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DEFINING ALTERNATIVES FOR MINING AND TUNNELING EQUIPMENT REMANUFACTURING

Normet Group Oy

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THESIS
Abstract

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Abstract

In this thesis the current situation and possibilities of mining vehicle equipment remanufacturing and rebuilding with the focus on Normet as a case study were examined. The main objectives were to create and define more affordable alternatives for equipment remanufacturing, as high prices and unfamiliarity have been among the main obstacles for such work. Defining alternatives for remanufacturing also included clarifying terms used in rebuilding and repair.

Based on research of rebuilding literature and previously conducted rebuilding status reports, development work resulted in reconditioning and custom rebuilds as more cost-effective options for remanufacturing. Reconditioning focuses on replacing the main components of the equipment, while custom rebuilds are composed of individual process and component kits.

To streamline the creation of rebuild PDM structures, a remanufacturing maxbom that has listed all the basic components and accessory options, was created for the more efficient and rapid PDM structure creation. In addition to defining other rebuild alternatives and the creation of remanufacturing maxbom, several recommendations and improvement possibilities for future rebuilding at Normet were provided. This thesis serves as a foundation for the development of more user-friendly rebuild alternatives. By offering mining and tunneling companies a well working rebuild choice instead of purchasing entirely new equipment, more environmentally friendly future in mining and tunneling can be achieved.

Keywords
Rebuild, Remanufacturing, Reconditioning, Repair, Normet, PDM

CONTENTS

1 INTRODUCTION 5
2 NORMET GROUP OY 5
3 DEFINING TERMS 7
3.1 Condition rating 7
3.2 Remanufacturing 8
3.3 Repair 9
3.4 Reconditioning 9
3.5 Rebuilding 9
3.6 Sovelia PDM 12
4 REMANUFACTURING AND REPAIRING AT NORMET 12
4.1 Aims 12
4.2 Practice 13
4.3 Spraymec cost calculation 14
4.4 UR structure creation 16
5 DEFINING REBUILD OPTIONS 18
5.1 Remanufacturing 18
5.2 Reconditioning 21
5.3 Component and process kits 23
5.4 Sovelia naming 24
6 REMANUFACTURING MAXBOM 26
7 FUTURE STEPS AND POSSIBILITIES 27
7.1 Testing and evaluating remanufacturing set 27
7.2 Instructions for creating rebuild structures 27
7.3 U&M kit discount 27
7.4 Redefining Normet grade system 27
7.5 NDT testing of equipment frames 28
7.6 Installed base 28
7.7 Component remanufacturing 28
8 CONCLUSIONS 29
9 REFERENCES 30

LIST OF FIGURES

FIGURE 1: SmartDrive fleet (Normet, 2023) 5
FIGURE 2. Revenue distribution between business lines (Normet, 2021) 6
FIGURE 3. Normet condition grades (Normet, 2020) 7
FIGURE 4. Frame grade definitions (Normet, 2020) 7
FIGURE 5. Product lifecycle process (European Remanufacturing Network, 2023) 8
FIGURE 6. Mining vehicle manufacturer's rebuild solutions. 10
FIGURE 7. Cost calculation Excel sheet (Normet, 2022) 14
FIGURE 8. Total cost for Spraymec 8100 remanufacturing. 15
FIGURE 9. Equipment UR structure. 16
FIGURE 10. Equipment power transmission BOM. 17
FIGURE 11. Work steps on remanufacturing. 19
FIGURE 12. Work steps on reconditioning. 22
FIGURE 13. Sovelia rebuild structure. 24
FIGURE 14. Remanufacturing maxbom. 26
FIGURE 15. Installed base structure for equipment HE400. 28

LIST OF TABLES

TABLE 1. Terms related to remanufacturing (Oakdene Hollins, 2015) 11
TABLE 2. Main points for all rebuild options. 25

LIST OF ABBREVIATIONS

OEM - original equipment manufacturer

BOM - bill of material

NIL – Normet International Ltd

NOY – Normet Group Oy

NDT - Nondestructive testing

PDM – Product data management

PLM – Product lifecycle management

BEV – Battery electric vehicle

1 INTRODUCTION

The aim of this thesis was to develop Normet's mining and tunneling equipment remanufacturing and repair processes with overall improvements and by creating and defining cheaper alternatives. The remanufacturing of Mining and tunneling equipment was started a few years ago at Normet Service Centers around the globe as a market response to increasingly growing interest in sustainability and material reuse. In addition to sustainability, shorter lead time is the one main advantage of remanufacturing for both the customer's and Normet's own production.

Unfortunately, during the few remanufacturing years, high remanufacturing price for the customer has been a significant factor for the low volume of done remanufacturing work. Part of the high price is indeterminacy of remanufacturing process that increases the need for active planning thus increasing the price. By properly defining and creating cheaper remanufacturing and repair options it is hoped that this will increase sales with a better overall profit margin and harmonize work processes between global Service Centers.

2 NORMET GROUP OY

Normet Group Oy is a fast-growing technology leader in designing and manufacturing of underground mining and tunneling vehicles, equipment, construction chemicals and rock reinforcement. There is a wide variety of concrete spaying, concrete transportation, rock scaling, personnel lifting, explosive charging, and underground logistics vehicles. (Normet, 2023.) A lot of company's development effort is nowadays put to designing battery electric vehicles. Fleet of Normet's SmartDrive (electric) vehicles in FIGURE 1.

FIGURE 1: SmartDrive fleet (Normet, 2023)

Normet was established in 1962 in Peltosalmi, Iisalmi with the name Peltosalmen Konepaja by farmer brothers Jaakko and Jussi Sarvela. Among the first year's products were mostly farming and forestry equipment attached to tractors, mining equipment was a small part of the business. After selling the company to Orion group the mining vehicle production and sales started. This was the starting point for the Normet as a mining and tunneling equipment manufacturer. (Sarvela, 2008.)

Today the company has over 1600 employees operating globally in over 33 countries worldwide with over 50 locations of factories, service centers and warehouses. The main factory is located at Iisalmi, Finland but a new factory has been opened to Jaipur, India at the start of 2023. Normet has manufactured during the years over 14000 vehicles in total for the world's mining and tunneling sites. (Normet, 2023.)

Normet Group Oy's revenue in 2021 was 359 million euros with the 36 million euros operating profit. Most of the revenue (44%) came from service business line that has been steadily growing as seen in FIGURE 2. Equipment (EQ) and Ground Control & Construction Technologies (GCCT) makes the rest of the revenue with the distribution of 38% in EQ business line and 19% in GCCT business line. (Normet, 2021.)

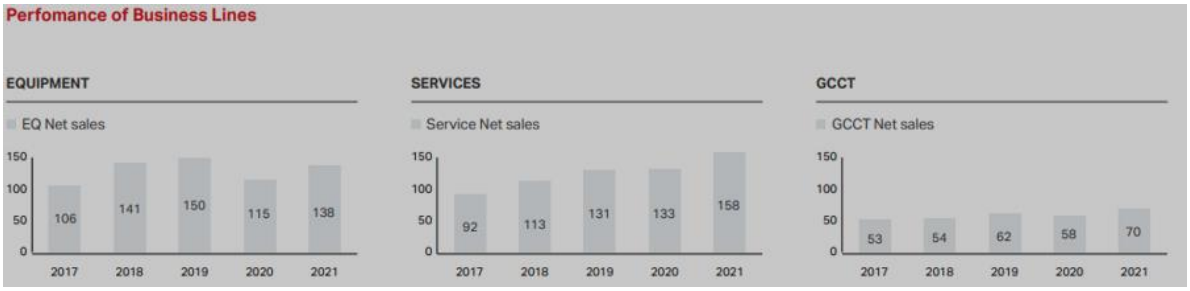

FIGURE 2. Revenue distribution between business lines (Normet, 2021)

Normet Group Oy has multiple daughter companies of which the most important are Normet Oy (NOY) and Normet International Ltd (NIL). Normet Oy consists of Iisalmi factory's and Service Center's functions with the machine manufacturing and R&D. Normet International on the other hand consists of international sales to regional smaller daughter companies, gross margin is added to sales price for regional companies to keep profits centralized.

3 DEFINING TERMS

3.1 Condition rating

Condition rating is a method used to assess the state or physical condition of the equipment, building or other assets across various industries such as insurance, real estate, factories, and service operations. Normally condition ratings are based on the running numerical scale, for example from 1-10, from poor to new. Different ratings are usually explained in detail that considering factors such as overall functionality, age, appearance, wear, and operating environment. Condition ratings can be used as a tool for determining the extent and type of the maintenance that is needed for the asset or equipment to meet or uphold the desired operating conditions. (Queensland Goverment, 2017)

Normet has in use its own condition rating system (Grades) that aims at giving guidelines for classifying equipment condition within the organization. This rating system is used by experienced service personnel in equipment condition audit that defines what can and should be done to equipment in question as seen in FIGURE 3. The grade can be given for the whole machine, a module, or a part. (Normet, 2020.)

GRADE	DESCRIPTION
GRADE 5	Equipment or part is new.
GRADE 4	Equipment or part is remanufactured by OEM
GRADE 3	Good working conditions. Many parts can be worn, but still in acceptable working condition. Equipment cannot contain any defected parts.
GRADE 2	Equipment or its part is qualified to be repaired or replaced.
GRADE 1	Equipment or part is equal to unusable and cannot be repaired, scrap.

FIGURE 3. Normet condition grades (Normet, 2020)

In the document there are definitions for every grade at part level for example classifying at which condition frame is in Grade 3 as seen in FIGURE 4. The minimum grading is 1,0 and the maximum is 5,0. Grade numbers are not rounded to the closest whole number, for example machines grade can be 2,5 or 3,4 and so on.

CHASSIS	Grade 5	Grade 4	Grade 3	Grade 2	Grade 1
Frame (front and rear)	OEM. New Found no bends, cracks or corrosion	VG. Found no bends, cracks or corrosion. surface rust spots with diameter under 5 mm are allowed	GC. Wear on paint and rust may appear.	PC. Must not have any deformation. Welding's has to be intact.	X. Found bends or deformation / cracked or have deep corrosion.

FIGURE 4. Frame grade definitions (Normet, 2020)

3.2 Remanufacturing

Remanufacturing is an industrial process in which a previously used, sold, leased, worn or non-functional component or product is thoroughly rebuilt and revived to a "like-new" state. The machine or component is returned to a "like-new" condition by disassembling, cleaning, inspecting, replacing of all the parts with new or remanufactured ones, reassembling and testing. The objective of remanufacturing is to make remanufactured machine or component as reliable and capable as the original product by meeting or exceeding the OEM's original specifications with the full warranty for the customer. (TWI Global, 2023.)

There is no one way to answer what kind of products can be remanufactured, but the common characteristics are high value, complexity, and durable core. Furthermore, products with high quality materials and long-lasting technology used are usual remanufacturing targets. Remanufacturing is a popular process within many industries. Automotive parts, aircraft components, medical tools, office furniture and electrical equipment are good examples of remanufacturing products. (TWI Global, 2023.)

Remanufacturing is a powerful tool for reducing environmental pollution and waste by making old products into "new-like" without need for material transformation that consumes energy as in like recycling. FIGURE 5 illustrates product's products lifecycle process with difference between recycling, remanufacturing, reuse, and repair. (TWI Global, 2023.)

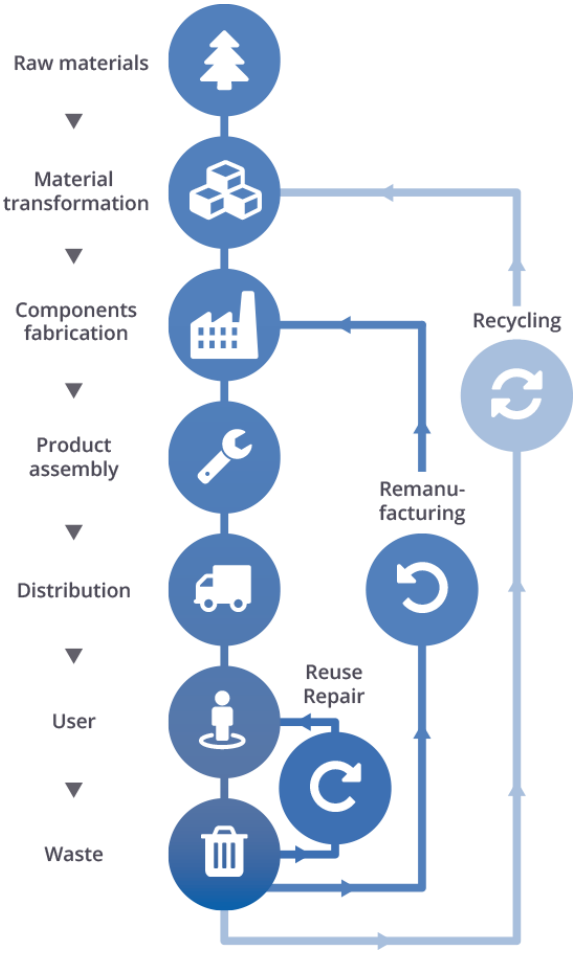

FIGURE 5. Product lifecycle process (European Remanufacturing Network, 2023)

Main disadvantages and problems for remanufacturing often involve high costs in low-tech applications and lowered product image. Often buying a new product is cheaper than reconditioning old ones in the case of low-tech products, in high-tech products the remanufacturing will still be cheaper than the new product. Another con is that customers tend to perceive remanufactured products as "second class" even if the performance and reliability is same or even better as in new equal equipment or part. (TWI Global, 2023.)

3.3 Repair

Repairing is a process in which something damaged, malfunctioning or not functioning as intended is restored back into the right working condition. The term repair can be applied to many kinds of products including machinery, electronics, vehicles etc. (Hohenemser, 2016)

To repair a product or component, the process usually starts with identifying the problem or issue. Once the problem has been diagnosed, the product or component is disassembled to access the internal parts. The damaged or worn parts are then identified and replaced or repaired as needed. (Hohenemser, 2016)

After the repair work is completed, the product or component is reassembled, and a final testing is done to ensure that it is functioning correctly. The testing process can involve a series of checks to verify that the repaired product or component meets all required specifications and functions as intended. (Hohenemser, 2016)

3.4 Reconditioning

As a middle ground between the repair and remanufacturing, there is a term "reconditioning". Reconditioning involves restoring used products to a working condition by rebuilding major components that are expected to be close to failure, even if there are no apparent problems in the components. Reconditioning does not necessarily aim to "as new" state of equipment or components as in remanufacturing. (Oakdene Hollins, 2015)

Reconditioning is generally a cheaper option than remanufacturing but more expensive than repair due to the different amount of component replacements and work related to these components changes. Equipment condition and performance is expected to be very good that works as intended role, but it is likely to be slightly inferior to that of remanufactured and new as only major components and faulty components are replaced. Reconditioned equipment has normally slightly shorter warranty time than in remanufactured or new equipment. (Oakdene Hollins, 2015)

3.5 Rebuilding

Rebuilding can be used as a term to describe similar work as reconditioning but in mining vehicle manufacturing industry rebuilding is commonly used as an umbrella term to describe all kinds of work that are more than just a basic repair. For example, one major mining vehicle manufacturer uses rebuild as an umbrella term for their own remanufacturing (reborn) and other rebuilds seen in FIGURE 6 from their company webpage. See TABLE 1 for more information on terms related to rebuilding and remanufacturing and their short explanations.

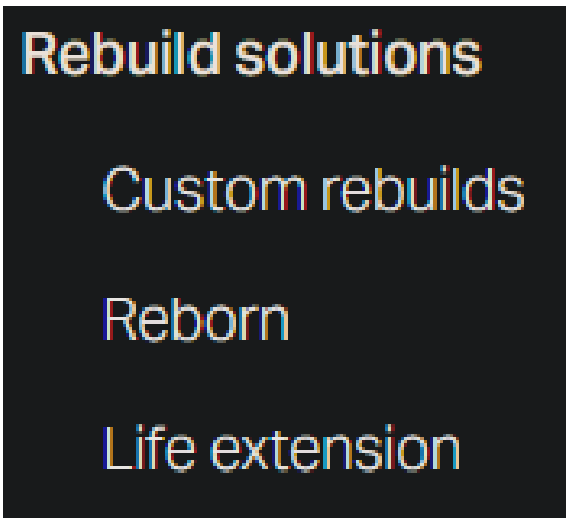

FIGURE 6. Mining vehicle manufacturer's rebuild solutions.

TABLE 1. Terms related to remanufacturing (Oakdene Hollins, 2015)

Term	Definition	Reference
Recondition	The potential adjustment to components bringing an item back to working order, though not necessarily to an 'as new' state.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Return a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components.	BS 8887-2: 2009
	Notes • Generally less expensive than remanufacture but more than necessary for repair. • Performance after reconditioning is expected to perform its intended role but overall is likely to be inferior to that of the original model. • Subsequent warranty is generally less than new or a remanufactured product.	
Refurbish	The largely aesthetic improvement of a product which may involve making it look like new, with limited improvements to functionality.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
Repair	Fixing a fault but with no guarantee on the product as a whole.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Returning a faulty or broken product or component back to a useable state.	BS 8887-2: 2009
	Fixing what is broken or worn.	Lund, n.d. *The Database of Remanufacturers* http://www.bu.edu/reman/The Remanufacturing Database.pdf
	Notes • Repair may use remanufactured or reconditioned parts. • Minimum manufacturing effort required to address the specified fault. • Subsequent warranty is generally less than that of newly manufactured, reconditioned or remanufactured and may only apply to the replaced component.	
Re-use	The simple reuse of a product with no modifications.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Operation by which a product or its components are put back into use for the same purpose at end of life.	BS 8887-2: 2009
Recycle	Extracting a product's raw materials to use in new products. This is a good option for products which are easily constructed and have minimal numbers of components.	Triple Win *The Economic, Social and Environmental Case for Remanufacturing*
	Shredding or disassembling products to recover materials value.	Lund, n.d. *The Database of Remanufacturers* http://www.bu.edu/reman/The Remanufacturing Database.pdf
	Process waste materials for the original purpose or for other purposes, excluding energy recovery.	BS 8887-2: 2009

3.6 Sovelia PDM

PDM is a system that is used for engineering process and design data management. Typical information that is stored in PDM is for example BOMs (Bill of material), drawings, technical specifications, engineering documentation and other documents such as images of the part or assembly. (PIMVendors, 2023) Revisions of all the data are also stored to help to keep track of changes.

This system provides data to all other systems within the company that require information about that product such as ERP (Enterprise resource planning) (PIMVendors, 2023). ERP systems are used for example for managing production, warehouse stocks, material and resource management, billing, and accounting according to BOM (Itewiki, 2023).

Sovelia PDM is a system owned by Finnish Symetri that is used for Normet's product data management.

4 REMANUFACTURING AND REPAIRING AT NORMET

4.1 Aims

Remanufacturing at Normet has the aim to restore equipment to at least to grade level 4 by changing flawed parts with the new or remanufactured ones. The equipment will be completely disassembled, and all the parts that have been defined to be saved for remanufacturing will be sandblasted and re-painted. All the other parts are new. After disassembly and re-painting, equipment is reassembled utilizing the available remanufactured parts and components beside new ones. Lastly, new machine plates are installed with the remanufacturing information in addition to the original manufacturing information. The remanufactured equipment is given a full 1 year / 2000 hours warranty.

Repairing at Normet has the aim to restore equipment at least to a grade 3 by changing flawed parts with the new, remanufactured or grade 3 ones. The main idea is to only change parts that are causing the malfunction, so no working parts are changed unless decided otherwise. In practice repair usually consists of more work than just replacing the flawed parts. The warranty for repaired equipment is 3-6 months or 250-500 hours. (Normet, 2021)

In addition to remanufacturing and repair there are other custom repairs done for Normet's equipment according to the customer's needs. These custom repairs have differing condition aims.

4.2 Practice

During the winter and spring of 2023 there was done research on Normet's remanufacturing and repairing practices around the global service centers as a part of the school specialization project. The research was carried out with a list of questions and meetings concerning equipment remanufacturing and repairs with global service managers. A question list was sent to nine regions from which seven had responded before writing this thesis.

The main findings of that research were that there are several different terms in use related to or close to remanufacturing and repair. Terms like refurbishment, reconditioning, rebuilding, and overhauling are used sometimes as a synonym to remanufacturing but on the other hand they are used as independent terms to describe something less than remanufacturing that the equipment not necessarily has all new or remanufactured components. Different closely related terms that are used independently, which can create confusion and misunderstanding between employees and regions. (Kallinen, 2023)

In total 19 remanufacturing cases have been done during the last few years of which all of them, but one has been done in Latin America. The one not done in Latin America was done in Finland's service center. Other kinds of extensive rebuilds have been done more instead of remanufacturing. The repairing though is very usual and normal for everyone in Normet's business line and there have been hundreds of them done over the years. (Kallinen, 2023) Normal repairs are the most usual works done in service centers and workshops.

Remanufacturing and repairs nowadays lean heavily on the earlier gained experience of the personnel as there rarely are workshop manuals available for work steps and if there are, the instructions tend to be vague (Kallinen, 2023). Mechanical drawings are used for assembly work, but they don't usually tell the best assembly methods not the mention instructions for disassembly.

The biggest progress for disassembly/assembly instructions has been done in Australia in a form of SOPs (Standard Operating Procedures) (Kallinen, 2023). SOPs are kind of the most detailed written step-by-step instructions with the basic presumption that person with little earlier experience should be able to complete the job, for example replacing the battery pack for BEV safely and correctly.

4.3 Spraymec cost calculation

There was done proper cost calculation for Normet's concrete spraying machine, Spraymec 8100 at the end of 2022. The cost calculation includes all the parts used all the way to the smallest nuts and bolts with the needed information. Excel sheet had estimated quantity of items needed, unit, product name, average cost as a new part, if the component was remanufactured, remanufacturing cost, remanufactured component cost and new component bought from NIL (Normet International Ltd) as seen in FIGURE 7.

NIL is the Normet Group Oy's daughter company that is used to running international business centralized. All the spare parts to regional companies are bought through NIL, excluding locally produced components. NIL takes 35% gross margin from sold spare parts, after that regional companies sell parts with their own gross margins.

Estimat	Unit	Product name	AVERAGE COST/item	Repairable	repair cost	remanu cost	parts from NIL
1,00	pcs	SOCKET	219,67			219,67	337,95
3 897,11	Hr	Subcontracting work (EUR)	3897,11			3897,11	5995,55
1,00	pcs	HYDRAULIC MOTOR	1395,32	yes	980	980	980
1,00	pcs	AXLE PLATE	202,81			202,81	312,02
5,00	pcs	HOSE SUPPORT	112,99			564,95	869,15
1,00	pcs	AXLE PLATE	202,81			202,81	312,02
2,00	pcs	MOUNTING PLATE	46,44			92,88	142,89
2,00	pcs	PLATE	34,85			69,7	107,23
1,00	pcs	AXLE	4416,64	yes	3100	3100	3100
1,00	pcs	AXLE	4000,52	yes	2900	2900	2900

FIGURE 7. Cost calculation Excel sheet (Normet, 2022)

This remanufacturing was done so that all the under 1000€ parts were recycled and replaced with the new parts automatically without checking if the parts are remanufacturable. This is done so that cheaper parts do not end up costing more than new parts through used time on component inspection and repairing. Over 1000€ costing parts were disassembled and inspected, after that remanufactured if reasonably possible.

According to these calculations the total cost for remanufacturing of the machine was 223 465 € counting all remanufacturing work hours and components as seen in FIGURE 8. Components themselves cost approximately 169 000 € but as remanufacturing is labor intensive, the total cost was significantly higher. In total 690 hours of disassembly/assembly work was done with the cost of 21390 €. The calculations has been done in Finland with its local work and component costs.

	materials		168394,64	237223,29
	hours	690	21390,00	21390,00
OO 12,6% OF HOURS	12,60 %	2695,14		2695,14
CDM 5,6% MATERIALS	5,60 %	9430,10		13284,50
IL 12,8% MATERIALS	12,80 %	21554,51		30364,58
	overheads		33679,75	46344,22
	TOTAL COST OF REMANU		223464,39	304957,51
	PRICE OF NEW EQ		440000	440000
70% OF NEW	SALES PRICE OF REMANU		308000,00	308000,00
	MARGIN EUR		84535,61	3042,49
	MARGIN %		27,45 %	0,99 %
			NOY	AREAS parts from NIL

FIGURE 8. Total cost for Spraymec 8100 remanufacturing.

On top of that so-called overhead expenses were calculated consisting of OO (Operating Expenses), CDM (Cost for Design and Management) and IL (Inventory & Logistics). Overheads are ongoing business expenses that can't be directed to a one specific activity when creating service or a product (Investopedia, 2022). Operating expenses are 12,6% of the total disassembly and assembly work done, this covers for example sick leave, benefits for employees and etc. Cost for design and management covers all the planning and design work needed for remanufacturing work. Inventory & Logistics covers expenses for moving and storing components.

As the machine is always sold at 70% of the new equipment's price, in this case 308 000€, the profit margin for remanufacturing work in question was 27,45%. The margin of this remanufacturing work was less than what is aimed for generally withing the company but on the other hand it is relatively good considering the small amount of done remanufacturing works.

4.4 UR structure creation

So called UR structures are created when defining the needed components and price for rebuild. UR structures have a U structure (the used equipment) that is basically duplicate of the original equipment structure. So called UA structure is under UR structure too, that works as an audit structure. In addition to UA and U structures, there are all the needed parts and assemblies. UR structure example can be seen in FIGURE 9.

	(R).P...	Type	Name and description	(R).Q...	Unit o...
100031850UR1.0		92-Renovation	REBUILD, FOR, SPRAYMEC 8100VC EN116		pcs
100031850UA.0	1	92-Renovation	WORK, SPRAYMEC 8100VC EN116, SERVICE CENTER AUDIT	0.0	pcs
100031850U.0	2	EZ-Used Spraymec	SPRAYMEC, 8100VC, EN116	0.0	pcs
100155253.0	3	1G03-Brakes and wheels	WHEEL, NOKIAN TYRES, HTWS01140, 10.00-20"	1.0	pcs
100014628.2	4	1H01-Measuring	PRESSURE SENSOR, GENERIC ITEM, G1/2 / M12, 10-30VDC, 4-20MA	1.0	pcs
100016108.1	5	1M03-Filters	AIR CLEANER, DONALDSON, TOPSPIN HD, H002854, 10-20 M3/MIN, ID129MM	1.0	pcs
100018421.0	6	1K02-Piping	HYDRAULIC HOSE, DUNLOP HIFLEX, 122T-16, ST/RUBBER, ID1", 88BAR	50.0	m
100018789.0	7	2A24-Electrical assembly	INLET PLUG, CAVOTEC PC4-SX04-S100 + 95MM2 PINS	1.0	pcs
100024362.2	8	1K03-Valves	COMPRESSED AIR VALVE, SMC, VXD25-FIU00063	1.0	pcs
100065283.0	9	1J02-Electrical switches	LEVEL SWITCH, IFM ELECTRONIC, LMT100, M12, 18-30VDC, 0.05A	1.0	pcs

FIGURE 9. Equipment UR structure.

For smaller repairs and rebuilds creating BOM by selecting specific components one by one for rebuilding is easy to handle. The problem comes when BOMs for the whole equipment remanufactures or other large rebuilds are done. There is need to select every component one by one from axle fitting assemblies for example in FIGURE 10 if it is wanted to use a remanufactured axle instead of a new one because specific components cannot be deleted under structure and keep it as an original item number. The remanufactured components are separated from the new ones with the letter R after the original item number. This has created situations where there have been well over 1000 positions under UR structure. This high number of positions has caused data transferring problems in production planning software. Creating BOMs of over 1000 lines takes lots of time which is not desirable either.

	(R).P...	Type	Name and description	(R).Q...	Unit o...
100087307.1	102	2A153-Spraying equipment	POWER TRANSMISSION, FOR SPRAYMEC 8100 STD COMPLETE/ NEW SENSORS	1.0	pcs
100087186.1	1	2A21-Mechanical assembly	POWER TRANSMISSION, NGE2, SPRAYMEC 8100	1.0	pcs
D100087186_PDF.1		PDF drawings	POWER TRANSMISSION, NGE2, SPRAYMEC 8100		
D100087186.1		Drawings	POWER TRANSMISSION, NGE2, SPRAYMEC 8100		
100087177.3	1	2A22-Hydraulic component assy	AXLE, DANA FITTINGS MOTOR END 602/212/112, SPRAYMEC 8100	1.0	pcs
D100087177_PDF		PDF drawings	FITTINGS, DANA AXLE FITTINGS MOTOR END 602/212/112, SPRAYMEC 8100		
D100087177.3		Drawings	FITTINGS, DANA AXLE FITTINGS MOTOR END 602/212/112, SPRAYMEC 8100		
100009825.0	1	1G04-Hydraulics and pneumat...	HYDRAULIC MOTOR, DANFOSS, H1-B-110-A-P2-D2-N-B-TA-DN-JN-N-A-15-NN-040-...	1.0	pcs
52062114.0	2	1E01-Fasteners	HEX SCREW, ST8.8ZN, M16X40MM, DIN933	4.0	pcs
52214285.1	3	1E01-Fasteners	LOCK WASHER, WEDGE TYPE, ST-DELTA, M16X25MM, DIN25201	4.0	pcs
100102550.0	4	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 8M14F87OMXS, STZN, 1/2", M14X1.5 - ...	2.0	pcs
52452125.0	5	1K02-Piping	T-COUPLING, PARKER, 8S6MXS, ST, 3/4-16 JIC, 350BAR	2.0	pcs
100035329.0	6	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 6M14F87OMXS, STZN, 3/8", M14X1.5 / ...	2.0	pcs
52452265.0	7	1K02-Piping	T-COUPLING, PARKER, 6S6MXS, ST, 9/16-18 JIC, 350BAR	2.0	pcs
52453982.0	8	1H01-Measuring	MEASURING PLUG, DUNLOP HIFLEX, 8TT4MXS, 29-6040-04-08, 1/4-19 BSPP / 3/4...	1.0	pcs
52449162.0	9	1K02-Piping	MEASURE QUICK COUPLING, HYDROTECHNIK, MINIMESS 1620 TEST POINT, 2103...	3.0	pcs
52450848.0	10	1H01-Measuring	MEASURING PLUG, DUNLOP HIFLEX, 6TT4MXS, 29-6040-04-06, 1/4-19 BSPP / 9/1...	2.0	pcs
52450368.0	11	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 4M10F82EDMXS, STZN, 1/4", M10X1.0 ...	2.0	pcs
52451432.1	12	1K02-Piping	ANGLE COUPLING, PARKER, 4C6MXS, 29-1130-04-04, STZN, 1/4", 7/16-20 JIC / 7/...	2.0	pcs
45904890.0	13	2A55-Change of purchased co...	SENSOR HOLDER, M22X1,5 - M14X1,5MM	1.0	pcs
52390143.0	14	1F02-Seals	COPPER SEAL, 22X27X1.5MM	1.0	pcs
52390366.0	15	1F02-Seals	COPPER SEAL, 14X18X1MM	1.0	pcs
100063900.0	16	1J02-Electrical switches	TEMPERATURE SWITCH, BEDIA, TSM226-001V1, M14X1.5MM, 12-30VDC, 10/16A	1.0	pcs
100151597.0	17	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 8M18F87OMXSS, STEEL, 1/2", M18X1.5...	2.0	pcs
52451234.0	18	1K02-Piping	ANGLE COUPLING, PARKER, 8C6MXS, 29-1130-08-08, STZN, 1/2", 3/4-16 JIC / 3/4...	4.0	pcs
52453727.1	19	1K02-Piping	REDUCTION COUPLING, PARKER, 8-6TRTXNS, ST, 3/4-16X9/16-18" M, 3/4-16 UNF...	2.0	pcs
52453438.0	20	1E01-Fasteners	FITTING NUT, DUNLOP HIFLEX, 8BMTXS, 29-200-08, ST, 3/4-16"	2.0	pcs
52450459.1	21	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 12F5OMXS, STZN, 3/4", 1_1/16-12 UNF ...	2.0	pcs
52451440.1	22	1K02-Piping	ANGLE COUPLING, PARKER, 12C6MXS, 29-1130-12-12, STZN, 3/4", 1_1/16-12 JIC ...	2.0	pcs
100009697.3	23	1G02-Couplings and axles	AXLE, DANA, 602/212/112, 602.97.212.112, DIN120	1.0	pcs
52450798.0	24	1K02-Piping	STRAIGHT THREAD CONNECTOR, PARKER, 6F5OMXS, STZN, 3/8", 9/16-18 UNF / 9/...	1.0	pcs

FIGURE 10. Equipment power transmission BOM.

In some situations, choosing between new and remanufactured components in rebuild has been handled in production planning software which unfortunately does not leave any marking to PDM that could be used to monitor the equipment's history of rebuilds and repairs.

5 DEFINING REBUILD OPTIONS

Based on research and problems in current remanufacturing, two proposals for cheaper alternatives in addition to the remanufacturing are called reconditioning and custom rebuild. Custom rebuild is not a clearly defined process because it can vary significantly depending on the customer's needs. It will be made up of basic parts that every kit has and then different kinds of component and process kits with fixed prices. TABLE 2, located after chapters 5.1 to 5.4, summarizes the main points for each of the three rebuild options.

5.1 Remanufacturing

From the most parts the remanufacturing would stay the same with the basic idea of reusing the frame that is built with remanufactured and/or new main components alongside with new cheaper components that cannot be be remanufactured cost effectively. Deciding whether the new or remanufactured component is used depends on the component availability and price as there are often situations where the times for certain components are very long, on the other hand the core part might be in so bad condition that it can’t be fixed. If possible, remanufactured components should be used over new components. The price of the remanufacturing stays the same in 70% of the new equivalent machines as increasing profit margin and price would shy away interested customers. The process chart of the remanufacturing process can be seen in FIGURE 11.

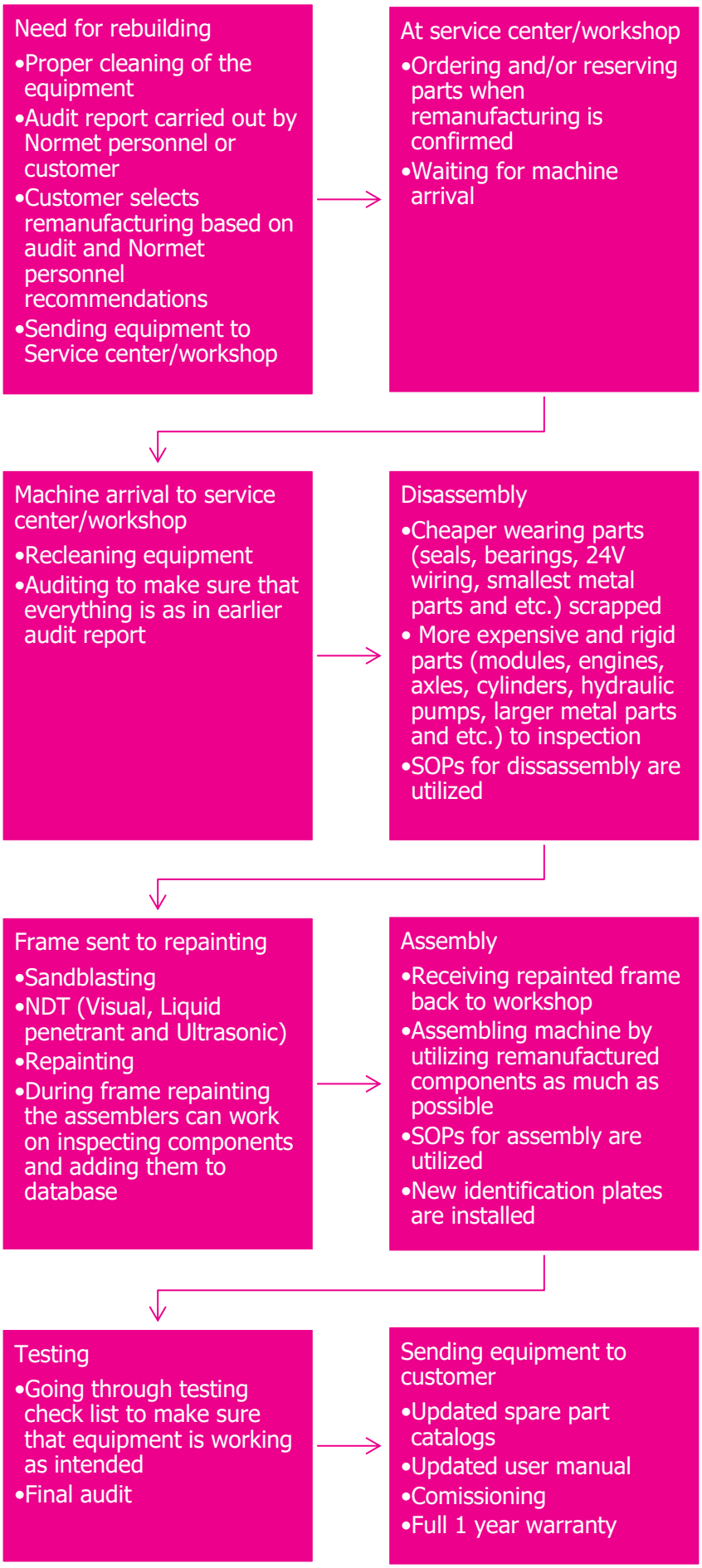

FIGURE 11. Work steps on remanufacturing.

The first step would be auditing the equipment at the customer's end, which includes cleaning of the machine and evaluating equipment condition rating done by Normet personnel or other capable personnel. If the equipment remanufacturing seems the best solution for the customer, then the equipment is sent to the closest Normet service center or workshop for remanufacturing work. When information of the remanufacturing gets to the service center personnel, the component reservation and creating Sovelia structures for work are started before the equipment arrival.

When the equipment arrives at the service center, it is audited again and checked that it meets the conditions that were defined at the customer's end. If some conditions do not match it is solved between the customer and service center personnel and the work and pricing are agreed.

Disassembly is started after the final agreement. All the visibly broken, and minor components are recycled or scrapped. Main components and larger metals parts are taken aside. Frame is sent to NDT testing and repainting after equipment disassembly meanwhile the components are checked and stored or sent to remanufacturing. SOPs or other instructions are utilized at all disassembly steps if possible. If the disassembled components are needed for the reassembly in case there are no remanufactured components in storage, the disassembled components are sent to remanufacturing.

When repainted and NDT tested, the frame returns to the service center and the assembly is started according to general instructions or SOPs. New identification plates will be installed onto the equipment after the assembly is ready.

Equipment goes through the same tests and quality checks as in the case of whole new ones. If the machine passes these tests, it can be sent to the customer with the full one-year warranty and commissioning if needed. Spare part manuals and user manuals are updated if any upgrades or changes are made.

5.2 Reconditioning

Reconditioning is stripped down remanufacturing work that focuses on the main components of the equipment which includes axles, motors, hydraulic pumps, hydraulic motors, drive shafts, hydraulic cylinders, concrete pump, compressor and etc. In addition to changing the main components, all filters, oils, bearings, and seals are changed. Main components would be replaced with new or remanufactured ones depending on availability and cost. Hydraulic and pneumatic fittings part of main component assemblies are changed to new along with electric connectors on main components. All the hydraulic hoses are changed for safety and reliability reasons as broken hydraulic hoses are one of the most common failures that prevent equipment use. If the wiring harnesses or other minor components show signs of imminent failure, they should be replaced as part of the rebuild process.

The process for reconditioning would be like remanufacturing with the exception that not every smaller component is scrapped and instead of repainting, the frame and other components are overpainted after removing loose paint from the surfaces. Reconditioning work steps that follow remanufacturing steps in FIGURE 12.

With these changes to full remanufacturing, it is hoped that cost will go down significantly, and it still is almost as good as new. For example, overpainting the equipment frame is way cheaper than repainting the whole frame by sandblasting and painting. Even though paintjob gets cheaper it is not particularly that much worse because mining vehicle working environment tends to corrode paint anyways fast. Changing all the wiring harnesses can be a costly thing with no real impact on reliability as the main components are usually the ones that cause major machine failures. By reducing the amount of wiring harness only faulty ones, it will save on costs slightly. Changing fittings and harnesses on main component assemblies is done because they are usually pre-assembled with fittings and harnesses before installation to machine. Cost calculations for reconditioning like for remanufacturing will be done at a later stage.

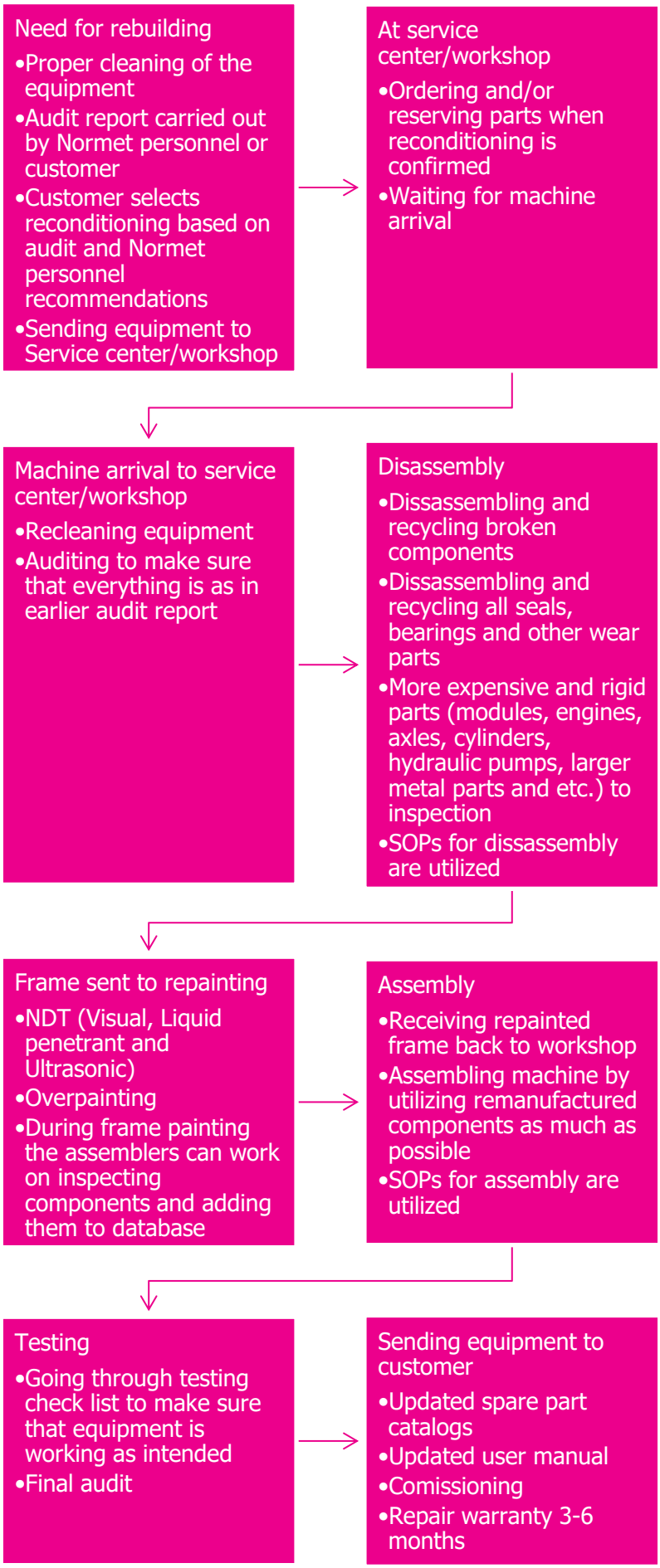

FIGURE 12. Work steps on reconditioning.

5.3 Component and process kits

As a third option for rebuilding there are different kinds of component and process kits that can be selected to compose custom rebuild according to the customers' needs and wants. Custom rebuild kits include all the needed parts and work instructions. As a base for custom rebuild there would always be changing of the axle brake discs, overpainting and changing of all the filters and other service parts. Available kits in custom rebuild for example Spraymecs would be:

- Bearing kit
- Engine kit
- Process kit
    - Concrete pump kit
    - Shotcrete boom and line kit
    - Additive pump kit
- Powerpack kit
- Hydraulics kit
    - Transmission kit
    - Hydraulic hose kit
    - Compressor kit
    - Oil cooler kit
    - Pressure washer kit
- Electrics kit
    - High voltage module kit
    - TB1 kit
    - Control electrics kit
    - Transformer kit
    - Cable reel kit

The price of these kits would be predefined so that customers will know the price immediately when selecting this rebuild option. The problem with the wide variety of machine types and eras is that these kits would differ from machine to machine a lot, even though the main components could be similar. Kit structures needs to be created and priced if not done earlier when customer is interested in custom rebuilding option and pricing.

The customer has the possibility to select the main components as new or remanufactured. Using remanufactured components lowers the price of the kit by some margin that will be defined at a later stage by sales personnel.

Customizable rebuild was the result of not coming up with any reasonable predefined rebuild lesser to reconditioning and remanufacturing. Also, other mining vehicle remanufacturers have this kind of custom rebuild where customers can choose which components are changed. There might be problems with some component assemblies by braking usually and unpredictable, in this kind of situation it is resolved easiest by changing the whole component assembly to a new one.

5.4 Sovelia naming

The first step in defining different rebuild options is to recognize a problem within the Sovelia PDM system with naming and classifying rebuild. Normally every kind of rebuild is named as just a "REBUILD", after that machine specific information is added. There is example of the Sovelia structure in FIGURE 13 that tells item type (Rebuild) machine model (Spraymec 8100 VC) and its serial number (EN218)

100127797UR3.3		92-Renovation	REBUILD, FOR SPRAYMEC, 8100 VC, EN218
100127797U.0	1	EZ-Used Spraymec	SPRAYMEC, 8100 VC, EN218
100013075.0	2	1N01-Component spare parts	OIL FILTER CARTRIDGE, HYDAC, 0200 MX 010 MM/B3.5-SO462
57624780.0	3	1M03-Filters	OIL FILTER CARTRIDGE, HYDAC, 0185 R 010 MM, 1287180, MOBILEMICRON, 185, 10BAR

FIGURE 13. Sovelia rebuild structure.

This kind of naming does not describe at all what kind of work is done other than by checking the item structure what is added under the main item structure. The number of components gives some kind of idea how large-scale work is done but that does not describe it very well. For future rebuilds there should be added type of rebuild to additional information in following way:

ITEM TYPE, ADDITIONAL INFORMATION, MODEL, SERIAL NUMBER

And example:

REBUILD, RECONDITIONING, SPRAYMEC 8100 VC, EN218

TABLE 2. Main points for all rebuild options.

Name	**Remanufacturing**	**Recondition**	**Custom rebuild**	**Other information**
What is done?	Complete disassembly Sandblasting and repainting Every component is remanufactured or new NDT	Limited disassembly Overpainting of visible parts All the main components are changed with remanufactured or new NDT	Limited disassembly Overpainting of visible parts Faulty components are changed in addition to selected component kits	Filters and oils are changed in every rebuild
Price	70 %	60 %	According to audit	
Warranty	Full 1 year warranty	Repair warranty for the machine, full warranty for new components	Repair warranty for the machine, full warranty for new components	
New machine plates	Yes	No	No	Some of the mines do not allow over 5 years old machines
Updated manuals	Yes	Yes	Yes	If any changes to components
Recommissioning	Option	Option	Option	
Final inspection	Yes	Yes	Yes	Every rebuild goes through final testing
Grade aim	>4	>3,5	>3	

6 REMANUFACTURING MAXBOM

Remanufacturing maxbom (FIGURE 14) for the Spraymec 8100 was created based on the production line maxbom for this equipment type. Maxbom is a PDM structure that has listed all possible options and accessory variations for the equipment type in question. Maxboms can be used to create equipment structures quickly and clearly by selecting components according to customer's needs and wants. The remanufacturing maxbom differs from the production line maxbom in that each assembly's main components have been moved up to one higher BOM level and a remanufactured (R) part has been added as an alternative to a new part with the same position number. This gives flexibility to choose which best suits every region's labour costs and component availability.

	(R).P...	Type	Name and description	(R).Q...	Unit o.
100210281.0		2A11-Maxbom structures	SPRAYING EQUIPMENT, REMANUFACTURING MAXBOM, SPRAYMEC 8100		pcs
100210933.0	100	2A153-Spraying equipment	STANDARD PARTS, REMAN 2022, SPRAYMEC 8100	1.0	pcs
100020031.6	1	2A153-Spraying equipment	EQUIPMENT KIT, FOR SPRAYMEC 8100	1.0	pcs
100019629.1	2	2A57-Labels	SYMBOL, 5100VC LABELS	1.0	pcs
100016948.22	101	2A4-Weldment	FRAME, 894X2260X7330MM, SPRAYMEC 5000/8100, STEEL	1.0	pcs
100207094.0	102	2A11-Maxbom structures	POWER TRANSMISSION, REMANUFACTURING SET, SPRAYMEC 8100	1.0	pcs
100210082.0	1	2A22-Hydraulic component assy	FITTINGS, DANA AXLE FITTINGS MOTOR END WITHOUT AXLE 602/212/112, SPRAY...	1.0	pcs
100210081.0	2	2A22-Hydraulic component assy	FITTINGS, AXLE FITTINGS REAR END WITHOUT AXLE 212HY/901, SPRAYMEC 8100	1.0	pcs
100210080.0	3	2A21-Mechanical assembly	OSCILLATION LOCK, POWER TRANSMISSION WITHOUT HYDRAULIC CYLINDERS, SP...	1.0	pcs
100009698.2	4	1G02-Couplings and axles	AXLE, DANA, 212HY/901, 212.97.000.901, DIN120	1.0	pcs
100009698R.0	4	96-Renovated parts	AXLE, DANA 212HY/901	1.0	pcs
100009697.3	5	1G02-Couplings and axles	AXLE, DANA, 602/212/112, 602.97.212.112, DIN120	1.0	pcs
100009697R.0	5	96-Renovated parts	AXLE, DANA 602/212/112	1.0	pcs
100009825R.0	6	96-Renovated parts	HYDRAULIC MOTOR, DANFOSS, H1-B-110-A-P2-D2-N-B-TA-DN-JN-N-A-15-NN-040-...	1.0	pcs
100009825.0	6	1G04-Hydraulics and pneumat...	HYDRAULIC MOTOR, DANFOSS, H1-B-110-A-P2-D2-N-B-TA-DN-JN-N-A-15-NN-040-...	1.0	pcs
100009721R.0	7	96-Renovated parts	HYDRAULIC CYLINDER, HYDROLINE, 1NOASY287V, 117502V, 80/40-250MM, 1/4 ...	2.0	pcs
100009721.0	7	1G04-Hydraulics and pneumat...	HYDRAULIC CYLINDER, HYDROLINE, 1NOASY287V, 117502V, 80/40-250MM, 1/4 ...	2.0	pcs
100015073.5	300	2A611-Hydraulic and pneumat...	HYDRAULIC SCHEME, OSCILLATION LOCK, SPRAYMEC 8100	1.0	pcs
100205066.0	301	2A611-Hydraulic and pneumat...	HYDRAULIC SCHEME, DRIVING TRANSMISSION, SPRAYMEC 5000/8100	1.0	pcs
100015538.2	302	2A22-Hydraulic component assy	FITTINGS, OSCILLATION LOCK, SPRAYMEC 8100	1.0	pcs

FIGURE 14. Remanufacturing maxbom.

Remanufacturing maxbom structure is used when creating remanufacturing structures for equipment. It is used in same manner as production line maxbom, every component that is installed in the equipment is selected from the list and put under the rebuild structure. Using remanufacturing structures with the main components removed reduces the number of assemblies that are split up into separate position numbers.

7 FUTURE STEPS AND POSSIBILITIES

7.1 Testing and evaluating remanufacturing set

The usability of the remanufacturing set needs to be evaluated and tested before creating and using similar sets on a larger scale. A test structure is created based on a manufactured Spraymec machine, and then the structure is downloaded to the AX production planning software. It is monitored for any problems or errors and to ensure that all the necessary components are included. The results of the testing and evaluation will indicate if similar structures are worth implementing.

7.2 Instructions for creating rebuild structures

If the remanufacturing set is evaluated and found to be suitable, instructions for creating similar structures can be provided. These instructions should explain the basic idea and function of future remanufacturing maxboms for different equipment types. Creating these instructions will enable standardized working procedures for every region and personnel within the company.

7.3 U&M kit discount

It should be noted that offering different upgrades and modifications during repair or remanufacturing works could provide advantages. No separate delivery to the customer is needed, saving time and money as deliveries can take many weeks. Normet's personnel would also install the kits, so any problems and component absences would be solved within Normet. This eliminates the awkward and expensive situations where a kit is not working as intended, leaving the machine unusable for the time it takes to reverse the change or modify the kit.

These advantages could be used as a reason to offer U&M kits with a slight discount, at least for so-called A-category kits that are either available options for similar new machines or very universal plug-and-play upgrade kits. It would be good to have a cost cap for the discount, for example, a 20% discount for the first 10,000€. After that, kits would be priced normally without a discount. This discount could attract customers to explore the possibilities of U&M kits, increasing sales for service operations while also increasing customer efficiency and safety via U&M kits.

7.4 Redefining Normet grade system

There is a big aberration in the Normet grade system regarding remanufacturing grading. The gap between the new and remanufactured is too big, as new is grade 5 and remanufactured is grade 4. Remanufacturing as a term means repairing used products back to at least as good as new condition; therefore, remanufactured products should be graded 5 or even 5+. In practice, a grade of something like 4.8 could be seen as acceptable to be called remanufactured product as grading is done by different persons who might have a slightly different idea of what is defined as grade 3, for example.

Overall, this grade system could be revisited with a new perspective. This way previously explained flaws could be fixed to improve machine grading process accuracy and its influence on what actions are carried out at which grade.

7.5 NDT testing of equipment frames

Already frames are NDT tested with liquid penetrant from weld seams in remanufacturing process but there is space for improvement to make this phase a bit faster and accurate by using FEA and strain gauge measurements to locate the structures that are under the most stress. The problem today is that the liquid penetrant testing locations of equipment frames are not based on real data but more to feeling that what structures might be under a lot of stress. Unnecessary locations that would never brake first are checked causing extra work that could be avoided with implementation of FEA calculations in NDT testing procedure.

Investigation with the R&D department has been started already. Use of the FEA result data has been agreed so the spread of this information for 3rd party can be avoided. The service business line has not got the information yet, but it will be the next step on improving the NDT testing guidance.

7.6 Installed base

For creating rebuild structures there could be a possibility to utilize Sovelia's installed base feature that can be used to track, for example U&M kits that has been installed after the equipment left the factory. This is because the equipment's Sovelia structure is frozen when it leaves the factory, and no further follow-up can be done through PDM. Installed base structure is basically a copy of the original structure but every component gets a new, installed base specific object ID that is not dependent on original equipment structure seen in FIGURE 15.

	Serial number	(R).Pos	Type	Name and description	(R).Qty	Object ID
100125637.4	HE400		Equipment	UTIMEC, LF 600 AGITATOR AUS, HE400		IB-113075283
100066110.4		99	Other traced components	STANDARD PARTS, LF-SERIES 2013 NGE2	1.0	IB-120547955
100100641.1		100	Other traced components	ENGINE ASSY, MB 906 T3 / NGE2, LF-SERIES 2016	1.0	IB-120547060
100061586.0		101	Other traced components	EXHAUST SYSTEM, WITH EXHAUST GUIDE MB 906 L-SERIES	1.0	IB-120547151
100022362.0		102	Other traced components	VARIABLE DISPLACEMENT PUMP, 65CM3 PUMP CLARK 24 / 32	1.0	IB-120550686
100025184.1		105	Other traced components	HEAT INSULATOR, JLX INDUSTRY, OM906 EXHAUST, 12NOR1000251...	1.0	IB-120547159
100036061.0		108	Other traced components	EXTENSION, MUD-GUARD EXTENSION, L-SERIES	1.0	IB-120548095
100089930.1		110	Other traced components	WHEEL, NOKIAN TYRES, HTWS00048, 14.00-24"	5.0	IB-120554163
100058547.7		120	Other traced components	POWER TRANSMISSION, ENGINE END/ SUSPENSION, LF-SERIES	1.0	IB-120550639
54927991.2		142	Other traced components	POWDER EXTINGUISHER, PRESTO, P6, 6KG	1.0	IB-120554143

FIGURE 15. Installed base structure for equipment HE400.

If any main component needs to be changed into a remanufactured part, it could be done with no impact on lower assemblies. It is not clear whether this could be utilized as the installed base is a new feature withing the company, but it is at least worth investigating.

7.7 Component remanufacturing

Properly working component remanufacturing is one of the important improvements that could be made to streamline equipment remanufacturing. Critical components are sent for remanufacturing when they are disassembled from the machine, which can create bottlenecks for assembly work due to component shortages. An ideal situation would be to have a sufficient supply of remanufactured components available for common and standard components, for example concrete pumps and axles. The improvement for remanufacturing components is currently being investigated as part of a master's thesis work, which will be completed in 2023

8 CONCLUSIONS

In this thesis the potential of rebuilding and remanufacturing in the mining equipment industry, with a specific focus on the case of Normet, were explored. The research has revealed that rebuilding can bring significant benefits to both the company and its customers, including cost savings, reduced environmental impact, and improved equipment performance. Main focuses on the improvement of rebuilding were in creating cheaper alternatives for full machine remanufacturing that became reconditioning and custom rebuilds that are lesser compared to remanufacturing. Reconditioning focuses only on the main components of the equipment and custom rebuilds are composed from the individual process and component kits. To help with the creation of the rebuild PDM structures, the remanufacturing maxbom was created that could be utilized for fast and efficient creation or rebuild structure.

In addition to creating remanufacturing maxbom and defining other alternatives, several future recommendations and possibilities was given to further improve rebuilding at Normet in order to define the future underground.

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