Lightweight Forging Initiative
Phase II: Lightweight Design Potential for a Light Commercial Vehicle

For a medium-sized passenger car, forging allows a weight reduction of 42 kg in powertrain and chassis parts. How about a Light Commercial Vehicle with 2394 kg? The Lightweight Forging Initiative discusses this issue and shows in its investigations that weight savings of 99 kg can be identified on the basis of the lightweight design potential which may be achieved through forging, alternative steel materials or lightweight design concepts.

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FIRST PHASE FOR PASSENGER CAR

The Lightweight Forging Initiative was formed in 2013 by 15 forging and nine steelmaking companies under the auspices of the German Forging Association (IMU) and the Steel Institute VDEh. During the first phase, a medium-sized passenger car was analysed and a lightweight design potential of 42 kg was identified for components in the powertrain and chassis [1].

Based on the tremendous interest that the results received from customers and driven by the intensive cooperation within the two participating industries, a decision was made to launch Phase II in 2015 to focus on the lightweight design potential of forgings in a light commercial vehicle. Phase II of the Lightweight Forging Initiative brings together 17 forging companies, ten steelmakers and one engineering service supplier, **FIGURE 1**.

LIGHTWEIGHT DESIGN POTENTIAL IN A LIGHT COMMERCIAL VEHICLE

During the second phase of the initiative a Light Commercial Vehicle (light duty truck, LDV, following US american denomination) was analysed for the aim of getting lighter with forged components. In contrast to cars, the weight of LDVs still continues to increase from one generation to the next. However, the stipulations for decreasing CO_2 emissions in cars likewise apply to LDVs. It should also be noted that the total cost of ownership is more critical in commercial vehicles than in cars – weight reduction leading to the decrease of fuel consumption has a bigger impact on purchasing decisions [2]. Finally, lower vehicle weight allows for a higher payload to be transported, which can be another factor in the purchasing decision of the professional vehicle owner.

1.44 million light commercial vehicles (gross vehicle weight up to 3.5 t) were sold in the EU in 2013. Here, legislation requires a reduction in CO_2 emissions of 13 % to stand at a CO_2 value of 182 g/km by the year 2020. The vehicle chosen for this lightweight design potential analysis is very representative for this class. The vehicle has a 2.1-l four-cylinder diesel engine with 120 kW power, a manual six-speed transmission and rear wheel drive, thus representing the most widely sold configuration. The total mass balance for powertrain and chassis, but also body, interior and electronics as well as the spectrum of manufacturing processes applied are shown in **FIGURE 2**.

The same procedure was used for generating ideas for the lightweight design potential as in the first phase of the Lightweight Forging Initiative [1]. After finding a representative model for this application segment, the vehicle (ensuring it was the latest generation) was purchased second hand (age: 12 months, mileage: 23,000 km). The vehicle was then dismantled. Two hands-on workshops took place in which the members of the initiative analysed all 2536 parts and generated lightweight design potential ideas. The ideas were classified according to weight reduction potential, possible impact on manufacturing cost and finally according to the level of implementation difficulty.

THREE IDEA GROUPS FOR LIGHTWEIGHT DESIGN POTENTIAL

In total, 535 ideas for lightweight design potential were generated for parts made from rolled long material (forgings, bolts, nuts, tubes or springs). With the classification data attributed to each idea, an overview for a meaningful prioritisation of lightweight design suggestions can easily be generated. The ideas may be clustered into three groups in a portfolio chart, **FIGURE 3**. On the horizontal axis the ideas have been placed with cost impact versus realisation potential (with a weighting coefficient of 2:1). On the vertical axis, the level of the lightweight design potential is shown.

FIGURE 1 The Lightweight Forging Initiative – phases I and II as well as research project (status in winter 2015) (© Lightweight Forging Initiative)

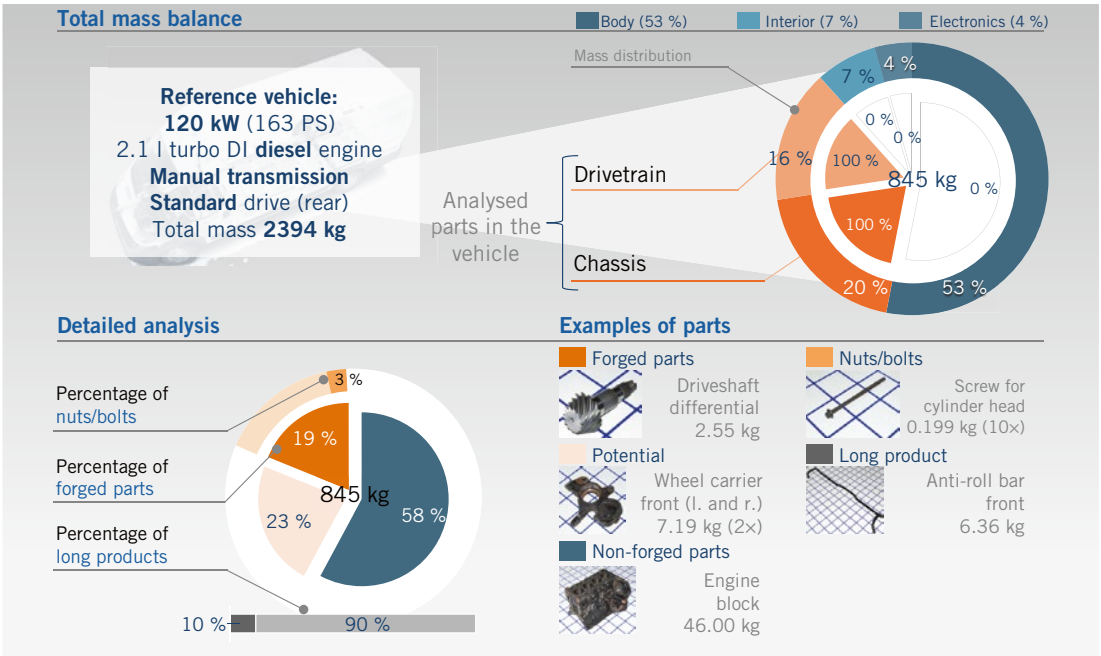

FIGURE 2 Total mass balance especially for the powertrain and chasiss domains as well as manufacturing processes for the analysed light commercial vehicle (© Lightweight Forging Initiative)

The first group of ideas A in **FIGURE 3** is that of the "Quick Wins". These ideas should be pursued fast and with high priority. They offer a decrease in weight with no or hardly any cost increase and pose no or only little implementation difficulty. The Lightweight Forging Initiative, however, clearly wants to state that this is not at all to be understood as criticism of any kind towards the designers at the manufacturer of the vehicle. These ideas are meant as suggestions in order to apply the current state of the art of forging and materials technology (especially modern steel solutions), in order to support the megatrend of "Lightweight Design".

The second group B in **FIGURE 3** encompasses those ideas with balanced lightweight potential. They offer weight reduction at increased cost and require greater implementation efforts. It should be noted that these efforts need to be compared thoroughly with other weight reduction options in a vehicle, which are currently dominating the headlines (CFRP, sheet-metal steels, plastics). Forging is a proven technology and can offer a better weight reduction cost per kilogram of weight saving than many other manufacturing methods – if given its appropriate attention (which is one of the primary goals of the Lightweight Forging Initiative).

The third group C in **FIGURE 3** is the class of "Tough Nuts". Here, cost and effort increase further for a lightweight design action.

IN TOTAL 99 KG SAVINGS POSSIBLE

For the whole vehicle, weight savings of 99 kg in total were identified on the basis of the lightweight design potential which may be achieved through forging, alternative materials or lightweight design concepts. The steel based lightweight design potential reaches 65 kg. As this vehicle exhibits a higher ratio of iron-based solutions (for example cast iron parts) than the passenger car analysed in Phase I [1], the lightweight potential by using non-ferrous metals could contribute another 34 kg.

Implementing all the best lightweight proposals would mean that the weight of the powertrain and chassis in this vehicle could be reduced by 11.7 %.

TAKING MATERIAL AWAY WHERE NOT NEEDED

Many lightweight design potential ideas have been detailed in CAD models, comparing the idea with the original component. This allows for a comparatively exact calculation of weight difference. Depending on the competence of the respective consortium member, the lightweight idea was even simulated in FEA programmes in order to confirm its validity. Similar to phase I [1], weight reduction was primarily generated by taking material away where not needed, thus utilising the shaping possibilities of forging technology to a greater extend.

Secondly, steel materials with better performance allowed for lightweight design. For selected components, the use of aluminium alloys to replace cast iron or some steel sheet based components allowed for notable weight savings. The economic validity of these ideas, like in all cases, needs to be assessed thoroughly. Finally, some conceptual ideas were able to fulfil the given functional requirements on parts or subsystems with lower weight. The broad spectrum of the ideas can be accessed in the extensive overview presentation [3] provided by the Lightweight Forging Initiative.

STRONGER STEELS FOR LIGHTER TRANSMISSIONS

The call for lightweight design is increasing in the entire field of automotive technology. The Lightweight Forging Initiative thus considered it worthwhile to explore the relationship between the increased cost of higher performance steels and the possible weight reduction for transmissions resulting from this. In order to do so, a transmission design study was commissioned at the Institute

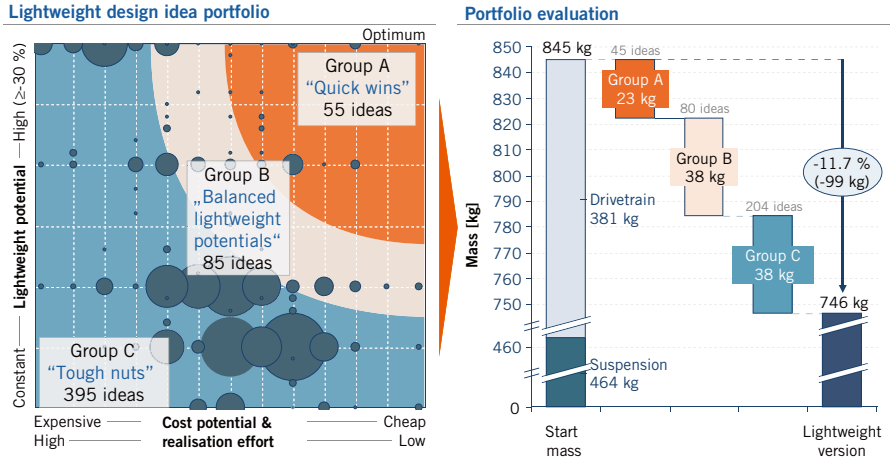

FIGURE 3 Portfolio chart: overview of the three groups of ideas A, B and C for lightweight design potential and their evaluation for weight reduction (© Lightweight Forging Initiative)

of Product Engineering (IPEK) at Karlsruhe Institute of Technology (KIT).

The data of the LCV manual transmission were modelled in an MS-Excel sheet, **FIGURE 4**. The Excel model takes into account tooth flank load, tooth root load, shrink fit torque transfer capacity and shaft fatigue of the medium alloyed carburising steel used in this transmission. Based on fixed input values (engine power, torque and vehicle speed) and on the transmission topology, it is now possible to vary "pitting resistance" and tooth root fatigue strength. Depending on the increase in these strength properties, the model can predict savings in system weight and size, **FIGURE 4**. The decrease in size of the gear wheels and shafts is directly taken into account. An additional programme step calculates the secondary weight effects within the shrinking transmission housing.

In order to compare steel based weight reduction cost against possible weight loss now, strength parameters for a higher alloyed steel were then fed into the transmission model. This results in predicted weight savings of 2.45 kg. If the manual transmission were to be equipped with the high alloy steel, it would be necessary to switch approximately 21 kg of shafts and gear wheels to the higher alloyed steel. This steel exhibits an increased material price (base price plus largely the alloy surcharge). If it is now assumed that the input weight for the forged components drops by the same amount of 2.45 kg, the total cost increase for the lightweight design transmission is only 2 euros.

It can thus be assumed, that a weight saving of 2.45 kg may be achieved at an increased cost of less than 1 euro per kg of weight saved. Saving weight by using higher performance steels in transmission applications is thus a very cost-effective lightweight measure. This not only applies to the transmission itself, but to all systems where gears mesh (differentials, transfer boxes, etc.). Additionally, the transmission model predicts, that further weight reduction could be expected with even higher strength values.

ECONOMICAL WEIGHT REDUCTION SOLUTIONS

The Lightweight Forging Initiative has demonstrated on two different vehicles (passenger car and light commercial vehicle) that modern forging technology and forging materials, especially high-strength-steels, can significantly contribute to economical weight reduction solutions in the automotive industry. In its second phase, the importance and effectiveness of high quality steel in transmission applications has been more intensively highlighted.

The federally funded research project "Lightweight Forging" will yield even more lightweight design potential in the future. One key insight will always remain true: Only by good communication the optimum combination of component design, materials and manufacturing technology is reached in order to

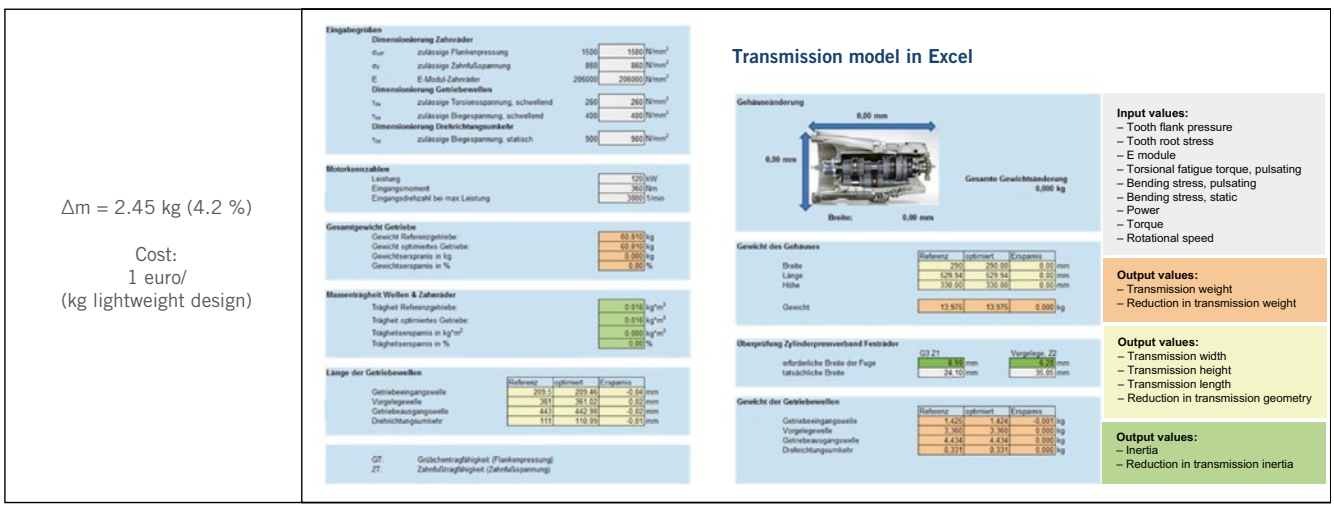

FIGURE 4 Transmission design model, takes into account secondary weight effects within the shrinking transmission housing besides weight optimisation of the gear set (© Lightweight Forging Initiative)

ensure the development of a high quality lightweight solution in mass production at a competitive lightweight design cost.

SUMMARY

The Lightweight Forging Initiative has, during phase I, demonstrated a lightweight design potential of 42 kg in the powertrain and chassis of a mid-size passenger car. This successful undertaking was being continued in a Phase II in the light commercial vehicle segment. A vehicle has been dismantled at fka and all the components have been documented. In hands-on-workshops, material, forging and conceptual lightweight design ideas were generated. Additionally, in a transmission design study the cost of weight reduction by using stronger transmission steels has been quantified.

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