Remanufacturing Inspection Models

Mark Errington
PhD Student Exeter University
m.errington@exeter.ac.uk

INTRODUCTION

Case studies were carried out with a number of companies engaged in remanufacturing in the UK. Some of the cases remanufacture a large volume of products and operate in a highly competitive market while others remanufacture smaller numbers of items and are know for their expertise and competency. Many of the cases studied were not found to describe their process as remanufacturing. For the purposes of this research the process was considered to be remanufacturing if it met the definition developed by King, Burgess et al. (2006) and regularly quoted by Oakdene Hollins. It defines a remanufacturing process as follows;

> *"Remanufacturing is the only process where used products are brought at least to Original Equipment Manufacturer (OEM) performance specification from the customer's perspective and, at the same time, are given warranties that are equal to those of equivalent new products"*

The main objective of these case studies was to gain a detailed insight into the role and process of inspection carried out by remanufacturing firms. It aimed to establish the objectives of inspection and testing at all stages of the remanufacturing process and the differences in the methods used in processes run by different organisations.

METHODS OBSERVED

There were many differences found in the way the case study companies carry out their inspection and testing processes. Many of the differences exist for product specific reasons. This may be due to constraints from the product's OEM, customer quality demands and time constraints. It is thought probable that methods used in some sectors can be successfully replicated in others.

The following diagram shows the main strategies that were observed in the case study companies.

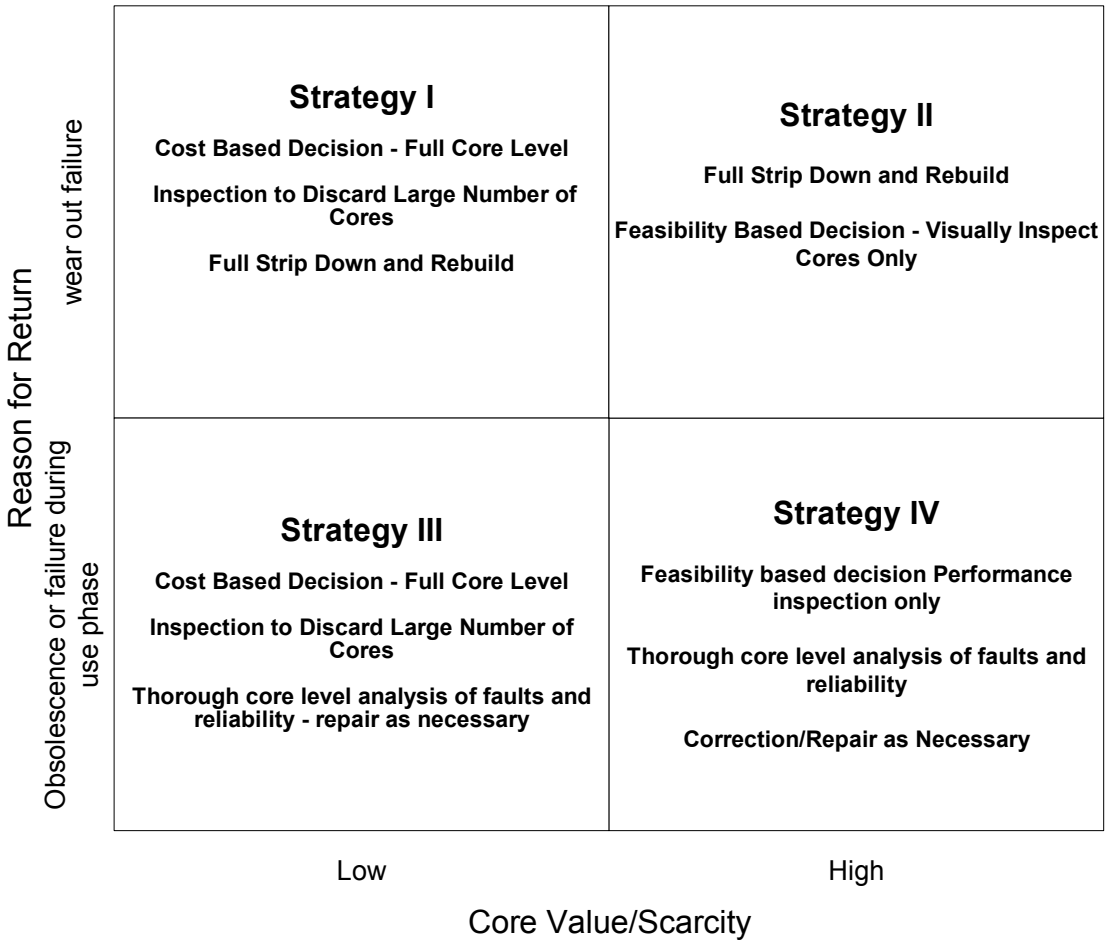

Figure 1 - Core Remanufacturing Decision Making Process Strategic Framework

It can be seen from Figure 1 that the main reasons for the different strategies used by the case studies were due to core value and type of core. Core value can be used interchangeably with scarcity of core. If cores are relatively cheap, disposal is an effective way of increasing the reliability of the population as a whole. If cores are expensive they must be processed almost regardless of cost. In the case of low value cores there is often a new alternative that can be purchased in its place.

If cores are scarce the situation is very different. It is sometimes the case in the defence industry that it is impossible to get a new unit made at any cost. The alternative to a remanufactured product is to upgrade a wider system to accept a new unit. Although this leads to a clear cost limit, this is often so high that it is not considered during the remanufacturing inspection process itself. If it is feasible for a product to be remanufactured, and new products cannot be made, then it will be almost certainly be done regardless of cost.

The reason for the return of a core is the second key variable that was identified. The reliability of a new, fully working product would not be increased by complete

disassembly and reassembly of it. In the same way, a product with a large life expectancy does not need to be disassembled to be remanufactured so long as it is found to be fully working or if a minor fault is repaired. In contrast products that have failed due to a worn part need to be carefully inspected on a part level to insure that other components aren't also close to failure.

GENERIC INSPECTION PROCEDURES IN REMANUFACTURING PROCESSES

A generic inspection procedure was developed from the case studies using the IDEF0 modelling standard. This was then compared with each of the cases in turn. Notes from case study visits were used along with product characteristics to explain the differences in the processes.

In the cases that were studies three key areas of inspection in were found each carried out at a different stage in the remanufacturing processes. These were:

- Core inspection/testing
- Part inspection/testing
- Final product inspection/testing

Each of the stages of inspection has different objectives. The objective of core inspection and testing is to remove cores that will be uneconomical or impossible to remanufacture. This improves the reliability of the population of items that are produced and ensures that cores that are uneconomical to remanufacture do not enter the process.

The second stage of inspection is carried out once the core has been disassembled. Part inspection and testing aims to remove non reusable components from the product in order to increase its reliability once it is reassembled. These parts may be non reusable because they have already failed, or are likely to fail within the next product life.

The final product inspection stage is carried out to insure that the products are in full working order before they are shipped. Products that fail this stage are reworked before being retested and sold.

Core Inspection

Cores are usually inspected as soon as they arrive at the remanufacturing facility. The following figure shows the details of how this inspection is carried out.

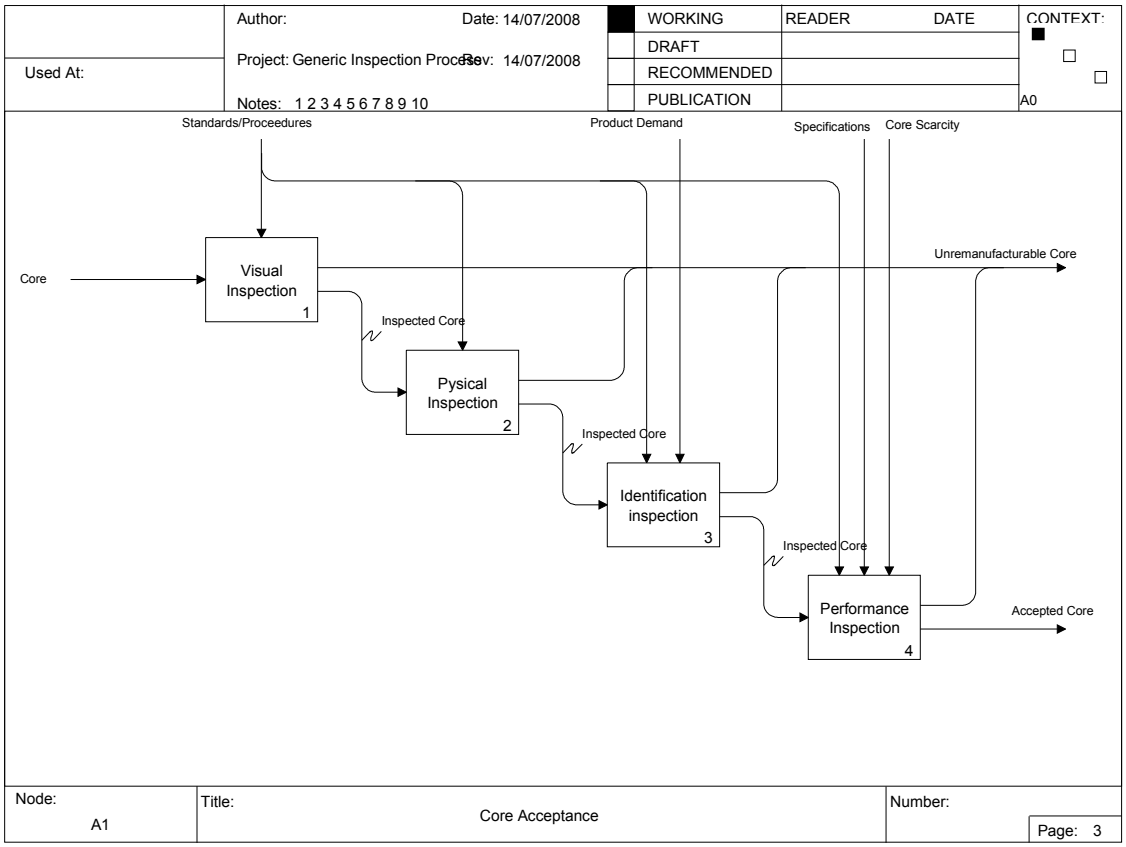

Figure 2 - IDEF0 Diagram of Generic Core Inspection Procedure

The figure shows the four main tasks in the core acceptance procedure that were identified. The first is a visual inspection. This is carried out simply through looking at a core and deciding if it has obvious major damage which would make it unremanufacturable. An example of products that would be rejected at this stage would be products that have been crushed during transit to the remanufacturing facility.

Cores that have no obvious signs of major damage are subjected to the second test in the procedure. This has been described in Figure 2 as the physical inspection. Again this is still done manually but the actual process varies depending on the core being inspected. For automotive components two main methods are commonly used. The first is to attempt to rotate any part of the product that should normally move and the second to smell electrical components to test for burn out. Cores that fail this test are sent for recycling and/or disposal.

The third stage of the process is to identify the part type and part number of the core. This is used in order to estimate the demand for and value of the product after it has been remanufactured. Cores for which there is no demand are disposed of at this stage. The fourth and final task within the core acceptance procedure aims to access the performance of the core. This is usually done using test rigs specifically designed for the procedure. The standards the product must meet are set by industry bodies, international standards or the remanufacturing firm themselves. The aim of this process is twofold; firstly to

establish if the core is economical to process and secondly to establish if the finished product is likely to conform to specifications once it has been remanufactured.

Part Inspection/Testing

Once cores have passed the core inspection and testing procedure they are sent for remanufacture. Firstly the cores are disassembled and extensively cleaned. After this they are passed to the second set of the inspections and tests. The process diagram for this process is shown in *Figure 3*

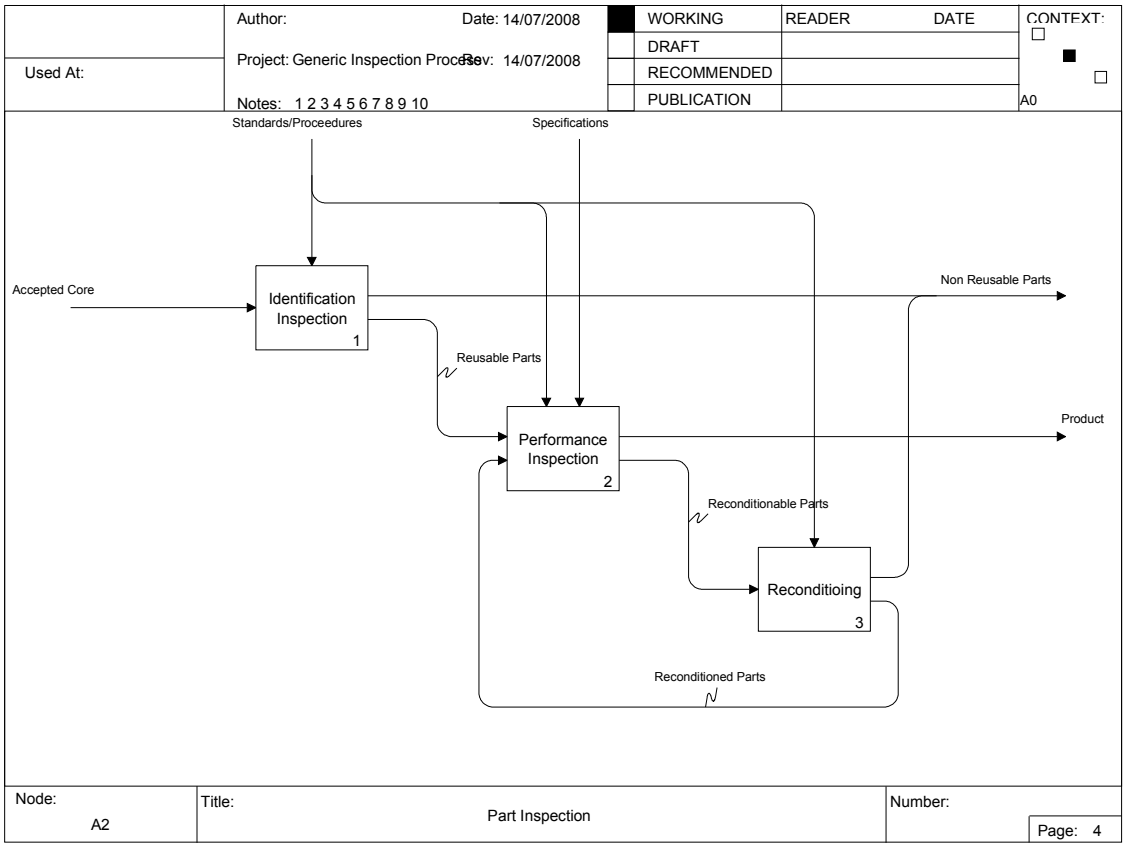

Figure 3 - IDEF0 Diagram of Generic Part Inspection Procedure

It can be seen from the diagram that some of the tasks are similar to those carried out the core level. Firstly the part is identified, if, according to company procedures, it is a part that is always replaced then it is discarded immediately. These are usually wear components and are often the reason for previous user discarding the product. Parts that are sometimes reused are sent through a performance inspection process. Typical activities in this process include measurement and leakage testing. If they are found to not conform with required specifications then they are either discarded or reconditioned. After reconditioning parts are inspected once more for performance in order to ensure they meet requirements.

Final Product Inspection/Testing

Once the quality of parts has been proven, they are passed through to the next stage of the remanufacturing process. Additional parts, either new or reconditioned from other sources, are used to replace the ones discarded in the previous inspection stage and the product is reassembled. Once it is reassembled it is passed through to the third and final stage of the inspection procedure, the product testing stage.

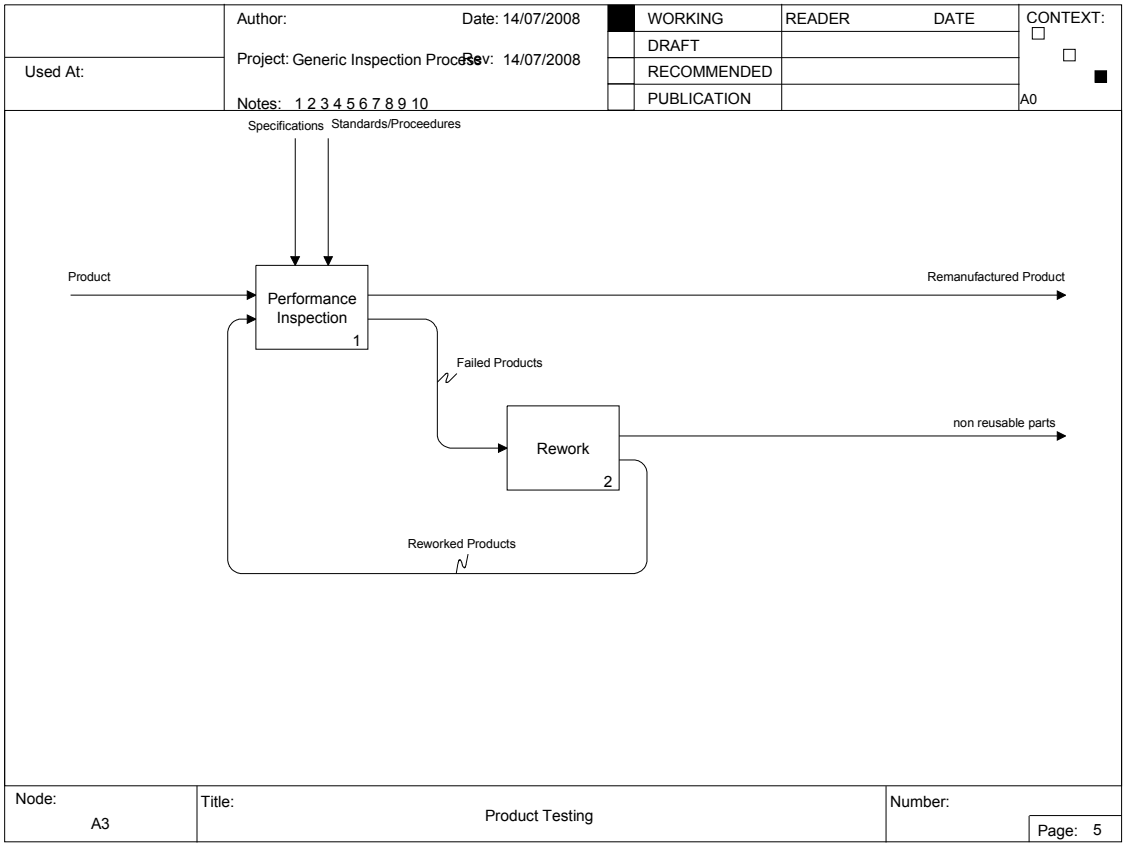

Figure 4 - IDEF0 Diagram of Generic Final Product Inspection Procedure

It can be seen that performance inspection is once again the key part of this inspection and testing procedure. This is the final stage at which the reliability of the final product can be estimated and/or ensured. The process and standards carried out during the performance inspection are different for each product. In the case of OEM approved remanufacturers these are developed with the involvement of the OEM for the product concerned. Products which fail the performance inspection are reworked and retested before they are sold.

FRAMEWORK PROCESS DIAGRAMS

This generic framework was modified for each of the sectors shown in *Figure 1*. This section will outline the major differences between the process diagrams. A complete set of diagrams for each strategy can be found in the appendix.

Strategy I

This strategy includes all of the processes shown in the generic process. A cost based decision is used to identify the most economical cores for remanufacturing. A large part of this is an assessment of the amount of work required to process the core. This is done through simple tasks such as testing to see if relevant parts move smoothly. Once accepted cores are fully disassembled and parts are inspected. All cores are processed in the same way. This has been described in the literature as the 'Bang Bang' approach.

Strategy II

When cores are scarce less emphasis is put on core inspection. The aim of this process is to establish if it is possible to remanufacture a given core rather than if it is economical. This is usually done at a core level using a simple visual inspection. It is sometimes the case that an individual core will be remanufactured at a loss if that means the maximum lead time for a given contract is not exceeded. Once considered feasible all cores are disassembled and inspected following a process similar to Strategy I.

Strategy III

This strategy relies heavily on discarding unsuitable cores in large numbers at the earliest possible stage. Cores that are un-sellable once processed perhaps due to their age and/or demand will be reject immediately. Borderline cases that do not pass a turn on test will also be discarded. Only those cores with high value fail the turn on test are analysed further. Faults are identified and those that are deemed economical to repair are processed. Disassembly is only carried out to the level required to replace the failed component or components. Cores are not routinely disassembled. Final product testing is used to ensure the product will function for a full second life.

Strategy IV

As with Strategy II the main aim here is to assess the feasibility of the remanufacturing of a given core. Less emphasis is put on some of the inspection procedures however the performance inspection is critical for finding the faults with an item and in some cases providing a quote to the customer for the work. As with strategy III disassembly is only carried out in order to facilitate the replacement of failed components and final product testing is used to ensure the product will function for a full second life.