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ULTRA-CLASS TRUCK TIRE OPERATION & MANAGEMENT

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ABSTRACT

Tires have historically accounted for approximately 30% of the operating costs of large capacity rigid haul units used in open-cut mines.

The advent of the Ultra-class rigid haulers of 270 tonnes (300 short tons) and larger capacity has substantially increased this figure, and tires remain the principal limiting factor in the design of larger haulage units. The largest of these Ultra-class trucks are currently rated at 360 tonne (400 short ton) payload capacity.

This paper discusses tire management on Ultra-class trucks with particular reference to Caterpillar 797 trucks. Tire costs, operating parameters and tire maintenance issues are examined and compared with tire operation on 220 tonne (240 short ton) class haul trucks.

Historical truck designs and truck/tire combinations are also examined in order to predict the performance potential for existing Ultra-class tires and trucks, and the possibility of larger capacity haul trucks and tires over the next few years.

1. ULTRA-CLASS TRUCKS & TIRES

General

There are five main manufacturers of Ultra-class truck. These trucks range in capacity from 270 to 360 tonnes. The smaller units are fitted with 57 inch rim diameter tires, while the larger ones use 63 inch rim diameter tires in a range of sizes and load capacities.

These trucks are listed below, with their nominal payload capacity and tire size options.

Ultra-Class Truck Models

- Hitachi-Euclid EH4500, 270 tonne (300 short ton) payload capacity, 50/80R57 tires
- Liebherr TI272, 290 tonne (320 short ton), 50/80R57
- Komatsu 930E, 270 tonne (300 short ton, 50/90R57. Subsequently replaced by the Komatsu 930E-2, 290 tonne (320 short ton), 53/80R63
- Liebherr T282, 325 tonne (360 short ton), 55/80R63
- Terex-Unit Rig MT5500, 325 tonne (360 short ton), 55/80R63
- Caterpillar 797, 325 tonne (360 short ton), 55/80R63, 58/80R63. Currently being replaced by the Caterpillar 797B, 360 tonne (400 short ton), 59/80R63

History

Komatsu started the Ultra-class trend in 1996 with its 930E, a 270 tonne capacity truck fitted with 50/90R57 tires each capable of carrying approximately 78 tonnes[1]. This truck was upgraded to the 290 tonne 930E-2 in 1999, incorporating larger 53/80R63 tires each with a load capacity of 82 tonnes – substantially overcoming the problems experienced by the earlier model on the smaller tires.

Liebherr and Caterpillar entered the Ultra-class market in 1999 with their 325 tonne trucks, the T282 and 797 respectively, fitted with even larger 55/80R63 tires each rated at 93 tonnes. Liebherr subsequently introduced their TI272, a smaller truck, at 290 tonne capacity, but with a revolutionary body/chassis/rear axle arrangement designed to minimize truck tare weight and to improve tire load distribution across the drive axle.

Terex-Unit Rig introduced its MT5500 (325 tonne payload / 55/80R63 tires) in 2000, while Hitachi-Euclid entered the market with a tire/payload configuration similar to that of the original Komatsu 930E.

In 2000, Caterpillar offered 58/80R63 tires as optional fitment to its 797, each with a load rating of 96 tonnes. The company is currently releasing a new model, the 797B, a 360 tonne truck, that is fitted with 59/80R63 tires. This tire size is rated at approximately 99 tonnes load capacity at its design pressure of 87 psi, but is capable of a 104 tonne load at

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[1] Tire load ratings vary slightly by tire manufacturer. They vary also according to the tire inflation reference pressure. All tire load ratings noted in this paper are at the design inflation reference pressure (generally 87 psi) unless otherwise stated.

100 psi. For clarity and ease of reference, the original model Caterpillar 797 truck fitted with 55/80R63 or 58/80R63 tires will henceforth be referred to as the “797A” in this paper and the new model truck fitted with 59/80R63 tires will be referred to as the “797B”. The term “797” will refer to Caterpillar 797 trucks (both models) in general. Other manufacturers are expected to upgrade or are currently in the process of upgrading to 360 tonne capacity units.

While there are three major manufacturers of large earthmover (EM) tires – Bridgestone, Michelin and Goodyear – only Bridgestone and Michelin currently manufacture tires in the Ultra-class size.

Ultra-Class Truck Populations

Current & projected

There were approximately 250 Ultra-class trucks operating on 27 mines worldwide at the end of 2000. One estimate of the current market potential for Ultra-class trucks is in the order of 1,200 units.

Distribution by mine type

Industry predictions of the mine types most likely to have the greatest demand for Ultra-class trucks are oil sands and copper primarily, with a lesser demand from coal and iron ore mines. Generally it will be only the very largest mines that will use these trucks because of the potential impact of individual truck unavailability, in a limited number Ultra-class fleet, upon overall production statistics.

Ultra-Class Tire Characteristics

Tire size, weight & load rating

Table 1 shows approximate dimensional, weight and load rating details for 40.00R57 tires used on 220 tonne trucks compared with 50/80R57, 50/90R57, 55/80R63, 58/80R63 and 59/80R63 tires that are fitted to Ultra-class trucks. The newly released 59/80R63 tire is approximately 75% more expensive than a 40.00R57 tire, costing in the order of US$165,000 for a set of six compared with around US$95,000 to outfit a 220 tonne truck.

Tire size	Truck class (payload capacity)	Tire diameter (mm)	Tire width (mm)	Tire weight (tonne)	Tire design load rating at 65 kph (kg)	Tire max. load rating at 65 kph (kg)
40.00R57	220 tonne	3,560	1,125	3.5	53,000 (at 87 psi)	58,000 (at 110 psi)
50/80R57	Ultra-class 270-290* tonne	3,600	1,215	3.9	72,000 (at 87 psi)	77,000 (at 100 psi)
50/90R57	Ultra-class 270 tonne	3,810	1,260	4.1	78,000 (at 87 psi)	83,000 (at 100 psi)
53/80R63	Ultra-class 290 tonne	3,750	1,330	4.3	82,000 (at 87 psi)	87,000 (at 100 psi)
55/80R63	Ultra-class 325 tonne	3,890	1,400	4.7	93,000 (at 87 psi)	99,000 (at 100 psi)
58/80R63	Ultra-class 325 tonne	3,890	1,470	4.9	96,000 (at 87 psi)	101,000 (at 100 psi)
59/80R63	Ultra-class 360 tonne	4,025	1,480	5.3	99,000 (at 87 psi)	104,000 (at 100 psi)

** fitted to low tare weight Liebherr TI272*

Table 1 – Tire dimension, weight & load rating (approximate)

Photograph 1 highlights the difference in size between 220 tonne and Ultra-class tires.

Photograph 1 – 40.00R57 and 59/80R63 tires
(Courtesy of Bridgestone)

2. ULTRA-CLASS TIRE LIFE & OPERATING COST
Case Study - Caterpillar 797A vs. 220 Tonne Trucks

Tire life

BHP Billiton's Escondida mine in Chile is the largest copper mine in the world in terms of production – moving almost one million tonnes of material per day. The mine is located at an altitude of 3,200 metres in the Atacama Desert close to the Tropic of Capricorn. Rainfall is almost zero, and ambient temperatures range from a minimum of minus five degrees Celsius in winter to a maximum of 35 degrees Celsius in summer.

Escondida operates a fleet of 89 haul trucks – 14 Caterpillar 797A trucks, and 75 units of 220 tonne capacity (composed of 28 Komatsu 830E, 24 Caterpillar 793B and 23 Caterpillar 793C). The mine is a deep open-pit operation with, generally, a combination of uphill haulage out of the pit and flat haulage from the pit limits to waste dumps and stockpiles. One-way haul lengths vary from two to eight kilometres. Average fleet speeds[2] are relatively high for a hard rock mining operation, ranging from 20 kph to in excess of 25 kph. The material in the upper development benches of the pit tends to be harder, blockier and more competent than the material on the deeper benches presently being mined. The 797A trucks are restricted to waste and stockpile haulage and generally haul from the upper benches on the flatter, faster hauls. The 220 tonne fleet operates from both the upper and lower benches.

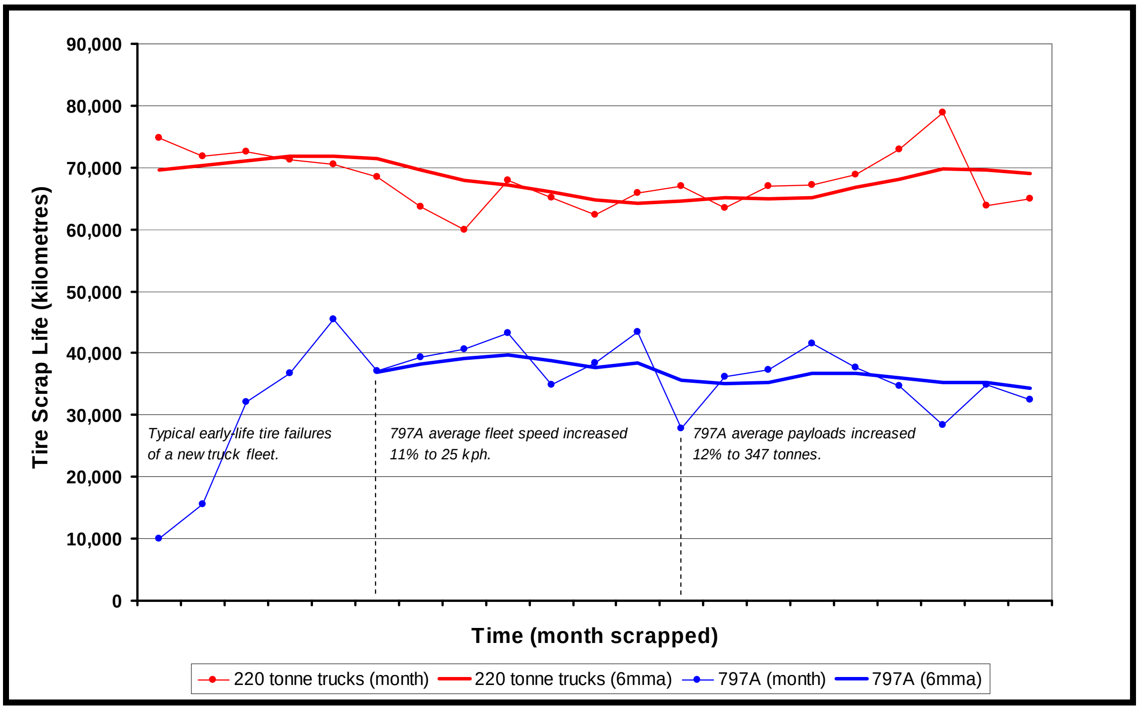

Figure 1 – Caterpillar 797A (55/80R63) vs. 220 tonne (40.00R57) tire life

[2] Average fleet speed, in kilometres per hour, is calculated as total kilometres travelled by the truck fleet during the month, divided by the total effective (operating) hours for the truck fleet during the month.

Figure 1 compares 55/80R63 tire life on the 797A trucks with that of 40.00R57 tires running on the 220 tonne trucks. The graph shows monthly and six monthly moving average (6mma) scrap life for each of the two truck fleets. The initial very low scrap life of 797A tires followed by a period of strongly improving life is typical of the tire scrap life results for a new truck fleet on a mine site. Some six months after the fleet commenced on site, 797A average fleet speed increased significantly to 25 kph, and seven months later average payload also rose considerably – to more than 345 tonnes. Both of these changes have contributed to improved productivity of the 797A fleet but both have been delivered at the cost of lower tire life, as is shown in the graph, and higher tire cost. At Escondida, 220 tonne tire life is currently 70,000 km; 797A tire life is half of that – 35,000 km.

Tire life on Ultra-class trucks is generally well below that of trucks of up to 220 tonne capacity. Based on data from several mine sites running both Caterpillar 797A and 220 tonne trucks, 797A tire life generally ranges from approximately one-third to two-thirds of the life of tires on 220 tonne trucks running under similar conditions on the same site.

Tire cost per tonne-kilometre

There are various measures of tire cost performance, the most common being tire cost per kilometre (or mile) and tire cost per hour[3].

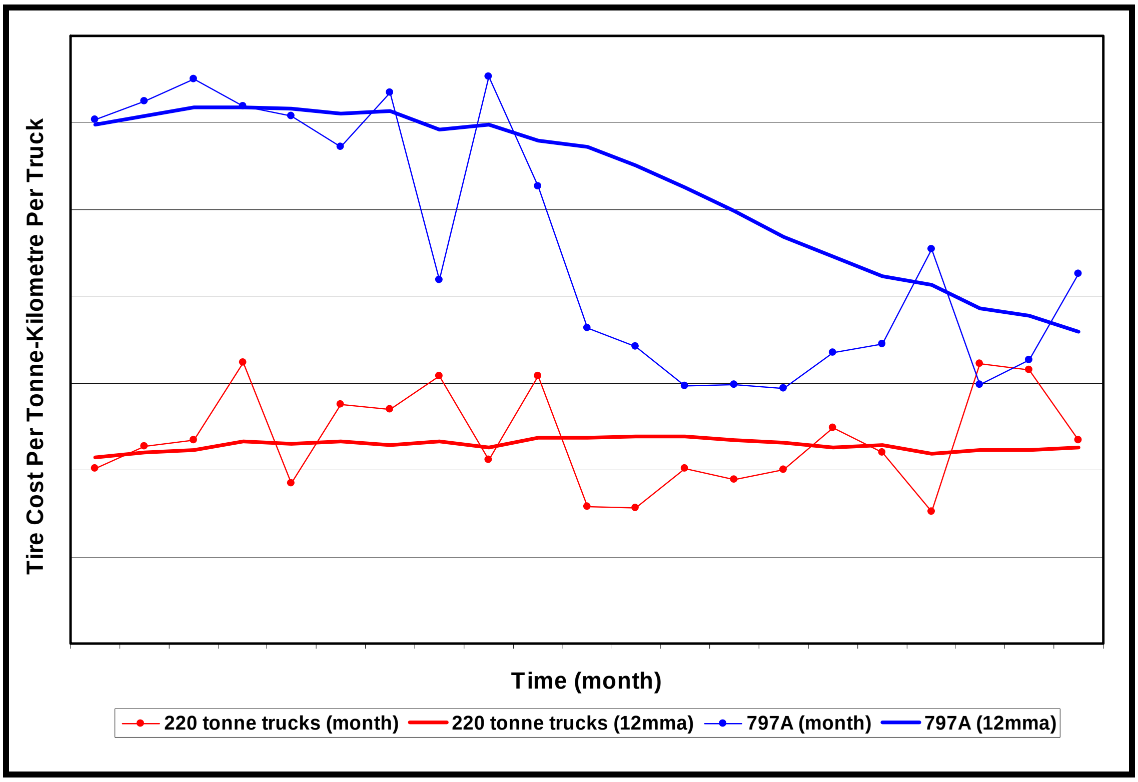

Figure 2 – Caterpillar 797A (55/80R63) vs. 220 tonne (40.00R57) tire cost per tonne-kilometre

[3] Operating hour, engine hour or other site specific hour measure.

Escondida uses the measure of tire cost per tonne-kilometre per truck[4], as this includes the two parameters most important to the tires' operation and performance – distance travelled and tonnes hauled.

Figure 2 shows the monthly and 12 monthly moving average (12mma) tire cost per tonne-kilometre per truck for Escondida's 220 tonne and 797A fleets. Caterpillar 797A tire cost per tonne-kilometre per truck at Escondida has been improving since this fleet entered service in June 2000, mainly because of the improvement in 797A productivity over time (in terms of tonnes hauled and kilometres travelled per truck per month). It is expected to stabilise at a level approximately 50% higher than that for the 220 tonne truck fleet (refer Figure 2).

Overall truck operating cost per tonne

The overall truck operating cost[5] (tires, fuel and labour) per tonne hauled is very similar between the 797A fleet at Escondida and the combined 220 tonne fleet[6] (refer Figure 3).

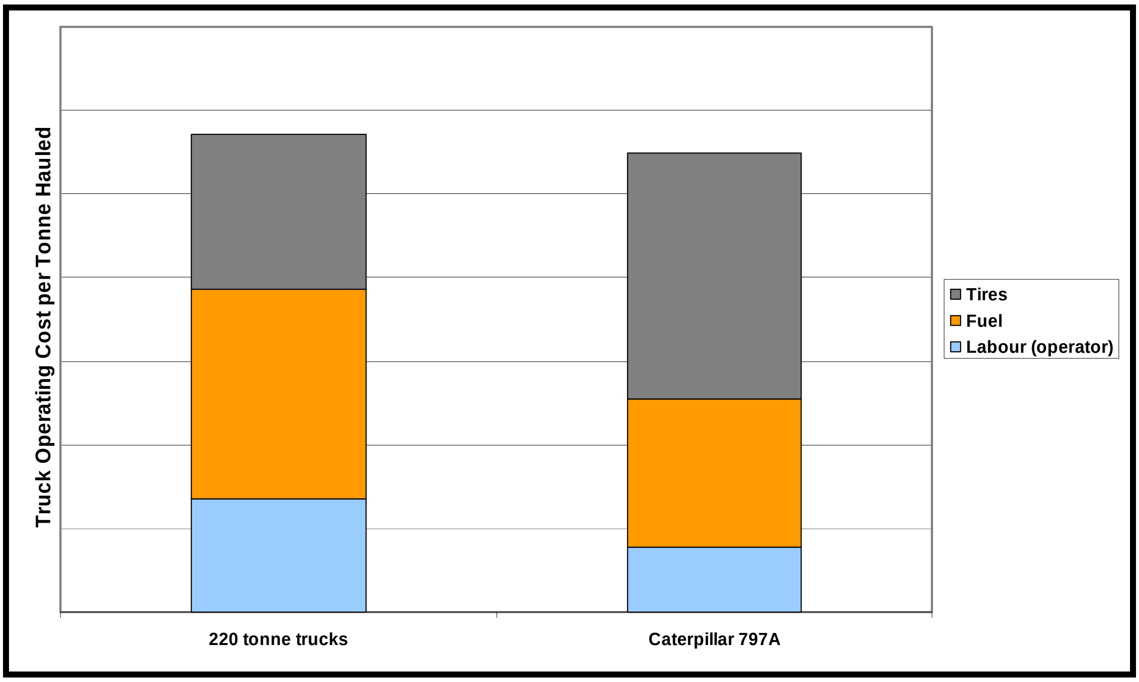

Figure 3 – Caterpillar 797A vs. 220 tonne overall operating cost per tonne

[4] This performance measure is calculated, for each of the two truck fleets (797A and 220 tonne), as the total cost of tires fitted per truck during the month divided by the product of tonnes hauled per truck and kilometres travelled per truck during the month.

[5] This paper does not compare maintenance cost (shops and service, mechanical and electrical parts and lubricants) per tonne hauled between the 797A and 220 tonne truck fleets for two main reasons that would render the comparison contentious: a) the Caterpillar 797A fleet is less than two years old while the 220 tonne fleet has been in service for many years on site, and b) the 797A fleet is maintained under a Caterpillar MARC contract while the 220 tonne fleet is maintained by Escondida.

[6] The operating cost per tonne hauled for the 797A fleet is 4% lower than that for the 220 tonne fleet.

However, tires account for 54% of the 797A operating cost, compared with only 32% of that of the 220 tonne fleet[7]. Basically a set of tires costing approximately US$140,000 on a 797A truck lasts for an average of four and a half to five months, while a set of tires on a 220 tonne truck costing only US$95,000 averages nine to ten months operating life.

Failure reasons

At Escondida, which is a relatively high speed site in terms of a rear dump truck/hard rock mining operation, the two most common failure reasons for 797A tires are mechanical separation and sidewall rock cut (refer Photographs 2 and 3). While these failure modes reflect the operating conditions of the 797A truck on this particular mine, they are probably representative, in regards to sidewall damage, of Ultra-class tire failures on many other sites as well.

Photograph 2 – Mechanical separation of the tire shoulder (55/80R63)

Escondida’s 797A trucks are presently carrying an average payload of between 345 and 350 tonnes (380 to 385 short tons), and travel at a high average fleet speed (between 20 and 25 kilometres per hour). Maximum speed is 65 kilometres per hour. The mechanical separation failures – where tread rubber detaches from the tire casing, usually initiating in the shoulder area – are mainly the result of high tire load and speed, particularly during cornering or turning of the truck. Deep tread E4 tires, that are traditionally fitted to rear dump haul truck fleets, have proven to be more susceptible to these shoulder mechanical failures (because of high truck speed and payload) than shallow tread E3 tires which are providing better tire life than the deeper tread specification. Because of this, Escondida is

[7] In comparing these results among different countries it should be borne in mind that while tire and fuel prices are usually relatively constant from country to country, labour costs can vary significantly.

presently purchasing all its 55/80R63 tires for Caterpillar 797A fitment in the E3 shallow tread specification.

The 797A's width and the total breadth of its tires' tread in contact with the road increases the difficulty, compared with smaller trucks, in avoiding running over rock spillage lying on the roadway. In attempting to manoeuvre around spillage, truck drivers often clip the spillage with a tire shoulder or sidewall resulting in a sidewall cut failure.

Photograph 3 – Sidewall damage (55/80R63)

Separation damage is a major failure mode on Escondida's 220 tonne fleet as well, also reflecting the relatively high fleet speed of these trucks. However sidewall damage accounts for the lowest incidence of premature failures on the 220 tonne fleet.

3. ULTRA CLASS TRUCK & TIRE OPERATION

Truck Characteristics

Speed, acceleration & load

Ultra-class trucks are not only big but very powerful. They typically have acceleration, braking and top speed capabilities that out-perform any of the smaller trucks in the respective manufacturer's model range. They are therefore very productive trucks, but these capabilities have come at a price – particularly in relation to tires.

Tires, and engines to a lesser extent[8], have always been the constraining factor in developing larger trucks. As tires get larger it becomes far more difficult to design and manufacture them to withstand the stresses to which they are exposed. Tires are designed to travel at a maximum speed of approximately 50 kilometres per hour; however they are now routinely expected to handle continuous loaded speeds of up to 65 kilometres per hour. The new low-profile tires that are fitted to virtually all of the Ultra-class trucks are designed to operate at a reference inflation pressure of 87 psi, but because of load and speed conditions, often have to be run at reference pressures ranging from 100 to 110 psi – seriously reducing the rock enveloping capability designed into these low-pressure tires.

Higher centre of gravity

The higher centre of gravity of the Ultra-class trucks makes their tires particularly susceptible to lateral stress damage during cornering or when turning into a loading or dumping area[9].

This damage usually manifests as tire shoulder, sidewall or bead failure.

Dynamic tire loading

Ultra-class trucks have far more rigid suspension characteristics than smaller sized trucks. The suspension of the Caterpillar 797A is in the order of 50% more rigid than for the 793 truck and in loaded conditions the tire can act almost totally as the suspension. One result is that the dynamic tire load for the 797A is approximately twice the static tire load[10], a far higher multiple of static load compared with 793 trucks.

The results of higher dynamic loads tend to be a higher incidence of casing fatigue and shoulder separation failures.

Large tire area on road

Ultra-class truck tires are more exposed to tire cut and penetration damage than tires on smaller trucks. The Caterpillar 797A is 23% wider than a 793 (9,150 mm versus 7,410

[8] Transmissions have also been a deciding factor in changing from electrical to mechanical drive format and in creating even larger mechanical drive trucks.

[9] The additional width of these large trucks appears not to adequately compensate for the greater lateral tire stress associated with the trucks' higher centre of gravity.

[10] Although the design ratio of dynamic tire load : static tire load for the Caterpillar 797A was closer to 1.5 (source Michelin).

mm). The effective tire ground contact width across a 797A fitted with 55/80R63 tires is 6,220 mm – 24% more than the 5,034 mm contact width for a 793. In the case of a 797A fitted with 58/80R63 tires, the contact width increases to 6,500 mm – 29% more than on a 793 (refer Photograph 4).

Photograph 4 – Truck and tire width comparison – 150 vs. 220 vs. 325 tonne class
(Courtesy of Finning Chile/Caterpillar)

On a 30 metre wide haulroad, the tires on two 793 trucks passing each other would cover an effective total width of 10 metres – 34% of the haulroad width. On the same haulroad, the total effective width covered by 58/80R63 tires on two passing 797A trucks would be 13 metres – 43% of the haulroad width.

Mine Conditions & Practices

Rock spillage

As discussed above, the larger the truck, the more difficult it is to avoid rock spillage lying on roadways, and hence the more important it is to avoid spillage occurring and to remove it when it does occur.

On some mine sites this may necessitate improving loading practices to avoid volumetric overloading or off-centre loading, both of which contribute heavily to spillage as trucks negotiate ramps, corners and turns. With mechanical drive trucks, drivers should select the appropriate gear prior to hauling up a ramp to prevent gears having to be changed-down and rocks falling from the back lip of the body. Ramps should also be designed on a constant grade to avoid similar consequences.

Rock spillage is probably the number one concern for Ultra-class truck tires on the majority of mine sites.

Road width

The likelihood of tire rock damage increases considerably on narrow roadways. This is always a potential problem when upgrading to a larger capacity fleet, because haul road width is usually designed to accommodate the size of truck in service at the time when the road was constructed.

Mixing fleets on the same hauls

If Ultra-class trucks are operated on the same haul routes as smaller trucks then the side spillage from smaller trucks tends to lie directly in the path of the tires on the larger trucks. Operating different sized trucks on the same haul cycle should be avoided at all costs (refer Photograph 5).

Photograph 5 – Ultra-class & 220 tonne trucks operating on the same haul

Cornering speed

Ultra-class truck tires are more susceptible to damage arising from cornering or turning at speed – usually shoulder separations. This is due mainly with the higher centre of gravity of these trucks and the greater lateral stresses exerted on their tires.

For this reason drivers must be particularly careful to drive according to conditions when negotiating corners, curves or turns. Road curves should be adequately super-elevated to minimise tire lateral stress (and spillage).

Photograph 6 shows a 797 negotiating a large radius curve on a level haulroad at a speed of approximately 65 kph. The body roll is obvious and could be eliminated by a combination of roadway superelevation and reduced speed on the curve.

Photograph 6 – Severe body roll induced by negotiating a curve at excess speed

Road undulations

Road undulations (refer Photograph 7) have proven to be a particular problem for Ultra-class trucks on some operations, leading to casing fatigue, heat failures and sidewall separations.

Photograph 7 – Undulations in a haulroad

As mentioned previously, suspension settings on Ultra-class trucks can be much more rigid than on smaller capacity trucks with the result that the tires provide almost all of the suspension function on a loaded truck. Combining this condition with an undulating road way is guaranteed to lead to premature tire failures.

Cleanup Equipment

Spillage removal efficiency

Rock spillage is one of the principal enemies of Ultra-class truck tires. Every practicable means should be adopted to prevent spillage occurring. However, if it does occur then it must be removed as quickly as possible. This means that cleanup equipment (rubber-tired dozers and graders) must be effectively deployed in the mine and that operators must be ever vigilant. It may even be worthwhile to fit rock blades to mine pick-ups (similar to light vehicle snow plough attachments) to assist in spillage cleanup.

Properly matched grading equipment

Ultra-class trucks require grading equipment properly matched by size. The use of large motor graders, in the size range of 400-500 hp and in sufficient quantities for the size of the mine and number of trucks, is essential to properly maintain haulroads and benches on which Ultra-class trucks are operating.

4. ULTRA-CLASS TIRE MAINTENANCE

Tire Maintenance Equipment

Because of the size and weight of Ultra-class trucks and their tire and wheel components, special equipment and care is required for tire maintenance.

The minimum sized tire manipulator necessary for handling 63 inch tire and rim assemblies needs to be capable of 11.5 tonne (25,000 lb) lift capacity and of sufficient span to hold one of these tires when inflated. A manipulator of 13.5 tonne (30,000 lb) capability is recommended (refer Photograph 8).

Photograph 8 – 13.5 tonne lift tire manipulator with 55/80R63 tire

Jacking equipment of at least 200 tonne lifting capacity is recommended, together with safety stands of equivalent capacity.

Nut-running equipment needs to be of sufficient capacity to handle the high wheel nut torques typically encountered on Ultra-class trucks. For example, in the case of Caterpillar trucks, whereas the wheel nut torque for a 793 is 750 ft lb, the wheel nut torque for a 797 is 2,300 ft lb. A torque meter of sufficient capacity is also required to allow regular torque checks on the nut-runner to be performed.

Large bead breaker tools, several rams (of various lengths and up to 30 tonne capacity) and an adequate hydraulic pump are required for tire changing and tire stripping work.

On most mine sites a large tire press, with a capacity of at least 350 tonnes, will be required to dismount the tire from the rim and, in particular, to extract the bead seat band from the tire. In many cases, bead breaker tools have insufficient power to accomplish this task (refer Photograph 9).

Photograph 9 – 350 tonne tire press

Changing Tires

The low-profile, flexible carcass design of Ultra-class tires combined with their greatly increased weight results in a tire that is much less rigid and considerably more difficult to handle when uninflated (refer Photograph 10), compared with smaller sized, standard profile tires such as the 40.00R57.

Photograph 10 – Handling an uninflated 55/80R63 tire
(Note the amount of sidewall distortion required to safely hold the tire)

This makes fitting and removing the tire to and from the rim a far more complicated proposition, aggravated by a flatter rim design and a higher tolerance (tighter) fit between the tire bead and the bead seating faces of the rim. Ultra-class tires can be very difficult to properly mount on the rim, resulting at times in the heel of the tire bead not being tight against the rim flange. This can distort the tire bead (refer Photograph 11) and result in tire sidewall separation failure (Photograph 12).

Photograph 11 – Distorted tire bead resulting from imperfect rim mounting

Photograph 12 – Sidewall separation resulting from distorted bead

The extremely tight fit between tire and rim may also result in bead damage when the tire is removed from the rim.

Wheel attachment architecture can also effect tire maintenance equipment requirements and tire change procedures. Caterpillar 797 trucks use an adaptor ring to attach each outside rear wheel to the axle hub. This ring is very heavy and of two part construction[11] and requires a proper handling jig to manipulate it to avoid damage to wheel studs and other components. Because of this, inside rear tire changes on 797 trucks are best accomplished by leaving the inside rim in place, thereby eliminating the need to remove the adaptor ring, and removing and replacing the tire in-situ using rams and bead breaker tools to free the tire from the rim.

Number of men per tire change

On some mines, tire changes on haul trucks of up to 220 tonne capacity are done by one person. An Ultra-class truck tire change almost always requires two people (some of the large nut runners require two people to operate them).

Tire change time

Average tire change time is considerably higher for Ultra-class trucks compared with their smaller brethren. If a mine site averages 1.8 hours per tire changed on a 220 tonne truck, then they are unlikely to average lees than 2.5 hours per tire on an Ultra-class truck – more probably closer to three hours.

Tire Stock Holdings

Tire stock holdings are an important issue in Ultra-class truck tire management. At present, tire production is limited to two suppliers (Michelin and Bridgestone) and this is unlikely to change in the short to medium term. While tire production capacity is still limited, the number of Ultra-class trucks in service is growing at a steady rate and demand tends to outstrip supply. Mines that require tires of uncommon specification (eg. E3 shallow tread tires[12]) are particularly vulnerable to supply delays.

Many mines, particularly those located in isolated areas, typically adopt a policy of holding three months usage of new tires in stock to account for tire production or shipping delays. For the Ultra-class trucks this is more advisably extended to five months stockholding – at least until there is equilibrium between tire manufacturing capacity and the demand for these tires.

[11] Whereas a 793 adaptor ring is attached to the outboard side of the wheel hub attachment flange, the 797 adaptor ring is attached on the inboard side. This necessitates a two-part construction to allow its removal.

[12] Production of an E3 tire is especially disruptive to the manufacturing process as it requires a change to the tire mould (the more common E4 mould needs to be replaced by an E3 mould), whereas changes to tread compounds can be accomplished far more readily with almost no loss of production.

5. ULTRA-CLASS WHEELS & RIMS

A rim varies from a wheel in that a rim is attached to the axle hub by means of a clamp, cleat or wedging device while a wheel is attached to the axle hub by means of a mounting disc, similar to the system used by most passenger vehicles. Whereas for the large haul truck sizes up to 220 tonne capacity, Caterpillar is the only major truck manufacturer that uses wheels rather than rims, in the 63 inch Ultra-class range, all manufacturers apart from Terex-Unit Rig employ wheels instead of rims. The main reason for this is the high rim-pull force associated with 63 inch wheel and rim assemblies. For the remainder of this section the word “rim” will be used to refer to either a wheel or rim assembly.

Rim Compatibility by Manufacturer

There are three main manufacturers of haul truck rims worldwide – Topy, Rimex and Titan. In comparison with the sub-63 inch rim sizes, where there is an industry standard of rim component dimension and compatibility within each rim diameter sizing[13], each manufacturer of 63 inch rims has adopted a different dimensional standard for its various components. Hence rim bases, bead seat bands, flanges and lock rings are generally not interchangeable by brand in the 63 inch size.

Rim Dimensions

There is a range of rim widths by 63 inch tire size. The 53/80R63 tires are designed for 36 inch width rims, the 55/80R63 tires for 41 inch width rims and the 58/80R63 and 59/80R63 tires for 44 inch width rims. Flange sizes also vary by height and width combinations, ranging from 5 inch height/5 inch width to 5 inch height/6inch width, depending on the specific tire size.

Effects of Rim Design – Maintenance & Operation

As discussed in the *Changing Tires* section, several factors related to 63 inch tire and rim design conspire to make the proper mounting of 63 inch tires onto 63 inch rims a more difficult proposition than for smaller tire sizes. These same factors can also lead to difficulties in stripping the tire from the rim. They are:

- Wide rim width,
- Flat rim base profile,
- Less rigid, more difficult to manipulate tire casing,
- Tight fit between the tire bead and rim bead surfaces.

Some mine sites have experienced serious tire indexing problems with 63 inch tires. Tire indexing refers to a tire slipping on the rim due to rim-pull at the tire/rim interface exceeding the torque capability of this interface. This has resulted in premature tire failures on some operations and with some brands of rim, a problem that is being addressed through redesign and evaluation at present.

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[13] Although one or more of the manufacturers often offer optional non-industry standard versions of rim in sub-63 inch sizes.

6. LEARNING FROM THE PAST

Whenever a new larger class of mining equipment is introduced, requiring a matching jump in tire capacity, there is usually an initial period of poor tire life and high tire costs, often accompanied by unacceptable levels of equipment downtime. However on-going technical development plus improved matching between the particular machine and tire (often involving the fitment of higher capacity tires with successive model releases) almost always overcomes the initial tire problems.

Equipment Evolution of The Past

Notable examples have been the evolution of 100 tonne trucks in the early 1970s requiring the move from 49 inch to 51 inch tires[14], and the 170 tonne trucks in the mid 1980s with the jump to 57 inch tires[15]. Similarly, the introduction of 10 cubic metre plus loaders required a change from 39 inch to 45 inch tires[16]; more recently the introduction of 16 cubic metre plus loaders has necessitated the change to and the development of 57 inch loader tires[17].

Radial Tire Development

Especially memorable was the conversion of large haul trucks from bias ply to radial tires in the mid to late 1980s. Many mines went through enormous difficulties in this process, including a spate of low-life failures, dramatically reduced tire life and refusal of acceptance by drivers.

Why Are There Problems?

The problems have usually stemmed from one or other of the following causes:

1. a new untried tire (and usually rim) size or tire construction undergoing a development phase, and/or
2. a tire whose capacity is inherently incapable of withstanding the stresses placed upon it.

Both of these factors have been reflected in the experience with Ultra-class tires to date, and we have already seen examples of rectification, eg. Komatsu’s move from 930E / 50/90R57 to 930E-2 / 53/80R63 and Caterpillar’s upgrade from 797A / 55/80R63 to 797B / 59/80R63. While both changes have increased truck capacity the former has definitely resulted in a better truck/tire combination and the latter will almost certainly be proven to achieve the same.

This is no surprise. There are many precedents of tire life and operating cost being dramatically improved by the fitment of larger tires (whether offered as an option by truck manufacturers or not). The best examples were the change, on various mine sites,

[14] eg. Wabco 120A and B models.

[15] eg. Dresser 190, and Unit Rig MT3600 and MT3700 models.

[16] eg. Caterpillar 992A, B and C models.

[17] eg. Le Tourneau L-1800 and Caterpillar 994.

from 30.00R51 to 33.00R51 tires on Wabco-Dresser 120CM and DP trucks, and modification of Euclid R170 and Terex MT3600 trucks from 36.00R51 to 37.00R57 tires.

However, even the best matching of Ultra-class truck and tire to date has been unable to provide the same tire life and tire operating cost as on 220 tonne and smaller classes.

Low-Profile Design

Ultra-class tires are not only bigger in size but they incorporate a new (for haul truck tires) design concept – low profile[18] and low inflation pressure. This follows the historical progression of tire design and construction changes flowing from sports cars to passenger vehicles to light trucks to heavy road trucks and finally to mine haul trucks. In 1960 only 2% of passenger vehicles were fitted with radial ply tires – virtually all other tires, including road and haul truck tires, were of bias ply (conventional) construction. During the 1960–70's the use of light vehicle radial tyres became widespread – firstly on passenger vehicles, then on light trucks and finally on heavy road trucks. By 1980, radials comprised the majority of light vehicle tyres in service, but only 5% of earthmover tyres. Since then radial tyre acceptance by the mining industry has increased dramatically – the proportion of radial earthmover tyres rose to 65% by 1990 and is around 95% today. This change has increased haul truck tire life by approximately 30% and has reduced tire costs by about 20%[19].

The change from standard to low profile tires also started with sports cars, and has progressively worked its way through each class of vehicle (passenger, light truck, road truck) to the earthmover haul truck. The focus of the low profile tire, particularly in passenger vehicle sizes, has been more directed towards road holding performance rather than increased life and lower costs; nevertheless there have been improvements in these areas for on-road tires.

The progression of the radial-ply tire concept from car to road truck to mine haul truck has been very successful; hopefully the same benefits will be seen with low profile tires.

Outlook

Whether further tire development will enable Ultra-class tire life and operating cost to match that of 220 tonne and smaller class tires remains to be seen, but history indicates that this goal will probably eventually be attained.

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[18] The profile of a tire is calculated as tire section height (tire radius minus rim radius) divided by tire section width (tire width). A 55/80R63 tire has a nominal profile of 0.8, designated an 80-series tire.

[19] Radial tires are typically 10% higher priced than bias ply tires, although the increase in life more than compensates for the price premium.

7. FUTURE TRUCKS

And what of even larger trucks in the future?

If we continue with the two-axle/six-tire rigid frame concept, then larger tires fitted to larger rims (69 inch diameter or bigger) will be required. Realistically, several years more development work will be needed to improve and stabilise 63 inch tire life; only then could any serious commercial release of larger sizes be considered. And this only addresses the technical aspects; a 69 inch tire would have an approximate diameter of 4.5 metres (15 feet) creating serious additional problems in tire transportation, particularly by road.

Options

There are several other potential options for larger trucks:

1. prime-mover/trailer haulers,
2. three-axle/ten-tire (or bigger) rear dump rigid frame trucks, and
3. autonomous haul truck technology combined with a lower tare weight/more efficient axle weight distribution design.

Prime-mover/trailer

Prime-mover/trailer units are simply not viable for the vast majority of hard rock mining operations because of the problems related to traction on grades and manoeuvrability at loading and dumping areas.

Three-axle rigid frame

Three-axle rigid frame haulers have more potential for success, but there would be major problems with tire wear to be overcome. There have been two main incarnations of this truck configuration (three-axle/ten-tire) in the past, both during the 1970s – the 200 tonne capacity Wabco 3200 series trucks on 33.00x51 tires (model A) or 36.00x51 tires (model B), and the 320 tonne Terex Titan on 40.00x51 tires. However both trucks suffered from exceptionally bad tire scrubbing during cornering[20] – the front tires were particularly susceptible, wearing at three to four times the rate of the tires on the tandem rear axles. The Terex truck attempted to overcome the problem by incorporating semi-steerability into the first of the two drive axles but it was fraught with mechanical troubles. Eventually, the combination of unacceptable tire wear, the mechanical problems with the Terex semi-steerable axle, and inadequate engine technology caused the decline of both trucks.

Two-axle/eight-tire autonomous

It is possible that the road to even larger trucks may lie in the integration of several concepts, eg. autonomous trucks, combined with a two-axle/eight-wheel configuration

[20] The trucks, especially the Wabcos, were subject to dramatic understeer. The eight drive tires on the tandem rear axles tended to push the truck directly ahead irrespective of the steering direction of the two front tires.

(similar to the V-Con truck of the 1970s and more recently the Kress truck) and incorporating the Liebherr TI272's integral body design. The advantage of autonomous trucks is that with the driver and driver's cabin eliminated, the truck can be far more efficiently designed in relation to axle weight distribution (for both tare and gross conditions) and tare weight can be reduced. The two-axle/eight-tire configuration would increase gross vehicle capacity by 33% and the TI272 style of using the body as a structural member would reduce tare weight considerably[21]. This concept could conceivably take us to a 550 tonne (600 short ton) payload capacity using currently available 59/80R63 tires. There would also be significant tire life improvement potential because of the better weight distribution[22] of tires throughout the complete haul cycle – the unloaded sector as well as the loaded section.

[21] Interestingly, the Liebherr TI272 rear axle design is very similar to that of the V-Con front and rear axles.

[22] The two-axle, six-tire design considerably increases the average cycle load of front tires compared with rear tires – this is the main reason why front tires are more prone to heat separations and why front tires generally determine tire TKPH (tonne kilometre per hour) rating.

SUMMARY & CONCLUSIONS

Ultra-class trucks are very productive but this productivity currently comes at a high cost in relation to tires. The potential operating cost per tonne hauled advantage of Ultra-class trucks over smaller haulers is severely reduced, and in some cases eliminated, because of high tire cost.

Ultra-class tire life is considerably lower than 220 tonne tire life – in the order of one-third to two-thirds – where both fleets are operating in similar conditions on the same mine. Tire cost per tonne-kilometre hauled ranges from between 15% higher to 125% higher for the larger trucks.

In order to maximise tire life on these very large trucks, close attention needs to be paid to mine operating conditions and operator practices.

Purchase of a fleet of Ultra-trucks requires additional investment in motor grader capability and workshop maintenance equipment. Even a very small fleet of these trucks could require significant outlays in larger tire handling and maintenance equipment.

Tire supply issues are far more critical for these trucks than for smaller haulage units.

It is difficult to envisage a significant increase in truck capacity past the 360 tonne capacity mark unless there is a marked shift in haul truck design philosophy.

An all inclusive tire management philosophy must be adopted in order to effectively operate an Ultra-class fleet of trucks.

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Reference: Gilewicz, Peter. “Big It Up.” *World Mining Equipment*, July/August 2001, pp. 44-52.