Heads Up for Tapered-Tread Crane Wheel Users

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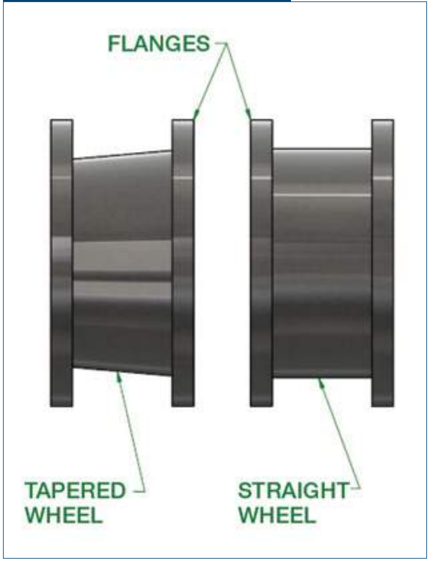
This article provides a first-hand account of the difficulties encountered by the use of tapered-tread wheels on overhead crane bridges and the inconsistent theory behind their use. The author believes tapered-treads can actually skew the crane rather than steer it straight, compounding the problems with wheel and rail failure.

Last summer I read the fascinating, controversial and very courageous paper by Charlie Totten titled: "Taper Wheels Should Not Be on EOT Cranes."[1] It brought back some long-forgotten memories. Charlie made many valid points about the problems with tapered-tread wheels. I would like to respectfully add an afterthought or two.

A number of years ago when I was an engineering and maintenance manager for what was then the new Nucor mill in Nebraska, I had an interesting experience with those tapered wheels that I would like to tell you about as a "heads up." At the time we had fairly new cranes. Our mill was about two years old. Business was good, so we added on a new warehouse and shipping building and needed a new crane for it. We decided to buy one from a different, well-regarded crane manufacturer. This crane had tapered-tread bridge wheels on the drivers and flat treads on the idler wheels (see Fig. 1).

Figure 1



Tapered-tread bridge wheels (left) and flat tread idler wheels (right).

At the time, I had no experience with tapered wheels and did not question the validity of using them, trusting in the judgment and experience of the crane builder. Tapered wheels were known to cause the crane to steer straighter on the rails. The tapers were engineered and designed to keep the crane from skewing and riding against the wheel flanges excessively.

After the new crane was put into service, we immediately started having severe problems with the bridge rails. The rails were new and the building was new. We contacted the crane manufacturer about the problems and also had the building contractor do several extensive evaluations of the building and rail alignment. The crane manufacturer sent their technicians, who thoroughly checked the crane for bridge squareness and wheel alignment and looked for any other potential causes. The crane was deemed perfect. It even had state-of-the-art tapered-tread wheels to ensure that the crane would track straight and would guide itself right down the runway, unlike those with flat-tread wheels. The building contractor did several more surveys of the building alignment. Neither the contractor nor the crane builder found anything wrong, but the wear problems continued and grew even more severe. The "J" bolts that attached the track to the runway beams were constantly breaking. Parts of the new rail had to be replaced because it was so badly worn. The building's structural steel started showing signs of stress. We were at a loss to understand the cause of the problem. We even bought high-alloy steel wheels, but they just tore into the track rails more aggressively. The bridge motor would nearly stall at times from the overload! We needed the new warehouse and shipping bay to handle steel product. We built it because we needed it and things were getting desperately worse with the shipping department backlog.

Finally, late one night, at about 3 o'clock in the morning, my home phone rang. It was Jerry, my night shift maintenance supervisor, telling me the crane wheel flanges had climbed on top of the rail and he was at his wit's end! He was convinced the crane was going to fall if we didn't do something. I was convinced he was right.

I had ridden on the crane several times while trying to identify the problem. I noticed that the crane traveled adequately to the east, but it would bind up and the wheels would squeal and screech when going any distance to the west. Sometimes it would skew to the left and at other times to the right. It was a real puzzle. Was it a bad wheel bearing? Mismatched wheel diameters? It just didn't make any sense. I even considered that the crane might have been built out-of-square somehow. It was a dilemma that demanded an answer, and it just wasn't adding up. I didn't have the solution and couldn't find anyone else to turn to for help. The building erector was certain he had done his job correctly and the crane builder was just as certain he had, too! With tapered wheels to correct any minor track variation, that building had to really be out of alignment, but how? We even considered the possibility that the soil under the column footings was spongy and was being vertically pumped as the weight of the crane passed over them.

This young maintenance manager was desperate for an answer and the job demanded it be the right one. The time was up. What should he do? He knew the answer could be obtained if he got to the root of the theory of how the tapered-treads steer the crane. He thought about the many possible reasons. Why would it only skew badly while traveling in one direction and be fine in the opposite direction? He began to suspect those tapered wheels were the problem, but how could they cause the crane to skew when their very purpose was to prevent it? After a great deal of thought, he reasoned that the wheels could steer out of a skewed condition, but only in one direction. When traveling in the opposite direction, they steered the bridge further into misalignment, making it worse instead of better. And the worse it got skewed, the harder the crane steered into it. Finally, the crane actually climbed on top of the rails.

While I was talking on the phone with Jerry I knew I had to do something. I gave in to my hunch. It had to be those tapered wheels that were causing the crane to skew, while traveling in the one direction only. I asked Jerry to measure the wheels to see if the idler wheels were tapered or straight and if they could interchange with the driver wheels. He called back and said the idlers had straight, flat treads, and had matched diameters, and would interchange with the drivers. He started to swap them right away. Several hours later they were switched and ready to try. By that time I had arrived on-site. I climbed aboard to test it. It was a completely different crane! No binding or skewing. No more screeching! Running free in both directions! But how could it have been those tapered wheels? Weren't they universally accepted as "The Way" to keep the crane centered on the rails? Don't they steer the crane right straight down the runway? How could the taper theory possibly be wrong against this generally accepted truth? It was almost like questioning Albert Einstein's beliefs!

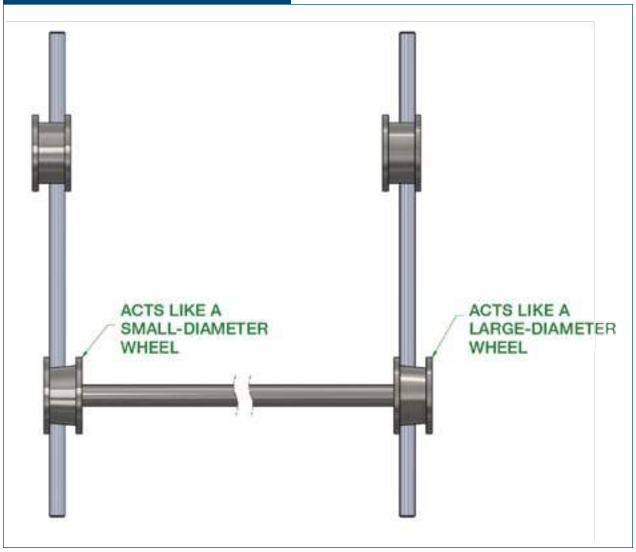
But there I was, grinning that morning, feeling great relief, and satisfied that I had solved a real dilemma — and one that almost ate my career!

Later, when I tried to relate the experiences to the crane manufacturer during a lunch meeting, an older engineer said, "There is no way you will ever convince me that tapered-tread wheels don't work." He wasn't being disagreeable, just expressing a deeply held belief in the theory. That was many years ago and it is doubtful that he is still working, having long since retired. But I was resolved that there was no way I would ever buy another crane with tapered wheels! And I never did. All of my crane wheel experiences have been routine since then. I put it away as a learning experience and mostly forgot about it until I saw Charlie Totten's recent paper on the subject. I was surprised to learn that it was still causing controversy.

Here is what I figured out from the experience: when the driven wheels are tapered, they will help to steer the crane when it is traveling in the direction that has the driven wheels in the lead, with the drivers "pulling" the crane, as it were, and with the idlers trailing behind. When the bridge skews, or if the wheels are shifted too far to one side, the larger end of the taper is in contact with the rail. The larger taper makes that wheel act just like it is a wheel with a larger diameter (see Fig. 2).

On the opposite end of the bridge, that wheel is riding on its smaller taper. It acts like a smaller-diameter wheel, so it travels less distance with each revolution; therefore, it lags the faster, opposite end of the bridge. This is while it travels in the "good" direction with the drivers in the lead (see Figs. 3 and 4). If it moves toward either side, after a few revolutions, the active

Figure 2



The larger taper diameter makes a tapered wheel act like a wheel with a larger diameter.

diameters equalize and the crane is traveling straight. The crane will hunt for a centered position on the rails.

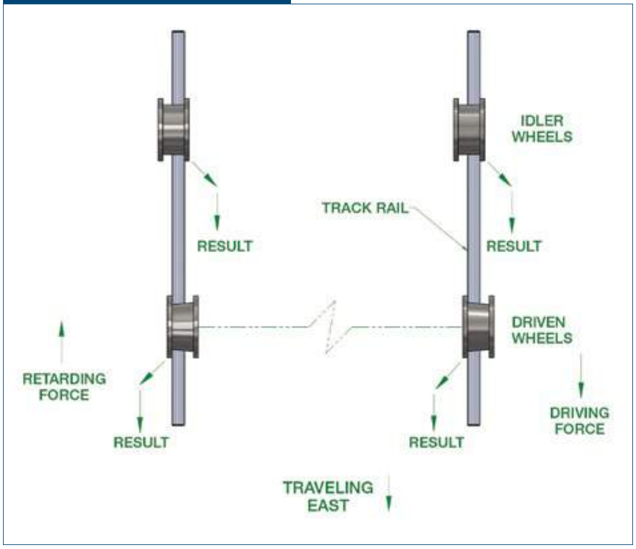
However, when the tapered wheels are "pushing" the crane, the exact opposite happens (see Figs. 5 and 6). When the crane starts to skew, the larger taper will cause that end of the bridge to push even harder when it is the dominant, faster-traveling wheel, so that the farther the crane skews out of alignment, the more the "larger" wheel pushes in the wrong direction. The skewing problem is compounded, not relieved, and the flanges will grind on the rail. Unless the flanges are much harder than the rail, the flanges will wear away since there is more rail than there is flange.

The crane I had the bad experience with had a line shaft connecting the two drive wheels, an A-2 drive. If the wheels had been independently driven with an A-4 arrangement, with independent drive motors, the problem might have been somewhat reduced. I suspect it still would have been present, but not quite as severe since the independent motors would allow some speed slip as the load varied due to the differences in torque required to drive the wheel. A line shaft drive is unable to compensate.

If the tapered-treads have adequately robust, lubricated flanges, if the tread width is not much greater than the width of the rail, and if the rail is straight and parallel with the opposite rail, then they may work. But in a steel mill, there can often be large differences in the rail environment from one side of the building to the other. Even variations while traveling the length of the building can be large. Local processing temperatures can vary greatly, with undesirable thermal expansion distortions.

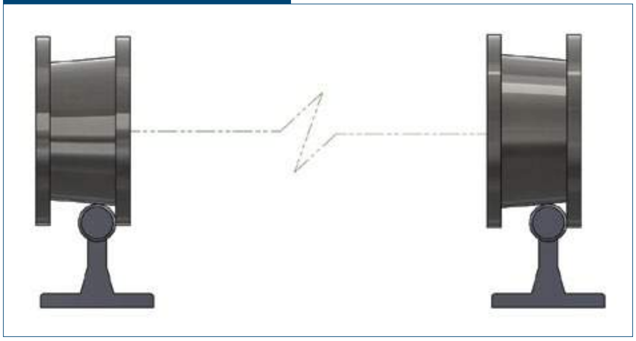
As an analogy, allowing me to visualize the problem, I personally want to think about it as being similar to something as familiar as steering a grocery cart. Pushing the cart along, if it starts to go to the left, we instinctively push with the left hand to cause it to turn back to the right, while also pulling slightly with the right hand. If, instead, we used my understanding of

Figure 3



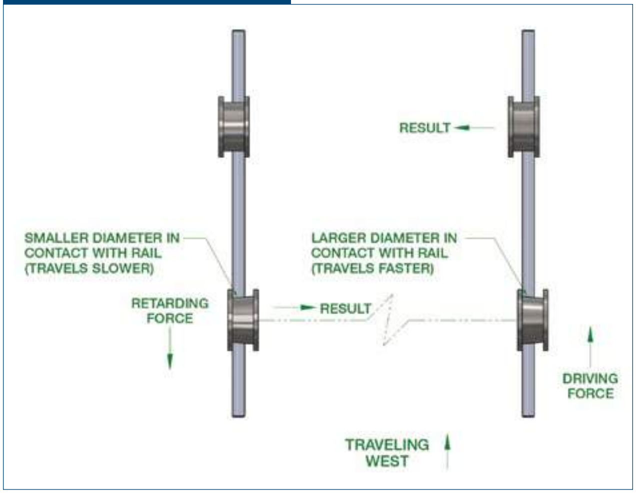
Crane traveling in the "good" direction with the drivers in the lead. If the crane skews toward either side, the active diameters equalize after a few revolutions and the crane travels straight.

Figure 4



With the wheels traveling "out of the page," the left wheel travels farther with each revolution; therefore, the wheels steer to the right and the idlers will follow. The crane will center on the rails as the active diameters equalize.

Figure 5



Crane traveling in the "bad" direction with the drivers "pushing." When the crane starts to skew, the larger taper will cause the end of the bridge to push harder since it is the dominant, faster-traveling wheel.

Figure 6

With the driver wheels traveling into the page, the left wheel travels farther with each revolution than the right wheel. The idler wheels (not shown) will be forced to the right. The drivers continue to push forward and to the left, compounding the skewing problem.

the tapered-tread wheel concept, we would push on the right hand to try to get the cart to turn to the right. When it then goes harder to the left, we would push even harder with the right hand. That will work fine with a motorcycle but not with grocery carts or with cranes, in my experience.

I have no quarrel with tapered-tread wheel suppliers or users. I recognize that my experience with tapers was with one crane in a particular building, under specific circumstances. Perhaps there are very strong theories validating their use. My experience is just one out of thousands. I am guessing there must be many other users out there who are doing well with them. Otherwise they wouldn't be using them, would they? I would very much like to understand how tapers are able to steer their cranes.

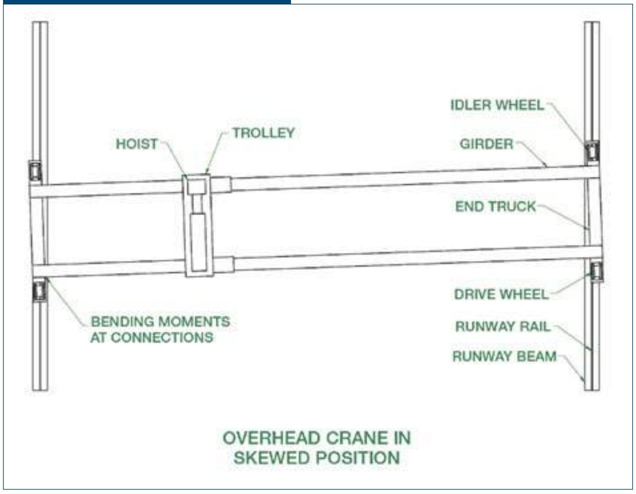
The crane itself can possibly undergo some hefty stresses where the bridge girders connect to the end trucks if the crane is continuously subjected to skewing (see Fig. 7).

Other authors have discussed the wear problems with tapered-tread on flat rails.[2,3] I would like to elaborate on the problem with a simple look at the geometry and mechanics involved. With a tapered-tread on a flat rail, the entire load is concentrated on a single point on the wheel tread. It also bears on a single point on the edge of the rail (see Fig. 8).

With straight treads on a flat rail, the load is distributed, in a line, across the width of the rail (see Fig. 9). In both cases the unit forces are high; with tapers they are much higher.

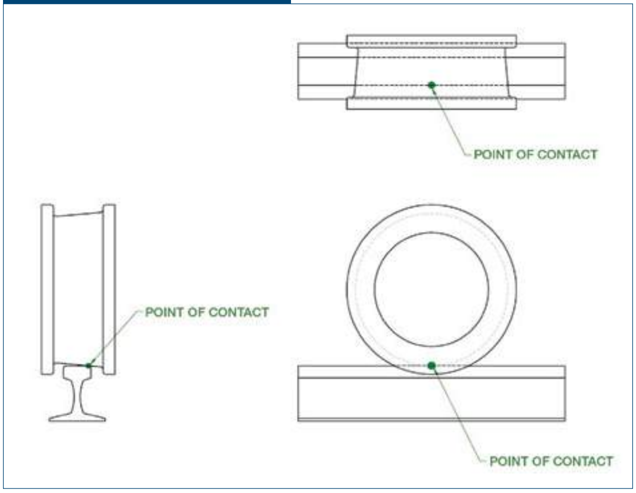
With tapered-treads, the stress in pounds per square inch (psi) is extremely high. In that instance the area of a point is theoretically zero. So the stress in psi

Figure 7



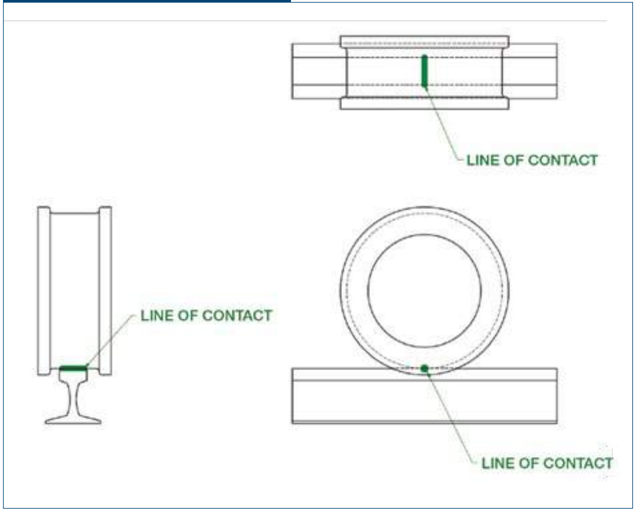
Skewing causes stresses where the bridge girders connect to the end trucks.

Figure 8



Tapered wheels with flat rail head showing single points of contact.

Figure 9



Flat wheels with flat rail head showing the load being distributed across the width of the rail.

is: stress = weight/area. Since the area is essentially zero, the weight divided by zero results in a force that approaches infinity, S = weight/zero = infinity. Neither the hard rails nor the alloy steel wheels can handle these stresses. They must undergo deformation. When the elastic yield point is exceeded, the plastic deformation is permanent.[4] There is a dish-shaped depression at the point where the force is applied, with the greatest stress in the center of the dimple. The rail surface is gradually reshaped as the moving wheel plows it down in parallel rows. The top of the rail is gradually cold rolled into the sloped, angular shape of the tapered-tread. But now the tapered-tread has different diameters in simultaneous contact with the rail, so part of the tread is now traveling faster and other parts are slower. Most of the wheel surface is skidding down the track as the crane travels along. Depending on the coefficient of friction, different areas of the wheel are sliding while other areas are gaining traction. Wheel and rail wear are the result, along with skewing.

For reference, the specifications of the crane discussed in this article are:

- Capacity: 15 tons.
- Lift: 42 feet.
- Span: 75 feet.
- Wheelbase: 13 feet 9 inches.
- Bridge drive arrangement: A-2.
- Bridge speed: 330 feet/minute.
- Bridge wheels: 4 total, 18 inches in diameter, built with flat tread idlers, tapered-tread drivers (amount of taper unknown).
- Runway rail: 80 lbs.
- Wheel load: 37,000 lbs. max.
- Elect: 480 Volt/3 Phase/60 Hz.
- Duty: Steel warehouse and shipping.
- Year built: 1975.

Acknowledgment

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