Investigation of Power Peak Reduction in Rail Freight Transport

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ABSTRACT

Powerful locomotives with high traction performance would exert burden on the power supply system and be a bottleneck for future freight transport. To avoid large-scale modifications to the existing systems but ensure operational reliability, this study investigates the formation of power peaks and explores power peak shaving concepts to let the existing systems be more reliable and accommodate more freight traffic. Different from previous studies which focus on energy saving, this study aims at lowering the power peak demand by optimizing the train speed profile without changing running time. This study is performed by simulation based on a standardized freight operation. The study shows the formation of power peaks in different conditions and suggests some measures to lower the power peak demand, which is needed to be studied in the future.

INTRODUCTION

To increase the attractiveness and effectiveness of rail freight transport for the future, it is important to boost the overall performance of rail freight in terms of higher capacity and efficiency but lower cost, energy usage and CO₂ emissions. Powerful locomotives with high traction performance and improved track infrastructures capable of accommodating large traffic volumes are being developed. However, they would exert extra burden on the traction system.

Today train operations at peak hours at some places are limited by the power supply of the infrastructure. To accommodate possible power peaks and to avoid challenging the operational reliability, sufficient system redundancy of the traction and power supply systems should be provided when designing and building new locomotives and infrastructures. Large-scale modifications should also be made to the existing systems. However, it is not an economic and feasible way to rebuild the power supply systems due to possible power peaks. Power peak demand would, therefore, become a bottleneck for the development of rail freight transport in the future.

Different from many previous studies, which focus on energy saving, this study aims at identifying the maximum capacity of existing traction and power supply systems and exploring the weakness and potential of existing systems. The present work investigates the possibility of power peak shaving concepts to let the existing systems be more reliable and accommodate more freight traffic than today. In this study, the power peak is lowered by optimizing the train speed.
profile to avoid the installation of extra power supply capacity. This study is performed by simulation based on a standardized freight operation. The formation of power peaks in different conditions is studied and then some possible measures to shave the power peak demand are investigated by optimizing the train speed profile without changing running time.

**SIMULATION**

Since railway freight transport is almost everywhere in Europe, the key factors, e.g. payload, train configuration, traction effort, operational speeds, track conditions and timetabling, are based on a standardized infrastructure and a synthetic freight train with pre-defined stations and stops. The present study on power peak shaving concepts is performed based on simulation.

The simulation tool used in the study is a Microsoft-Excel-based software STEC, developed by KTH and used in some European projects. This study is based on the “freight mainline” in EN 50591. It is a 300 km-long section with different speed limits and gradients, as shown in Figure 1. The detailed timetable including departure and arrival, and standardized freight train configuration without locomotives is from EN 50591 and the standardized locomotive is from a state-of-the-art vehicle reported in the Shift2Rail FINE1 project.

![Figure 1. Track height and speed limit of freight mainline.](image)

**RESULTS AND DISCUSSION**

**Power peak and power peak shaving.** High traction power is needed when a train is accelerating or overcoming an uphill gradient, so most of the traction energy becomes kinetic or potential energy. The basic working condition is a train running on level track with only running resistance considered. During acceleration, much power is needed especially when the train is approaching the top speed, as shown in Figure 2. The power peak can be reduced by lowering the acceleration when the train is approaching the top speed, but long distance and long time are needed. For uphill gradients, the train must overcome both running resistances and gravity. Since the freight train is heavy, a continuous and large power supply is needed. The condition studied here is a train entering an uphill section with constant traction power and with a constant gradient at a certain initial speed, as shown in Figure 3. The maximum traction power is not sufficient to maintain the speed, so the
train gradually slows down. To maintain a constant speed, the train speed is lowered before entering the section, but the running time becomes long. Allowing the train speed to be lowered by gravity can more effectively shave the maximum power than maintaining a constant low speed.

![Figure 2. Comparison of Speed profiles (a) and Traction powers (b) on level track.](image)

![Figure 3. Comparison of Speed profiles (a) and Traction powers (b) in uphill section.](image)

**Time loss and time saving.** The above power peak shaving measures lead to a longer running time within the corresponding section. Figure 4 compares the time losses with different top speeds and maximum power applied. We can see that power peak shaving at the acceleration phase or uphill sections prolongs the running time, but power peak shaving at the uphill section leads to more time loss than in the level-track section. To keep the original timetable unchanged, we have to compensate for the time losses. The possible measures are reducing coasting distance and increasing the running speed at the sections where the power peak is not high.

**Optimization of standardized operation.** The studied power peak shaving strategies are applied to the track section defined in EN 50591, cf. Figure 1. A gentle acceleration can significantly reduce the amplitudes of power peaks. For the mountainous section, to shave power peak, train-slow-down by gravity is used, in which the kinetic energy is gradually released and turned to potential energy, but the average running speed is not very much reduced. To compensate for the time loss, the train’s running speed is increased in the level-track and downhill sections.
Figure 4. Running time as a function of maximum power: (a) Acceleration phase plus cruising on level track; (b) Uphill section with constant gradient.

CONCLUSION

This work conceptually explores power peak shaving concept of freight transport. During acceleration or overcoming an uphill gradient, the freight train generates very high-power peaks. For the acceleration phase on level track, it is possible to lower the power peak by limiting the acceleration when the train is approaching the top speed and the time loss can be compensated by applying braking later or increasing the running speed. The uphill gradient is critical and the high power peak lasts for a long time. Lowering the train speed makes the time loss is considerable. To keep the timetable unchanged, it is necessary to let the train increase the running speed at sections where the power demand is not high. More comprehensive studies will be performed in the future.

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