TyreOpt - Phase I

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1 TyreOpt project

The project *TyreOpt - Fuel consumption reduction by tyre drag optimization* financed by Swedish Energy Agency and Volvo Group Trucks Technology (Volvo GTT) described in [12] is divided into four phases:

- Phase I — Perform a survey on how tyre rolling resistance function and related objectives depends on different parameters. Perform a survey on simulation models for tyre rolling resistance. Identify information and knowledge available in Volvo, require additional data.
- Phase II — Perform the deterministic optimization on the tyre rolling resistance function involving global optimization and meta-modelling for a limited number of combinations of truck configuration and operating environment. Develop a computationally efficient method that can optimize the tyre rolling resistance function for the large variety of vehicle configurations and operating environments.
- Phase III — Include uncertainties in data into the optimization framework. Perform a sensitivity analysis of optimal tyre configurations when vehicle configurations and operating environments are varying.
- Phase IV — Collect the missing data, improve the tyre rolling resistance function. Implement the developed methodology, test and evaluate it for a real Volvo truck.

Phase I is presented in this report.

1.1 General background

The fuel efficiency of each vehicle combination is improved when we minimize energy losses caused by its tyres, e.g., the rolling resistance. The function describing the rolling resistance can be represented by a complex function of a large amount of variables affecting each other of which only limited knowledge exists. The rolling resistance function will be found and this function will be optimized using mathematical optimization methods, while simultaneously balancing other tyre-dependent criteria such as handling properties, traction, tyre wear and ride comfort. Furthermore, there is an enormous variety of vehicle configurations, operating environments, and a large set of different tyres available, wherefore a specialized optimization strategy must be developed. An expected outcome of TyreOpt project is a tool in which the optimal tyre configuration is found given the vehicle configuration and the operating environment in which the vehicle is to be used.

1.2 Phase I

The aims of the first phase of the project are summarized below.

- Perform a survey on how the rolling resistance function depends on different parameters (tyre design parameters, vehicle parameters, and parameters describing the operating environment). The survey should include an investigation on how the affecting variables depend on the vehicle configuration, and also how different operating environments can be described.

- A discussion about important objectives and constraints that need to be considered when varying the tyres (e.g., requirements on vehicle performance regarding braking, traction, handling, and ride comfort) is to be included. The discussion should include an investigation on how the different parameters affect the objectives as well as the constraints.

- Perform a survey on simulation models for rolling resistance and other tyre related objectives that should be of consideration for tyres selection. The expected outcome from this surveying is a selection of simulation models to use for the objectives.

- Summarize in-house information and knowledge within Volvo GTT, customer databases, tyre suppliers and results published in the open literature. This investigation identifies what input data that is required, what is available, and within what areas additional data needs to be collected during the project.

Phase I needs to be done to be able to formulate and model a suitable optimization problem (variables, parameters, objective function, constraints) to be solved in order to find the tyre configurations minimizing the energy consumption for given vehicle configuration and operating environment.

2 Rolling resistance

The rolling resistance can be quantified as the moment on the wheel required to keep a given tyre rolling without longitudinal slip (pure rolling wheel). It includes mechanical losses due to aerodynamic drag associated with rolling, wheel bearing torque losses, plastic deformation of the tyre in the contact region, and losses within the structure of the tyre. The rolling resistance generates heat when a tyre rolls on the road.

2.1 Rolling resistance coefficient

The rolling resistance on a free-rolling tyre, i.e., no applied wheel torque, can be characterized through the rolling resistance coefficient

$$\mathrm{RRC} = -\frac{F_x}{F_z},$$

where RRC represents the coefficient of rolling resistance, $-F_x < 0$ is the rolling resistance force, and F_z is the vertical (normal) force at the tyre-ground contact patch. This definition of the rolling resistance does not include wheel torque, aerodynamic, bearing, and slip losses.

2.2 Survey on how the rolling resistance coefficient varies

A literature survey on how the rolling resistance depends on different parameters was performed. The most important parameters identified are

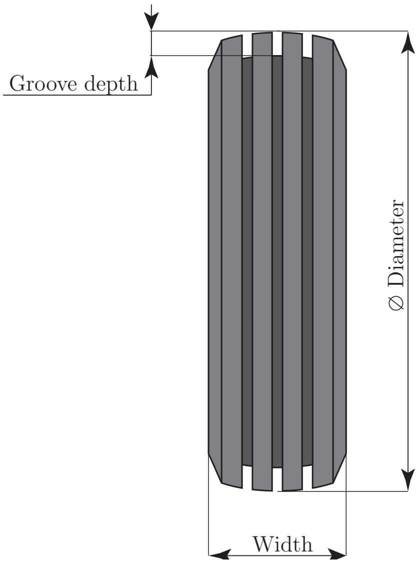

Figure 1: Tyre's dimensions: tyre diameter, tyre width, and groove depth.

- wheel longitudinal velocity — The rolling resistance increases with increasing longitudinal wheel velocity ([16, 19]). The velocity dependence can be explained by a shift in centre of pressure and a change in temperature in the air inside the tyre.
- tyre material and structure — Material nature and tyre structure play significant roles when determining the rolling resistance. The tread of the tyre and the geometry of the tyre are very important for damping properties of the tyre, and higher damping leads to higher rolling resistance. Damping is also influenced by the rubber compounds used to construct the tyre ([7]).
- tyre geometry — Increasing tyre diameter as the other parameters are kept constant decreases vertical deformation which results in lower rolling resistance ([19]). Increasing tyre width leads to lower rolling resistance coefficient due to increased contact patch area decreasing the force sustained by each element in the patch. As such, the compression of each element in the tyre is smaller compared to those of a tyre with a smaller width. Hence the hysteresis loss is lower and the rolling resistance decreases ([18]). The tyre size is a critical parameter wrt. many aspects of a vehicle other than rolling resistance, for example vehicle handling.
- temperature — The internal damping of the tyre decreases with increasing temperature which results in lower rolling resistance ([7]). The temperature changes with

change in velocity, normal load, and with the ambient temperature. Both material properties and the road surface influence how the temperature of the tyre changes. It is generally a challenging task to model the changes in tyre temperature with all of these parameters.

- inflation pressure — With increasing inflation pressure the rolling resistance on hard surfaces decreases ([19]) as other parameters are kept constant. As the pressure increases, the tyre holds its shape more firmly. Hence, the hysteresis losses reduce decreasing the rolling resistance.
- vertical load — With increasing vertical load the rolling resistance coefficient decreases ([10]). An increase in vertical load increases radial deformation of tyre elements, thus increasing the rolling moment produced due to shift in pressure centre increasing the rolling resistance.

The relations between the listed parameters and the rolling resistance are influenced by the operating conditions and may vary in different references. The most common relations were described above.

Various other factors affect rolling resistance, for example, curve density and manoeuvring (i.e., lateral tyre force), tyre degradation, and road surface ([9]). The effect of some of these factors on the rolling resistance is difficult to model (e.g., tyre degradation) or come into consideration with more complex models of vehicle and operating environment (e.g., curve density).

3 Objectives and constraints important for tyres selection

In an optimization problem, we need to identify variables we can control and influence. The values of the variables are to be decided upon. The remaining quantities are parameters in the problem. Then a real-valued function of the variables measuring the activity levels to be minimized or maximized defines the objective function. Normally, the activity levels cannot be arbitrarily large. The restrictions on activities form constraints on the possible choices of the variables values ([2]).

The rolling resistance is one aspect in the tyres selection optimization problem, it significantly influences several tyre related objectives and constraints. Nevertheless, there are also other important criteria when selecting tyres. Therefore, we have to identify the most important objectives and constraints for the optimization problem to find the optimal tyre configurations for varying vehicles and operating environments. The objectives and constraints (the roles may be interchanged) affected by the tyre design might be often conflicting and we wish to find the best possible trade-off among them. Below we propose one sorting into objectives and constraints suitable for typical truck users.

The objective function to be minimized is aimed to describe the operational cost of the vehicle ([12]) as a function of the tyres selection. Therefore, we should consider

- vehicle fuel consumption – directly influenced by the rolling resistance (more fuel is needed to overcome higher rolling resistance), and
- tyre wear – contributing significantly to the overall operating cost as well (higher rolling resistance typically leads to higher tyre wear).

The sum of the fuel and tyre costs is considered as the real-valued objective function depending on the variables describing the tyres selection to optimize.

Apart from the objective functions suitable constraints have to be considered to meet the safety, comfort, and other requirements on the vehicle configuration as functions of the variables describing the tyres selection. These requirements involve

- ride comfort,
- vehicle durability,
- startability,
- noise emissions,
- acceleration performance,
- braking performance,
- low speed lateral performance (e.g., swept path),
- high speed lateral stability (e.g., rearward amplification),
- pavement loading, and
- geometric packaging of tyre on wheel vehicle chassis.

We have selected the following three constraints to start with since they capture the vehicle behaviour in all three directions (longitudinal, lateral, vertical) and are fairly easy to model. We have to be prepared to add new constraints if the optimal tyre configurations do not provide the expected vehicle performance.

- startability – indicating the vehicle ability to start from stand-still and maintain steady forward motion on specified grade and constraining the longitudinal dynamics of the vehicle,
- handling (i.e., the high speed stability, exemplified by the understeering gradient) – describes the vehicle stability when cornering and constrains the lateral dynamics of the vehicle,
- ride comfort – expresses passenger feeling wrt. to vehicle vibrations as subjected to the environment perturbations and constrains the vertical dynamics of the vehicle.

4 Survey on simulation models for objectives and constraints important for tyres selection

The vehicle fuel consumption, and even the rolling resistance itself, is not only a property of the tyre itself. It is also dependent on the vehicle that the tyre is used on (since different forces act on the tyres) and the environment in which the tyre is used. Therefore, a joint model of heavy truck, tyres, and operating environment has to be utilized in order to model the rolling resistance sufficiently accurate.

4.1 Tyre models

It is not easy to create a model that realistically represents the full behaviour of the tyre in all driving conditions. Trying to do so would result in a very complex and computationally expensive model which would be practically impossible to handle. Therefore, many different simpler tyre models for different use cases were developed. Each model has its own limitations. A survey on various models for rolling resistance and other tyre properties was performed. The tyre models can be classified as follows

- Empirical models
    - Experimental data
      The empirical models based on experimental data consider the tyre as a black box. The tyre deformation is created and the tyre forces are then measured. Then a model of the dependence of the tyre forces on different parameters is built. These models are easy to handle since they are usually in a closed form expression and require low computation effort. However, a lot of expensive tyre measurements have to be done in order to populate the model and it is often impossible to generalize the model for varying tyre design.
        - Pacejka's tyre model (Magic formula)
          One of the most used tyre models for vehicle dynamics simulations which is completely empirical, see [15]. Several factors have to be found from experimental measurements in order to model lateral and longitudinal tyre forces as functions of the vertical load. The more advanced Pacejka's tyre model allows to investigate influence of the longitudinal speed, tyre radius, the inflation pressure and a simple description of tread pattern on the tyre forces.
        - Combined tyre model
          A simple quasi-empirical model using simple physical models for various tyre properties was verified and populated using experimental data ([18]). The rolling resistance is a function of inflation pressure, tyre diameter, tyre width, wheel velocity, vertical load.
    - Similarity method
      The similarity models are based on distorting, rescaling and combining the measured basic tyre characteristics. One of the similarity methods is based

on the observation that the pure slip curves remain approximately similar in shape when the tyre runs at conditions different from reference conditions. The reference curve is then shifted and multiplicated horizontally and vertically to obtain a pure slip curve for different conditions, see [15]. This approach can be used for other tyre characteristics as well.

- Theoretical models
    - Simple physical model
        - Steady state tyre models
          The steady state tyre models are suitable when the velocities are constant which is rarely true in reality since the vehicle goes through acceleration and braking but these models are often simple and provide an approximative representation of the tyre. Experimental data to validate the model needs to be obtained using specialized equipment.
            - Brush model
              A simple mechanical representation of the tread by brushes is used, see [19] for details. The model leads to a closed form solution and is based on modelling the longitudinal tyre deformation, longitudinal slip and side slip. Different brush models have been developed considering different distributions of the normal contact force. The stiffness of the tread rubber and of the carcass have to be known. The model gives lateral tyre force, tyre moment and friction coefficient as functions of the longitudinal speed, radius of the tyre, and vertical force.
            - String model
              A simple mechanical representation of the tyre belt by a string is used leading to a closed form solution, see [17]. The model is an alternative to the brush model and possess the same outputs and inputs.
        - Dynamic models
          The dynamic models capture the behaviour of the tyre-road contact forces under time-varying velocity conditions.
            - Dahl tyre model
              The model described in [5] is based on Coulomb friction. The investigation of the influence of the longitudinal speed, radius of the tyre, and vertical force on the tyre forces are possible.
        - SWIFT tyre
          A rigid ring type of tyre model for modelling both steady state and dynamic tyre behaviour using advanced physical models and tyre measurements, see [3] for more details. The model is semi-empirical and allows to investigate the influence of the vertical force, the longitudinal speed and the radius of the tyre on the tyre forces. The model was validated with an advanced tyre testing.

  - Complex physical model
    The complex models are difficult to handle and require a large computational effort because they describe the tyres in a greater detail. These models are typically performed using computer simulations, e.g., the finite element method (FEM), which guarantees an accurate and quantitative fit of the tyre characteristics to the real tyre behaviour in the considered conditions.
    - FEM tyre model
      There exist several different FEM tyre models. These models describe tyre behaviour accurately and are typically used for tyre design. An extensive testing and experimental parameter assessment is needed for validation of the model. These models cannot typically be involved in full vehicle simulations because they require large computational effort. See, e.g., [1] for a description of a FEM truck tyre model which allows to investigate the influence of the vertical force, the longitudinal speed, the radius of the tyre, the inflation pressure, the tyre width, and the groove depth on the rolling resistance coefficient of the truck tyre.

The main properties of the tyre models listed are summarized in Table 1.

4.2 Vehicle models

The vehicle models considered in this report allow to investigate the interaction of the vehicle and tyres on a specified operating environment ([11]). In this survey, we have mainly focused on the models available in Volvo GTT, but one can find similar models of the same type in other organisations as well.

- PERF (PERFormance) – Type: Longitudinal dynamics fuel consumption model – Vehicle analysis tool capable to evaluate the truck's power-train performance criteria on simple longitudinal driving cycles. It mainly aims to assess the fuel economy, and suitability of a particular vehicle specification for a desired environment. PERF is written in FORTRAN and therefore is complicated to modify. This limits any changes of tyre definition. The used tyre model is very simple, the rolling resistance coefficient is constant over the driving cycle. The tool is equipped with a graphic user interface, where all truck components (engine, gearbox) and parameters can be easily defined.

- VTM (Volvo Transport Models) – Type: Vehicle traction & handling model – A simulation environment created with the basic purpose to assess vehicle dynamic behaviour. Since the models are created in MATLAB/Simulink they can be edited. The VTM library contains different vehicle templates which can be evaluated. The environment is a multi body modelling system, which formulates automatically the equations of motion. A description of the power-train is missing in VTM. But the vehicle economy can be evaluated, e.g., by using total resistive forces. The tyre model utilized in VTM is based on Pacejka's Magic Formula ([15]) and requires experimental data to be populated.

- GSP (Global Simulation Platform) – Type: Longitudinal dynamics fuel consumption model – Platform based on MATLAB/Simulink allowing editing focuses on power-train system and its components, which are further used for evaluation of the vehicle performance in various drive cycles. The model of chassis is very simple and neglects suspension dynamics in vertical and lateral direction. Tyre-road contact is not modelled at all. Hence, the tyre representation is very simple. The influence of different vehicle configurations on the vehicle performance cannot be investigated since the vehicle model is too simple.
- CVM (Complete Vehicle Model) – Type: Structure and vibration model – Very detailed vehicle model built in NASTRAN FEM software concerning elastic behaviour of the vehicle components. The vehicle structure is defined by discrete elements and evaluated with a finite element method solver. The model is computationally expensive and working with the model requires a special training. The tyre model is relatively simple. Tyres are modelled as linear springs and dampers taking into considerations the slip equations. CVM evaluates the static analysis, handling, comfort, and durability of the considered vehicle.
- Computationally efficient model of a heavy duty truck – Type: Purpose built model – MATLAB/Simulink model which was built within the TyreOpt research project ([4]). The inverse dynamic principle and a simple model of the power-train are used for computation of fuel consumption. The tyre model used is based on an interpolation of sample points simulated by a FEA tyre model. A simple tyre wear model from [8] was implemented. Constraining events including startability, ride comfort and handling can be evaluated using this model. The main advantage of the model is its computational efficiency. However, many tradeoffs and simplifications were done, e.g., that dependencies between vehicle and power-train are missing and that the cornering is not modelled. The influence of various tyre parameters on the fuel consumption, tyre wear, and constraining events can be evaluated.

4.3 Operating environment specification

The amount of details required for the operating environment specification may vary depending on the vehicle and tyre models used. It is not complicated to construct (e.g., based on logged track data) an operating environment model of sufficient accuracy. The main ingredient in the operating environment model is typically its speed profile which can be modelled as a piecewise constant speed profile or as an exact speed profile including the acceleration desires.

Each Volvo customer is asked to specify number of Global Transport Applications (GTA) parameters ([6]) used to discretize the intended usage of the vehicle throughout various departments of Volvo. The GTA parameters characterize, e.g., road condition, curve density, and topography. Our intention is to build a road generator which generates a random but typical road for each combination of GTA parameters. The output from the road generator will then be used to model the operating environment.

5 Selection of simulation models for objectives and constraints important for tyres selection

The surveying resulted in a selection of simulation models to be used to evaluate the tyre-related objectives and constraints. Our aim is to keep the simulation models as simple as possible and keep the number of tyre parameters considered at minimum to get a solvable optimization problem. At the same time the most important interactions of the vehicle, tyres, and operating environment have to be captured when searching the optimal tyre configurations.

5.1 Tyre model

The selection of the parameters describing the tyres when searching for the optimal tyre configurations has to take into account the information available about each tyre in Volvo GTT's tyre database. The database contains

- tyre dimensions (diameter, mass, width, etc.),
- recommended inflation pressure,
- load capacity,
- tread class specification (code),
- recommended applications and positions,
- wet grip, noise class, RRC class,
- cornering stiffness, slip coefficient,
- aligning moment,
- load index (stipulating the maximum load each tyre can carry), and
- speed index (stipulating the maximum permitted speed).

The Pacejka's tyre model ([15]) considers the vertical load, the longitudinal speed, tyre radius, and the inflation pressure as the most important parameters for rolling resistance determination. We also wish to consider a characterization of the tyre tread which is very important for the rolling resistance of tyre ([13]). The description of the tread in Pacejka's tyre model requires many experimentally measured parameters for each tyre. These parameters are not available in Volvo GTT's tyre database. Hence, the tread will be described only by its groove depth in the current phase of the project, since the groove depth can be obtained easily for most of the tyres from tyre suppliers. We also add tyre width to describe the tyre geometry—critical for rolling resistance—closer. Finally, the most important parameters for the rolling resistance coefficient determination considered further are

- vertical load,
- longitudinal speed,
- inflation pressure,
- tyre radius,
- tyre width, and
- groove depth.

These parameters are further divided into *operating and vehicle parameters* (vertical load and longitudinal speed) and *tyre design variables* (inflation pressure, tyre radius, tyre width, groove depth).

There is a lot of other parameters significantly influencing the identification of optimal tyre configuration which are not considered in our model of the rolling resistance coefficient so far. Some of them can be considered as fixed (or co-varying) and some of them should be possibly added to get more accurate and realistic results, e.g., rubber specification (e.g., Young's modulus of the tread), tyre slip angle, axle suspension, groove pattern specification, and driving torque (allowing simulations of braking and steering situations).

As a result of a cooperation between University of Ontario Institute of Technology (UOIT) and Volvo GTT we have access to a full 3-Dimensional finite element analysis model of a free rolling truck tyre placed on a virtual road described in [1]. The rolling resistance is modelled as the longitudinal force present between the tyre and the ground contact patch so the rolling resistance involves tyre internal hysteresis and friction between the tyre and the road. The influence of all parameters selected on the rolling resistance coefficient can be investigated using this FEA model. The model requires a long computation time to be evaluated and has many limitations, e.g., a free-rolling tyre when there is no applied torque was modelled. Since we would like to use the functionality of the FEA model and at the same time keep the computation time at an acceptable level we have created a surrogate model (i.e., response surface) of the FEA model. The surrogate model of an expensive function is typically an explicit function interpolating or approximating sample points evaluated by the computationally expensive simulations. The FEA model was used to create a set of sample points at which the rolling resistance coefficient varies due to changes in the parameters. Each parameter was varied between upper and lower bounds determining a validity region of the surrogate model. The surrogate model is then constructed as a radial basis function interpolation of the sample points, see [14] for details. The resulting model of the rolling resistance coefficient built in MATLAB is a linear combination of linear radial functions.

Table 1 motivates why the surrogate model was selected to model tyres in this research project. Other tyre models available ([5, 17, 19]) are designed as functions of a subset of the selected parameters influencing the rolling resistance coefficient. It is not possible to merge several models because they have different levels of accuracy and are based on different measurements.

Tyre model	Type	Parameters modelled	Comp. efficiency
Magic formula	Empirical	load, speed, radius, pressure	High
Combined	Quasi-physical	load, speed, radius, width, pressure	High
Brush	Physical	load, speed, radius	High
Dahl	Physical	load, speed, radius	High
SWIFT	Quasi-physical	load, speed, radius	Medium
FEM	Physical	load, speed, radius, width groove depth, pressure	Low
Surrogate model	Mathematical	load, speed, radius, width groove depth, pressure	High

Table 1: Properties of tyre models considered

5.2 Vehicle model

We consider the straight highway driving of the vehicle configuration so far. There is no applied torque on tyres and we assume radial tyres. These assumptions are done to make the problem to start with easier. In the next phases of the project we plan, however, consider also braking and steering situations requiring adding the influence of the drive torque on the rolling resistance to our tyre model. Other situations like cornering and low speed manoeuvring may be also considered since they have a direct impact on the fuel consumption. Adding these situations requires a significant modelling afford.

The computationally efficient model of a heavy duty truck was developed for the needs of TyreOpt research project. The model can evaluate all selected objective functions and constraints. This model was selected as the simulation tool to be used further. Another candidate is to use VTM. VTM has to be combined with more general tyre model which can be used to investigate influence of various tyre parameters and additional changes have to be done in order to make it applicable in TyreOpt. The adapted VTM can be used both to verify the results of the optimization done using the computationally efficient model and to replace the computationally efficient model.

Let us summarize the approaches used within the computationally efficient model of a heavy duty truck used for modelling individual objectives and constraints considered.

- Fuel consumption – The inverse dynamic principle is used for computation of fuel consumption. The model consisting of vehicle block, gearbox block, engine and fuel tank blocks created with the aid of MATLAB/Simulink and QSS toolbox is simulated over the operating cycle. A simple half vehicle model is used in the vehicle block. Both the vehicle model and the powertrain model can be more complex considering, e.g., load transfer and differences between the right and the left sides of the road. The simple driver model used can be also changed to get more realistic results.

- Tyre wear – There is no single accepted method for calculating tyre wear, various wear models exist for different operating conditions. The wear models are typically not so accurate and require many measured parameters describing the tyre.

Based on the literature survey in [4] Schallamach model ([8]) based on slip influence was selected as it is simple and includes tyre surface temperature calculation. The model contains several constants which have to be provided by the tyre manufacturer or measured to fit the model to reality. The model provides only very approximate wear rates.

- Startability – The model is using a simplified equilibrium equation of the vehicle in longitudinal direction. The tractive force has to be able to overcome all resistive forces acting on the vehicle at the required grade.
- Handling – The understeer gradient is calculated to predict the handling performance even though there is no steering information in the model. The model was supplemented by a regression model of lateral stiffness of the tyre to include the influence of tyre design variables. When the vehicle model considers also the lateral dynamics handling can be modelled by driving uphill or downhill till the truck flips over. The complexity of the model is then influenced by the brake model.
- Ride comfort – To model the ride comfort a 4 degrees of freedom model of vertical vehicle dynamics was built. The model was supplemented by a regression model of vertical stiffness of the tyre to include the influence of tyre design variables.

5.3 Operating environment model

Since the straight highway driving was considered, piecewise constant set speed and height profiles of the road resulting stemming from discretized speed and height profiles and three additional parameters describing the road roughness (road spectra density, road spectre inclination, frequency range) are sufficient to describe the operating environment. Curvature is currently not defined in the environment model since the curvature effects are not captured by the current tyre model.

5.4 Setting of the joint model

To be able to evaluate all objective functions and constraints considered, all necessary parameters describing truck, road and tyre need to be defined. We need to assign values of

- 40 parameters of vehicle model,
- 3 parameters and the discretized speed and height profile of road for the operating environment model, and
- 10 parameters for the tyre model (some parameters describe tyre design, some are used for wear calculation).

The values of the parameters describing the vehicle can be obtained as each vehicle is well documented in Volvo GTT systems. The parameters describing the operating environment can come from both logged data or a basic road model. The tyre parameters are difficult to obtain because an extensive experimental tests that are not practically possible to perform for all tyres are required and moreover there exist numerous confidentiality issues with tyre suppliers. Therefore, apart from the tyre design variables found through optimization, these 10 tyre parameters are kept fixed for varying tyres.

6 Current status of tyres selection at Volvo

The current status of tyres selection at Volvo was investigated to find possible gaps which should be filled by the TyreOpt project. The customer or the seller state several inputs about the vehicle configuration and also about the future usage of the vehicle. The usage of vehicle is discretized in Volvo using the so-called GTA parameters ([6]). The GTA parameters characterize, e.g., road condition, operating cycle, curve density, topography, annual temperature, tyre size, region of usage. The customer is then provided a set of feasible tyres for different positions and for different seasons to be used for the specified vehicle. We want to find the optimal combination, i.e., give some recommendations which tyres from the feasible set should be preferably used in order to decrease the fuel consumption while balancing the other tyre-related objectives and constraints. These recommendations are currently not provided.

7 Conclusions

The parameters influencing the rolling resistance coefficient to be used in the TyreOpt project were identified. The objectives and constraints considered in the tyres selection optimization problem were selected and their models were described. Alternative tools to model the tyre-related constraints and objectives available in Volvo were summarized. The surrogate tyre model and the computationally efficient model of a heavy truck and the adapted VTM were selected to be used further in the TyreOpt project. The information available about each tyre in the Volvo database was presented same as the current status of the tyres selection at Volvo.

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