Behind the Wheels Podcast Transcription

Bonus Episode 10: Engineering with Grant DeGeorge
Wheels: They're More Than Just Round

ANNOUNCER
You're listening to Behind the Wheels with Doug Mason, Dave Walters, and Mike Yagley. This is a show where we talk about heavy truck and medium duty axle ends. Doug, Dave, and Mike bring close to 100 years of experience and expertise in the transportation business.

Join us once a month to learn new things about axle ends. Sponsored by Alcoa® Wheels, the global leader in aluminum wheel innovation.

MIKE YAGLEY
Welcome back to TMC 2020 and we're here, Mike Yagley.

DOUG MASON
And Doug Mason.

MIKE YAGLEY
And joining us is Grant DeGeorge. Grant, great to have you.

GRANT DEGEORGE
Yeah, nice to be here Mike, thanks.

MIKE YAGLEY
So Grant is the global design manager for Alcoa Wheels.

DOUG MASON
He's also one of the main secretaries here working for the S2 Tire and Wheel Subgroup.

GRANT DEGEORGE
Yep. Happy to support the Tire and Wheel Group here at TMC.

MIKE YAGLEY
Oh great. So one of the things that I wanted to talk a little bit about is and I don't think a lot of people really understand how complex a wheel is.

DOUG MASON
A wheel is round, Mike, what's the big deal?

MIKE YAGLEY
I know my background was wiring. I started out in CAE and then I did wiring for about 14 years. And when I had this opportunity to come join the Wheel Group, I was talking to my manager and I said, "I'm thinking about going into wheels," he goes, "Well, that's not a problem." I said, "Well, I don't know anything about wheels." And he said, "That doesn't matter. Make it round. It'll be fine." And that is pretty much the standard answer I've gotten for years. And I think we've all heard that, "Make the wheel round and it's going to be fine."

MIKE YAGLEY
And wheels are far, far more complex. And I would argue that wheels are probably... I've worked with differentials, I've worked with other components in a vehicle, and I know pistons are very complex and a lot of the same problems that pistons have, for example, back many years when I was doing CAE on pistons, the problems pistons had were very similar to the kinds of problems wheels have. Wheels are really surprisingly difficult to design and I didn't understand that, I didn't expect it. And so I wanted to bring Grant in to talk about that a little bit.

DOUG MASON
Well, wait a minute. How long have you been designing wheels, Grant?

GRANT DEGEORGE
Been with Alcoa Wheels for almost 13 years now. So I designed wheels for approximately 10 of those.

DOUG MASON
Well, you really still helped design them now.

GRANT DEGEORGE
Exactly.

DOUG MASON
Yep. Okay.

GRANT DEGEORGE
The first 10, yeah. Grant was the one who came through with the breakthrough early on in his career on designing the seven spoke wheel. That was a very, very complex...

DOUG MASON
You might want to explain more what a seven spoke wheel means. People are going to think that's just a simple seven spoke.

MIKE YAGLEY
Well, Grant, you want to talk about that?

GRANT DEGEORGE
Well, like you said, Mike, usually our wheels are round and our hand holes around, but the seven spoke wheel was a special wheel. We have one designed for one of our OEMs and they had some very aggressive styling in that wheel. Typically, in the truck we would industry styling stops with not much flare, but a lot of the truck customers want auto style wheels, auto style hand holes. So what we did was is we looked at a wheel and pushed the limits to our style and capabilities in the hand hole with a seven spoke wheel. Much like a trapezoid, it had a lot of deep bevels to the design. So very complex geometry in the hand hole that we had to make sure we kept the stresses in check, something we haven't really done before or would typically see with a round hand hole.

DOUG MASON
Right. So you're talking about stresses, you might want to explain a little bit to the crowd, what we're talking about. Obviously, you went from a round hand hole, you went to like a trapezoid. So what's the big deal, it just is a different window?

GRANT DEGEORGE
Right. So typically, when you're looking at an FEA for a wheel, you're looking at max principal's stresses, you're looking at min principal stresses and how that operates within a round hand hole is much different than what you would see in a stylized hand hole. The location changes, the stress amplitudes change. And it's really just really understanding how that wheel will performed in the field and on our tests to make sure that it still is a good wheel. So we got to look at a lot of those things for those stresses in the hand hole to make sure it works.

MIKE YAGLEY
One of the things that maybe our listeners can get their heads around is when you think of a round hand hole wheel, every edge of that hand hole has an equal radius to it. And when you have a straight line and then have a radius, you're really concentrating your stresses right in that radius. And so those radii, really sort of grabbed the stresses. And when you limit the number of radius, instead of having the whole thing just being one circle, you're concentrating the stresses in a trapezoid in those three locations. And you really have to be careful how you manage those three locations. I remember the kind of work went into that. And then you also have to work with the manufacturing capabilities. You're having to take into account what manufacturing can do. I mean, if we could design anything, if we didn't have to worry about actually making this in the hundreds or thousands or millions of wheels at a time, it'd be way easier. But the fact is that we have to be looking at this from a standpoint of, "Is this manufacturable?"

DOUG MASON
That's where I started out my career, basically, was working in the facilities and the plants, we were making wheels. And I remember engineers coming in and saying, "Hey, it worked on our tube. We did the FEA, it's fine. How come this wheel isn't passing? You're doing something wrong in manufacturing." And it's never as easy as it seems, regardless of what you're making, but obviously with a wheel and getting those radiuses, again, that are no longer a consistent radius from a round hand hole. Now you're coming in and if you have any type of a tooling chatter, or if you have a camber that didn't get put in place right, that's a sharper than it's supposed to be, you've now concentrated those stresses even further. And I know that you have to take that into account, Grant, when you're doing the designing.

GRANT DEGEORGE
Yeah, we definitely know our limits and when we start getting close to those, we know we have to take manufacturing into account. And if it's something we can avoid, that's something we will. But definitely was a seven spoke, we were pushing our limits and we were able to get us a successful design onto that one.

MIKE YAGLEY
So when you're designing a wheel, just let's pull back and look at this from a bigger picture and some of the things that make designing a wheel complex. Let's start at the beginning, you've got to load.

DOUG MASON
Let's start with that, like you're saying, because I think you get a little perspective to people, we're talking about if we look at a pass car, light truck wheel, your wheel load rating, maybe what? 1500, 2000 pounds?

MIKE YAGLEY
Yeah.

DOUG MASON
Something like that. So that's normal, you're driving along in your light duty pickup truck or whatever it might be and a wheel for that application, a stylized wheel, you might see weighs 30 pounds, 32 pounds, highly stylized might be even more than that. I know I worked with some OEMs and we made 40-pound wheels for them, for their larger pickup trucks. We are now making wheels that carry what load?

GRANT DEGEORGE
7,400 pounds.

DOUG MASON
And how much do they weigh?

GRANT DEGEORGE
40 pounds. 39, actually.

MIKE YAGLEY
39. All right there we go.

GRANT DEGEORGE
We just launched all 39 pound wheel, yes.

DOUG MASON
So a 39 pound wheel that holds 7,400 pounds is a significant engineering feat, when you consider that a standard pass car light truck wheel can weigh up to 30 to 40 pounds carrying not even a third of that weight.

MIKE YAGLEY
So now you add onto that, that load is coming to the wheel through the tire. And this kind of thing, no two tire manufacturers are identical, they all have different strategies.

DOUG MASON
Yeah, we've learned that the hard way.

MIKE YAGLEY
We've learned that the hard way. So, the tire manufacturers have different strategies and then the tires have very different… if you're going with Michelin, has many 275/70 they have all these different…

DOUG MASON
Different applications.

MIKE YAGLEY
Different applications. But all those applications are going to be using our wheels. So how do you handle that, Grant?

GRANT DEGEORGE
Yeah. So we got to make sure that we take a look at the whole system. As you say, it's the tire, it's the mounting system, it's everything that goes into how the load is transferred into that wheel. But you bring up a good point, as no tires the same. So we've done some testing, we know what may be the most severe application, so we incorporate that into our FEA to make sure that we are designed that wheel that make sure they can handle those highest loads.

MIKE YAGLEY
Another component to all of this so you've got this tire, the load coming through the tire into the wheel and the tire is not a solid piece, it's rubber, it's inflated, so the air pressure plays a role in all this. There's all these different things that are playing a role in getting the load from the road into the wheel, going through that tire. So that's a whole complex calculus all by itself that if anybody really wanted to get into it, you could dedicate a lifetime just to understanding that. That's the first complexity to designing a wheel.

MIKE YAGLEY
The second major complexity to designing a wheel is the fact that it's rotating. Grant, you want to talk about that a little bit? What does the rotation due to the stresses?

GRANT DEGEORGE
Because the load is being transferred through the tire into the wheel at different locations throughout the rotation, you've got to make sure you're taking into account, I guess, that full cycle, as the stresses are being transferred it's not just in one spot and the load changes. So you got to make sure that the wheel can handle that change in load as it's going through that rotation.

MIKE YAGLEY
For example, and this is where it's more similar when I was talking earlier about little bit of work I did on pistons, right? The pistons were going through the same problem, they were getting just millions of cycles of this stress. And then it would go through this... It wasn't like a tensile test machine. A tensile test machine for our listeners is when you take a bar of metal and you pull it apart and until it breaks and then that's a very predictable failure. The bar will stretch and then it stretches elastically where it can go back to its original shape and then it eventually starts stretching to the point where like a spring, like we talked about in our first episode, where the spring starts giving way, and now it's not going-

DOUG MASON
It yields.

MIKE YAGLEY
It yields, it's not going to go back to its original shape. Then it eventually will completely break if you continue to pull it. So it goes through elastic, then yield, then ultimate and failure. And so it's a very predictable failure.

DOUG MASON
It's one cycle.

MIKE YAGLEY
And it's all one cycle.

GRANT DEGEORGE
One cycle, yeah.

MIKE YAGLEY
But what this is, is something way more complicated.

DOUG MASON
The best way to describe we're talking about like fatigue now in cycles is really what you're trying to get at. And you basically create damage in a wheel where there's a high load, a high stress area. And you can think about it as an old-fashioned metal hanger, I don't know if any of you when you were kids, at least, we used to do if you think you were tough, you take a hanger and you'd start bending it back and forth and back and forth and back and forth and finally you'd break it. Well, you could have never just pulled it apart and broke it, right? You can't do that. But what happens is you start bending, you create a high stress at that bend point, you start causing deformation or damage to occur, I'll put it that way. And you bend it once, no big deal. You bend it back, no big deal. You bend it again, it's a little harder to bend, but you keep bending it. And finally it breaks because you've created enough damage that it no longer can hold or sustain the load you're putting in. And that's really kind of what happens to a wheel. Right, Grant?

GRANT DEGEORGE
Well, that'd be great if it always happened in the same spot.

DOUG MASON
Right, right, right. Yeah, that would be.

GRANT DEGEORGE
Fortunately with a wheel, there's a lot of different areas we got to look at, with the rim, the hand holes, basically any interrupted surface. You want to make sure we apply that hangar methodology to each of those spots. So it is very difficult to understand each of those area's limits as it goes through that cyclic load with the tire involved.

MIKE YAGLEY
Now, typically we use something called the RR Moore Test to try to predict if you have a piece of metal and let's take 6061 aluminum, you take 6061, you machine it to a very precise geometry and then you put it into an RR Moore machine, an RR Moore tests, which is basically just cyclic fatigue testing. And let's say, you do 10 of them.

DOUG MASON
Well you do them at different stress levels, right? I mean, you're starting to get into the discussion of what we call a fatigue curve or an SN curve. How many cycles does it take at a certain load for it to fail? You can go into many textbooks, when you look at material properties, you were talking about basically yield strength, ultimate strength, elongation, all of those play a part in what your actual fatigue strength or fatigue life is going to be.

DOUG MASON
And so, we would take a material, like you said, that bar, we would pick different stress levels. And with that, we would then run fatigue on it, rotating beam fatigue, fully reversed loading. And then that would allow us to say, "At this stress level, I get this many cycles. This stress level, I get so many more cycles. This stress level, I get so many more cycles." And you can almost get to a point, especially in steel, not so much in aluminum where you can't fail it anymore. You could run infinite cycles and it wouldn't fail, but that's such a low stress level. And so we have to project what the life of the wheel we want to be and balance that with the weight of the wheel and the structure that has to be in place. Right, Grant?

GRANT DEGEORGE
Right, absolutely.

MIKE YAGLEY
And Grant, I've seen the test data multiple times, these RR Moore samples, what Doug was talking about was getting it at different stress levels. But if you do multiple ones at the same stress level, you'll get-

DOUG MASON
A lot of scatter.

MIKE YAGLEY
There's a lot of scatter.

DOUG MASON
Yeah.

MIKE YAGLEY
And this is sort of what I was getting at is things come into play and it gets very, very difficult, making Grant's job that much more difficult because that fatigue is going to cause, there's going to be failures. Sometimes they're going to come in short, sometimes we're going to go long, you don't know. And things like heat treat, grain structure, there're all sorts of stuff that comes into play that influences when you're talking about a fatigue failure rather than a tensile failure.

GRANT DEGEORGE
Way before we get to the design.

MIKE YAGLEY
Right. To understand that deep understanding of the material you're working with is another component to the complexity of designing a wheel. Now that complexity goes into any item that is subjected to fatigue.

GRANT DEGEORGE
Correct.

MIKE YAGLEY
The fatigue issue is notoriously difficult to predict. Now we do a pretty good job, Grant and his team do a pretty good job at that.

DOUG MASON
And we designed with safety factors in mind as well.

GRANT DEGEORGE
Exactly, yeah.

DOUG MASON
And so, I think, that's another part of it too, is you use statistical theory really based on what we've done to allow us to design to a statistically safe level of stress, right? And then we have our own fatigue testing that we do that will replicate what's going on in the field as best as possible.

MIKE YAGLEY
Well, you bring up one last point that I wanted to talk about is the field. Who knows what happens out in the field, apart from Dave Walters, there's a very, very small population of people who truly understand what's happening out in the field. Anything can happen out there. And unfortunately too many engineers aren't aware of what's happening in the field.

DOUG MASON
No. And that's the one thing that we do as well. And I think, Grant, you take a look at what our warranty is when you design a wheel, we take a look at... How do you do that? How do you...

Grant DeGeorge
Yeah. I mean, that's the best place to look is how actually people are using our wheels. Basically, because the damage we're putting on a wheel in the field may not be the damage we're considering or testing for initially. So when you get that feedback that just gives you the idea of what targets you need to design for. So there's different damage cycles maybe more lateral loads, maybe more cornering loads, where it's positioned on the vehicle. If you're getting to vocational applications where they're really, really going to the extremes for that wheel, you got to make sure that you're designing for those specific applications.

MIKE YAGLEY
So I think that gives our listeners a little bit of an understanding, just a thumbnail sketch-

DOUG MASON
Maybe just one more topic while we've got Grant here, because I know you have some constraints when you design a wheel, you can't just go design a wheel any way you want, right?

GRANT DEGEORGE
That's true.

DOUG MASON
What are some of those constraints? Just so maybe people will understand some of the specs maybe, some of the things out there that limit what you do.

GRANT DEGEORGE
Right. It's not a cookie cutter design. When somebody wants a 22.5"x8.25" wheel, we just don't pull a design from our back pocket and run it through a test. There's a lot of things we've got to get from the customer, whether it be a mounting system, the offset, whether it's going to be used in the steer position, sometimes some customers are more sensitive to the inset. If it's using the dual application, obviously, the half dual space and the offsets more important. But between that, the load rating, the pressure ratings, what application they're using it in, whether they're using disc brakes, whether they're using drum brakes. It's the whole system solution that we need to think about when we're designing a wheel.

GRANT DEGEORGE
We've brought up tires before, it's very important to cross reference the wheel you're designing for with the tires that are available in the market. Michelin, Goodyear, all the big players in the market, they're always coming out with new tires, new load ratings, new applications, so we want to make sure that we have a wheel that matches those applications. So it's things we all look into every time we're designing wheel.

DOUG MASON
Very good. And then there's also SAE, not SAE but Tire Rim Association, there's some standardization that's out there that limits us in certain areas of the wheel as well, right?

GRANT DEGEORGE
Absolutely. There're standardized mounting systems developed by SAE, so we make sure we follow those. There're international standards that we also have to be aware of if we're not just selling the will in North America. And you mentioned Tire and Rim, they do a great job in telling us how to design the rim to make sure it fits the tires that are available in the market. The last thing we want to do is design a wheel that the moment you try to put a tire on it, it doesn't work or you mess up the tire. So yes, Tire and Rim gives us those min-max dimensions on the tire side that helps us design a rim to make sure it's all compatible. So that's other things we got.

DOUG MASON
Yeah. Very good. All right.

MIKE YAGLEY
Okay. Well I think that does it. Grant, thank you for stopping by.

DOUG MASON
No, appreciate it, Mike.

MIKE YAGLEY
I really loved having you.

DOUG MASON
Thanks Doug.

MIKE YAGLEY
And thank you for joining us on Behind the Wheels. See you next time.

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