select the correct marking technique among original equipment manufacturers to track products over their entire life cycle. The traceability will improve product’s quality. It helps to find the root cause for any errors and quality defects. Choosing the correct technology for product marking is important and is affected by many factors such as for example material, marking technique, space for the marking, process before and after marking. The aim is to find a method that the company can use for a fast, durable and economical way to mark their products with good quality. The mark should be read by using a scanner. The scanner reads and transfers the information
from the selection to the business system in the computer.

A thorough analysis of the problem identified two parts of the problem

1. Marking
2. Reading of the marking

1.2.4 Research questions

- Analyze current methodology and risks of error.
- What safety does matrix marking invite?
- In which part of the process, shall the products be marked?
- Which parts of the data that are marked on the product will come in matrix form and which ones should be readable by the human eye?
- How to read the matrix code in production flow?

1.3 Limitations

Current marking’s systems and the process should be controlled. Possible options for changes in the process and the marking’s method are investigated.

All tests of new methods for marking pinion and crown wheel must be carried out in the company's test center or at the supplier of the equipment.

The project does not cover …

- … production of new pinion and crown wheel.
- … any changes in the business system.
- … work in any other field than above the labeling of pinion and crown wheel.

1.4 Study environment

The project is carried out primarily at the company where an office has been offered, including office furniture and office supplies. The supervisor and all the technicians are located in the same corridor and are accessible when needed to discuss technical issues. They help with the facts about the company's approach and knowledge of the production of pinion and crown wheel.
Part of the project description will be carried out from home, where there are opportunities for communication with the supervisor of Halmstad University through Emil and phone calls. The supervisor at Halmstad University stands for competence, including knowledge surrounding metal production where he has experience in the mentioned field, and about the selection methods. The assisting supervisors are there to help with, inter alia, labeling technology and other technical assistance.

1.4.1 Technical issue

In order for the reader to cope with the reading, requires good quality of the marking and a suitable light source. Marking quality is affected by various factors as hardness of the material, machine’s air pressure, pin tip’s angle, pin tip’s diameter, surface roughness and surface processing after the marking. Another important factor is light and light reflection. This is influenced by surface background color; light sources nearby for example sunshine radiation through a window, the light sources within the reader and setting of the angle when holding the reader.

1.4.2 What the company has done in the past

The company uses dot peen technology to mark its products. Entering the marked information on the products in the business system is done manually. In the last station in the machining process, the operator reads the article and serial number, and types these data into the business system and forwards the products to the store. Then, the assemblers take up the products from the store according to their assembly orders. It is important that the patched crown wheel and pinion is assembled in one and the same gear kit. In this step an error can be discovered. The assembler cannot find the correct patched details to be assembled. The assembler looks at the computer screen in the business system where the article number does not match the article number listed on the products. The company has found the root causes of the error and tested in various ways to eliminate the error. One of the root causes of reading errors is unwanted marks from the lathe chuck (see figure 1.8) on the pinion surface, the same surface to be marked. Another reason is the product surface color that changes after hardening and becomes even fuzzier after blasting and phosphating. Some examples of measures that the company has done until now to eliminate the reading error is to change the format style of some figures for example 8 and 3 to facilitate to separate them from each other.
If a mark from the lathe chuck meets on the number 3, it becomes difficult to separate it from the number 8. They use an oil-based white wax in the form of pen for easier reading. Dragging the white wax on the surface fills the track with white wax, which makes it easier to read text or numbers that are on the surface.

![Unwanted marks from lathe chuck on the pinion surface.](image)

**Figure1.8, Unwanted marks from lathe chuck on the pinion surface.**

### 1.4.3 What others have done

Many manufacturers have started using direct part marking (DPM), which permanently marks parts with a serial number that provides the ability to track a product throughout its life cycle because the traditional non-direct part marking technology for example stickers, do not allow tracking throughout the life cycle. DPM is used extensively by medical manufacturers to facilitate reliable identification of parts. The information may be in the form of readable alphanumeric and barcode or Data Matrix codes.
2 METHOD

In this project, qualitative methods have been used. The choice of method is based on the search for deeper understanding of the advantages and disadvantages of different marking methods for metal products and various marking styles, e.g. clear text or matrix codes. The second area investigated during the project is the reading of the selected data on metal products using the scanner.

Data collection approaches for qualitative research usually involves:

1. Direct interaction with individuals on one to one basis
2. Or direct interaction with individuals in a group setting

Qualitative research data collection methods are time consuming; therefore data is usually collected from a smaller sample than would be the case for qualitative approaches- therefore this makes qualitative research more expensive.

The benefits of the qualitative approach is that the information is richer and has a deeper insight into the phenomenon under study

The main methods for collecting qualitative data are:

1. Individual interviews
2. Focus groups
3. Observations
4. Action research.[6]

2.1 Information collection

During the work, collected information and source criticism has been important for a well-conceived report. The reference materials used were taken from books, Internet articles, and from the company Meritor.

Printed literature has been simple to double check and revise for a secure source reference in this report. Traceability has been high, but the information has not been enough than that which has seemed to be "state of the art" for the best, latest information. For this reason, more reference material has been downloaded from the Internet and corporate websites specialized in the business field, than from the books.

The sources on the Internet has been more difficult to see through and examine for safe source references but thinking of source criticism has permeated the work to convey a credible report in the work of marking and reading of data marked information on the metal products. Traceability can therefore be low on many
pages, but the information is more current than the books of the websites where information has been obtained. No sources which lacked creator or good background information have been included for the reason that the information may be false.

A large part of the information collected by the contact and visits to some companies within the marking technique to examine their technology and opportunities for both marking and reading, as well as trying their recommended methods and compare the results with the company's requirements.

2.2 Visit at Sign & Print 2015-03-05 in Stockholm

An exhibition in the folder production presented cutting, creasing, folding, laminating wire binding, PUR bonding and laser marking. In this exhibition was collected some information about laser marking technology. General information about laser marking was useful but directed more towards 3D printing, label printing and marking on plastic and packaging.

2.3 Visit at NERMANS Märkning 2015-03-25 in Karlstad

NERMANS Märkning is a company with a broad range of marking machines and marking equipment. They have labeling technology in the engineering, wood products and packaging industry. NERMANS Märkning has advanced noticeably in machines with high precision that works on most materials. This includes for example, laser marking, industrial inkjet and pin stamping machinery (Dot peen marking system).

Various tests of marking methods made during the day based on clear advantages and disadvantages of different approaches with regard to Meritor's needs and requirements.

Test methods include pin stamping with different air pressure and pin sizes, laser marking and reading of marked data on test pieces (iron sheets) and pinion and crown wheel before the curing and phosphating process at Meritor. The purpose of the marking of data in the form of numbers and letters, as well as matrix codes is to evaluate the readability after curing and phosphating process. Pinion and crown wheel will be hardened and phosphated later at Meritor and then the marked information using two different readers is read. A reader is from NERMANS Märkning and another reader from Metric Industrial. The reason for test reading with two readers is the use of two different technologies and lighting systems.
Tools and conditions used in various parts of the tests:

- Pin stamping machine (air pressure)
- Pin M14 and M7 (More information about the pins, refer to Chapter 3)
- Oil-based white wax
- Laser Marking Machine
- Reader (scanner)
- Metal test pieces, 9x6x4 mm with hardness 140 HB (Brinell) for dot peen marking
- Metal test pieces, 6x5x0.4 mm for laser marking.
- Distance between the pin tip and the testing surface is 4 mm.
- Digital Microscope Magnifiers (10 mm ~ 50 mm 200x)

2.3.1 Dot peen (Pin stamping) method test

The first sample was made on one of the iron plates and pins M14 in two steps:

1. With air pressure of 4 bar and the number of strokes 3, marked matrix 1 and the horizontal lines. The results show that the matrix points are not tangent and the matrix was readable with the help of the reader and horizontal numbers and letters (see figure 2.1) were clear and readable to the naked eye.

![Figure 2.1, air pressure 4 bar, 3 strokes](image)

2. With air pressure of 4 bar and the number of strokes 6, marked matrix 2
and the vertical lines. The results show that the matrix points are touching each other, yet the matrix is readable but not as easy as matrix 1. When the matrix points tangent to each other (see figure 2.2) and point forms and matrix shape change, it will be difficult for the reader to read the matrix code. That which can be tested is to change the reader's position by reducing or increasing the distance between the reader's lens and the marked surface or angle the reader to the right or left. It gave the best results was to keep the reader 45° to the surface with 100-150 mm distance. If the form changes are too large the reader cannot do to read the information from the matrix code. Use of white wax on the matrix surface provided assistance to easier reading. Vertical lines of numbers and letters are clear and readable to the naked eye. The difference between horizontal and vertical lines is that because of the higher number of strokes on one point pressure out more material from the designation tracks. This difference is not visible to the naked eye but can be felt as higher edges by a touching finger.

Another test was made on one of the iron plates and pins M07 in two steps:

1. With air pressure of 4 bar and the number of strokes 3, marked matrix 2 and the horizontal lines. The results show that the matrix points are not joined together and the matrix was readable (see figure 2.3) with the help of the reader and horizontal numbers and letters are clear and readable with the naked eye. The use of white chalk on the matrix surface assisted to the testing of other options to facilitate the reading of the situations required but the array was fully readable and tool for reading would not be needed. Vertical lines of numbers and letters are clear and readable to the naked eye.
2. With air pressure of 6 bar and the number of strokes 1, marked the matrix 1 and the vertical lines. The results show that the matrix points are not tangent to each other (see figure 2.4) and the matrix is fully readable. The difference between horizontal and vertical lines and even matrix points is that because of the higher number of strokes on one point of the matrix 1 was pressed out more material from the designation tracks and matrix points. This difference is not visible to regarding of designation tracks by the naked eye but it can be felt as higher edges when touched by a finger. Difference between matrix points visible to the naked eye, the points in the matrix 1 is deeper than the matrix 2. It would require a depth gauge to saturate the depth of the designation tracks and matrix points in both tests.

The use of white chalk on the matrix 2 had three causes:

1. Compare between two different options that facilitate reading. The results show that both works as well but the visible image 2.2 is kept clean around the matrix with using the white chalk but the use of white wax, the wax
spreads around the matrix and it becomes difficult to keep clean around the matrix. Another disadvantage of using wax is that the wax can cause chemical reactions on treated surfaces. Chemical reactions happen when a metal reacts with a gas or vapor; a coating is formed in the contact surface which is the result of a chemical reaction between metal and gas. This coating is the reaction’s product of the reaction. Depending on which gas and metal is concerned in the reaction, it can be different coatings on the metal surface. In order to study more closely the content of the white chalk see Appendix 10.

Vapor deposition is a process in which the substrate (work piece surface) is subjected to chemical reactions by gases that contain chemical compounds of the material to be deposited. The coating thickness is usually a few microns, which is much less than the thicknesses that result from the mechanical surface treatments and mechanical plating and cladding. The deposited materials can consist of metals, alloys, carbides, nitrides, borides, ceramics, or oxides. Control of the coating composition, thickness, and porosity are important. The substrate may be metal, plastic, glass, or paper. Typical applications for vapor deposition are the coating of cutting tools, drills, reamers, milling cutters, punches, dies, and wear surfaces. There are two major vapor-deposition processes: physical vapor deposition and chemical vapor deposition. [7]

2. Test the reader on white wax and white chalk to investigate reader reaction to those two materials. The results show that both work just as well for reading. White chalk is solid because it is easier to be controlled compared with white wax.

3. Facilitated comparison between matrix forms and how close the points are associated with each other.

The important point with both white wax and white chalk is that both are harmless to the environment and human health. Some of the safety data sheet and image of white chalk in the form of a pen is on the Appendix 10.

Another interesting area for testing is the matrix size. The goal of this test was to find out:

- How much information takes place in a matrix?
- How large is the matrix with the amount of information presented in the matrix?
- How much can be reduced the matrix size with respect to the location on the smallest pinion and crown wheel.
Four matrices of sizes 4, 6 and two matrices 9 mm (see figure 2.5) are marked by dot peen method. The reason for the testing of two matrices of the same size is to analyze the difference between the air pressure 4 to 6 bar on the same matrix size and the same information.

- Matrix 1: 4×4 mm, air pressure 4 bar, pin N14 and number of strokes 1.
- Matrix 2: 6×6 mm, air pressure 4 bar, pin N14 and number of strokes 1.
- Matrix 3: 10×10 mm, air pressure 4 bar, pin N14 and number of strokes 1.
- Matrix 4: 10×10 mm, air pressure 6 bar, pin N14 and number of strokes 1.

The test results show that:

Matrix 1 is not readable, the points went into each other and at some points of the matrix are the points are not round anymore, they become like drawn lines. Matrix 1 is not readable, the points went into each other and at some points of the matrix are the points are not round anymore, they become like drawn lines. Therefore, the scanner cannot read the matrix. This is due to higher number of points that were marked on the one part of the matrix, inasmuch as the matrix size is not enough, the machine struck points very close to each other and at some places the points went together. The size of the matrix 1 (4 × 4 mm) is not acceptable because it is not readable with respect to the amount of data to be stored in the matrix. It is out of Solutions.

Matrix 2 is readable, some points touching each other (see figure 2.6) in some places, but the matrix is fully readable. But also that the matrix is readable it cannot be a safe option because the company will store more data in the matrix and will be the margin in order to increase the amount of stored data in the future if it is needed.
Matrix 3 is fully readable (see figure 2.7) with respect to the amount of data stored in it.

Matrix 4 is fully readable. The difference between the matrix 3 and 4 are deeper points on the matrix 4 because of the higher air pressure.

The speed of the dot peen method is dependent on the marking’s parameters. For example: character size to be marked.

Eight matrices are marked by dot peen method on a pinion and six matrices on a crown wheel, before hardening and phosphate process. Reason for selection is to examine how the marked matrices react after hardening and phosphate process.

The continuation of this test should be done at Meritor in two steps.

Step 1: reading the marked matrices after hardening. The aim is to examine the hardening effect on the marked matrices.

Step 2: reading of the marked matrices after phosphating. The aim is to examine the phosphating effect on the marked matrices.

They nominated matrices are marked at NERMANS Märkning. The matrices were tested for reading by NERMANS Märkning scanner. The result was that all marked matrices were completely legible without a matrix; the matrix was marked on the edge of the crown wheel.

See Appendix 13 for the pinion image and Appendix 14 for the crown wheel image.
2.3.2 Ansys analysis

Ansys analyses were done to investigate the material impact of pin pressure after one stroke with 4 and 6 bar air pressure. Selection of the material in the Ansys program is based on material hardness and this is the same as Meritor uses for pinion and crown wheel in the marking process (170-180 HB). Ansys analyses cover equivalent stress, equivalent elastic strain and total deformation at a point on the material surface where the pin meets. Results of the analyses show that the material can handle the stresses of the pin pressure, and will not be major changes in the material structure.

Ansys analysis (see figure 2.8) for equivalent elastic strain with air pressure 6 bar, one stroke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 4.5774 \times 10^{10} \text{ mm/mm}

Minimum value: 1.3729 \times 10^{10} \text{ mm/mm}

![Figure 2.8, Equivalent elastic strain with 6 bar air pressure](image)

Ansys analysis (see figure 2.9) for equivalent stress with air pressure 6 bar, one stroke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 0.88419 \text{ MPa}

Minimum value: 2.7458 \times 10^{10} \text{ MPa}
Ansys analysis (see figure 2.10) for total deformation with air pressure 6 bar, one stoke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 1,7532 $\times 10^{-10}$ mm

Minimum value: 1,948 $\times 10^{-10}$ mm

Figure 2.9, Equivalent stress with 6 bar air pressure

Figure 2.10, Total deformation with 6 bar air pressure
Ansys analysis (see figure 2.11) for equivalent elastic strain with air pressure 4 bar, one stoke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 3,0516 10 mm/mm
Minimum value: 9,1413 10 mm/mm

Figure 2.11, equivalent elastic strain with 4 bar air pressure

Ansys analysis (see figure 2.12) for equivalent stress with air pressure 4 bar, one stoke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 0,58946 MPa
Minimum value: 1,8283 MPa

Figure 2.12, equivalent stress with 4 bar air pressure
Ansys analysis (see figure 2.13) for total deformation with air pressure 4 bar, one stoke and by pin with diameters 2 mm and the radius 60° (N14).

Maximum value: 1, 1688 10 mm

Minimum value: 1, 2986 10 mm

Figure 2.13, total deformation with 4 bar air pressure
2.3.3 Laser marking

Some matrices were marked with laser marking technology (see figure 2.14) in some test plates. The laser marking works on test plates and matrices were readable. The matrices contain different amounts of data and are marked in different sizes.

![Figure 2.14, laser marked matrices with different effect](image)

The laser marker was tested on a phosphated surface, but it was no good result. The reason for the poor result was that the phosphated surface was dark. It was poor contrast with less power (for example: 20% of 20 W) and burned edges of the matrix at high power (for example: 100% of 20 W) because the matrix was not fully visible and not readable by scanner. Marked matrix was a bit darker than the background color of the phosphate surface and scanner could not find the matrices to read it.

Metal color change after curing process due to the heat in the oven. The influencing factors on metal color changing in a hardening process are for example: holding time in the furnace, the temperature and the cooling process.

Additional two experiences of the tests made:

- Laser marking is faster comparing to dot peen method.
- The laser marking burn marks on the surface of the material, which is not deep track, the marking is just on the surface and is not in the material. Therefore, the marked matrices or designations cannot withstand mechanical movement.
3 THEORY

The main area is in mechanical engineering when the work concerns sustainable marking technologies of metal products by the company in accordance with the prescribed requirements for traceability. In the context of the project, are used more areas of mechanical engineering as mechanics, production engineering, physics, materials science, product development and ensuring product quality. Different methods are analyzed to review the proposed improvements for future product or if the company wants to mark the products with more information.

Together they constitute a project with versatility, when knowledge is needed in several technological areas and factors should be taken into account that will simplify production, continue to work with the marking and to enable reading of marked information.

The project is treated with a number above mentioned areas that are rooted in some theories. These theories are connected at the implementation stage to ultimately result in a comprehensive basis for marking metal products as well as reading the marking.

In the project is examined the information presented about various methods for marking on metal products, which of them are less affected by processing after the marking. The relevant machining operations which cause problems for the reading of marked data in the pinion and crown wheel is hardening and phosphating in this case. The necessary information is generated with respect to the company's option on marking of pinion and crown wheel.

To get a better understanding of the project, the manufacturing process is summarized in the following steps:

1. The blank work piece is delivered from the supplier in wooden pallets. There is a pallet’s flag on each pallet that informs what the pallet contains. When orders come for soft turning, an associated pallet is transported using the forklift and the role of the courts from the warehouse to hardening ovens. See Appendix 1 for images of the pallet flag and Appendix 2 and 3 of the blank work piece.

2. Soft annealing: The steel is heated in the oven, the treatment gives a softer but tougher steel. The purpose of soft annealing is to obtain material tough enough to facilitate later machining in the process. After soft annealing, pinion and crown wheel have hardness between 170-180 HB (Brinell).
Annealing is a general term used to describe the restoration of a cold-worked or heat-treated alloy to its original properties— for instance, to increase ductility (and hence formability) and reduce hardness and strength, or to modify the microstructure of the alloy. The annealing process is also used to relieve residual stresses in a manufactured part, as well as to improve machinability and dimensional stability. The term “annealing” also applies to the thermal treatment of glasses and similar products, castings, and weldments.

The annealing process consists of the following steps:

I. Heating the workpiece to a specific range of temperature in a furnace;
II. Holding it at that temperature for a period of time (soaking), and
III. Cooling the workpiece, in air or in a furnace. [7]

3. Soft turning: The blank is machined and marked by pin stamping technology. The mark consists of the part number, serial number, material code, the number of cogs on the crown wheel / pinion and number of cogs on the corresponding crown wheel / pinion, LS stands for Lindesberg and M stands for Meritor. Meritor dot peen almost 1000 parts daily. See Appendix 4 for the image of the pinion and Appendix 5 for the image of the crown wheel after smooth turning.

4. Gear cutting: The cogs milled by using CNC machines. See Appendix 6 and 7 for images on pinion and crown wheel after cogs cutting.

5. Case hardening: detail warms up to get a hard surface layer. The hardening depth is typically between 0.2-1.5 mm and is controlled by the temperature and holding time in the oven. After case hardening, pinion and crown wheel have hardness between 59-61 HRc (Rockwell).

6. Washing, washed away any residual chemical agents, small chips, oil and dirt from the details.

7. Blasting, to the surface is clean and remove sharp edges, blown metal bullets with a strong current towards the surface of the part.

8. Shot Peening, Compressive stresses in the surface layer being constructed by bombarding the surface with small balls (from 0.25 to 5 mm) of steel.
The bullets are fired through a nozzle by means of compressed air. The goal of the shot peening process is to eliminate residual stresses in the material which formed due to plastic deformation. Pinion and crown wheel will have better abrasion strength after shot peening. Shot peening are not made for all details at the Meritor.

Because case hardening is a localized heat treatment, case-hardened parts have a hardness gradient. Typically, the hardness is a maximum at the surface and decreases below the surface, with a rate of decrease that depends on the composition of the metal and the process variables. Surface-hardening techniques can also be used for tempering, to modify the properties of surfaces that have been subjected to heat treatment. Various other processes and techniques for surface hardening, such as shot peening and surface rolling, improve wear resistance and other characteristics. [7]

Improving Fatigue Strength, Fatigue life is greatly influenced by the method of preparation of the surfaces of the part or specimen. The fatigue strength of manufactured products can be improved overall by the following methods:

a. Inducing compressive residual stresses on surfaces—for example, by shot peening or by roller burnishing.

b. Case hardening (surface hardening) by various means.

c. Providing a fine surface finish (see figure 3.1) and thereby reducing the effects of notches and other surface imperfections; Note that the reduction becomes greater as the surface roughness and the strength of the steel increase.

d. Selecting appropriate materials and ensuring that they are free from significant amounts of inclusions, voids, and impurities. See diagram 3.1, from reference [7].

![Figure 3.1](image-url)  
Figure 3.1, Reductions in the fatigue strength of cast steels subject to various surface-finishing operations [7]
9. Hard turning: Fine adjustment after the hardening providing finer surface and contributes to the exact dimensions.

10. Patching (lapping): The pinion and the crown wheel are combined into pairs.
Lapping and fine grinding are processes used where the surface finish, flatness, or parallelism of the work piece must be held to very close tolerances. Lapping can achieve flatness rating of \(2,54 \times 10^{-8}\) m, parallelism tolerances of \(2,54 \times 10^{-7}\) \(\mu m\) and surface finishes to \(Ra= 0,01524\) m. Using special handling and tooling techniques. [8]

11. Phosphating: Gives the surface a thin layer of phosphates as corrosion protection and with better tribological properties. Meritor does not phosphate their own products, but Volvo parts which are produced in Meritor should be phosphated according to Volvo’s drawings. Phosphating makes the detail black and is being reduced large part of the light reflections from the part and then it becomes difficult to read the designations marked.

Finishing describes treatments applied to the surface of the component or assembly. Some aim to improve mechanical and other engineering properties, others to enhance appearance.

Finishing treatments to improve engineering properties: Grinding, lapping and polishing increase precision and smoothness are particularly important for bearing surfaces. Electro-plating deposits a thin metal layer onto the surface of a component to give resistance to corrosion and abrasion. Plating and painting are both made easier by a simple part shape with largely convex surfaces: channels, crevices, and slots are difficult to reach. Anodizing, phosphating and chromating create a thin layer of oxide, phosphate or chromate on the surface, imparting corrosion resistance. [9]

12. Storage: Store finished products in stock before assembly. See Appendix 8 for ready pinion and Appendix 9 for ready crown wheel to the mounting.

13. Assembling: The matched pinion and crown wheel is assembled in the gear kit.
3.1 Marking of metal products

There are different methods used in different cases for marking metal. Different metal product manufacturers choose the method that fits their products best. This report examines the methods closely at dot peen method respective laser marking method.

3.1.1 Different methods for marking of metal products

Metal products can be marked by different tools and methods. Selection of tools and methods depends on such factors as material hardness, amount of product to be marked, desired marking lifetime and several other aspects.

- Stamp
- Dot peen (pin stamping)
- Inkjet printer
- Laser marking
- Thermal Transfer
- Sign / label
- Paint Stamp
- Punching

3.1.2 Dot peen method (pin stamping)

Dot peen technology involves embossing a series of points on the surface of the material to create the readable text, identification, logos, alphanumeric and 2D Data Matrix codes. The method is preferably used for code marking of metal as machine parts and nameplates, but also for the marking of products made of plastic. Dot peen is achieved with an oscillating hard metal tip which is moved by the stepper motors in a coordinate system. Characters and characters are built up of a very close succession of points which results in "smoothwall" lines.

Considering the specific focus on global quality and unique identification requirements for components, the dot peen technique is widely used throughout the automotive and aerospace industries. Since the dot peen systems are particularly suitable for permanent marking of details. The technology is also used
extensively in agricultural machinery, oil and gas industry, metal industry, electronics, transportation and logistics, construction equipment, and many more. Dot peen is ideal for permanent marking of metal and plastic parts, regardless of surface properties or the working environment. The dot peen technique uses a sharp-pointed needle to mark the product. The needles are available in various diameters. Choosing the correct needle depends on the text size. If the text consists of small letters / numbers, pin should be smaller. Options narrower pin is to highlight the slow and hit some more strokes to get the mark clearly. Larger pin is heavier and is used to mark larger letter / numbers or symbols. Dot peen is made by two different drivers. At scribing, unlike dot peen the pin points do not vibrate in the material, rather pushed the pin into the material. In that position is then moved diamond needle by two stepping motors in the X and Y directions. The system fits virtually all materials - from hardened steel to pressure-sensitive finished parts. Another difference is the pin’s tip in scribing is made of diamond, but in dot peen entire pin is made of massive solid hardened steel with a hardness of 63 HRC (Rockwell).

Dot pin marking can be done by using two different driving forces:

1. Electric
2. Air pressure

1. Electric

Electric systems are best for marking with low stresses and can be used at point marking. This is due to the fact that the needle is not moving up and down quickly enough to draw the line. Electric-powered dot peen is an option when the air compressor or air line is missing. Because often rated electrical machines have a needle with a larger diameter which makes it more difficult for marking on smaller places. Advantage of electrical dot peen machine is that it requires less maintenance.

2. Air pressure

Air pressure can be used on most materials that require permanent marking. The depth of marking is controlled by air pressure, number of strokes, speed and pin diameter. When the material is soft, air pressure and the number of strokes should be lowered, even the speed can be increased to become fewer strokes in one place. With the term speed is meant the pin movement in X and Y direction. If the speed is increased too much, the pin movement is speeded up and this results in single
points (see figure 3.2) instead of the line in case ordinary characters are to be marked.

Figure 3.2, Dot peening with high speed. [9]

3.1.3 Different dot peen machines

Dot peen machines are available as individual workstations, integrated systems in production lines, or handheld devices.

• Portable (see figure 3.4), this is used when the product is too heavy or is fixed and cannot be moved to the marking machine.

Figure 3.4, Portable machine for dot peen marking. [11]
• Integrated machines are available in different varieties stationary (see figure 3.5) and combined (see figure 3.6) portable and stationary.

• Fixedly mounted dot peen machines at production lines, are marking machines designed for production lines and cells. The machines are encapsulated and can be mounted at the production lines in the form of half / fully automatic (robotic cells).

3.2 Pin

Pin is the part of the dot peen machines, which is hitting points in close succession and form thus marking text or matrix code. Letters, numbers, logos and special characters are formed thereby on the component. A marking pin is in hard metal; the pin’s tip is pressed into the material and moves in a coordinate window. The pin has an important role in marking; the marking process is directly affected by the pin size (see figure 3.7), the pin’s top angle and radius (see figure 3.8).

See Appendix 15 for more specifications about the pin N7 and Appendix 16 for pin N14.
The pin is manufactured in different lengths and thicknesses; the pin is also produced in the same diameter with different lengths. This is due to different circumstances and necessities applicable to product marking. The pin’s weight affects the marking depth; heavier pin allows deeper markings with the same pressure force. Pin with sharper angled tip is used to produce narrower and deeper point, such a pin can be used for marking on small surfaces, especially in the marking of small matrices.
3.3 Material hardness

With the term hardness is meant how large forces are needed to deform the material plastically. Material hardness is one of the most important factors for product marking. Harder material needs more force to be marked. The marking can cause plastic deformation on the marked surface. The deformation may be so low as to not affect the marked area that can be counted as damage. With the wrong choice of tools and marking method, the marked surface of the product becomes damaged.

Hardness is a commonly used property; it gives a general indication of the strength of the material and of its resistance to scratching and to wear. Hardness is usually defined as resistance to permanent indentation; thus, steel is harder than aluminum, and aluminum is harder than lead. Hardness, however, is not a fundamental property, because the resistance to indentation depends on the shape of the indenter and on the load applied. [7]

Material hardness measured by different methods: Vickers, Brinell, Rockwell and Knopp. The Rockwell’s method resembles best the dot peen marking as it use a conical indenter. The studies have showed that after unloading it will be a pile-up (see figure 3.9).

![Figure 3.9, Pile-up deformation after unloading](image-url)
3.4 Laser marking

Most use of laser marking is in the medical devices, because laser does not penetrate deep into the material; for this reason, bacteria do not gather in the marked areas. In laser marking, a thin layer of marking on the surface is burned; therefore marking is not deep in the marked surface.

The mark may be formed by illuminating a mask, or reticule, that contains the desired pattern, as illustrated in Fig. 3.10. The mask may be a metal stencil, which contains connecting strips, or glass substrates covered with dielectrics. It may be positioned close to the workpiece, or the transmitted pattern may be focused to the desired size on the object using a lens. Mask marking is rapid if the mask does not need to be changed. Different masks can be mounted on a revolving wheel and positioned accordingly, although this reduces the marking rate. Since only a part of the beam is transmitted to make the mark, fairly high power lasers are needed. [13]

![](image1)

Figure 3.10, marking using a mask [13]

Dot matrix marking systems, produce characters by producing small dots in given patterns to generate the characters required. The beam is scanned over the matrix, and pulsed when a dot is required. The pulse is generated by a rotating polygon mirror, (see figure 3.11) acoustic-optical device, or piezoelectric scanning. Dot
matrix printing is particularly suitable for producing characters in a well-defined series, such as alphanumeric codes. [13]

3.5 Marking’s style

Marking can be done in different style according to need, location, amount of information which must be marked and various requests.

- Clear text, written designations as they are with a customizable size that is readable. Advantage of this marking manner is that it can be read with the naked eye without the need of readers (scanners).
- Symbols marking, the can be marked different symbols for different requests on product.
- Matrix code is the most common two-dimensional code which can be read using the reader. The method dot peen matrix codes consist of a number of round points in a square shape containing a certain amount of information. Matrix size has a direct relation with the amount of information in the matrix.
3.5.1 Combination of clear text, symbols and matrix code

It is feasible to combine the marking with clear text, symbols and matrix code. The combination provides the opportunity to be able to read the data marked on the product both with the naked eye and readers. Advantage of this combination is that some flows require that the operator reads the information marked on the product with the naked eye to identify the product. The information may include the product part number as the operators needs to know to perform their duties. Symbols can be marked in the marking combination. Symbols can provide information about the product for example warning for danger at use of the product, even information which can help with the environmentally friendly scrapping of product after its service life.

3.5.2 Matrix code

Matrix Code is a 2-dimensional code that often designed in square shape and can be marked directly on products. Advantage of matrix codes is that they can be read from all four sides of the matrix and they are readable when even up to 35% of the matrix is damaged. The damaged part can be replaced by using calculations that lie behind the matrix system. Some parts of the matrix (see figure 3.12) are sensitive of damage for example: Quiet zone. The disadvantage of the matrix is that they are not readable with the naked eye.

The process of decoding a DPM mark involves finding the mark, determining the symbol size; identifying “on” and “off” cells; applying error correction; and reporting results. [14]
Consequently, there are several attributes of the Data Matrix symbol that contribute significantly to its overall readability. The quiet zone, or clear area surrounding the symbol on all four sides, should be free of defects. The finder pattern should be well formed, and the modules or light and dark cells that make up the clock track and data region should be uniform and easily distinguishable. [14]

3.6 Direct part marking (DPM)

There are various methods for the direct part marking. Selection of the method depends on for example materials, product life, marking surface and the surroundings. Another factor which is important for choice of DPM method is processes that should be done before and after marking. Since the marking may be affected by various machining or chemical reactions during the manufacturing process.

Direct part marking (DPM) is a process to permanently mark parts with product information including serial numbers, part numbers, date codes, and barcodes. This is done to allow the tracking of parts through the full life cycle.

The interpretation of 'permanent' often depends on the context the part is used. In the aerospace industry an aircraft part may be in service for over 30 years. Within telecom and computer industries the life cycle may only last a few years.

DPM is often used by automotive, aerospace, and electronic manufacturers to facilitate a reliable identification of their parts. This can assist in data logging for safety, warranty issues and satisfy regulatory requirements. Also the United States Department of Defense demands a physical mark on tangible assets in conjunction with the Item Unique Identification. [15]

3.7 Reading the marking

There are three crucial factors which affect reading of the marking:

1. Quality of the marking.
2. The ability of the scanner.
3. Light reflection and contrast.
3.7.1 The reader (scanner)

All the data marked on the product are read and transferred to the business system with the help of the reader. This helps to eliminate human error in both the reading of marked information and transfer them to the business system. The reading can be done with a portable scanner or fixed reader at production lines. The reader is connected to the business system, reads the marked information and transfers them to the business system. Eventual marking errors are detected by the reader and warning is sent to the operator in the form of signal lights or other appropriate options with regard to the flow. In an automated flow, signals can be sent to the robot which controls the path and the robot puts aside the erroneously marked product.

There are different models of scanners with different technologies. The major technological difference, parts these into two main groups:

1. Readers with integrated camera are able to take pictures from the selection while they read and transfer the data to the data system. The images are saved in the computer system and can help the company to more easily track the incorrect marking. The disadvantage of this is that the image takes place when it comes to mass production. There is a possibility in their program to take a photo of only the faulty labeling.

   The readers are available as portable (see figure 3.13) or fixed mounted at production lines (see figure 3.14).

2. Readers without a built-in camera in itself can be divided into two groups, those who can read 2-D codes, and those who can only read barcodes.
4 RESULTS

To clarify the reason for the choice of methods for marking on the pinion and crown wheel, a summary of the tests is presented here. Two relevant marking methods were tested; the results showed that dot peen method is more compatible with Meritor products. The marking shall be a combination of clear text and matrix code. Reading of the marked data on the pinion (see figure 4.1) and crown wheel (see figure 4.2) shall be made by using the scanner.

Results are considered to be possible to use directly in other products, such as similar parts that are mounted in a gear kit.

Figure 4.1, marked pinion to the mounting

Figure 4.2, marked crown wheel to the mounting
4.1 Dot peen method test

The following figures below show the results of testing during the project. The tests were done with dot peen method in different air pressure, number of strokes and pin size. Figure 4.1 shows the result of the test with the pin N 14 and figure 4.2 shows the result of the test with pin N 7.

![Figure 4.1, Dot peen test with N14 pin.](image1)

![Figure 4.2, Dot peen test with N7 pin.](image2)

4.2 Laser marking test

In laser marking heat goes into the material and affects the material's structure, which in turn may damage the material.

In view of the use of many metals and alloys in nuclear applications, extensive studies have been conducted on the effects of radiation on mechanical properties.

Typical changes in the properties of steels and other metals exposed to high-energy radiation are increased yield stress, tensile strength, and hardness, and
decreased ductility and toughness. Radiation has similar detrimental effects on the behavior of plastics. [7]

4.3 QFD-template

In this QFD template, 7 solutions are assessed regarding 6 requirements. When it comes to solutions we have only two general ways to improve the process. First, improve the marking process, and second improvement in reading process. Since the marking equipments in the Meritor are limited to just dot peen marking, most of improvements should be focused on the reading process.

It should be mentioned that the top part of the table is rather negative because most solutions are substituted and cannot be used at the same time. Fast reading, which is a requirement of the laser marking process, is not suitable because the mark would eventually fade after hardening and the phosphating process would then be difficult to read. The difficulty level of this method it is rather high at 7. Advantage of the laser is that damage to the product can be minimized. Dot peen marking on the other hand has a strong relationship with first three requirements. It is easy to install and compatible with the production line. The only disadvantage is that product damage is probable.

It seems that matrix marking can satisfy more requirements compared to clear text marking. There are two main weaknesses for this method. First, the fact that we need is a proper database and scanners and also it is not recognizable for operators. Regarding the importance of requirements the fourth column, right before requirements show the relative weight of them associated with their importance. On top of the table, substitute solutions have negative relationship and complementary solutions have positive relationship such as matrix marking and dot peen marking technique.
4.4 Discussion

Henceforth, the results are considered to be credible given that...

4.4.1 Laser marking

Laser marking is not a suitable solution for Meritor in this context. Meritor completes the marking of their products with dot peen method and has functioning equipment and expertise within the company. The goal for Meritor with this project was to eliminate the number of errors caused by pinion and crown wheel ending up in the assembly. This happens due to unclear identification marked on the products and the assembler is unable to read the information needed. Meritor want a sustainable marking to allow the traceability of their products and the dot peen method meets the requirement proven through tests performed.

- … Meritor has the customer in focus, wants to fulfill customer requirements and enhance customer value. The new investments in laser marking do not increase the customer value. It is important for Meritor customers to get a working gear kit with good quality and traceability of their products is important for Meritor.

- …traceability is not value increasing for Meritor products but by reducing scrapping can reduce production costs.

- … Laser marking does not give new opportunities for Meritor in order to track their products more effectively.

Customer value is the value of the benefits a customer can get out of a specific goods or service. [17]

- … The new investment requires both expertise and investment budget. Marking technology in itself gives no guarantee for the customer getting a better product quality or value increase, besides product traceability can increase quality. Product traceability is achieved by sustainable marking of products and because the dot peen technique meets this requirement, the new investments for laser marking is not suitable for Meritor in this case.
Many organizations focus only on one of these quality dimensions; for example, they might focus on defect elimination but fail to design products that customers really want, or they design great products that are plagued with defects and service errors.[18]

4.4.2 Dot peen method

A durable and rapid marking method is made using a vibrating pin. The durability is due to the deeper track designation compared with the laser marking. The marking can be done with portable or stationary machines that can be powered by air pressure or electricity.

The dot peen method is a relevant method for Meritor to mark the pinion and crown wheel. The company does not need big investments and big changes in their production flows. What is needed to improve the current use of dot peen method is using a combination of matrix code readable with a scanner and part in the form of ordinary numbers that are readable to the naked eye.

- … By continuing to mark products with a dot peen method, the technology that the company has used for several years and has accumulated strong work experience and expertise in the marking of metal products, increased opportunity for development and superficial improvements desired by the company.
- … No great efforts are required to train operators in the use of dot peen machines.
- … It requires no large and isolated areas of work for dot peen equipment compared with laser marking equipment.
- … In laser marking some heat is transferred to the material and affects material structure. Material structure modification may be contrary to the desired and counted as material damage in the affected area. In the dot peen method is the material pushed aside; it does significantly less damage to the material.

A common form of pyrometric analysis uses emissions at two wavelengths, e.g. 1300 and 1700 nm, and provides a temperature conversion within an operating range, e.g. 500–1600 °C. Pyrometry is useful in controlling surface temperature during transformation hardening, and can be incorporated into on-line adaptive control systems that adjust process variables such as laser power and traverse rate to maintain a required surface temperature. [19]
• … The dot peen method of marking is sufficiently deep inside the material to qualify as sustainable against the mechanical movements which receives the laser marking; the marking is on the surface and cannot withstand many mechanical movements. You can adjust the depth of the marking traces in both practices to some degree. In the laser marking, the depth of the marking traces requires that more energy is transferred in form of heat on the material surface which itself can affect the material structure more. In the dot peen method, the increase of the depth of marking traces requires an increased air pressure when the needle hits harder on the material surface or reduced speed leads to more impact on a single point. The material structure is not changed to a large extent in one of the last mentioned cases in dot peen method.
5 CONCLUSIONS

The purpose and goal of this project is to implement that marking of the gear kit by using the matrix code is met. To find the best method for marking of pinion and crown wheel was tested the two more relevant methods with regard to the product's properties and the company's requirements for traceability of the mentioned products in the future.

The result is based on the different tests with different methods and some from technical literature and company websites working within marking technology and scanner.

The work continued on a couple of steps as mentioned below:

- Analysis of demanding information during the process: investigate which of the marked information as pin stamped at the first stage of production is needed in the continuation of the process.

- Technology Analysis: Investigate current technology for marking of metal products. There are various methods and equipment to implement marking on metal products. By analyzing the advantages and disadvantages of different methods with respect to the company's needs, is presented as the best method.

- Contact different suppliers: Contact and visit different suppliers who have experience in the industry. Discuss the problem and study their ability to deliver technologies and equipment that can solve the problem.

- Studying the production flow, Check which of the information marked on the pinion respective crown wheel should be readable for operators during the process and which can be marked in the form of matrix codes which are readable by the reader.

- Testing of marking methods, in order to ensure that the method is capable of selection with good quality so that the reader can read the code after hardening and phosphating, they were tested individually in the company/supplier's test center by each method is tested before and after hardening and phosphating.

- Testing of the reader: There are different readers with different technologies; they have their advantages and disadvantages. The samples will show which of them is better suited to Meritor products with consideration to weight, light sources, work environment, economy, and widespread opportunity for programming and communication with Meritor’s business.
5.1 Conclusions

According to test results, facts from technical literature, information gathered by companies working in the marking industry, material properties, and the Meritor situation; the dot peen method is suited for marking on pinion and crown wheel because:

1. Dot peen marks are clearer and more readable than the laser ones.
2. There is a risk that the thin thickness of the laser marks can be removed mechanically or chemically.
3. Dot peen marking does not damage the material’s structure at right choice of air pressure and pin size.
4. Meritor already has all the equipment, work experience, and skills that are needed in the dot peen method.
5. There is no need for major changes in the production flow for dot peen method, because the company has been using the method. Therefore, no large investments are needed.
6. Dot peen method is environmentally friendly and does not harm the environment; no chemicals are used in this marking method.
7. Long training is not required to use the method when hiring new personnel or moving personnel into processes where the method is used.
8. Results of dot peen marking are a sustainable method, which Meritor wishes to accomplish.

5.2 Recommendation to future activities

The future looks bright. What remains to be done is to complete the labeling of the products and carry out the same marking method on the pinion.

Suggestion for improvement:

- A routine check is needed to ensure that the needle is not damaged and works as it should and that there is no risk of marking defects.
- Durability and selection of the pins should be investigated since the material of the pinion and crown wheel are quite hard.
6 CRITICAL REVIEW

In addition, work has been carried out smoothly and it has been instructive although there have been setbacks with several obstacles that stopped the work. For example, more counting for a longer time than planned was done because more detailed and more precise investigations in different tests were regarded as being needed. Another impediment was the need for many equipment and long waits for a response from the different machining processes that a detail would go through. A structured approach and the idea that almost any problem can be solved, has resulted in greater understanding of engineering.

As the responsibility for completing the project lies with the project recipient. The requirements of both the university and the company to please all parties in this work were also needed to be taken into account. This has been considered the most challenging part of this work, since the different opinions have weighed heavily in the discussions and choices have been more concerning, for example, how the report was designed. But this has resulted in much learning and is thought to be a good indication of the real life as an engineer.

6.1 Product traceability

With traceability means the ability to follow a product’s way from the raw material to finished product. Traceability can be used to find information about the process or product history. This helps to quickly find information about product defects or errors in the process. The company and their customers can have a big benefit of an effective traceability system at the company. The company can find out the root causes of the error and correct them. By stopping the defect in good time the company to get great profit in both money and time, no delivery delays, and the most important is customer trust. For customers, the company’s capability in product traceability is a good customer service; they can quickly be informed about product defects or hazards in the use of the product because of random error.

The traceability requirements allow tracing the history of the product and support market surveillance. It allows market surveillance authorities to find the liable economic operators and obtain evidence of the product compliance. The traceability requirements include labeling the product and identifying the economic operators in the distribution chain. [21]
6.1.1 Product traceability system

In order to track the product requires a computer-based business system that all internal information about the product can be stored in it. This business system helps the company to effectively have an overview of the entire process, from customer orders until the customer receives the product. From a manufacturer’s perspective traceability matters because it enables effective control of the production process and suppliers before the marketing of the products, and control of their distribution chain after the placing of the product on the market. In case of non-compliance, manufacturers are able to reduce the impact of recalls or withdrawals depending on the detail of their traceability system. [21]

6.2 The external requirements for product marking

In many societies, especially in the EU, there are also external demands on product marking. This depends on which type of product comes to be marked. There are higher requirements for marking and traceability of food and medicinal products that affect the health of people directly. Obviously, those other products may affect human life and health. For example: an error detail that is mounted in a car can be dangerous and cause major damage to the driver and the population of the society involved.

6.3 CE-marking

The CE-marking of products is a requirement in the EU and traceability is a basic requirement for CE-marking. Marking sustainability is a basis for traceability; therefore the choice of an appropriate method to mark the manufactured products is very important.

- greater legal protection for the CE marking, avoiding confusion caused by the existence of too many marks;
- full identification and definition of responsibilities for all those placing products on the market;
- a traceability guarantee for any product placed on the market; [22]
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Appendix 1

Picture of pallet flag of delivered raw material from the supplier.

Explanation of numbers 1-6 in the image:

1. Delivery address.
2. Supplier's name.
3. Supplier item number.
4. Amount of detail in the pallet.
5. Product’s Name.

Note: the other numbers standing on pallet flag is the supplier's business codes and uninteresting for Meritor production flow.
Appendix 2

Pinion, raw material before smooth turning.
Appendix 3

Crown wheel, raw material before smooth turning.
Appendix 4

Pinion after smooth turning (the first step of the process)

The first step of the pinion production is smooth turning. It turned Pinion subject, and marked with the following designations:

- Article number: 1524937
- Material code: 41376
- LS: Lindesberg
- M: Meritor
- Serial number: 0101
- 12: Number of teeth on this Pinion
- 25: Number of teeth on the matching crown wheel
Appendix 5

Crown wheel after smooth turning (the first step of the process)

The first step of the Crown wheel production is smooth turning. It turned crown wheel subject, and marked with the following designations:

- Article number: 1524937
- Material code: 41376
- LS: Lindesberg
- M: Meritor
- Serial number: 0101
- 12: Number of teeth on the matching pinion
- 25: Number of teeth on this crown wheel
Appendix 6

Pinion after cogs cutting
Appendix 7

Crown wheel after cogs cutting
Appendix 8

Ready pinion to the mounting
Appendix 9

Ready crown wheel to the mounting
Appendix 10

Image and part of safety sheet for white chalk.
Appendix 11

Image of matrix 2, is taken by using the digital Microscope Magnifiers.
Appendix 12

Image of matrix 3, is taken by using the digital Microscope Magnifiers.
Appendix 13

Image of 8 matrices, are marked by dot peen method on a pinion before hardening and phosphating process.
Appendix 14

Image of 6 matrices, are marked by dot peen method on a crown wheel before hardening and phosphate process.
Appendix 15

The specification for pin N7 [11]
Appendix 16

The specification for pin N14 [11]
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