UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND ANALYSIS OF SHAFT AND HOUSING FOR FLYWHEEL HYBRID MODULE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree in Mechanical Engineering Technology (Automotive Technology) (Hons).

by

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DECLARATION

I hereby, declared this report entitled
"Design and Analysis of Shaft and Housing
for Flywheel Hybrid Module"
is the results of my own research except as cited in references.

Signature	:	…….
Author's Name	:	……
Date	:	……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the Bachelor's Degree in Mechanical Engineering Technology (Automotive Technology) (Hons). The member of the supervisory is as follow:

……

(Project Supervisor)

ABSTRAK

Dewasa kini perkembangan teknologi hibrid pada kenderaan berkembang pesat akibat kenaikan harga minyak dan meningkatnya keperihatinan manusia terhadap masalah alam sekitar. Selain hanya bergantung kepada kuasa yang dihasilkan oleh enjin pembakaran dalam, kenderaan hibrid menyediakan kuasa alternatif sebagai bantuan untuk memacu kenderaan tersebut. Teknologi hibrid mekanikal merupakan salah satu teknologi hibrid yang mengalami perubahan yang progresif sejak akhir-akhir ini. Teknologi hibrid ini malah digunakan dalam perlumbaan Formula One atas dasar keperihatinan Federation Internationale de l'Automobile (FIA) terhadap alam sekitar. Tujuan projek ini adalah untuk merekabentuk dan menganalisa aci dan perumah bagi Modul Hibrid Roda Tenaga yang akan diintegrasikan pada roda depan motosikal konvensional. Langkah-langkah merekabentuk semua komponen modul tersebut mematuhi susun atur proses merekabentuk kejuruteraan mekanikal. Kaedah yang digunakan untuk pemilihan konsep adalah kaedah matriks pemarkahan atau lebih dinali sebagai Kaedah Pugh. Spesifikasi aci telah diketahui melalui proses penanda aras. Kemudian, pembangunan spesifikasi produk telah ditetapkan supaya ukuran kesuluruhan modul tesebut tidak melebih had ruang yang ada. Carta Morfologikal kemudiannya disediakan bagi menjana idea untuk setiap fungsi yang terdapat dalam modul Hibrid Roda Tenaga tersebut. Idea-idea tersebut digunakan bagi menajan gabungan idea-idea yang membentuk sebuah modul yang lengkap berfungsi. Selepas itu, beberapa idea yang terbaik telah dipilih berdasarkan markah keseluruhan idea yang dipeoleh bagi setiap idea yang dijana. Akhir sekali lakaran konsep telah dilakar bagi memberi gamabaran penuh cara modul Hibrid Roda Tenaga tersebut berfungsi.

ABSTRACT

The development of hybrid technology in vehicle nowadays are growing fast due to the hike of petrol price and increasing in environmental cautiousness among people in the world. Hybrid vehicles come with alternative power sources instead of only depending to the power produced by internal combustion engine to move a vehicle. Mechanical hybrid technology is a type hybrid technology that undergoes progressive development these days. This hybrid technology is used in Formula One Racing as the concern of Federation Internationale de l'Automobile (FIA) to the environmental cautiousness. This project aims to design and analyse the shafts and housing of Flywheel Hybrid module that will be integrated into front wheel of conventional motorcycles. The design stages of all the components follows the flow of mechanical engineering design process. The method used for concept selection is the scoring matrix or usually called as the Pugh Method. During benchmarking process, the specifications of shafts is studied. Then, the product development specification is determined to set the limit of dimensions for the whole Flywheel Hybrid module. Morphological chart consisting of ideas is prepared so that the ideas for every function in the module can be generated to form sets of components from different ideas to form a complete module in concept generation stage. Several concepts are selected based on the scores accumulated by the concept. Finally the sketching of conceptual design for the selected ideas combination is made to get the overview system of the Flywheel Hybrid module.

DEDICATION

To my beloved parent, brothers and sister.

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I would like to thank Mr. Muhammad Zaidan Bin Abdul Manaf
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CHAPTER 1

1. INTRODUCTION

1.1 Background of Study

The automotive industry nowadays has evolved basically from resources and human transportation to a whole new level such as racing events and researches. This trend of development is important to fulfill the demands of human needs. We cannot argue that the automotive industry plays a big role to move the world to current state of technology and economic structure. However, the current state of the environment, gas prices, and dependence on foreign oil leads the automotive industry to counter the drawbacks of its own development. The oil price worldwide is impossibly maintained nor reduced and the same goes to the current environment condition. These situations lead the people to greatly reduce the usage of fuel as well as reducing the emission level. By considering those factors, a hybrid vehicle is invented and widely used around the world. A hybrid vehicle is any vehicle that uses more than one fuel source. As such, an electric hybrid vehicle use two motors to make the vehicle run, an internal combustion engine that uses gasoline, and an electric motor. The electric motor is recharged during driving, both from the fuel burning in the engine and through the kinetic energy that is recaptured during braking. As a result, most current hybrid vehicles do not need to be plugged in to an electrical outlet to recharge the batteries.

A mechanical hybrid drivetrain is equivalent to the more common hybrid electric system in that it can recover braking energy, provide supplementary power for better acceleration and reduce fuel consumption. Flywheel hybrid is a type of hybrid system that uses a mechanical flywheel storage device instead of an electric

battery to accumulate energy. The energy is absorbed during braking process using the regenerative braking system which is then released back when needed for acceleration As a result, most of the energy that is usually wasted during braking is used as a power to move the vehicle for a certain period of time. This somehow helps to reduce the fuel consumption and also the release of emission gas significantly. This technology also can be used in conventional motorcycles because currently in Malaysia, the percentage of motorcyclist is greater than that of the car users. All in all, the real advantage of flywheel energy is the high rate of energy input and release possible. This is particularly advantageous on regenerative braking system. This mechanical hybrid system also eliminates the use of wiring electronic control system that can make the system become more complex.

1.2 Problem Statement

The Flywheel Hybrid System will be installed into the front wheel of the system so that it will not interrupt the power transmission from the engine. The motorcycles model that is to be implemented with this system must be specific because each motorcycle has different size of front fork. Also, only motorcycle with front wheel brake disc system is chosen so that the whole part of the Flywheel Hybrid System can be placed in between the fork of the front wheel. The model of the motorcycle must also widely used nowadays to secure market place for this system. For this case, the most suitable motorcycle model is the Yamaha LC 135 which meet all the requirement above.

Figure 1.1 (a) Yamaha LC135 V1 (b) Yamaha LC135 V2

Both Yamaha LC135 V1 and Yamaha LC135 V2 have similar front wheel dimension. The flywheel hybrid system that will be produced should fit into both motorcycle models as they have the same wheel dimensions and configurations.

When designing the shaft and the housing of the Flywheel Hybrid module, lots of factors must be taking into account optimize the efficiency of the Flywheel Hybrid System. Those factors are:

- Shafts are subjected to torque due to power transmission and bending moment due to reactions on members that supported by them. The design and material selection of the shafts should be optimized so that they will not undergo stress deformation because of these factors.
- Factor such as friction induced in rotating shaft may cause wear and generate excessive heat and loss to the surroundings. So, the shaft that is to be designed must be able to transmit power as efficient as possible.
- The flywheel hybrid module must be kept in a durable container such as housing to give protection from any external unwanted moving objects from the surrounding to keep it in optimal condition.

1.3 Objectives

There project consists of two objectives

1. To design the shaft and housing for flywheel hybrid module.
   - This will cover the design stages of all the components follows the flow of mechanical engineering design process.
2. To analyze the shaft and housing for flywheel hybrid module.
   - The 3D modelling of the shafts and housing will be analyzed on certain characteristics using FEA software and the result obtained will be discussed later on.

1.4 Project Scope

The Flywheel hybrid module will be used on the front wheel of conventional motorcycles. This project consists of designing and analysing the Flywheel Hybrid Module by following the engineering design process:

i. Conduct series of benchmarking for flywheel shafts and housing available in market and study the type, design and material of each shaft and housing product.
ii. Determine the customer requirements for flywheel shafts and housing and design several set of shafts and housing that meet the characteristics.
iii. Produce several conceptual designs of shafts and housing based on multiple parameters and types.
iv. List out several selected configuration design by referring to parameters such as orientation and dimension, solid or hollow circular cross-section etc.
v. Generate an observable three dimensional design for each variable characteristics and configurations using 3D CATIA software.
vi. The selected shaft and housing design will be analyzed using Finite Element Analysis (FEA) software to determine the best design.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Flywheel Hybrid System

Flywheel hybrid system is a hybrid system that uses a mechanical flywheel storage device instead of an electric battery. Both mechanical and conventional hybrid system applies the same concept of regenerative braking system. During braking process, the brake energy would normally be dissipated and wasted as heat during braking in a conventional vehicle. In contrast, vehicle with hybrid system would take benefit of that energy to aid it during acceleration (Lee, 2005).

Flywheels seem to be especially well suited to hybrid powertrains. Flywheels can effectively assist the hybrid powertrain with meeting the significant peak power requirements for heavy vehicles. During acceleration and hill climbing in a typical urban driving cycle, flywheels can provide to the vehicle the relatively high power levels required for relatively short durations. During regenerative braking, high power levels can be absorbed by the flywheel system at efficiencies far superior to those attainable by batteries alone. When the power required to propel the vehicle is less than the power produced by the primary power source, the excess energy can be stored in the flywheel for later use. This load leveling capability provided by flywheel systems is an asset to energy/power conversion and management (Hansen & O'Kain, 2011).

2.2 Shaft as the Mechanism to Transfer Power

A shaft is a rotating member, usually in cylindrical shape, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulley, flywheel, sprockets and many more. Ideally, shaft would be required to possess these criteria:

i. High strength
ii. Low notch sensitivity
iii. The ability to heat treated and case hardened to increase wear resistance of journals

In determining on an approach to shaft sizing, it is necessary to realize that a stress analysis at a specific point on a shaft can be made using only the shaft geometry in the vicinity of that point. So, the geometry of the entire shaft is not required. In design it is usually possible to locate the critical areas. Then, size these to meet the strength requirements. Finally, size the rest of the shaft to meet the requirements of the shaft-supported elements.

This project is focusing on designing a hollow shaft. This is because the (shaft) weight decreases more rapidly than the strength because the material near the center is not highly stressed and carries only a relatively small part of the total bending and torque loads. The reliability of the material is increased by using hollow shafts.

The general layout of a shaft to accommodate shaft elements such as gears, bearings and pulleys must be specified early in the design process. This is done in order to perform a free body force analysis and to obtain shear-moment diagrams. The geometry of a shaft is generally like a stepped cylinder. Each shoulder in the shaft serves a specific purpose. It is determined by observation. The best decision is to support load-carrying components between bearings. Only two bearings should be used in most cases. More than two bearings will be needed if the shaft is extremely long. Shaft should be kept short to reduce bending moments and deflections. A

shoulder provides a solid support a solid support to minimize deflection and vibration of the components.

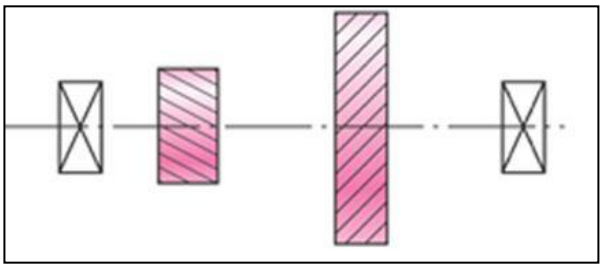

Figure 2.1: Shaft configuration to support and locate the two gears and two bearings

Shaft is usually made to have circular cross-section and could be either solid or hollow. Straight shaft is the most commonly used for power transmission. It is usually designed as stepped cylindrical bars with various diameters along its length. The stepped shaft corresponds to the magnitude of stress which varies along the length. Furthermore, the various diameters of a stepped shaft are designed to be compatible with assembly, disassembly and maintenance process. The design of stepped shaft would ease the fastening of the parts fitted to them, particularly the bearings. This is because bearings cannot be restricted against sliding in axial direction. The cross-section for each step in a stepped shaft must be that each part fitted onto the shaft has convenient access to its seat.

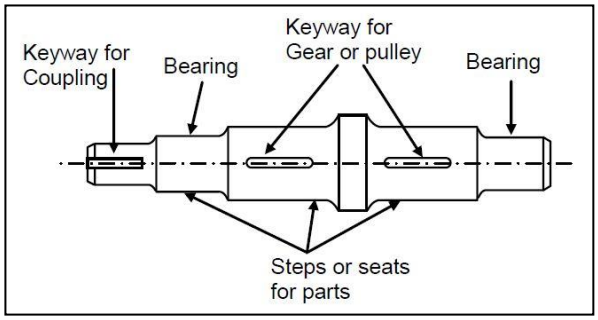

Figure 2.2 Example of stepped shaft

Figure 2.2 shows a stepped shaft with three seats for supported parts which can be gears, coupling or pulleys. Two seats for bearing are also included. The two bearings will be rolling contact type. (Budynass & Nisbett, 2008)

2.3 Housing as the Front Motorcycle Rim

A wheel or specifically a motorcycle rim is a circular device that is capable of rotating on its axis, facilitating movement while supporting a load or performing labor in machines. A wheel works together with an axle overcomes friction by facilitating motion by rolling motion. In order to make the wheels rotate, a moment needs to be applied to the wheel about its axis, either by means of gravity, or by applying another external force. Commonly the term is used for other circular objects that turn or rotate, such as steering wheel, fan blades, bicycle's wheel and flywheel. Steel disc wheel is a rim which possesses the steel-made rim and the wheel into by welding. It is mainly used for mopeds vehicle especially equipment tires (Saurabh & Sameer, 2013).

2.4 Bearing as the Friction-Reduction Component

Bearing used to hold shafts that rotate relative to fixed supports such as a housing. It is divided into two broad groups: journal and rolling contact. Journal bearings have no rolling elements. Instead, the shaft basically rotates within a polished sleeve that is lubricated by oil or another fluid. On the other hand, Rolling contact bearing comprises the following components:

- An inner race
- An outer race
- Rolling elements in the form of balls, cylinders or cones.
- A separator which prevents the rolling elements from rubbing up against one another.

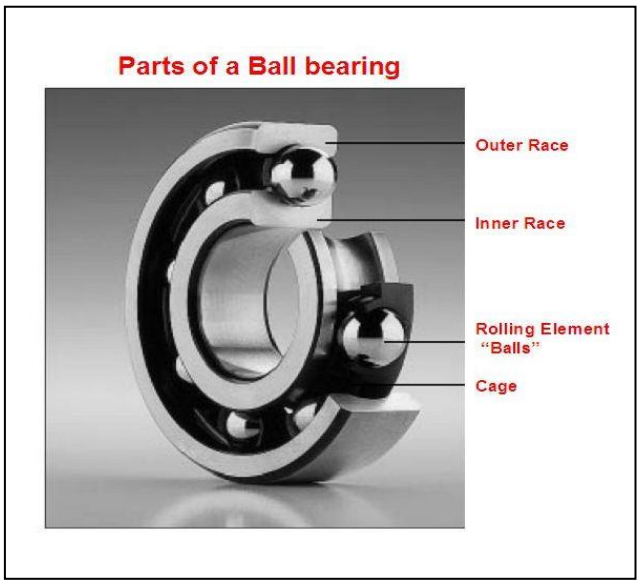

Figure 2.3: Example of ball bearings

To illustrate how is the components of a rolling contact bearing function, the shaft and the bearing's inner race rotates together, while the outer race and the case are fixed (Lewis & Wickert, 2013).

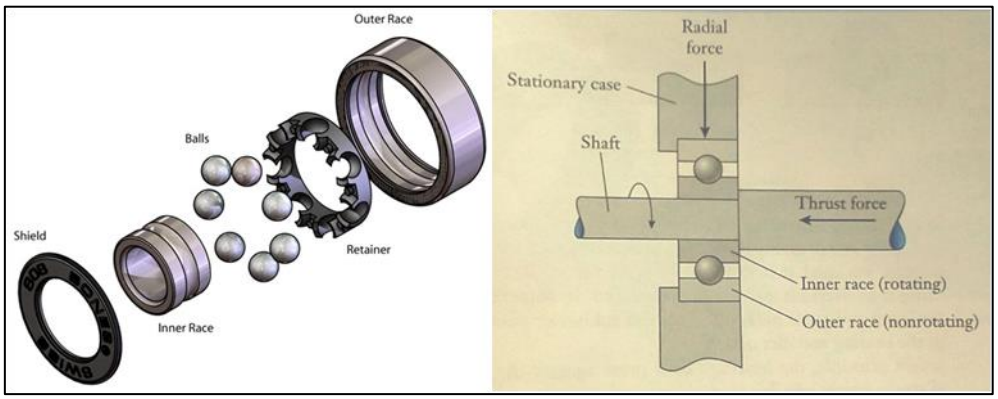

Figure 2.4: Exploded view of a ball bearing and bearing outline in cross-sectional side view

2.5 Computer-Aided Design(CAD) and Finite Element Analysis(FEA) as the Tool of the Study

The capability to model a structural system in 3D can provide a powerful and accurate analysis of almost any structure. Generally, 3D models can be generated using a range of common computer-aided design packages. Models have the tendency to range largely in both in file format and its complexity, depend on 3D model creation software and the complexity of the model's geometry. Nowadays FEA is a leading and growing industry in product design, analysis, and development in engineering. The development in computer processing power, FEA, and modeling software has allowed the continued integration of FEA in the engineering fields of product design and development. In the past, there have been many issues that restrict the performance and greatly the acceptance and utilization of FEA in conjunction with CAD in the product design and development stages. The limits in compatibility between CAD file formats and FEA software restricted the extent to which companies could easily design and test their products using the CAD and FEA combination. Typically, engineers would use CAD and modeling software in the design of the product. Then, they wish to export that design into a FEA package to run a test. Thus, the creation of many models external to FEA environments was considered to be the major problem in the success of FEA. The current trend in FEA software & industry in engineering has been the increasing need for integration between solid modeling and FEA analysis. During product design and development stages, engineers require automatic updating of their current models between CAD and FEA environments. It is still required for the link between CAD and FEA to improve, making them technically closer together. However, the demand for unitary CAD-FEA integration coupled with the improved computer and software developments has introduced a more robust and collaborative trend where compatibility problems are beginning to be extinguished. Without the need to modify and to recreate a model to suit with FEA environments, designers are now beginning to introduce computer simulations capable of using pre-existing CAD files.(Ruzana, 2008)

CHAPTER 3

3. RESEARCH METHODOLOGY

3.1 Flowchart of the Bachelor's Degree Project

The flowchart shows the exact processes involved in obtaining the concept design for the Flywheel Hybrid module. Starting by conducting benchmarking process on shafts and housing are produced by several manufacturers. Followed by preparing the product design specification of the shafts and housing, the measurement of other components in the whole module are also must be taking into account for this process. After that, a morphological chart is prepared. This will generate variations of idea from different person. The process is then followed by generating combinations of ideas with ideas of other components to create a complete Flywheel Hybrid module. Using Pugh Method, each individual ideas were given scores. Finally, the accumulated scores from all combinations generated is calculated so that the design team can proceed to select the best concept available for the conceptual design.

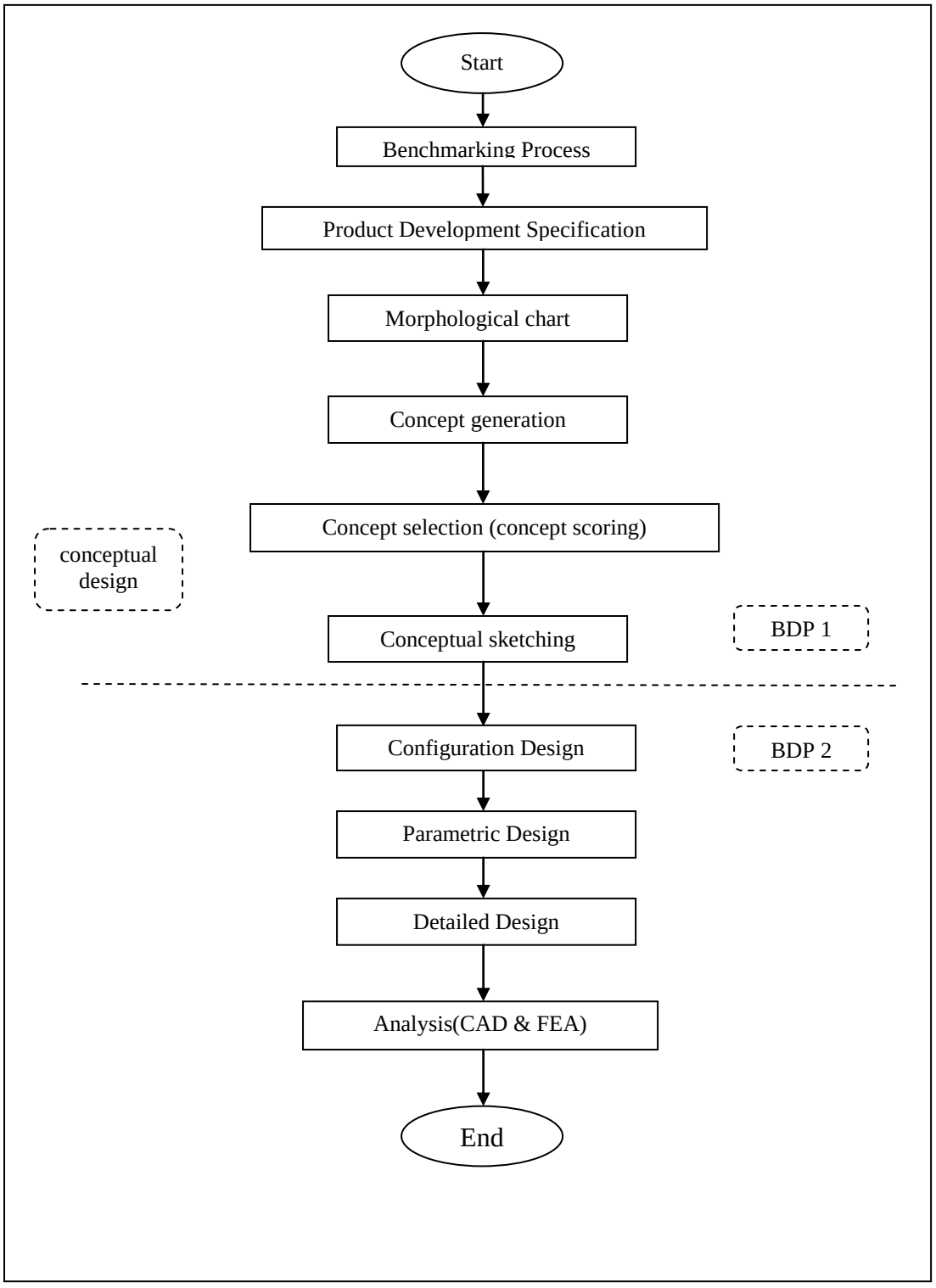

Figure 3.1: Flowchart of the Bachelor's Degree Project