"There are still blanks on the lightweight design map"

In an interview, Hans-Willi Raedt from Hirschvogel, who also chairs the Lightweight Forging Initiative, explains how considerable weight can be saved in series production vehicles using simple forging methods. At the same time, he criticizes the cost and effort involved in developing lightweight design technologies, if their usage is restricted to a limited series of vehicles.

lightweight.design: Steel, forging and lightweight design: how do these three concepts fit together?

Raedt: Seamlessly, even if the combination of "forging" and "lightweight" seems surprising at first glance. This was brought home to us in 2011. A discussion at the "Steel in Cars and Trucks" conference addressed the importance of sheet metal for lightweight design. With their TRIP, TWIP and dual-phase classes of steel, press-hardening, tailored blanks and a whole lot more, recent years have seen developers of flat-rolled steel break new ground in sheet-based lightweight design. And we forging technologists were certain that we could equal the feat. A year later, we decided to switch from "something needs to happen" to "let's make it happen" ...

... which then spawned the Lightweight Forging Initiative in 2013.

Since then, we have addressed automotive forging technology across the board, from heavy crankshafts to fasteners. Rounding off the whole are the several steel producers who manufacture our raw material. It was no longer enough to show how one company can save 200 g in an individual component. Instead, the idea involved showcasing the overall lightweight design potential of forging on a vehicle.

You disassembled three vehicles and allowed experts from participating companies to discuss the lightweight design potential. Did new and previously unexplored ideas arise?

Yes, the exchange between materials producers and forging companies in particular brought forth a large number of new ideas – especially for the steel mills, which are often far removed from the final component. The steel mills often have no knowledge of the stresses imposed on a component or the heat treatment and processing sequence it undergoes. Conversely, more than a few forging businesses lack any strong connection to the materials. While they might be familiar with their particular materials, no further development ensues – and many materials have become more efficient in recent years. This realization arising from the close interaction with the steel mills immediately led to new ideas among the forging companies. Can the part be made a little more compact? Or can some areas of the component accommodate a greater load? But possible design changes from advances in forging were also taken into consideration. Can you leave out this area from a forging perspective? It soon became evident where materials are wasted and where there was scope to manufacture net or near-net shapes using forging. Paving the way for the partners to inspire each other and generate new ideas.

> Today we dare to produce very filigree lightweight designs.

But don't even the best ideas remain shelved if those around the table with you are direct competitors?

We work in a pre-competitive area. But yes, nobody is about to spill the beans on any brilliant and patentable idea. Nevertheless, ideas have emerged from the dialog between competitors and along the supply chain from steel mills to forging that one individual would have found impossible to contribute.

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Dr. Hans-Willi Raedt

Hans-Willi Raedt has headed Advanced Engineering at the Hirschvogel Automotive Group since 2012. During that time, his remit has included managing innovation and developing new business fields. Since coming on board in 2002, he has also been Head of Production and Head of Research & Development. Having studied metallurgy and materials engineering, he was awarded a PhD from RWTH Aachen for a thesis on tribological systems in the cold forging of steel. Raedt chairs the Lightweight Forging Initiative.

What insight does this abundance of ideas suggest?

Look, we already have many thousands of steel varieties. And here comes one more addition to the pile. Do we really need it? Definitely. There are new types of steel that develop properties similar to those of quench-and-temper steels when cooling from the forging heat, but eliminating the need for heat treatment processes, saving both energy and costs in the process chain. You're now working with a more efficient type of steel – and more economically. So one key insight to remember is that even with established technology, room for improvement remains wherever you look. In the area of steel as well as in forging engineering.

What innovation does forging engineering bring to the table?

The fresh potential centers on forging simulation. At Hirschvogel alone, we run a 120-node cluster, i.e. a type of mini supercomputer, to perform forging simulations. Firstly, this enables us to combine component design and loading with the forging process and in the process, tease out previously unworkable potential. Secondly, forging simulation allows far more complex geometries. 15 years ago, there were some shapes that a product developer would never have approved. Today, however, producing such forms is feasible because the designer can run 20 optimization loops within a week cost-effectively. Previously, we would have had to produce tools 20 times over for this, experimentally forging them on the press before starting the next optimization loop. Back then, that would have taken three years and have cost the earth. Today, we can produce thinner walls, more complex forms and more delicate structures, while keeping development times very short.

Is word of the new possibilities yet to spread?

Well, for our customers, yes. It would suffice to start engaging the forging company in a dialog at an early stage. Instead, we still find completely rotationally symmetrical components in vehicles, like hubs. Designed like a turned part. Doing it properly, however, means acknowledging that hubs are not rotationally symmetrical and need to be designed taking the loads into account. Such examples are found in sports cars with free contours and a forged surface on the finished component. This delivers a weight-optimized part with optimized contours that cannot – and need not – be produced through turning, since that is what forging is for.

But are your proposals concerning lightweight design gradually being implemented in everyday practice?

Well, a precise before-and-after comparison is not possible, as you know. The vehicle for which we proposed optimizations in phase 1 was succeeded by a follow-up model during the evaluation period. Our proposals did not make it in time for the follow-up model, but maybe for the one after that. Instead, we strove to showcase new solutions to designers, project managers, motor and gearbox developers, and purchasers and engage them in a dialog. And we can already see how customers are approaching companies, saying: "Hey, I've seen this non-rotationally symmetrical hub – can you tell me more?"

> The additional costs of lightweight design with forging are more than competitive.

However, lightweight design in solid forging also involves greater development effort and the use of higher quality steels. How much does lightweight design in solid forging cost?

Costs for the automotive industry are undeniably crucial. During phases 1 to 3, we demonstrated how some components can be produced to be lighter and more affordable at the same time. These are what we call quick wins. They let us make lightweight parts while saving on materials, which more than offsets any increased production costs. Such quick wins may be scarce, but still, they do exist. That's what

we need to tackle right away, since there's not one hurdle in terms of cost.

But aren't most approaches to lightweight design associated with higher costs?

Let's take the example of a gear shaft. We can make it hollow by first cold-forging it, then drilling it. The drilling step comes at additional cost, which means that production will be somewhat more costly than the solid part. Even so, the example still shows the potential to produce lightweight designs using quality assured technology scalable for volume production at a very good price. Advanced forging technology also lets us produce hollow shafts directly. All of which is very resource-efficient, since eliminating the drilling step boosts material efficiency. That said, adding value created by forging technology usually also increases the cost.

Do you think you have an advantage over other approaches to lightweight design, like fiber composites, ...

... which nowadays tend to dominate the headlines: CFRPs and all that crazy stuff. And, as mentioned above, a lot of work has long been performed on very high-strength sheet steel materials. However, even here, we are reaching an asymptotic point from where components which are 2 % lighter end up 20 % more expensive. This is where we, the forging companies come into play, saying, "Hey, there are still blanks on the lightweight design map." Measured against what one kilogram of lightweight design can feasibly cost in a vehicle, the additional costs of solid forging are very competitive. Forging has far more potential in store, some of which is a breeze to realize. You just need to put it into practice.

So why does solid forging in lightweight design still go largely under the radar?

Because, unfortunately, we don't dictate the headlines. CFRPs are somehow sexier, newer or more fashionable. Or take 3-D printing, for example – the mere thought of which bewilders me. Just count the number of vehicles where CFRPs or additively manufactured components are used. You can read about additively manufactured parts fitted to some super sports car or other. The number is unbelievable. Perhaps as many as 300 or 400 vehicles a year? Great, that will certainly have a huge impact on CO_2 savings!

Are you worried, from a commercial perspective, when composite materials and other new processes dominate the headlines?

Yes, very much so, because it draws attention away from the economics of deploying a lightweight design with forging for widespread use. A couple of solutions using CFRPs or additive manufacturing might trickle down from the luxury class to the premium segment, but there are also many lower cost solutions there. In the hybrid

Lightweight Forging Initiative

The Lightweight Forging Initiative was established in 2013 by nine steel industry companies and 15 other companies engaged in forging under the leadership of the German Forging Association and the Steel Institute VDEh. Three phases have already been completed. The goal was to boost awareness of the potential of forged parts in the powertrain and chassis. While these areas of application have collectively comprised up to 40 % of a vehicle's weight, they have always been overshadowed in the field of lightweight design by the vehicle body, which as the heaviest single component also comprises up to 40 % of a passenger vehicle's weight.

Phase 1 of the initiative saw the partners analyze a mid-range diesel-engined estate car, with dual-clutch gearbox and four-wheel drive. It was systematically disassembled by the automotive research organization Forschungsgesellschaft Kraftfahrwesen Aachen (fka) before experts from participating companies collaborated to develop proposals for the lightweight design of materials, construction and forging technology that ultimately spawned potential weight savings of 42 kg.

During a second phase beginning in 2015, the initiative, which had expanded to comprise 27 forging companies and steel producers, examined the lightweight design potential of a light commercial vehicle. Following this phase, experts presented their proposals for alternative steel materials and lightweight design concepts collectively allowing weight savings of 99 kg.

Since 2017, a set of now 39 companies from Europe, Japan and the USA have been evaluating the potential of lightweight design for a hybrid passenger car and a conventional truck powertrain. With this in mind, fka disassembled a hybrid split-axle four-wheel drive mini-SUV as well as the transmission, drive shaft and rear axle of a heavy-duty commercial vehicle. During a workshop held over several days, 80 experts from cooperating companies then developed 732 proposals for the lightweight design of the chassis, powertrain, transmission and electronic parts of the hybrid car and 251 weight-saving suggestions applied to the commercial vehicle powertrain. The lightweight design approaches put forward for the aforementioned hybrid passenger car systems, which had a reference mass of 816 kg, elicited a total weight reduction of 93 kg. For the truck powertrain, with a reference mass of 909 kg, experts could propose a total weight reduction of 124 kg. A summary of the results will be presented in ATZ 3/2019 and 4/2019.

In addition to the self-financed phases of the initiative, 2015 also saw the launch of a research project funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), involving ten research institutes and university departments, aiming to lighten car powertrains even further using new steel materials, parts designs and productions methods, while still meeting expectations of an exceptional service life. The results were presented in October 2018.

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vehicle, for example, we found a supporting chassis component – the steering knuckle – made from cast iron, which we also found in the light commercial vehicle. Using forged aluminum instead would roughly halve the weight straight off the bat. While costs are slightly higher, what you get in return is quality-assured technology. If you look at the costs per kilogram of lightweight design, it costs way less than what you would pay for a suspension arm made from composite materials.

Besides costs, do you also see advantages in terms of component quality?

Yes, definitely. How do things stand as far as the reparability of a composite material is concerned? CFRPs are relatively brittle and do not tolerate stone impacts. Or imagine driving too fast and mounting the curb, which subjects the parts to excessive load. If you have a forged part, you will notice this and take the car to a repair shop. If the part is made from CFRP, it will break, preventing you from steering – good luck with that!

Despite the benefits cited, is the automotive industry relying on outdated solutions when it chooses forged parts?

Forging is tried and tested, but not outdated. Many people do not realize how many kilograms of forged parts vehicles actually contain, and the potential to save weight easily using components produced using forging technology. Instead, they discuss a fender made from CFRP on which hundreds of engineers are working. Just 30 cm further down, however, there's a wheel hub with a design standard dating back to 1966. It's contradictory. A closer look at vehicles developed using lightweight design reveals excellent forged parts. And yet we still ask ourselves perplexed why round wheel hubs are still driving around on the road. It's sabotage committed on mechanical engineering. The German environmental protection organization Deutsche Umwelthilfe should target that and ask why materials and energy are wasted in production. And all this superfluous amount of material is then driven over 200,000 kilometers of road.

> We hope management will focus more on forged components.

How can designers be persuaded to focus on better solutions in future?

Please don't misunderstand me. We don't wish to make enemies of anyone. Basically, we're not accusing designers of anything, after all they aren't doing anything wrong. At least not on purpose. Instead, all we want is for management to pay more attention to forged components. We would like a designer to be allowed to spend a week optimizing a component, even if it has had the same function for a century. What designers nowadays hear, however, is more likely to be something like: "Just make the four new wheel hubs." To make the deadline, there is just about enough time to apply the drawing numbers to the new project, not more, while alongside, significant cost and effort is being invested in materials and technologies not economically suited to large-volume production. That is what is so disappointing. I'd rather save 300 g in a wheel hub which is then fitted four times into the 300,000 vehicles hitting the roads each year than save 1 kg in a super sports car, with an entire production run of just 5,000 units. And now consider which of these two vehicles is used to transport commuters daily? There you go …

Are you happy that a research network for solid forging has been publicly funded as part of the initiative?

Yes, delighted. And it is a clear sign of the research being performed into the steel mills group of materials and forging spawning real progress.

What will happen after phase 3?

We have been pursuing the subject for six years and believe that we have got our core message across. After the communication put out in autumn 2018, the third multilateral industrial phase will finish in the course of 2019. Each individual company will then re-engage their respective customers in the market and attempt to implement the solutions. Any phase 4 remains pending at this point. How would we further improve on what we have achieved to date?

Dr. Raedt, thank you for the interview.

Interview: Thomas Siebel