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An Overview of the Engine Remanufacturing Process Based on Independent Remanufacturers in Malaysia

(Proses Pembuatan Semula Enjin berdasarkan Pengilang Pembuatan Semula Bebas di Malaysia)

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ABSTRACT

The automotive remanufacturing industry is the largest remanufacturing sector, accounting for around two-thirds of global remanufacturing activities. Engine parts are a common target for remanufacturing due to their high value and demand. With the introduction of the National Automotive Policy (NAP) 2020 in Malaysia, many small and medium-sized enterprises (SME) are progressively taking part in the remanufacturing industry, especially engine remanufacturing. However, since the remanufacturing process is more complex than the primary production of the same products, challenges partaking in the operations and processes of remanufacturing are common in the industries, especially for independent remanufacturers. There still lacks data that shows the process flows of these engine-remanufactured products being conducted locally. In this study, a qualitative interview has been conducted through focus group discussion (FGD) with the SMEs to determine the processes and practices for automotive remanufacturing, thereby identifying key components of engine remanufacturing. Four different category questions, accompanied by several sub-questions to determine the processes and methods in their aspects of automotive remanufacturing, have been asked. The findings show that engine remanufacturing is a series of intricate processes being done carefully and extensively, from the cleaning process to the final assembly testing for which varies heavily depending on the components and industries. While the remanufacturing processes across the independent remanufacturers are almost the same, findings also suggest there exist additional processes that can be applied to increase the lifespan of the products, such as additive remanufacturing techniques, that these independent remanufacturers know but do not apply to their processes due to the cost and economics of the business. Further research exploring case studies of these independent remanufacturers is recommended to ensure a more holistic and critical aspects of engine remanufacturing to be captured.

Keywords: Automotive; engine; remanufacturing; independent remanufacturer; Malaysia

INTRODUCTION

Automotive remanufacturing has always been the early adopter of remanufacturing since the 1940s. In fact, automotive remanufacturing is the largest remanufacturing sector, accounting for around two-thirds of global remanufacturing activities (Golinska & Kawa 2011; Kim et al. 2008; Steinhilper et al. 2011). According to data from 2015, Europe's market share of automotive remanufactured components in comparison with new component is almost 55%, with a potential market share of 80% (Welland 2016).

At present, there is still a growing number of remanufactured parts and components from automotive, with the current growth in electrical and electronic parts (Gaudillat et al. 2017). Among these, engine parts are a common target for remanufacturing due to their durability with multiple lifecycles, high value, and high

market demand. With the ability to be remanufactured up to three times, Cummin's New and Recon Parts (NRP) organisation managed to remanufacture around 18,700 engines in 2018 while at the same time generating more than USD1 billion in sales, including other components (FL Magazine 2021).

Dated back to World War II due to a shortage of vehicles in the United States (W. Liu et al. 2017), automotive remanufacturing is not something new. To standardise, research by Ijomah (2002) has defined the means of remanufacturing as the returning process of used products to at least the original performance specification of the Original Equipmenet Manufacturer (OEM) and based on the customers' perspective, as well as giving the applicable product warranty matching or more of the newly manufactured equivalent.

Based on this definition alone, remanufacturing can be seen as an intrigue-and-entanglement process. Differentiating with the other recovery processes in the circular economy lifecycle, remanufacturing of products is often regarded as the most preferable process (Lindahl et al. 2006; Smith & Keoleian, 2004) as the result of higher quality and extended life in use. While the range and order of activities in remanufacturing may be diversified (Sundin 2004), the key processes of remanufacturing remain the same, which include disassembling, inspection, cleaning, repairing or replacing damaged component, reassembling and testing.

Various other benefits are being earned through the use of remanufacturing especially in terms of energy, raw material and landfill space conservation. Moreover, through remanufacturing, consumers will pay less for the same quality product. Based on data, the cost of processing a remanufactured product is 40-65% of the production cost for a new same product, lowering the energy required for production by more than 85% (Lee et al. 2017; Sutherland et al. 2008).

Further, an LCA study on engine remanufacturing and new-manufacturing (Z.-C. Liu & Zhang, 2013) found energy consumption and environmental impacts are lowered through remanufacturing, which is achieved through a reduction in CO2 emissions of more than 70% which is the main contributor to greenhouse emissions. To reap the benefits of remanufacturing, Malaysia Automotive Robotics and IoT Institute (MARii) an organisation under the Ministry of Trade and Industry (MITI) has introduced remanufacturing in the National Automotive Policy (NAP) 2014, which was later reinstated in NAP2020 as a vision for Malaysia to be a remanufacturing hub by 2030.

Based on a study by the United States Agency for International Development (USAID), vehicle component remanufacturing is worth up to RM207 million and has the potential to reach RM670 million in 2008 (USAID, 2015). In Malaysia, component remanufacturing is performed almost entirely by independent third parties or independent remanufacturers, with the exception of Caterpillar, Hitachi and Volvo. Some of the common remanufactured automotive components include engine assemblies, drivetrain components, rotating electric parts such as alternator and turbochargers or superchargers.

To enhance the Malaysian remanufacturing industry, MARii through the Malaysia Automotive Remanufacturing Roadmap (MARR) has introduced the Malaysian Standard (code of practice) for reuse, repair, remanufacturing and recycling (MS2697-2018) to act as guidelines on the remanufacturing process (Standards Malaysia 2018). This standard not only address the rising End-of-Life Vehicle (ELV) issues in Malaysia (Che Jamin & Mahmood 2015; Sulaiman et al. 2023; Wahab & Fadzil 2014), rather to achieve closed loop supply chain within the automotive industry in the local market thru remanufacturing implementation. Furthermore, to pamper remanufacturing, Malaysia has no significant institutional barriers that restrain remanufacturing activities apart from safety-related components, which resulted in the import of supply core usually from Japan and Europe (Gunasekara et al. 2019).

However, there are obstacles within the industry regarding remanufacturing process implementation that have affected their growth since the introduction of NAP2014 (Gerrard & Kandlikar, 2007; Ropi et al. 2020). Further, these obstacles have also discouraged these industries from further investing in new equipment and developments. Moreover, since the remanufacturing process is more complex than the primary production of the same products, challenges associated with the operations and processes of remanufacturing are common in the industries, especially for independent remanufacturers.

Table 1 highlights some of the observed barriers and challenges that hampers remanufacturing process in different countries. Some of the challenges that Malaysia is facing include insufficient worker skills, a lack of technology and facilities for remanufacturing and a lack of product information (Andrew-Munot & Ibrahim 2013; Seitz 2007; Yusop et al. 2016).

TABLE 1. Common remanufacturing challenges and barriers

Remanufacturing barriers	
Collection barriers	• High collection cost • Cores are not controlled • High competition for cores
Technological barriers	• Lack of published procedures or standards • Design not viable • Lacking in technology • Lack of product information • Insufficient worker skill
Regulatory barriers	• Restrictive government policy or regulation • Legal restriction • Trade barrier
Market barriers	• Low awareness • Low cost of new option • Low corporate acceptance

With these barriers, most of these expected local independent remanufacturers prefer to use "rebuild" terms for their in-house operations as well as products. They also possess good understanding and capabilities for conducting remanufacturing with limited operational processes due to these remanufacturing barriers. With the aim of evaluating and documenting the current operational process of the engine remanufacturing system carried out by local remanufacturers, this study has been conducted to further capture and minimise the gap in the local remanufacturing market.

METHODOLOGY

To facilitate some of the challenges mentioned, this study is focusing on the remanufacturing process being done by the independent remanufacturer to minimise the knowledge gap, especially for the engine remanufacturing process. To determine the necessary data, a focus group has been identified consisting of experienced companies in rebuilding and refurbishing products in Malaysia. These data for the possible companies have been supplied by MARii, consisting of several expected technical personnel from various remarkable manufacturers in Malaysia.

Before, four different category questions have been constructed that cover processes and methods they have used for engine remanufacturing to ease the discussion period with these companies. These categories range from questions related to process flow in general to core-related questions, testing methods and engine component remanufacturing. Further, a conceptualised remanufacturing process is also presented during the discussion to break the ice amongst the participating independent remanufacturers.

Figure 1 highlights the steps taken in completing this study. A set of key processes for engine remanufacturing are gathered through a literature study, which acts as a baseline operation used globally. These processes are then discussed with the independent remanufacturer, who assesses and validates the processes for engine remanufacturing. As mentioned above, a set of questionnaires is included to guide the discussions within the industry.

A total of six companies have participated in the focus group discussion (FGD). These companies with various backgrounds within the automotive industry have voiced the important aspects, from the operational processes to the needed testing for engine remanufacturing and their own limitations. From the data gathered throughout the discussion and the added online secondary sources through blog posts, articles or commentaries, an elaborated and reliable engine remanufacturing process can be constructed.

In accordance with guidelines highlighted by MARii, the diagram has been constructed based on the six steps of remanufacturing processes, starting with core management and ending with final testing for the complete product. Further, some of the companies feedback on engine remanufacturing is discussed and validated throughout the session, especially problems arising for the validation of remanufactured components, thus promoting information sharing between the industries.

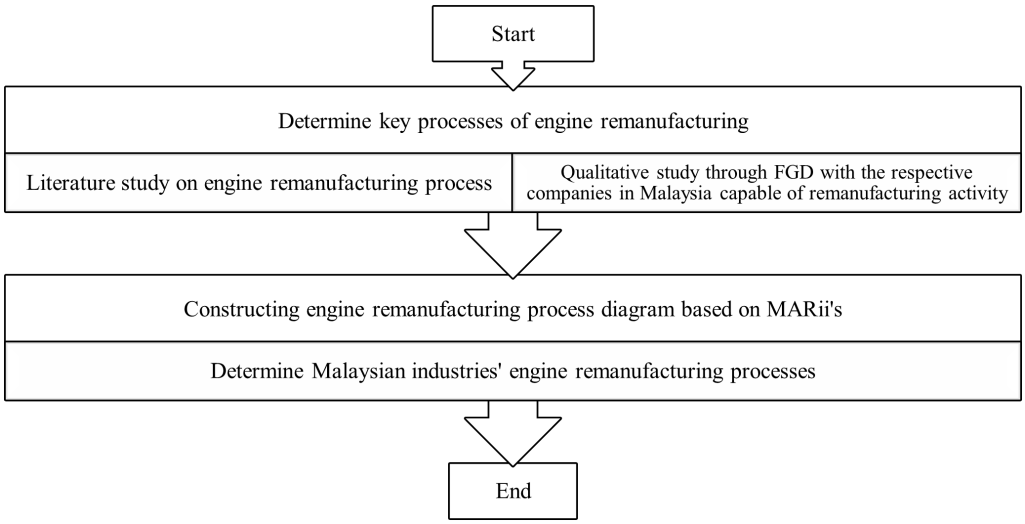

FIGURE 1. Research Methodology

RESULTS AND DISCUSSION

Based on the data gathered throughout the literature of secondary data and interviews, table 2 shows the categorised engine remanufacturing according to the MARii standard. These are the remanufacturing processes of different components making up an engine. There are 5 critical components focused on as the heart of an engine system consists of cylinder head, cylinder block, camshaft, crankshaft and connecting rod.

For the cylinder head and cylinder block, the remanufacturing process used is almost the same, with initial measurements of the deck height taken to determine the allowable tolerance limit for remanufacturing. Further, these two components will be inspected for their surface roughness conditions, dimensionally within specifications and thoroughly cleaned to remove carbon deposits from their surfaces.

Depending on the condition, a series of machining and reworking processes are done, including straightening and grinding at the same time testing these components accordingly. For the cylinder head, the focus grinding places are critical for mating surfaces, valve seats and valve guide holes, whereas for the cylinder block, proper consideration is given to determining the condition and reworking of the combustion wall to meet the required specifications.

The camshaft and crankshaft both encompass the same initial inspection method for surface roughness, straightness and dimension. However, the crankshaft is more critical than the camshaft as it bears higher forces generated by the combustion chamber. Both components will undergo a regrinding process for the lobes and the main bearings to meet the needed specifications. This specification limit is often taken based on the available mating bearing sizes that were prepared before the machining processes.

The connecting rod it is a critical component exposed to the forces generated in the combustion chamber. Some of the remanufacturers prefer to replace this component due to its criticality, but others prefer remanufacturing since the component itself could be hard to replace due to its non-availability especially if the engine is old. The processes needed for remanufacturing include cleaning, inspection for straightness and dimension, crack testing, grinding of the big end and small end bores as well as shot peening. Shot peening is done to improve the surface of the connecting rod.

As for the complete assembly of the engine, usually final performance testing will be done using a specialised test bed to ensure the engine is running at its capacity. While the remanufacturing process of these components looks simple and effortless, every component has its own subassemblies, which makes the remanufacturing process complicated with the need for available technical knowledge on parts compatibility such as the cylinder head, which is interconnected with the valve assembly and camshaft. The need for technical compatibility is crucial in maintaining proper order of firing.

Wear and tear components are replaced with new components, such as the valve assembly. Next is the cylinder block, which is interconnected with the piston assembly, crankshaft and connecting rod. Typically, the piston assembly is replaced, but depending on the condition, the crankshaft and connecting rod may be remanufactured. As mentioned before, while the order of the process may vary, the same remanufacturing flow remains, which ends with different testing for each component. Moreover, the inspection process can be done

throughout the remanufacturing process to ensure the component is within the targeted new tolerance limit.

Besides, cleaning and testing activities are both critical steps throughout remanufacturing that are being focused on by these independent remanufacturers. To account for these needs, different cleaning methods such as using a spray machine, bath water and an oven are being adopted to ensure different stains and impurities are removed from the components. Further, depending on the materials of the components, cleaning agents ranging from kerosene to alkaline water and acidic solutions are often used. Whereas for the testing process, it consists of individual testing of components and final testing of products, with usually a 3-months warranty given for the remanufactured products.

Table 2 highlights the processes gathered throughout this study, focusing on the five components mentioned. While there are more detailed processes done for engine remanufacturing, these tables capture the simplified and available processes validated by the current independent remanufacturer in Malaysia.

TABLE 2. Engine components remanufacturing process categorised

	MARii remanufacturing process steps					
	a)	b)	c)	d)	e)	f)
Components	Core management, core sorting, dismantling	Cleaning of all internal and external components.	Replacement of all missing parts, restoration of impaired, defective or substantially worn parts	Reworking, machining or performing such other operations as are necessary to put the part in original working condition or better	Component assembly	Final testing of each remanufactured part
Cylinder head	Deck height – check tolerance Dismantling Initial inspection on surface roughness (pitting, crack, straightness) Dimensional checking	Clean in hot steam tank, acid Pressure test	Valve system remove (guide, seat, spring) New valve system in (guide, seat, spring)	Straightening Grinding all surface (rough) Grinding mating surface Pressure test Grinding new valve seat angle Grinding valve guide size Taping bolt holes	Camshaft assembly (lifter, rocker arm)	Pressure test Vacuum test
Cylinder block	Dismantling Deck height – check tolerance Sleeve – available, tolerance Inspection on surface roughness (pitting, crack, straightness) Magnaflux	Clean in hot steam tank, acid	Replace journal bearing	Grinding all surface (rough) Surface ground or milling mating surface Reboring, resleeved, cylinder Honing – inspect line bore Paint	Crankshaft Bearing	Crank test Inspection
Camshaft	Dismantling Initial inspection (roughness, straightness) Lifter clearance check Check bearing cover tap	Pressure wash cleaning	Replace camshaft if it beyond wear limit/lift beyond limit	Straightening Regrinding of lobes		Hardness testing Polishing and cleaning

continue ...

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	MARii remanufacturing process steps					
	a)	b)	c)	d)	e)	f)
Components	Core management, core sorting, dismantling	Cleaning of all internal and external components.	Replacement of all missing parts, restoration of impaired, defective or substantially worn parts	Reworking, machining or performing such other operations as are necessary to put the part in original working condition or better	Component assembly	Final testing of each remanufactured part
Crankshaft	Disassemble from the main bearing Check bearing condition	Soak in hot tank All oil holes will be wire brushed to remove caked on residue Inspection (trueness test) Magnaflux Check counterweight – unbolt Check straightness Check bolt holes	Not all crankshaft can be straighten	Straightening Magnaflux Thermal spray Welding process Relieve structural strength Recheck for straightness Rough crankshaft grinding Finished crankshaft grinding Shot peening	Replace or retighten counterweight Determine proper balance Micro polishing	Test hardness
Connecting rod	Disassemble Remove the cap	Cleaning process Inspection (straightness, measurement) Magnaflux	Replace pin bushing	Grinding or milling process Deburring process Shot peening Honing process	Insertion of new bushing Bushing honing process	Verify dimensions accordingly

CONCLUSION

The findings show that engine remanufacturing is a series of processes being done carefully and extensively, starting with the cleaning process and ending with the final testing of the assembly. While the process can be simple, most of the time the challenges will be in determining the technical specification limits, which are crucial for the machining and reworking processes of the engine components.

Through information sharing regarding the engine remanufacturing process, it is hoped that Malaysia can realise the NAP2020 vision of being a remanufacturing hub in 2030. While the remanufacturing processes across the independent remanufacturers are almost the same, findings also suggest there exist additional processes that can be applied to increase the lifespan of the products, such as additive remanufacturing techniques.

While the technique is known by these independent remanufacturers, they seem reluctant to apply it, which could be due to the cost and economics of their business. Additive remanufacturing, while relatively new, is a good process in which it can restore the tolerance limit to the original rather than the subtractive remanufacturing technique (Rahito et al. 2019b, 2019a).

On the bright side, this shows that the remanufacturing industry in Malaysia is on the right track and has the right capabilities, especially in terms of process know-how, especially for the engine remanufacturing process. As a conclusion, this study has managed to evaluate and validate the current process for engine remanufacturing based on interviews with independent remanufacturers in Malaysia.

Finally, further research exploring case studies of these independent remanufacturers is recommended to ensure that more holistic and critical aspects of engine remanufacturing are captured while at the same time properly assessing Malaysian remanufacturer capabilities.

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DECLARATION OF COMPETING INTEREST

None.

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