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The Need for Weight Optimization by Design of Rolling Stock Vehicles

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Abstract

Energy savings can be achieved with optimum energy consumptions, brake energy regeneration, efficient energy storage (onboard, line side), and primarily with light weight vehicles.

Over the last few years, the rolling stock industry has experienced a marked increase in eco-awareness and needs for lower life cycle energy consumption costs. For rolling stock vehicle designers and engineers, weight has always been a critical design parameter. It is often specified directly or indirectly as contractual requirements. These requirements are usually expressed in terms of specified axle load limits, braking deceleration levels and/or demands for optimum energy consumptions. The contractual requirements for lower weights are becoming increasingly more stringent.

Light weight vehicles with optimised strength to weight ratios are achievable through proven design processes. The primary driving processes consist of:

- material selection to best contribute to the intended functionality and performance
- design and design optimization to secure the intended functionality and performance
- weight control processes to deliver the intended functionality and performance

Aluminium has become the material of choice for modern light weight bodyshells. Steel sub-structures and in particular high strength steels are also used where high strength - high elongation characteristics out way the use of aluminium. With the improved characteristics and responses of composites against fire and smoke, small and large composite materials made components are also found in greater quantities in today's railway vehicles. Full scale hybrid composite rolling stock vehicles are being developed and tested.

While an "overdesigned" bodyshell may be deemed as acceptable from a structural point of view, it can, in reality, be a weight saving missed opportunity. The conventional pass/fail structural criteria and existing passenger payload definitions promote conservative designs but they do not necessarily imply optimum lightweight designs. The weight to strength design optimization should be a fundamental design driving factor rather than a feeble post design activity. It should be more than a belated attempt to mitigate against contractual weight penalties. The weight control process must be rigorous, responsible, with achievable goals and above all must be integral to the design process. It should not be a mere tabulation of weights for the sole-purpose of predicting the axle loads and wheel balances compliance.

The present paper explores and discusses the topics quoted above with a view to strengthen the recommendations and needs for the weight optimization by design approach as a pro-active design activity for the rolling stock industry at large.

Keywords : *Rolling stock, Weight Optimization, Design*

1. Introduction

Nowadays, lighter rolling stock vehicles are the order of the day. Rolling stock designers and engineers are locked in a constant struggle to deliver lighter vehicles against ever shrinking delivery schedules and pressures for lower production and maintenance costs. The demand is primarily driven by the energy consumption issue on one hand and the vehicles and infrastructure running costs on the other. There is also a greater awareness of the long term environmental and economic impacts new trains have.

In the following sections, topics pertinent to lowering the weight of passenger rolling stock, with an emphasis on the bodyshell/carbody structure and trims are touched upon and discussed.

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2. Train Weight Status Definitions

A light rolling stock vehicle is a vehicle that can carry more passenger payload and yet be lighter than the existing older stocks. This is sometimes quantified by a carried payload to carrying mass ratio.

There is a need to rate the weight condition and status of any given train according to its intended function for comparison purposes against similar trains. A common understanding of vehicle weight definitions should be promoted accordingly. In Europe, the draft standard prEN15337 [Ref.1] for example, provides some logical and useful definitions to that effect. Agreed definitions could allow a certain degree of harmonisation of loading condition for given types of rolling stock vehicles and related sub-systems.

3. Materials

3.1 General

"Newer" and lighter materials already in use in the automotive and aircraft industries can also offer solid opportunities for weight reduction in trains. The conventional base materials such as steel and aluminium remain at the core of bodyshell design. Higher strength steels and joining method less prone to the HAZ effects in welded aluminium components can also contribute to lower car-body weights.

"New" materials without a well documented rolling stock use maybe perceived as risks. However, analogies and lessons can be drawn from the automotive and aircraft industries. These industries have well established long-term development strategies and appear to be more energy consumption aware than our industry at the present time.

3.2 Bodyshell

Aluminium has become the material of choice for modern light weight bodyshells. Double skin extrusion fully welded monocoque with fabricated body-ends is, nowadays, a fairly standard construction method for rolling stock car-bodies. Although aluminium fabricated components have also been used for crashworthiness purposes, steel remains the preferred material for purposely designed energy absorbing structural sub-assemblies. Steel substructures and in particular high strength steels are used where a high strength - high elongation characteristic out way the use of aluminium. Conventional fusion welding methods such as MIG welding used for wide and long extrusions, call for a local thickness increase along the weld run to compensate for the HAZ loss of strength. The HAZ induced strength reduction effect is less apparent in friction stir welded components.

Bolted joints while not suffering from HAZ effects do also carry a downside due the necessary joint members overlap.

3.3 Vehicle Interior and Glazing

Light weight polycarbonate materials with high performance have found a wide range of applications in rolling stock interior designs from seats to trim panels.

Glass is conventionally used for both external and internal windows, draft-screens and luggage stacks and racks shelving. Purposely developed polycarbonate glazing offers substantial weight savings compare to similar glass components.

Smaller bodyside windows would not only contribute to a weight reduction but also, in case of rolling over, increase the stiffness of the bodyside against structural collapse and also reduce the risk of passenger ejections.

The floor is another area where noticeable weight savings are usually recorded. Sandwich panels, thinner and lighter than conventional plywood boards, are nowadays commonly used.

Large structural components made of composite materials are also found in greater quantities in today's railway vehicles. Composites body end masks are routinely integrated in the body structure to carry windscreens and gangways. Full scale hybrid composite rolling stock vehicles are even being developed and tested.

4. Systems

From a weight saving and weight reduction perspectives the bogies are prime targets as they constitute, along side the car body itself, another large chunk of the overall weight of the train. In fixed consist trains, the use of Jacobs bogies can reduce the weight of the train (articulated) considerably. Bogies tend to be produced to suit several types of trains across a given product family. In some cases the bogie strength and functional performance might be greater than the requirements called for a particular application (e.g. bracket redundancy). This is usually translated in additional bogie weight. However, it should also be acknowledged that any design change on an existing bogie could adversely affect its hard won *proven design* status.

From the on-board power generator/converter (electric/diesel) and auxiliaries' aspects, efficiency should be the prime driver.

The case of regenerative braking is not a weight saving per say but a direct energy saving approach and a recommendable solution as such.

5. Design Process

Too often in the rolling stock industry early design

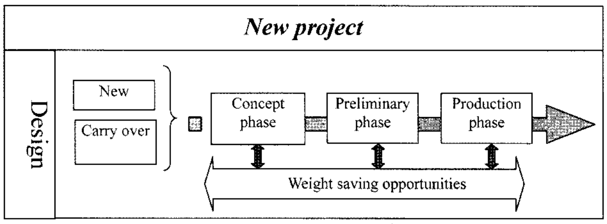

Fig. 1

weight optimizations are not promoted unless driven by specific needs and/or constraints. Typical drivers are axle load limits, braking and traction effort requirements and/or contractual demands for optimum energy consumptions.

A structural component that complies with its minimum strength requirements is not necessarily subjected to weight optimization exercises. While an "overdesigned" car-body may be deemed as acceptable from a structural point of view, it can, in reality, be a weight saving missed opportunity. The conventional pass/fail structural criteria and existing passenger payload definitions promote conservative designs but they do not necessarily imply optimum lightweight designs.

The weight to strength design optimization should be a fundamental design driving factor rather than a feeble post design activity. In other words, a weight optimization activity should be more than a belated attempt to mitigate against contractual weight penalties or overall performance short falls.

For any new project, be it a new design or a carry-over design from an established product family, the entire design process, from concept to production, should and must be viewed as an ongoing weight reduction opportunity for the duration of the project.

6. Weight Management

The weight management and control processes must be rigorous, responsible, with achievable realistic targets and goals. Above all, it must be integral to the design process. It should not be a mere tabulation of weights for the sole-purpose of predicting the axle loads and wheel balances compliance status.

For the production of a new stock, all the parties from owner/operator, main contractor designing and producing the trains, maintenance and infrastructure entities to all the suppliers must be stakeholders in the weight control and weight management process. A proactive approach will ensure that unnecessary weight excesses are captured and

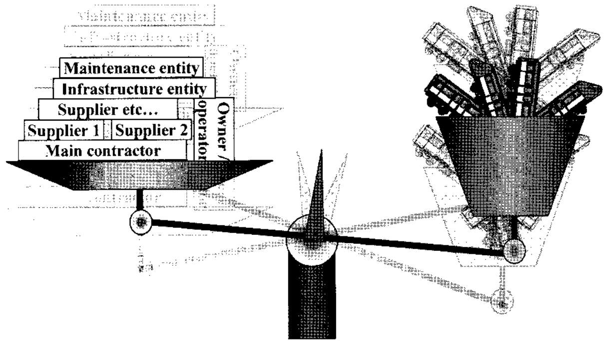

Fig. 2

addressed early in the design phase.

Often enough, weight saving opportunities are looked at on a "one by one" basis (component based/system based). While individually they may yield only savings of the "kg" order they could if combined return worthy reductions of the "10" to "100 Kg" orders and more.

7. Conclusion

Light weight vehicles imply lower rolling energy consumption. Weight reduction and weight optimization must be concerted efforts. Harmonisation of vehicle weight loading condition will allow meaningful comparison between similar stocks with similar operational function.

Robust weight management processes must shadow the entire project from concept stage to the production stage. The non-metal "new" materials should be given a greater consideration. On this front, there is a lot to learn from the automotive industry.

Every weight reduction opportunity must be fully investigated with all cost implication not limited to the design or production aspects but should also account for the operational dimension over the full life cycle of the product including its decommissioning.

It is recommended to pursue means of weight reduction and adopt a *weight optimization by design approach* as a matter of course for new rolling stock projects and the rolling stock industry at large.

Reference

1. Draft BS EN 15663 Railway applications - Vehicle Mass definition