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Benchmarking the Efficiency of Mobile Working Machines and Commercial Vehicles

With steadily increasing crude oil prices and growing fuel costs, it is important to optimize the efficiency of the drive train. In addition, stricter exhaust regulations force the manufacturers to ensure continuous innovation in drive train development. Especially in the sector of mobile machines and commercial vehicles, efficiency is a determining factor. To ensure the economic efficiency of a vehicle, as well as to fulfil the legal requirements, optimally selected drive train components are necessary. In this contribution, two fundamentally different methods for a drive train efficiency evaluation of commercial vehicles and mobile machines will be analysed under the above-mentioned aspects.

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In order to be able to assess vehicles efficiently, they must first be classified using general categories. Since only commercial vehicles and mobile machines are considered here, the classification in *Figure 1* has proven useful. Thus, a total of twelve general classes is created, whose specific characteristics can be regarded in more detail, which allows a profile of the drive train requirements of these vehicle classes to be developed.

In this evaluation method, this requirement profile is intended to be based on an objectivized survey among experts. This requires suitable parameters to be determined in advance, which represent the demands of a vehicle class on the drive train particularly well. Possible parameters could be e.g.: Fuel consumption, Transfer capacity, Purchasing costs, Durability, Construction space or Operating comfort. In this case, the evaluation method of pair-wise comparison according to [1] is used for assessment by experts. Pair-wise comparison is based on the mutual balancing of the parameters of each vehicle class and on the grading of the importance of the parameters for the vehicle class.

In pair-wise comparison, the evaluator´s assessment answers the following question: “Is parameter x more important than parameter y in this vehicle class?” In order to objectivize this subjective evaluation method as far as possible, several experts can be asked, and their evaluation results can be averaged out.

In addition, the different drive train systems are also evaluated based on the same parameters and the question of how well they fulfil the requirements formulated by them. During the evaluation of the drive systems by experts, the method of pair-wise comparison is used again. The difference is that the question to be answered by the evaluator in the evaluation matrices is: “Does this kind of drive meet the requirements of parameter x better than those of parameter y?”

The requirement side shows the properties relevant for the vehicle class, whereas the quality of the individual drive type with regard to the individual parameters stands on the offer side. Both have the form of a vector. The equation given in *Figure 2* allows requirements and offer to be correlated.

The sum of the products $req_1^X \cdot equ_1 + req_2^X \cdot equ_2 + \ldots + req_n^X \cdot equ_n$ describes the degree of fulfilment, i.e. how well a certain drive system meets the requirements of the considered vehicle class. The exponent x provides the possibility to increase the relevance of the requirements compared to the offer. If $x > 1$ is chosen, a very good offer for a less important requirement provides less partial fulfilment than a less good offer for a very important requirement. Due to its principle, this evaluation only comprises the included parameters and is based on subjectively gained, though objectivised results. However, this subjectivity has the advantage that it reflects the opinions in the industry and also enables the (subjective) require-

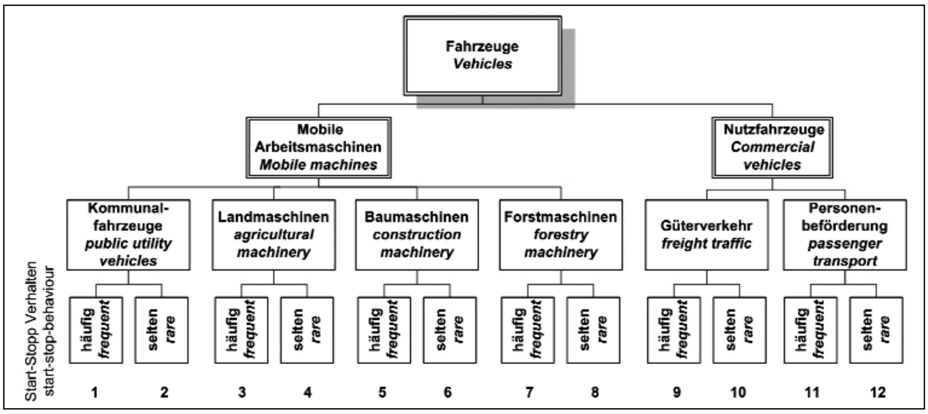

Fig. 1: Classification of mobile machinery and utility vehicles

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Anforderung\ /\ requirement = \begin{Bmatrix} Anf_1\ /\ req_1 \\ Anf_2\ /\ req_2 \\ \dots \\ Anf_n\ /\ req_n \end{Bmatrix}
$$

$$
Ausstattung\ /\ equipment = \begin{Bmatrix} Aus_1\ /\ equ_1 \\ Aus_2\ /\ equ_2 \\ \dots \\ Aus_n\ /\ equ_n \end{Bmatrix}
$$

$$
\begin{matrix} Erf\ddot{u}llung \\ fulfillment \end{matrix} = \sum_{i=1}^{n} Anf_i^{\,X} \cdot Aus_i = \sum_{i=1}^{n} req_i^{\,X} \cdot equ_i
$$

Fig. 2: Calculation scheme

ments of the customers to be taken into consideration.

Evaluation methods for the efficiency of drive systems based on load data

Drive train simulations suggest themselves for an objective evaluation of different kinds of drives with regard to their efficiency in certain vehicles. The modelling of the considered drives in the simulation software first requires detailed knowledge about the design of the drive. In addition, typical load data of the desired application must be available for a practice-oriented comparison of the variants. The absolute fuel and emission values in relation to the work process can be regarded as the results of the simulations. If no load data are available for the intended use of the drive system in a target application, they must first be collected.

Afterwards, the measured load data should be processed in order to keep the computing time for simulation within limits. In the focus of an optimization of computing, the duration for data processing is very important. For this purpose, the regarded work processes must be taken into consideration. The load data can consist of an alternation of certain, almost constant operating conditions, which might be interrupted by short-term discontinuous operation. These load sequences occur during ploughing with a tractor, e.g., when the plough is lifted and lowered on the headland. However, the load data can also be composed of cyclically occurring individual work cycles, as shown for a Y-cycle of a wheel loader in *Figure 3*.

For the processing of quasi-stationary operating points, the evaluation of the collected load data based on the frequencies of operating points suggests itself. This allows the frequently occurring operating points to be filtered out and the simulation models of the drives to be examined in more detail with regard to these operating points. If the load data are cyclically structured, frequently occurring operating points can also be used as the starting point of the evaluation. A more complex method of load data processing starts with the determination of the individual load cycles. This technique provides a number of individual cycles which follow one after the other. Based on a comparison of these cycles, a characteristic individual operating cycle can be chosen under qualitative aspects, which is then considered representative for the entire set of load data in the simulation. The statistical processing of the load data goes one step further. For this purpose, all individual operating cycles are first synchronized, based on the mean operating cycle time. Afterwards, the representative individual operating cycle is generated from the synchronized data by means of suitable mean value formation (e.g. the median). This technique suggests itself, if the number of load data is very large, which makes qualitative, subjective evaluation unmanageable.

Based on the determined and processed cycles, the drive system of the vehicle to be examined can be investigated in more detail. Simulations enable the fuel savings potential of certain drive systems as compared with alternative concepts to be shown in calculations. In addition to the analysis of the fuel savings potential, the simulations also allow possibilities of emission reduction by means of specific drive train management to be evaluated. In addition to the knowledge of the driving cycle, this requires either the inclusion of the simulation of a combustion engine or the use of the consumption and emission diagram data of existing engine models.

Conclusion

In this contribution, different possible approaches for the efficiency evaluation of mobile machines and commercial vehicles have been described. In principle, subjective and objective assessment methods must be distinguished. One possible subjective method has been presented here. Its advantage is the possibility of "emotional" evaluation and the inclusion of experts´ knowledge. The specific choice of the evaluating experts allows the result to be given different accents. It is possible to ask experts from the areas of development or application, which enables current wishes of the customers in addition to technical questions to be taken into consideration.

Due to its principle, however, subjective assessment has the disadvantage that the subconscious weighting of certain factors already results in a ranking. Moreover, it does not provide any tangible results which could be expressed in technical or monetary values.

Efficiency evaluation based on typical load courses is considerably more complex, in particular with regard to load data collection and processing. Modifications of the evaluation structure, however, can be realized more easily. In addition, other aspects beyond the evaluation of economic efficiency, such as the emissions of a drive variant concept, can be considered.

Therefore, it depends on the goal which method is appropriate. This decision must be made in each individual case.

Literature

Books are marked by •

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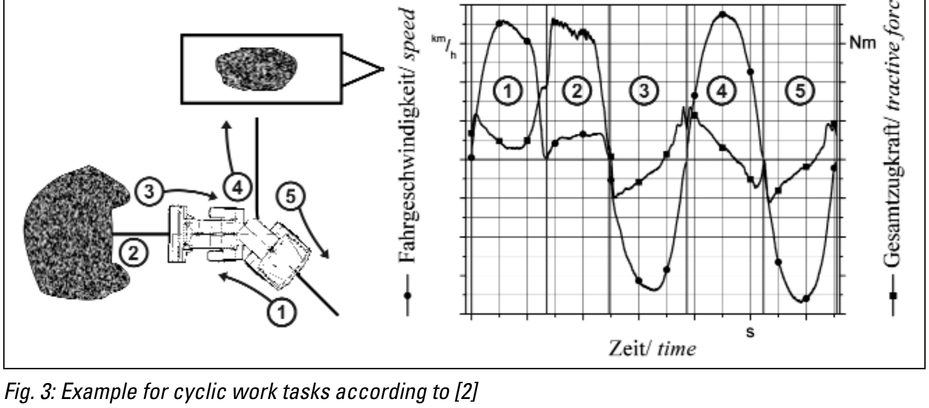

Fig. 3: Example for cyclic work tasks according to [2]