IOP Conf. Series: Earth and Environmental Science **1419** (2024) 012017 doi:10.1088/1755-1315/1419/1/012017

Aligning new product development with reverse engineering methodologies for headlamp jig

N I Omar[1*], I A A Bakar[4], N N Kamurazaman[2], S Ismail[2], S Omar[2], Z D I Sktani[3], W H W Mahmood[2] and Y Yusuf[2]

[1] Faculty of Mechanical Technology and Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia.
[2]Faculty of Industrial and Manufacturing Technology and Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia.
[3] Faculty of Engineering, Universiti Teknologi Brunei, Tungku Highway, Gadong, BE1410, Brunei Darussalam.
[4] School of Civil, College of Engineering, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia.

*E-mail: mav.irinah@gmail.com; Nooririnah@utem.edu.my

Abstract. This study explores the combination of reverse engineering (RE) and new product development (NPD) methodologies to enhance the manufacturing process of headlamp jigs. RE, utilised as a benchmarking technique, aids in regenerating parametric designs or innovating new product concepts. The distinctive appearance relies on headlamps with protective coatings cured at high temperatures in UV ovens, necessitating jigs capable of withstanding such conditions. Hence, employing RE becomes crucial to fortifying jig performance. While RE often signifies innovation or refinement, the current headlamp jig encounters deformation issues during manufacturing due to high curing oven temperatures and intense water jet cleaning pressures. The absence of an effective NPD approach exacerbates persistent jig deformation challenges. NPD, encompassing stages like idea generation, concept development, design, testing, and marketing, is crucial. The absence of NPD, along with the complexity of RE, could prolong timelines and escalate expenses in bringing marketable products to fruition. This study aims to propose an NPD model for headlamp jigs, leveraging RE methodologies to enhance composite jig fabrication processes. The integration of PDCA methodologies within NPD intends to rectify deformation issues while optimizing manufacturing processes for superior headlamp jigs.

1. Introduction

In the rapidly evolving manufacturing landscape, the ability to seamlessly integrate reverse engineering techniques into new product development (NPD) processes has become a crucial competitive advantage. This paper explores the synergies between these two complementary approaches, specifically in the context of headlamp jig design and development.
Reverse engineering has emerged as a powerful tool in the arsenal of modern product designers and manufacturers [1]. By closely analyzing existing products, engineers can gain invaluable insights that inform the development of next-generation offerings. This is particularly relevant in the automotive industry, where product lifecycles are relatively short, and the need for continuous innovation is paramount.
Recent research has highlighted the benefits of incorporating design for remanufacturing principles into the early stages of the product development process [2]. This holistic approach

enables manufacturers to not only create innovative new products, but also ensure that they can be efficiently maintained, repaired, and even remanufactured at the end of their useful life. In the case of headlamp jigs, this translates to a design that is not only optimized for initial production, but also adaptable to future technological advancements and changing market demands. Axiomatic design theory and quality function deployment (QFD) have been identified as effective frameworks for guiding this reuse-oriented redesign process [3].

The New Product Development (NPD) process is important for developing goods that suit the needs of industrial clients while also distinguishing companies from competitors. It has a distinct character for the industrial sector, taking into account product customization and partnerships with the end user. The traditional sequential process, based on concept, development, validation, and manufacturing phases, has been replaced by an integrated approach that integrates stages and functions.[4]

The car's headlamp, which offers illumination for driving at night and inpoor visibility circumstances, is one of its essential components. To ensure the quality and durability of the headlight, production engineering professionals must be aware of its components and construction process. The car's headlamp, which offers illumination for driving at night and in poor visibility circumstances, is one of its essential components. To ensure the quality and durability of the headlight, production engineering professionals must be aware of its components and construction process.

Headlight manufacturing entails several delicate steps that necessitate precision and accuracy. To ensure that the product fulfils the needed quality requirements, jigs must be used during the production process [5]. Jigs are essential for holding the work-piece in place during machining or assembly operations, allowing for accurate placement and reproducible part manufacturing. Jigs are tools that anchor a work-piece while executing a specific job such as drilling, cutting, or welding. Depending on the activity, numerous types of jigs are used in the headlight production process. Plate jigs, box jigs, channel jigs, and angle plate jigs are some examples. Curing is an important aspect of the headlights manufacturing process, which necessitates the use of specialized jigging equipment to support them while curing inside tunnel ovens. By chemically reacting with other molecules to generate cross-linked polymers, the curing process increases strength and endurance [6]. Various types of molds can be used at this stage, ranging from metal substrates covered with release agents such as silicone rubber coatings or Teflon-like coatings.

The current headlamp jig utilized in the manufacturing process has encountered a challenge of deformation during operation. This has affected production efficiency and compromised the final product quality. This happens due to the high temperature when entering the curing oven, which was 120°C for 100 hours and continued for another 1000 hours, and the high pressure in cleaning process when using high pressure water jet. Headlamps jigs are complex structures that require precise design specifications to function correctly in various conditions. Reverse engineering is the process of examining every detail of every structure to choose a better process for making headlamp jigs. The reverse engineering process involved identifying the process, gathering information, maps the steps, computer-aided design (CAD), testing, and continues improvement. Without incorporating an effective New Product Development (NPD) approach into the manufacturing process, the persistent issue of headlamp jig deformation is likely to continue. NPD is crucial as its tailor products to meet industrial demands, giving the manufacturer a competitive edge. NPD involves various stages, such as idea generation, concept development, design, testing and marketing. The complexity of reversed engineering process will elongate the timeline and expenses required to bring marketable product to fruition without NPD approach.

2. Methodology

New Product Development (NPD) is a research driven process aimed at creating and introducing innovative products to the market. By integrating reverse engineering into NPD by utilizing Plan, Do, Check, Act (PDCA) method, it harnesses the power of a creative and data driven approach to produce market-ready products. This integration not only enhances production timeline but also optimizes manufacturing processes for maximum efficiency.

2.1. Integration of PDCA with Reverse Engineering
This proposed process will help to guide the reversed engineering process using NPD with PDCA method in beta testing as shown in Figure 1 below. This flowchart explained steps of making headlamp jig using PDCA method with reverse engineering process.

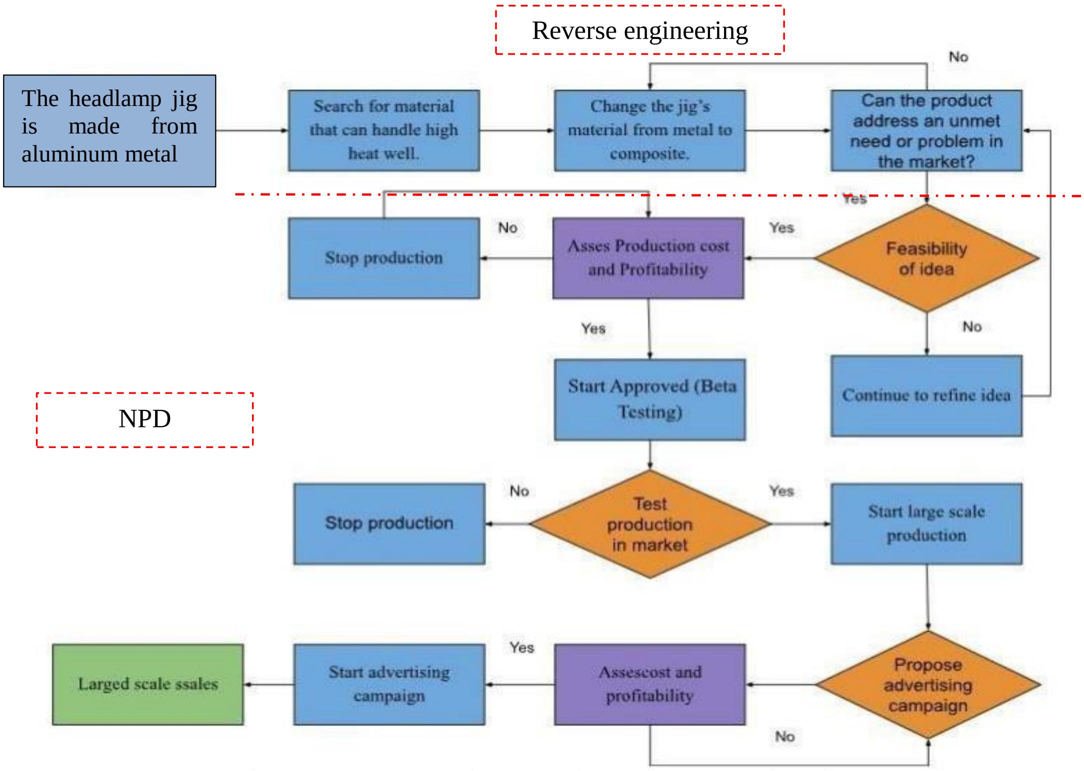

Figure 1. New Product Development (NPD) flowchart

2.2. Plan
The deformation issue in metal headlamp jigs because of their constant exposure to the curing oven. The jig's repeated thermal cycling within a temperature range of 120°C to 125°C during testing for durations of 100 to 1000 hours. On top of that, uses high water pressure in the cleaning process lead to compromises the jig's integrity. The headlamp's intrinsically elongated dimension increases its sensitivity to deformation and slowing the curing process. In order to overcome this problem, creating composite headlamp jig is proposed. Figure 2 below showed the proposed reversed engineering stage for creating composite headlamp jig from metal.

2.3. Do
The Do steps entails the execution of the headlamp jig production process. Figure 2 show the entire flowchart of the beta testing segment inside the NPD structure, outlining the intricate details of this phase.

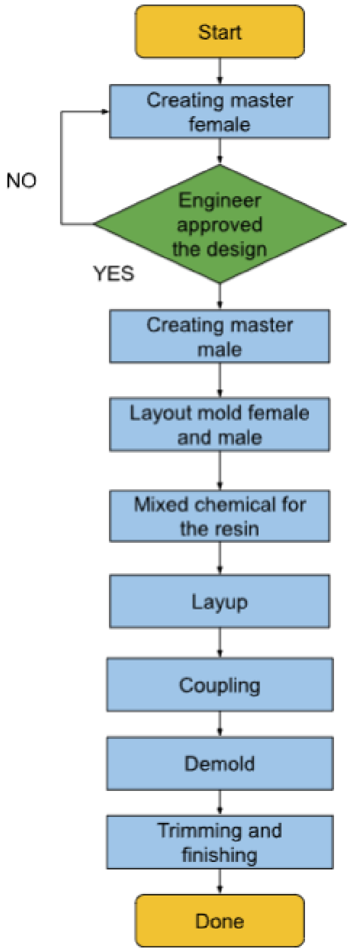

Figure 2. Reversed Engineering Stage

2.4 Check

In the check cycle, the headlight jig is undergo different types of testing. The dry fit test is the second crucial test in order to making sure the sample lenses fit the fixture precisely and securely is a crucial part of this inspection. Additionally, it carefully confirms that any gaps found in important areas are within tolerance limits. Through the implementation of the Dry Fit Test, an evaluates the accuracy and operation of the headlamp jig, confirming that the lenses fit with a smooth appearance while upholding the required tolerances in particular regions. This test is essential to ensure that the fixture works and meets the requirements.

The tap test is another essential step of checking procedure for headlamp jig. To check for delamination or debonding in the composite material, a careful inspection entails tapping the headlight jig sporadically on all of its surfaces. The testing intends to confirm the structural integrity of the composite components by putting the jig through these carefully calibrated taps. This will guarantee that all composite materials stay firmly bonded without sacrificing any structural quality. This examination protects against possible material flaws that can jeopardize the headlamp jig's overall longevity and performance.

3. Discussion

The ‘Action’ phase serve as a pivotal aspect of the PDCA method, facilitating the refinement and enhancement jig’s design and functionality. As seen in Figure 3, the headlight jigs designed for the have a notable feature in their design: an extended and large body layout. This elongation in the jig's structural makeup increases its vulnerability to deformation or fracture. This structure's large length and scale make it intrinsically less stable when exposed to external influences, increasing the possibility of structural breakdown. While the elongated design has some advantages, it makes it difficult to retain structural integrity, especially when subjected to large external stresses, increasing the likelihood of deformation or fracture. The action that can be taken is by adding a stiffener to the headlamp jig body. This suggestion is because headlamp is already a big and long body that make it more prone to break or creak. By adding a stiffener, it will support the body and make it stronger and harder to break into half. Considering that composites are generally non-reusable once they've undergone the setting process, a proposed approach to optimize both time and cost efficiency involves repurposing the existing finished mold. This suggestion entails modifying the mold to accommodate the stiffener, thereby avoiding the need to create an entirely new mold from scratch. The process of making these changes is suggested as Figure 3 below.

Hwang et al. confirmed the assessing the viability of reverse engineering laminated composites and enhancing the accuracy of these processes. The developed method offers a powerful tool for estimating lamina details in unfamiliar laminated composite structures, which could greatly benefit composite material design [7]. The integration of reverse engineering in product development processes can have a significant advantage for pouring insightful knowledge into their associated hands on activities [8].

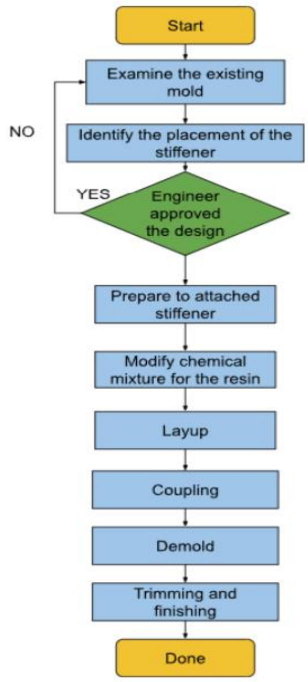

Figure 3. Improvement suggestion for reverse engineering headlamp jig's

4. Conclusions

The incorporation of the Plan-Do-Check-Act technique into the New Product Development (NPD) framework has demonstrated significant potential for improving product quality and efficiency. PDCA's iterative cycle of planning, execution, assessment, and refinement offers a systematic approach to problem solving and continuous improvement. The PDCA method enabled a systematic review of design flaws and vulnerabilities during the headlight jig's development. The jig's structural integrity was improved through iterative discovery, analysis, and implementation of solutions, particularly in terms of sensitivity to deformation during thermal cycling and high-pressure washing.

References

[1] Ian Mc 2008 14th IEEE International on Parallel and Distributed Systems
[2] Nina B, Ruud B, Conny B, Tanya T and David P 2020 J. Remanufacturing 1-24
[3] Yanbin D, Huajun C, Xiang C and Bentao W 2013 J.Clean.Prod. 39 79-86
[4] Marianna K and Magdalena G-K 2017 M. Syst.Prod.Eng. 25 246-250
[5] Radhwan, H., Effendi, M. S. M., Rosli, M. F., Shayfull, Z. and Nadia, K. N 2019 IOP Conf. Mater.Sci and Eng. 551 1-9
[6] Jayesh V. K and Harshwardhan C. P 2015 Inter.J.Sci&Resch 6 2467-2468
[7] Hwang, M.-Y, Park,J.H, Song,J, Hwang,S.W, Kang,H.H,Lee,H.C 2023 J.Compos.Sci 7 518.
[8] Akerdad, M, Aboutajeddine, A, Elmajdoubi,M 2020 5th NA International Conference on Industrial Engineering and Operations Management Detroit, Michigan, USA, August 10-14 394-401.

Acknowledgments

Authors wishing to thank Universiti Teknikal Malaysia Melaka for the support of this research work, under Antarabangsa (URMG)-AJMAN/2024/FTKM/A00068.