

A Systematic Approach for Load Cycle Generation Based on Real World Indian Drive Profile

Nabal Kishore Pandey, Satish Thimmalapura and R Ramachandran
Mahindra & Mahindra Ltd

ABSTRACT

Within the last decade, due to increasing fuel prices, unstable political situation in major oil producing nations and global warming, there is an increased demand for fuel efficient and environment friendly vehicles. In this context, research is being concentrated in the field of advanced, greener powertrain configurations ranging from hybrids to EVs to fuel cells to HCCI engines. The efficacy for any of the above stated powertrain technology, lies in the optimum component specification. Component specification, operational reliability, & life prediction are highly dependent on the traffic condition, driving nature and vary from country to country. For developing countries, like India, where the traffic & drive pattern are dense & slow moving, there is a dire need for generating load cycle based on Real World Usage Profile (RWUP). The paper will propose a systematic approach to create load cycles in order to derive component specifications for the powertrain based on RWUP. Load cycles refer to the load variation with respect to time for the component based on the vehicle operating condition. This paper will also discuss about the powertrain control algorithm for various vehicle operating conditions and also create multiple shift schedules for manual transmission. Based on Indian RWUP, shift schedule, vehicle load and powertrain control algorithm, a series of simulations will be run for generating the energy throughput for the specific powertrain components. This energy throughput will be further synthesized for generating the load cycle of the components.

CITATION: Pandey, N., Thimmalapura, S. and Ramachandran, R., "A Systematic Approach for Load Cycle Generation Based on Real World Indian Drive Profile," *SAE Int. J. Passeng. Cars - Electron. Electr. Syst.* 5(1):2012, doi: 10.4271/2012-01-0504.

INTRODUCTION

For any system to perform as intended, one of the key elements is that the system is designed according to the specifications and requirements. Thus, the onus is on the correct design of the system. It is imperative to understand the working environment of the system along with the intended boundaries of use. Without the knowledge of the boundaries, the system could be over designed resulting in additional cost or under designed leading to failure issues. System design should also take into account the reliability (repeatability) and durability (longevity). This mandates using of the right tools and approach for arriving at the specification of the components based on the boundaries and intended operation.

This paper describes the methodology to arrive at specification of components for the Indian conditions. The first section describes the criticality of specifications and its consequences. The mission profile which is to be used to derive the specifications is described in the next section. The powertrain control strategy employed for the simulations are

described. The methodology and results of various load profiles for the component is documented and discussed.

For automotive systems, specification of the components is vital. The specifications reflect the requirement of user-level functions at system and component levels. Incorrect or incomplete specification for a component can have unintended consequences. There are numerous examples of recall of vehicles by NHTSA in the US [1]. Many of them boil down to specifications of components not conforming to certain requirements. The reliability and durability targets for product/system have to be detailed to the specification level in order to meet the product level targets. This would result in reducing the rate of failures. In the undertaken study, a parallel hybrid vehicle [2] of SUV class is considered for deriving the specifications of the components.

REAL WORLD USAGE PROFILE (RWUP)

As mentioned in the introduction section, boundary of operation for a system is very critical for arriving at



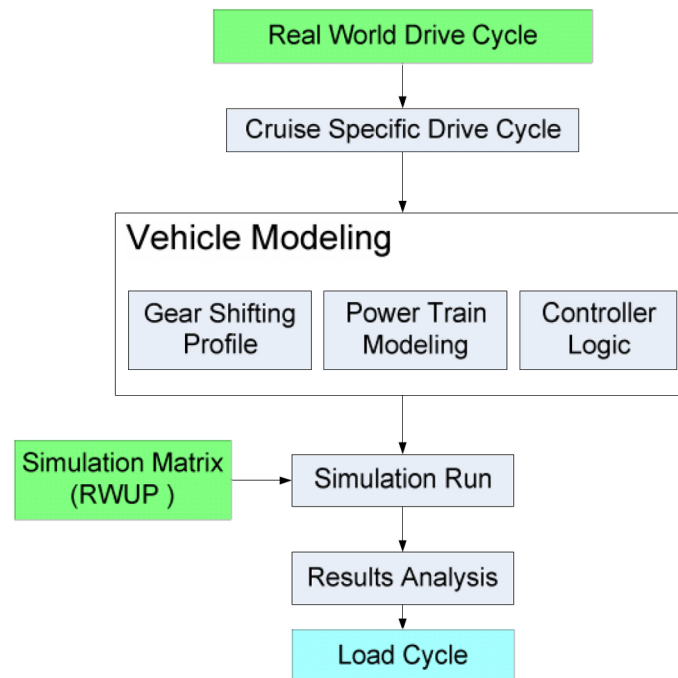


Figure 1. Load Cycle Generation Methodology

specifications for the components. The boundary conditions are in multiple domains like, mechanical, electrical, thermal, NVH, etc... In order to arrive at specifications it becomes necessary to define mission profiles. Mission profile refers to the indicative usage profile of the system or the component in real world. The challenge lies in defining mission profiles which encompass all the various usage conditions. From a vehicle perspective, the usage profile refers to the various conditions it will be driven in.

In the Indian scenario, the vehicle usability depends on the following parameters:

- a). Type of road: The various types of roads are urban, semi-urban, rural, highway, mountainous road etc...
- b). Vehicle load: The load on the vehicle depends on the number of passengers and also the cargo. Typically, it is classified into Driver/ Co-driver, 50% of GVW, GVW, Over GVW
- c). Type of users: This indicates the profile of the target users. This is broadly classified as rough driver, high speed driver, normal driver and cautious driver. Also the consideration is given to whether the vehicle is self-driven or driven by a driver.

Based on the knowledge of the Indian market and target customers the break-up of the utilization for the above defined categories was arrived. An internal study was commissioned to collect the data for the various scenarios mentioned above. Based on this data, drive cycles were arrived at for city driving, highway driving and mountainous roads. The drive cycles [3] have been used for deriving the load profiles of the various components.

LOAD PROFILE GENERATION METHODOLOGY

The methodology used for generation of load profile is depicted in [figure 1](#). The input for the process is the real world drive cycle, as proposed in [3]. This drive cycle has to be converted into AVL Cruise specific drive cycle. This is fed into the target powertrain model for different simulation runs which will be specified in the RWUP simulation matrix. The results will then be analyzed and the load cycle will be arrived.

CRUISE SPECIFIC DRIVE CYCLE GENERATION

The actual real world cycle was fine tuned and the synthesized to AVL Cruise specific cycles. The fine tuning was to increase the sampling time, the sampling time for the reference cycle was 0.02, and linear interpolation of the speed in the initial phase and the end phase of every micro-trip [3]. The segments of the drive cycle which were fine tuned are depicted in [figure 2](#).

These modifications of the drive cycle are required for optimization of AVL Cruise simulation while maintaining the critical characteristic of the cycle. [Table 1](#) shows the comparison between the actual reference cycle and the synthesized cycle. It is evident that the synthesized Cruise specific cycle has a good correlation with the drive cycle proposed [3]. The only major deviation between the two cycles is in the acceleration & a deceleration max value, which is due to the linear interpolation of the cycle in that start and end phase of micro trip.

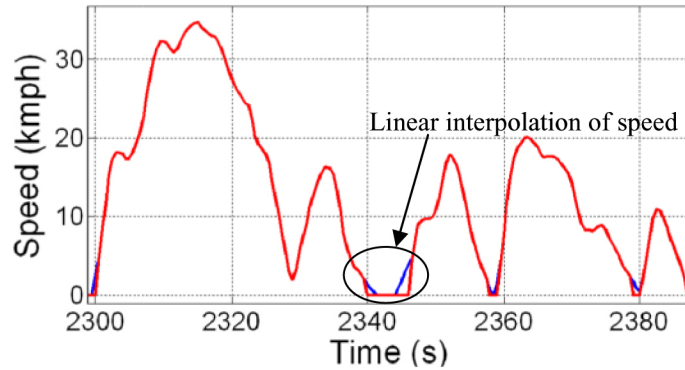


Figure 2. Linear Interpolation of Microtrip

Table 1. Comparison between Drive Cycle & the AVL Cruise Specific Cycle

MUDC	Drive Cycle	AVL Cruise Cycle
Acceleration (%)	41.3	42.5
Deceleration (%)	30.3	31.5
Cruise (%)	9.7	10
Idle (%)	18.7	16
Average Speed (kmph)	22	22
Max. Speed (kmph)	70.8	70.8
Max. Acceleration (m/s^2)	2.9	2.6
Max. Deceleration (m/s^2)	-3.1	-2.8
No. Of Start-Stops	2.12	2.05
Duration	3444	3444

MHDC	Drive Cycle	AVL Cruise Cycle
Acceleration (%)	65.6	64.5
Deceleration (%)	14.1	14.5
Cruise (%)	20.3	21
Average Speed (kmph)	90	90
Max. Speed (kmph)	125	125
Max. Acceleration (m/s^2)	3.4	2.9
Max. Deceleration (m/s^2)	-2.8	-2.5
Duration	1928	1928

VEHICLE MODELING

The proposed vehicle for load cycle generation is a concept hybrid diesel SUV with manual transmission. Vehicle modeling of such a configuration involves following inputs:

- Gear Shifting logic
- Powertrain architecture
- Controller logic

GEAR SHIFTING LOGIC

Gear shifting is a dynamic process and varies from driver to driver. There is no fixed pattern defined for the gear shifting logic for a manual transmission. As this is highly dependent on the driver, the gear shifting was mainly categorized into following two different patterns, namely:

- Economy gear shifting
- Sporty gear shifting

Economy gear shifting profile was defined for the driver who is particular about fuel economy and tends to upshift at

lower speeds whereas the sporty gear shifting profile was defined for the driver demands more power and tends to upshift at higher. Figure 3 shows the proposed gear shifting logic.

The critical point for defining gear shifting logic is the engine speed & vehicle velocity for each gear. The lower threshold and the higher threshold speed (n_{upper} , n_{lower}), for both proposed shifting schedules, are tabulated in table 2 (for gear shifting curves refer Appendix). n_{upper} refers to the engine speed at driver shifts to the higher gear and n_{lower} refers to the engine speed at which the driver downshifts.

Table 2. Threshold Speeds for Gear Shifting

	Economy Gear Shifting	Sporty Gear Shifting
Max (n_{upper})	2500	4000
Min (n_{lower})	1100	2750

With the above stated points the gear shifting profile was derived for sporty and economy shifts. The defined gear

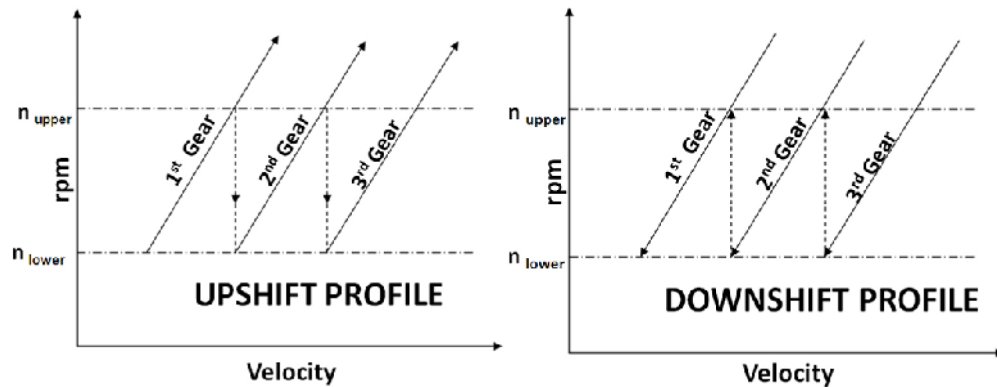


Figure 3. Gear Shifting Logic

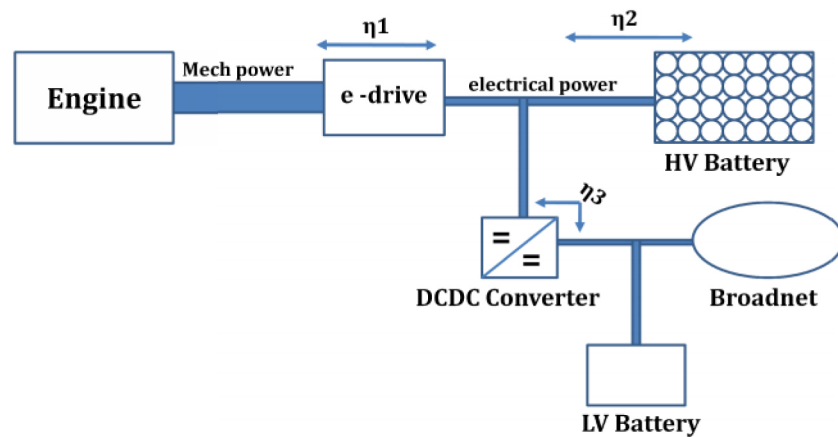


Figure 4. Hybrid Component Layout

shifting profile is a function of transmission output shaft speed and accelerator pedal position for every gear.

POWERTRAIN DEFINITION

Powertrain definition here refers to vehicle model development in AVL Cruise, which includes the hybrid powertrain architecture definition and detailing. The proposed concept hybrid vehicle is assumed to be a parallel hybrid configuration [2]. Figure 4 represents the hybrid component layout schematic. Efficiency based losses are assumed for the energy/power conversion in the system.

The proposed vehicle model, referred in figure 5, is assumed to be a FWD, 6 speed MT, Diesel SUV with parallel hybrid powertrain architecture. The gear shifting logic, as described in the previous section, is modeled with the "AMT Control" block and the "Gear Box Program" block. The other important facet of vehicle modeling is the vehicle controller logic definition. The proposed vehicle hybrid control algorithm comprises of torque assist, regeneration and stop-start as hybrid functions, which resides in the "HEV control", "HEV status" & "Stop & Start" block. Following section will describe the controller logic in detail.

CONTROLLER LOGIC DEFINITION

The hybrid powertrain with two power sources namely, engine and e-drive, requires intelligent control logic for arbitrating torque/power based on the real world condition and driver interface. The proposed control logic, for defining the hybrid functions, is based on accelerator pedal position, powertrain state (open/closed), gear and limitations of the engine and e-motor. Torque assist and regeneration functionality is described in the succeeding sections.

Torque Assist Function

In torque assist functionality; e-machine assists the conventional engine in meeting the driver demand by providing the additional torque. Inputs for enabling this function are accelerator pedal position, gear, powertrain state and battery SOC. In the proposed controller the torque assist functionality is mainly divided into following 2 main phases, as shown in figure 6, based on the engine rpm.