Technical White Paper

Analysing Impact Forces & Overcoming Speed, Heat and Pressure Issues in High-Capacity Belt Support Applications

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Belt conveyor transfers are the most likely location for high wear rates and failures. Belt transfers are necessary to change the direction of conveyed material and will remain a part of belt conveyor systems into the future.

Burden being accelerated due to fall and changes in direction from one system to the next, prevents steady state flow which introduces component fatigue. The conveyor belt is considered the greatest cost item over the life of a belt conveyor system and consumes considerable downtime to replace, therefore a financial incentive exists to preserve this high-cost item. Other issues created at the transfer include health risks of uncontained dust and product losses due to spillage.

Additional consideration to support the belt is one way to improve the life of components and contain dust within the transfer chute. The humble impact cradle/bed has changed little over the years whilst conveyor systems have achieved ever greater flow rates. Further development of the impact cradle is an opportunity to reduce maintenance costs and increase uptime.

The peak technology on the market for conventional impact belt support is the dynamic impact cradle, which ensures the belt support area under the chute allows for some dynamic travel, whilst also maintaining a consistent skirt board area. The impact energy at a transfer when installed with Kinder Australia's dynamic impact belt support system was measured to further understand the forces involved and how they compare with static belt support systems. Adding further dynamic capacity to the load zone has been shown to increase belt life by at least 30%. Other components also benefit from reducing impact energy in the transfer and the incorporation of polyurethane bushes at roller supports has been employed further increase roller and frame life.

Kinder Australia has developed a unique and innovative range of belt support technologies that further promote dynamic travel whilst maintaining a consistent skirt board area without a significant increase in belt-friction tension. This technology combines slider rails with rollers that can absorb impact independently within the support system and/or utilising exotic slider materials to overcome high belt speeds and/or system capacities. Kinder Australia has a vast library of documented case studies and application data to ensure the future systems being offered will survive, provide better chute sealing and protect the conveyor belt.

Given the high failure rate to components in the transfer above all other system components along with significant wear to the conveyor belt caused at the transfer, why have transfers?

- Avoiding environmental features or roadways. Finding the cheapest path.
- Avoiding vertical/horizontal curves which allows for a simpler conveyor design and better conveyor belt tracking.
- Reducing risk in the event of a belt puncture that may propagate through the full tape length of the conveyor belt. A smaller system will damage a lesser quantity of conveyor belt in this event.
- Running bulk material through other processes such as crushing, screening, washing, and stockpiling requires that a transfer be used to collect the product for transport to the next stage.

For these reasons, the conveyor belt transfer will remain a part of conveyor belt systems into the future, and engineering solutions have been developed and will continue to be further developed to solve issues around the transfer. Such issues include:

- Equipment and maintenance costs
    - Belt cover and carcass impact damage (large lump)
    - Belt top cover groove lines from material entrapment beneath the skirts
    - Idler and structure impact damage
    - Belt top cover wear induced by accelerating the bulk material from one system to the next
    - Carry back induced mis-tracking causing damage to the belt
    - Maintaining the chute itself (liners/steelwork)
- Health effects
    - Dust creation
    - Noise pollution
- Lost productivity
    - Chute blockages and hang-up
    - Carry back induced mis-tracking causing spillage

To prevent belt sag induced gaps at the transfer and to offer a more reliable belt support solution, the impact cradle was developed. Typically, a composite bar made up of a low friction UHMWPE top, an aluminium rail for rigidity and fastening plus, a low durometer rubber or polyurethane base to offer some dynamic travel to lessen the impact loading on the belt. The relative rigidity along the length of the bar offers a constant flat surface to prevent gaps opening between the belt and skirting system.

The impact cradle is a simple, effective and reliable solution for many belt conveyor systems, particularly at the primary end of small to medium size ore operations. They are also generally easy to maintain given drop-down wing set-ups or slide out retractability (Figure 1).

For lighter duty applications where the lump size, system capacity or drop height is significantly lower, a belt support system can be retrofitted to the existing frames and rollers. The K-Sure® Support (Figure 2), whilst strictly not an impact cradle, does perform the role of a constant flat surface upon which the belt to skirt gap is kept to a minimum.

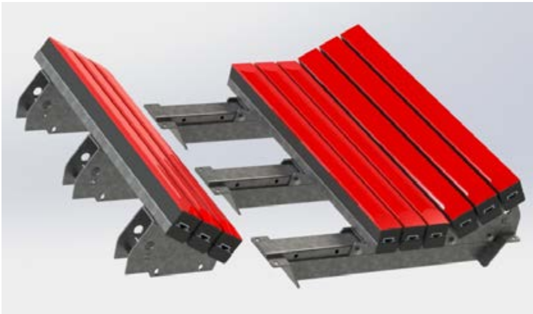

Figure 1 - K-Shield Impact Belt Support System retractability demonstration

Figure 2 - K-Sure® Support Retrofit Belt Support System

Keeping the product within the transfer has obvious advantages, such as spillage and dust reduction, but there is a more sinister issue caused in the form of groove lines in the top cover of the conveyor belt on systems that do not have adequate transfer support. Entrapped material can make its way between the belt and skirt, usually between roller sets as a gap is formed by the belt sag. As the material makes its way to the next idler set it gets compressed between the belt and skirt. This forces top cover wear that can be seen as two groove lines right where the skirting exists on the belt. These groove lines cannot be easily cleaned and lead to an early replacement of the belt, as further wear at this location starts to penetrate the belt carcass.

Solutions to combat this issue are the use of spray bars within a contact skirt to ensure no product is allowed to get caught in this area, the bonding of polyurea in the groove line to extend the belt life or the tapering out of the chute to spread the concentration of wear over a greater area. Given these options have downsides and are treatments that do not address the root cause, a belt support option is always a more preferred method.

Solution	Pro	Con
K-Hydra® Belt Shield (Figure 3)	Powerful material containment without wear to the top cover.	Adding water to the product stream is undesirable for some product types.
Polyurea groove line fill (Figure 4)	Extends the already installed belt life and can offer a greater wear resistant area at the skirt/belt interface.	A patented, cost effective process that is solving the symptom, not the root cause.
Tapered Chute (Figure 5)	Chute design allows the potential for top cover wear to occur over a greater area, reducing groove concentration.	Slightly more complex chute and skirting design (when belt is troughed). Difficult or impossible to implement on longer transfer points or where multiple transfers exist along a system.

Table 1 - Methods to combat groove lines in the conveyor belt top cover

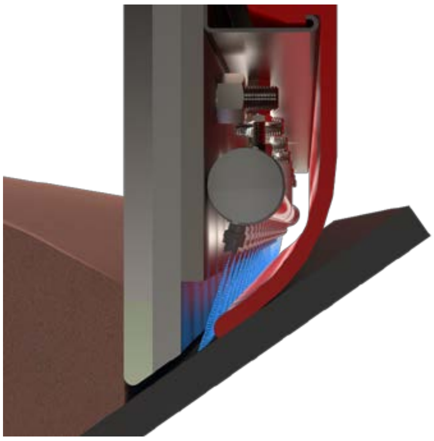

Figure 3 - K-Hydra® Belt Shield, high pressure water spray behind a lay in skirt

Figure 4 - Belt cover repair system shown here to fill in grooves caused at skirt zones (Wear Systems Solutions)

Figure 5 - Tapered chute on a flat belt conveyor system

In some cases, "treatments" from Table 1 are relevant and necessary, as a belt support system may be considered not suitable due to the belt speed and/or high pressure of a large material throughput. To counter this, Kinder Australia developed the Combi Impact cradle range, which uses rollers in the centre of an impact belt support system, where the bulk material pressure is highest (Figure 9).

Limitation to the parameters at which failure occurs have been found experimentally in the past, however Kinder Australia aim to predict a specification limit for our belt support systems to ensure most importantly that the system will survive in the given application and to further push the boundaries in terms of belt speed and capacity that these systems will be installed to.

Two main modes of failure to the impact cradle are the following:

- A failure to adequately support the impact bars by way of structure or ensuring the bar has sufficient rigidity to resist flow pressure and impact loading.
- Exceeding the allowable temperature of the slider bar surface (approaching melting point) due to friction induced heat generation.

A failure regarding insufficient support is unheard of within Kinder Australia, as all our “impact” rated systems have fully supported impact bars or fully supported rails on springs. Only the K-Sure® Support uses a slider surface that is not fully supported. However this system is not considered for severe impact loading, only as a slider surface for relatively free flowing bulk material, usually no more than 1000TPH and lumps size no larger than 50mm.

Ensuring the slider material will not exceed the allowable temperature requires a look at the actual system being used. We will first consider the dynamic impact cradle, as we have managed to collect some data on a system of this type in service (Figure 7). This installation is considered a success as the wear rate on the rails is to date negligible and the client is pleased with the improvements to spillage and reduced maintenance required in the area.

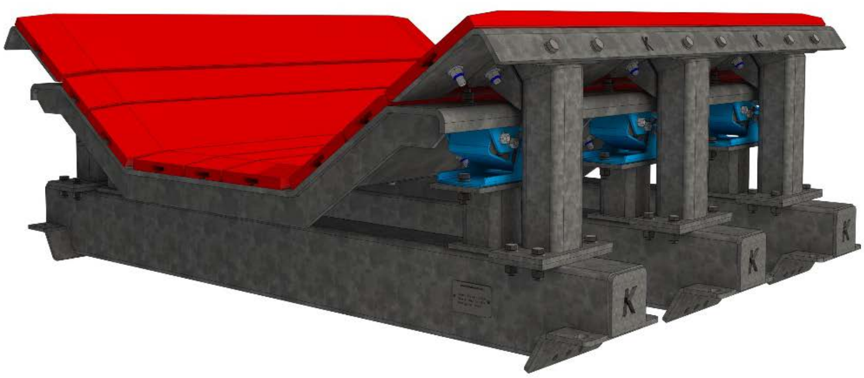

Figure 1 - K-Shield Dynamax® Impact Belt Support System

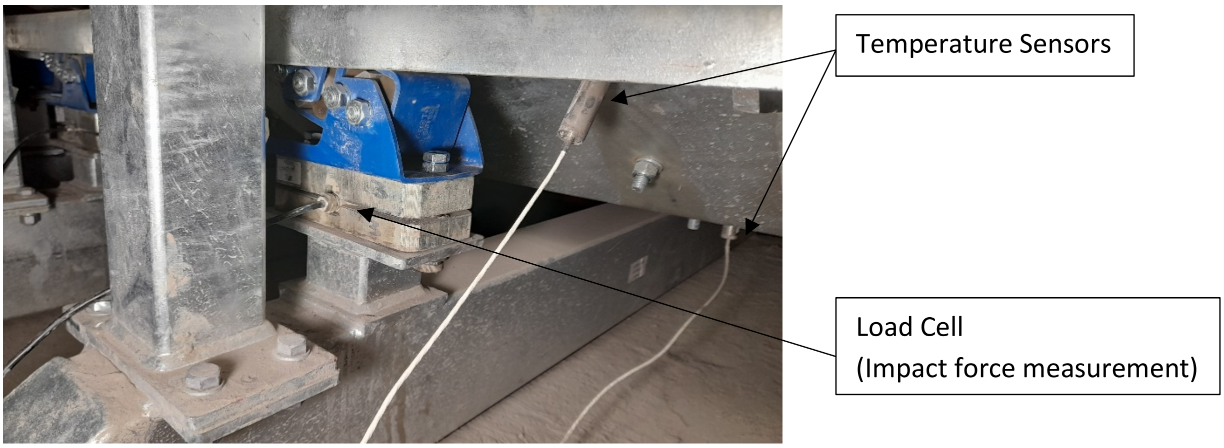

Figure 7 - K-Shield Dynamax® Impact Belt Support System with temperature and impact force data measurement devices

This type of belt support system consists of UHMWPE slider rails, fully supported by steel plate (Figure 6). The centre section is dynamic via six torsion springs to absorb impact and the wings are static to ensure a consistent belt to skirt gap. As each slider rail is a rather large surface being acted upon by friction induced heating, we will assume the problem to be of one-dimensional heat conduction transfer:

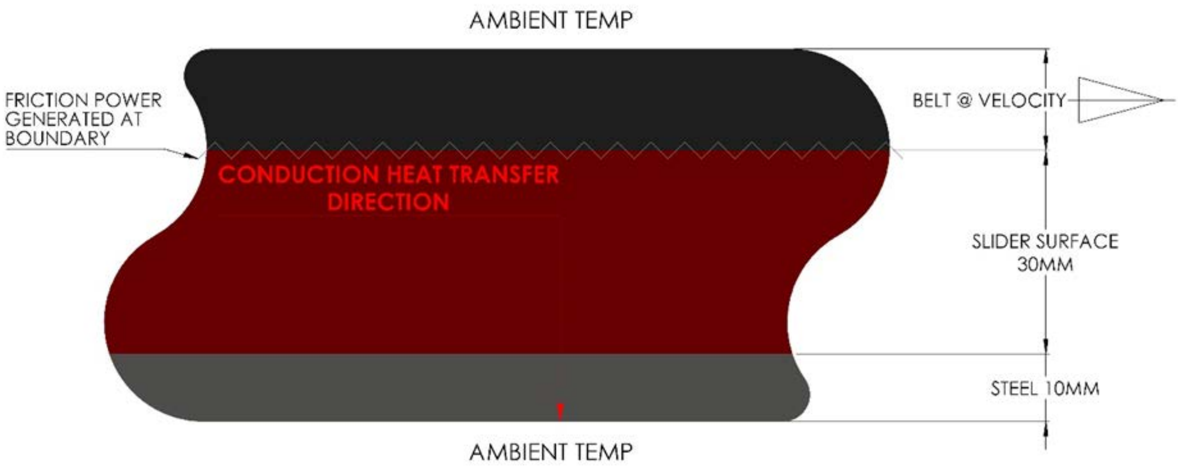

Figure 8 - Heat Transfer Schematic for full steel supported slider system

Case Study 1: K-Shield Dynamax® quarry install (hornfels 90%, granite 10%)				
Data	**Symbol**	**Qty**	**Unit**	**Notes**
System Capacity	TPH	600	$Tonnes/_{Hour}$	Nominal
Belt Width	BW	1.4	Metres	Equal three roll trough
Belt Speed	v	1.5	$Metres/_{Second}$	Measured
Slider Length	L	3	Metres	2 x 1.5 metre systems
Lump Size		250	mm	Note lump size greater than allowable for K-Sure® Belt Support System
Friction coefficient	μ_{UHMWPE}	0.22	----	Dynamic against rubber, proprietary formula test
Thermal conductivity	K_{Rubber}	0.13	$W/_{m.K}$	Soft Vulcanised (Çengel, 2006)
	K_{UHMWPE}	0.41		OK 1000 (OKULEN, 2013)
	K_{Steel}	~60		AISI 1010 (Çengel, 2006)
Temperature Ambient	$T_{Ambient}$	20	°C	Measured
Max allowable slider temperature	$T_{Allowable}$	80	°C	(OKULEN, 2013)

Table 2 - Data for full steel supported slider system

The rate of heat energy generated at the friction boundary can be quantified by the following:

$$P = Force_{Friction} \text{ x } v$$
Equation 1

$$N_{Burden} = \frac{TPH \text{ x } 9.81}{3.6 \text{ x } v} = 1090 \text{ N/Metre}$$

$$Force_{Friction} = \mu_{UHMWPE} \text{ x } (N_{Burden} + N_{Belt})\ L$$
Equation 2

$$N_{Belt} = 274 \text{ N/Metre}$$

$$Force_{Friction} = 0.22 \text{ x } (1090 + 274) \text{ x } 3 = 900N$$

$$P = 900 \text{ x } 1.5 = 1350 \text{ Watts}$$

Current values were measured at the drive motor before and after impact cradle installation. This allows us to confirm the accuracy of this value:

$P = V \times \Delta I = 415 \times 3 = 1245$ Watts
Equation 1

The current difference was an average when fully loaded and shows an absorbed power at the drive due to an increase in friction within an acceptable error can be quantified using Equation 1. At Kinder Australia, when quoting the extra drive power required, we use a friction coefficient of 0.3 as a conservative figure and for static cases (start-up).

If we assume all the friction power generated goes into heating the slider rail, we need to ensure the allowable temperature for the material is not exceeded:

$$Q_{In} - Q_{Out} = \frac{dE_{Wall}}{dt}$$
Equation 2 – One dimensional conduction in plane walls (Çengel, 2006)

Conduction Heat Transfer Rate $Q = k.A\frac{\Delta T}{L}$
Equation 3 (Çengel, 2006)

Given the belt is predominantly made of rubber which has a very low thermal conductivity value (poor conductor or good insulator) and that the steel support is a very good conductor, we can assume no heat will transfer to the conveyor belt and any temperature variation across the slider surface will be quickly conducted out by the steel support, keeping the underside of the slider at ambient or close to ambient. The steel components are large and have a large surface area for convection to then take place. We are considering this as a steady state conduction so, (dE_Wall)/dt = 0.

We want to consider the slider area that is under the greatest pressure. This area, given the trough layout is the centre of the belt where most of the product is piled onto. Typically, the mass distributed to the centre roller of an equal 3 roll idler is 66%. Given this is a transfer point, we will assume 70% is applied to the centre as a chute with vertical skirts typically narrows and steepens the burden profile than it would naturally sit in a regular carry trough along the system.

$P_{Centre} = P \times 0.7 = 945$ Watts

Using Equation 5 and a centre slider rail effective width of 450mm, we obtain a maximum heat transfer rate possible to avoid exceeding the maximum allowable temperature for the slider material.

$$Q_{Centre} = \frac{0.41 \times 0.45 \times 3 \times (80-20)}{0.03} = 1107 \text{ Watts}$$

The above is an allowable maximum to not exceed the temperature of 80° when in a 20° ambient temperature environment. Given we are only producing 945 watts of heat generation at the centre of the slider surface, theoretically 80° will never be reached.

It is however understandable why some designs have emerged whereby the centre section of the impact cradle uses rollers instead of a slider bed surface (Figure 9). This negates an estimated 70% of friction force generation and associated potential for slider material failure and risk of insufficient drive power. It does however require a very heavy roller be installed in this location so that it can resist the impact loading. Kinder Australia have also found a roller to be less reliable when considered as yet another moving part in the system and less accessible for maintenance than a slider rail system.

Figure 2 - K-Shield Combi Impact Cradle

The effect of a raised ambient temperature is clear if we consider a limit being where P is equal to Q for the centre of the impact cradle. This puts a limit on ambient temperature at 32.1°, entirely plausible given install occurred in winter, Melbourne experienced a relatively mild summer (no days over 40°C, (Australian Government Bureau of Meteorology, 2021)) and that the system is installed surrounded by a concrete structure under a jaw crusher that is shielding the system from direct sunlight and associated temperature rises.

The sensor data showed a 7°C difference measured over 20mm (Figure 10, sensor 3), which equates to 194 watts of conduction for the centre section. This is much less than the expected 945 watts. We know our friction factor is accurate, therefore there are other rates of energy lost from the slider material. Such losses may be attributed to convection from the sides of the slider rails, quite feasible given the 450mm effective width in the centre is made up of three 150mm wide rails, allowing for much surface area that can interact with some potentially turbulent air due to the moving conveyor belt (Figure 11). Additionally, conduction heat transfer to the conveyor belt may be playing a part, though given its poor conduction value, this is likely playing a lesser role. Further improvements will also be made to temperature measurement device placement on future testing systems, to increase accuracy and further quantify this phenomenon.

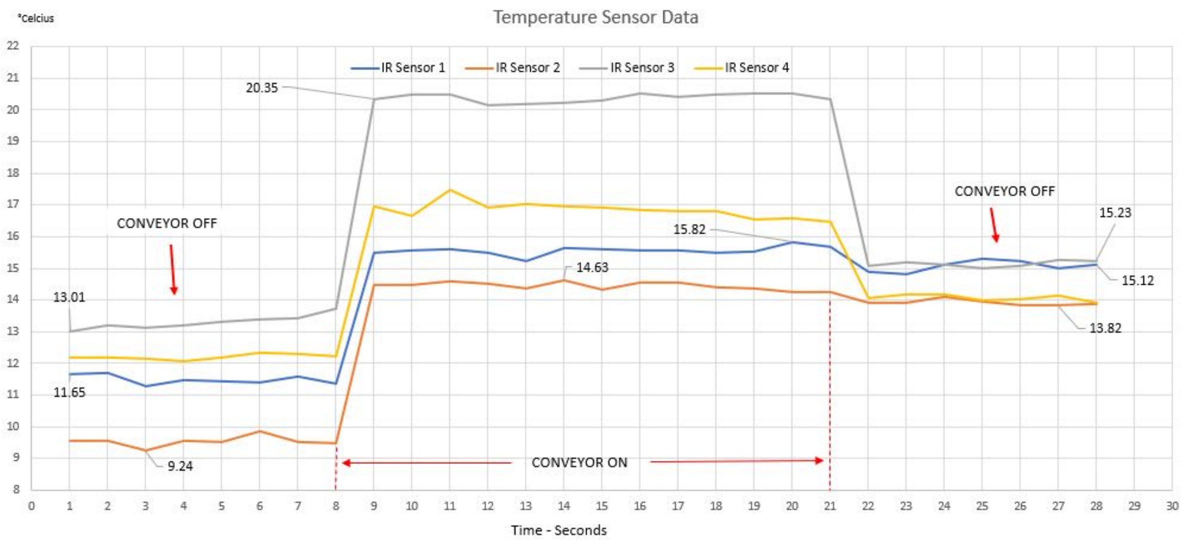

Figure 3 - Typical Temperature Sensor Data Log

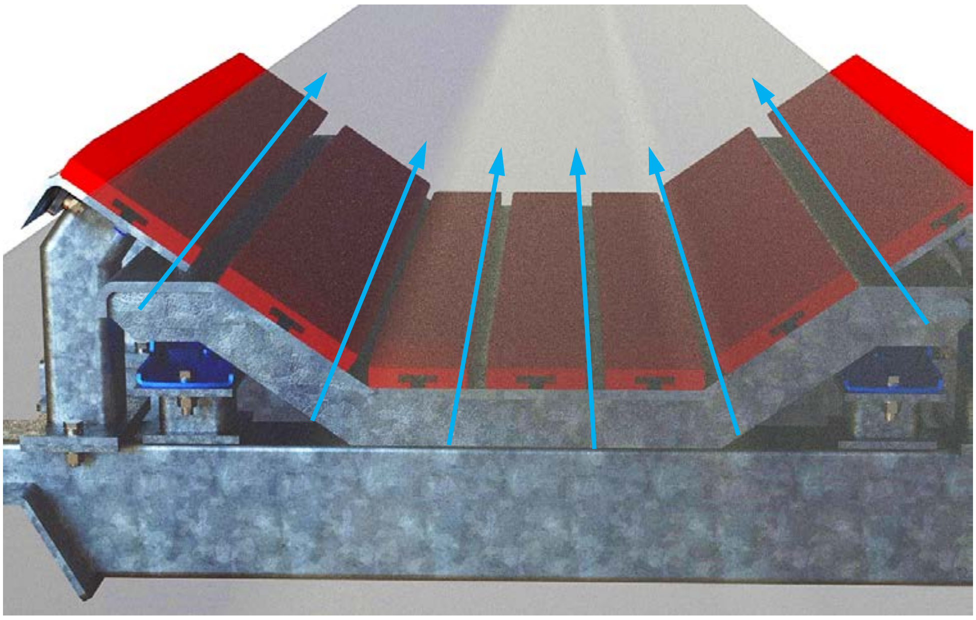

Figure 4 - Convection Heat Transfer Illustration, arrows indicate air being drawn into slider rail gaps by the conveyor belt

Further doubt to conduction only heat transfer analysis and assumptions is introduced when considering an impact bar made up of a low durometer rubber base with aluminium track and the same UHMWPE material slider surface, albeit a lesser 10mm of thickness. If the same assumptions are used here, the heat energy has nowhere to go, with rubber acting as “insulation”, both top and bottom of the rail. For completeness, we can work out the maximum permissible friction power for this system:

$$R_{Total} = \frac{L_1}{K_1 A} + \frac{L_2}{K_2 A} \ldots$$

Equation 4 (Çengel, 2006)

$$Q = \frac{\Delta T}{R_{Total}}$$

Equation 5 (Çengel, 2006)

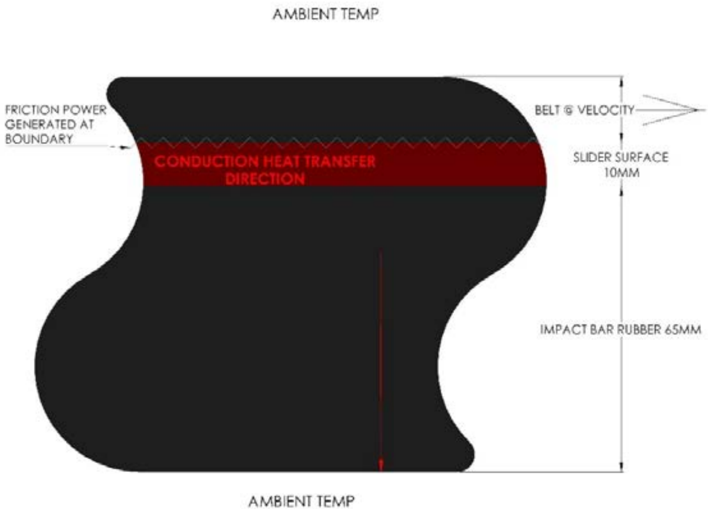

Figure 5 - Heat transfer schematic for a typical rubber based impact bar

Using the above equations and ignoring the quantity of heat transferred to the belt (if any at all), shows an allowable friction power of 171 watts for the centre of an impact cradle in the same application as discussed previously using data where necessary from Table 2. This is further proof that more research is required to properly ascertain for the materials and support system type, the friction power limit, and deriving a maximum heat flux with unit 'watts per square meter'. This method will be a practical shortcut to avoid numerical solutions for unknown properties such as convection heat transfer, which would be heavily dependent on the amount of turbulent air in the immediate area. We can also account for "reasonable" levels of allowable wear in the slider rail material using this method. For example, a slider material may not be reaching its temperature limit, though still wearing out in an unacceptable timeframe. Other variables include thermal contact conductance (conduction value for two disjointed surfaces due to microscopic air particles) and the fact that temperature and contact pressure significantly affect the kinetic friction coefficient (Ptak, Taciak, & Wieleba, 2021)

$P = Force_{Friction} \times v$

Equation 1

$P_{Max} = \dot{q} \times A, ({}^{W}/_{m^2} \times m^2)$

Equation 7

$$\frac{Force_{Friction} \times v}{A} < \dot{q}$$

Equation 6 – Material based limitation factor

$$\frac{Pressure \times v}{A} < \dot{p}$$

Equation 8 – Application based limitation factor

Equation 9 & Equation 10 do not consider ambient temperature. We can either take a conservative approach and limit all relevant systems to the worst-case scenario, or perhaps temperature dependant levels of q˙ and p could be derived. Additionally, q˙ will be material dependant as the friction coefficients vary. Equation 10 was developed so all material types could be compared against each other, removing the variable material friction factors, to realise the output as an application specific factor. Kinder Australia has a vast library of documented success and failure case study specifications which can be analysed. Preliminary data shows the K-Sure Support has a much lower allowable heat flux, which may point to a sagging of the rails after some heating, thus placing greater pressure and overheating the remaining supported sections of the slider (Figure 13).

Figure 13 - Possible failure mode under high ambient temperature or high belt speed and capacity conditions, placing higher loads on smaller areas due to sagged slider rails once the softening temperature is reached

Figure 6 - Variable wear thickness along slider rail

Figure 15 - Signs of friction generated burning on the slider rail

A superior slider material has been observed in a Kinder installed application since 2011 at a lignite fired power station (Case Study 2). An increase in belt speed or capacity insists that we either look at a Combi design, use a slider material with better properties or a combination of both methods to reduce friction in the transfer. This can also be necessary in slow moving feeder belt applications, where the pressure across the transfer is very high. For Case Study 2, the belt speed is high at 5.1m/s and moderately high capacity of 2500TPH. To ensure there were no drive power issues or overheating of slider materials, Kinder Australia opted to use both a centre roller and proprietary K-Glideshield® product at the wings as slider surfaces.

Figure 16 - Lignite fired power station high belt speed support system designed for Case Study 2

K-Glideshield® is a unique composite engineered plastic that has far superior mechanical and thermal properties when compared to all grades of UHMWPE which lends itself to be the preferred and to date only suitable material for higher capacity and or speed belt support applications.

Material	Dynamic friction coefficient	Thermal conductivity $W/_{m.K}$	Service Temperature °C	Notes
K-Glideshield®	0.09	0.64	250	Internal Test
UHMWPE	0.22	0.41	80	As per Table 1
Nylacast Nylube	0.075	0.25	110	(Nylacast, 2019)

Table 1 - Slider material comparison data

From Table 3, comparisons between K-Glideshield® and UHMWPE materials can easily be made:

1. Over 50% less friction induced heat will be produced due to the lower friction coefficient.
2. Heat that is generated will be able to move through the entire section of K-Glideshield® rail over 50% faster.
3. Any heat that must be stored by the K-Glideshield® rail will be permitted due to the much greater service temperature (assuming a similar specific heat).

Therefore, both belt speed and capacity of conveyor systems can be pushed much further if a system warrants a slider bed solution. Both much lower friction heat will be generated and the slider materials capacity for temperature is much higher.

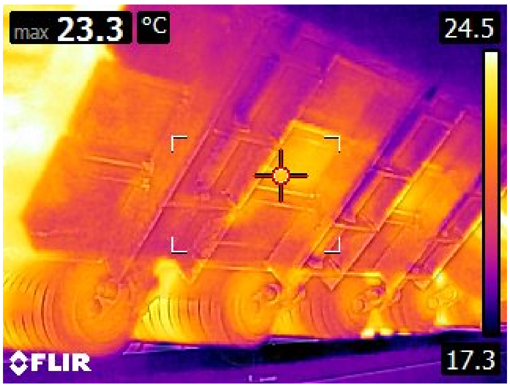

Figure 7 - Temperature data from the lignite fired power station showed temperatures were unlikely to be exceeding those allowable for the K-Glideshield® material

Figure 18 - Top view of the lignite fired power station application

Nylacast Nylube is another material that Kinder Australia has used on occasion without success. Whilst having the smallest friction coefficient of all three, it is likely that heat generated at the friction boundary is unable to propagate through the material relying on convection over a much smaller area (sides of rails, typically 10-30mm). The relatively minor increase in service temperature is another limit for use of this material in slider bed applications.

Whilst the Case Study 2 slider material sees much higher capacity and belt speed, the client has been impressed by the seemingly negligible wear over the past 10 years. A check performed in November 2021 showed wear of no more than 4mm on the 10mm thick wear surface. This system analysed as per Figure 1, shows a capacity of the K-Glideshield® material well above the actual heat it is likely to be experiencing. If UHMWPE were installed, it would likely be borderline as to whether the customer would consider the installation a success, even given there are further heat losses in these slider systems yet to be understood.

Kinder Australia have collaborated with clients that wish to push boundaries installing belt support systems in ever greater belt speed and capacity conveyor systems. Case studies that exceed the allowable temperature of the slider material has given us invaluable data which we can apply limits for systems, perhaps using Equation 9 or Equation 10. The above calculations show the heat transfer properties of a system depends on the system being analysed, whether a conventional impact bar system, dynamic slider system, K-Sure® Belt Support System or a Combi system.

Using Equation 10, which omits the friction factor to keep the limitation factor (p value) comparable across all materials, will allow us to impose limits for the different materials and system type combination. This is assuming a steady lead in and lead out idler set run the belt onto and off the belt support system. Without this, additional pressure will be applied to the slider material.

Some interesting K-Sure® Belt Support case studies arose when comparing this subset. Figure 19 shows some successful case studies in green and failures that occurred in red.

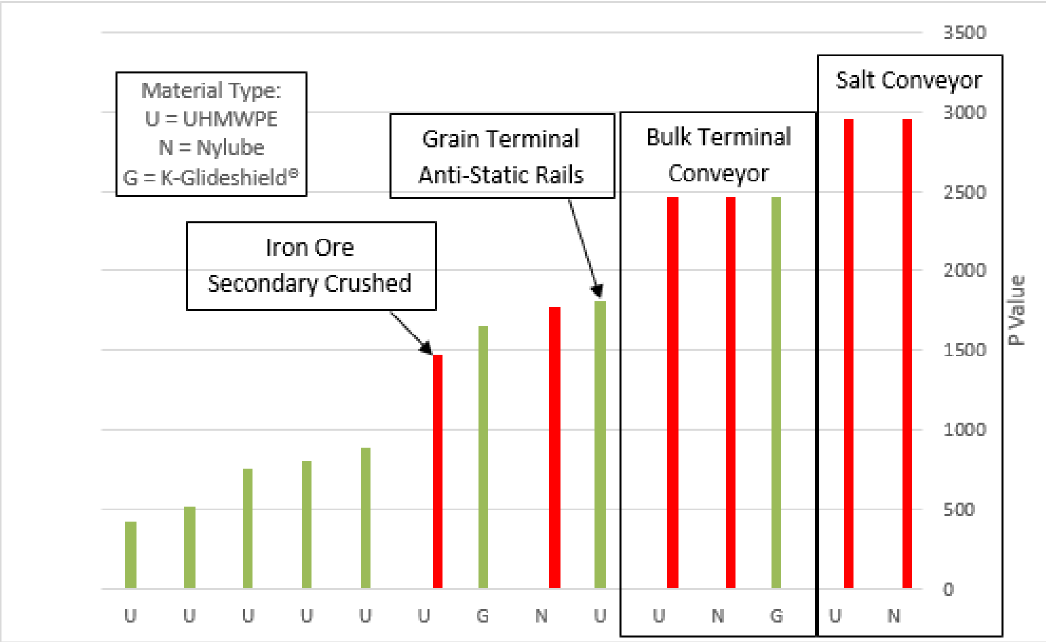

Figure 19 - Case Study Application Factor Comparisons (K-Sure® Support Only)

Case Study 3: Bulk terminal K-Sure® Support (mineral sand)

Belt Width: 850 mm
Belt Speed: 4.2 m/s
System Capacity: 1150 TPH
Drop Height: 2 metres

This bulk terminal provided us with invaluable data, given all three material types were tried. It is known for sure that to use anything less than the K-Glideshield® in this application results in a failure.

Case Study 4: Iron Ore Secondary Crushed Conveyor K-Sure® Support

Belt Width: 900 mm
Belt Speed: 3.4 m/s
System Capacity: 700 TPH
Drop Height: 2 metres

Our lowest application factor UHMWPE failure occurred in the Pilbara (North-West Australia) where temperatures regularly exceed 45°C (Department of Primary Industries and Regional Development, 2021). This shows a need to consider further limiting the application factor when ambient temperatures are high (Figure 14 & Figure 15). This was also a consideration for the salt conveyor, though with such a high application factor, it was no wonder these material types failed, however it's very likely both these applications would have succeeded using K-Glideshield®

Case Study 5: Grain terminal, K-Sure® Support with anti-static UHMWPE rails

Belt Width: 1050 mm
Belt Speed: 4.3 m/s
System Capacity: 1000 TPH
Drop Height: 2 metres

Our highest successful application factor using UHMWPE stands out, having outlasted lesser duty applications. Further investigation is required as the use of anti-static material may have played a part. This conveyor is located in a milder climate than case study 4.

Kinder Australia plan to apply this method to our other product types and rolling this out to the wider sales and engineering teams to ensure clients will only be supplied a successful system type and material combination. Further data is required to see the effect of the drop height. Initial theories are that a flow rate force is small enough to be excluded in applications where the K-Sure® Support is considered, however with a greater lump size and capacity warranting a more robust system, this may become a factor. For chutes where flow is interrupted with the use of ledges and rock boxes and other soft flow chute applications may allow for a complete exclusion of this force in playing a part.

Case Study 6: Primary Crushed Copper Ore K-Shield Dynamax® Impact Belt Support (Figure 20)

Belt Width: 2600 mm
Belt Speed: 4.5 m/s
System Capacity: 11,000 TPH
Drop Height / Lump Size: 7.3 metres / 600mm
p value: 22,600

Figure 8 – Case Study 6 Belt Support System

Another notable system installation for its ability to resist friction induced heat. This heavy-duty dynamic impact cradle with rubber based impact bars topped with K-Glideshield® was custom built to replace the standard UHMWPE rubber based impact bars supplied by Kinder's competitor, which started to smoke upon the early commissioning of the plant. This client has since asked for further cradle installations as the plant ramps up further.

A p value of around 12,000 is where Kinder Australia has started to see UHMWPE topped rubber based impact bar systems begin to fail. At 22,600, it is no wonder the copper ore client was witnessing an overheating of the originally installed slider surface, with which they attempted to keep cool by constantly hosing with water until the K-Glideshield® solution arrived.

Whilst Kinder Australia have not experienced a structure failure, there are opportunities to decrease the impact forces to protect the belt. One such solution developed by Kinder Australia was the dynamic impact idler, the first of which was commissioned originally for belt protection then went on to increase the conveyor belt system uptime, requiring fewer unscheduled shutdowns to replace failed rollers and idler frames. The case study was covered in more detail in an earlier submitted white paper (Portelli, 2019).

Case Study 7: Primary Crushed Iron Ore K-Shield Dynamax® Impact Idler (Figure 21)

Belt Width: 1800 mm
Belt Speed: 4.0 m/s
System Capacity: 5,500 TPH
Drop Height / Lump Size: 6.0 metres / 500+mm

The client would not entertain the use of slider beds in any form as a focus on maintainability of smaller lightweight components was within their scope. Thus, the client was willing to put up with the potential for further spillage. The heavy conveyor belt used on this system was not likely to sag enough between roller sets, keeping these gaps small enough to prevent spillage in the original layout, however the idler added dynamic travel and hence would further open skirting gaps, with the potential for further spillage. With a large lay in skirt panel effectively able to soak up some of the belt sag upon impact travel, the client was willing to bear any potential disadvantages for to increase conveyor belt life and to promote system uptime. Regarding the issue of potential skirting gaps opening upon impact, Kinder Australia have a polyurethane lay in skirt designed to follow the belt due to its pre-tensioned installation location. (Figure 22).

Figure 9 - K-Shield Dynamax® Idlers installed beneath a primary sizer

Figure 10 - K-Snap Loc® lay in belt skirting system can self-adjust to belt sag and skirting wear

Since a site trial and further implementation across both the primary sizer collection belts, this belt support system has been commissioned to another of this client's sites. Kinder Australia have also made improvements to these systems based on client feedback:

1. Risk of torsion springs to fill with bulk material dust. This build-up has the potential to cause the torsion spring to lock up and eventually crack its mount plates as has been the case on other types of equipment where these are used. (Figure 23 & Figure 25)
2. Roller shaft compressing the support plates due to severe impact. (Figure 25 & Figure 26)

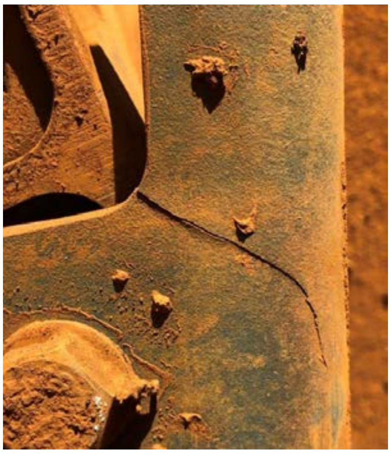

Figure 11 - Crack detail

Figure 12 - Torsion spring boot added to prevent ingress

Figure 13 - Roller shaft support plate steel compression

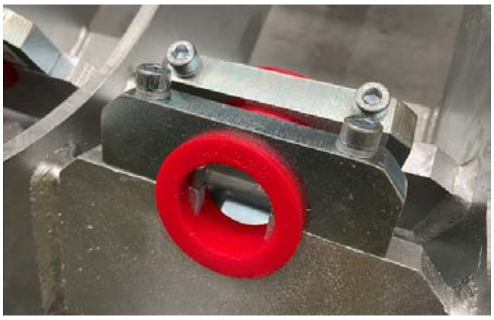

Figure 26 - Roller bush to minimise steel on steel contact (roller not shown as not supplied)

This site has seen shutdown cycles for belt replacement move from 6-9 months out to 12 months. This minimum 30% belt life improvement makes savings on a belt change that is reportedly a $250k exercise (as of 2019, likely much more now), not to mention the opportunity to allocate the labour elsewhere on site for shutdown works. With roller and idler frame sets lasting 4-6 weeks prior to the Dynamax® Idler install, requiring unscheduled shutdowns of the conveyor for replacement, they are now having no such issues and able to complete multiple shut cycles before offering any preventable maintenance on these items.

Kinder Australia have seen an improvement to belt life when incorporating dynamic travel in the belt support system as well as an overall more reliable transfer. Dynamic travel may be in the form of torsion springs like those used on our K-Dynamax® Idler and dynamic impact cradle, or it may be simply in the form of rubber based impact bars as this low durometer base provides for some dynamic travel. Where dynamic travel is great enough, it should be limited to the load area of the support system where practical, and hence why the dynamic impact cradle was developed with only the centre portion able to travel.

Impact force measurements were taken from our equipment installed to Case Study 1. An attempt was made to take baseline data from a basic impact idler system (Figure 27) prior to installation of the dynamic cradle solution. Use of the same load cells and housings to be used on the dynamic solution proved to be a wrong decision. To cover a comparable length of the transfer as would be covered by the dynamic idler, the load cells were placed under and bolted to a rail made from steel angle section. Once all bolted together, the load cells were unable to act independently and deliver much change in force data, even when the system was clearly delivering heavy lump material flow. Future development work is required to ensure the next project can obtain quality baseline data, to see what improvement (decrease in force) if any a dynamic impact cradle makes compared with an impact idler system.

We can observe the recorded data from when installed to the dynamic cradle, as one load cell was used per spring (independent). It was also possible to observe the impact loading live on site via the control box (Figure 30).

Figure 27 - Baseline impact data recording system

Figure 28 - Original idler system needed an upgrade

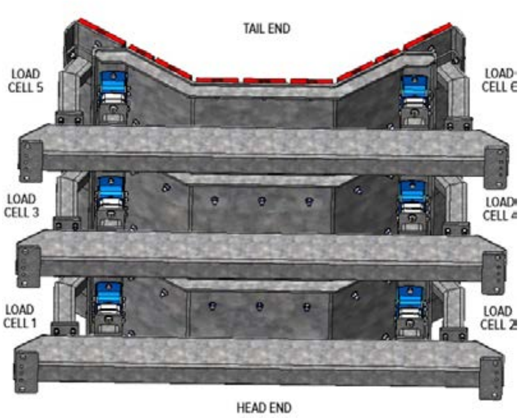

Figure 29 - Cell Numbering Layout

Figure 30 - Control box for live data view and logging

With so much data taken over many weeks, it was necessary to seek data of interest, for us this was the peak readings. On many occasions, we noted that higher force readings were recorded on the lead in and lead out torsion springs. Due to the 6 spring layout, this leads us to believe that under lump impact the trough panel is rotating about the centre springs (#3 & 4).

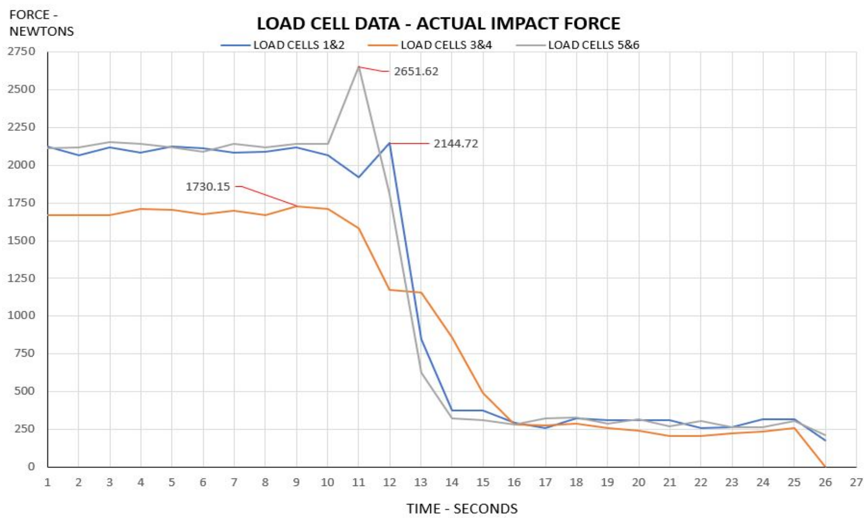

Figure 31 – Typical Peak Load Cell Force Data

Other spring layout configurations are an opportunity for further analysis for our dynamic impact cradles. For example, a stiffer 4 spring configuration may work better than the current 6 spring layout, potentially allowing a more dynamic capacity at the location of impact. As shown in , as a lump impacts the tail end of the load zone, the cradle is responding by taking up all the force on springs located at 5 & 6, whilst load is coming off the springs elsewhere. Whilst this shows that at least the cradle is semi-independent at the location of impact, there is further scope to allow the dynamic section to respond even better to impact by reducing the quantity of springs as there will be fewer non-impact loaded springs working to unnecessarily stiffen the system.

As this was our first attempt at data capture in a load zone application, further improvement will be made to the data collection system for another attempt at baseline data and subsequent belt support system installation. A summary of these improvements are:

- Ensure baseline data can be obtained accurately, perhaps using two cells per idler frame rather than trying to spread multiple frames over fewer load cells.
- Consider other load cell types and data capture that can produce higher frequency data collection to ensure peaks are accurately captured.
- Improve temperature capture to achieve more reliable data closer to the heat source.
- Allow load cell readings to be independent, rather than averaged across a set of two.
- Installation to a harder/denser rock or ore carrying system, given the horsfels rock from the initial data collection system is quite brittle, lessening the impact intensity.

Our final case study is one that pushes the innovation boundaries to further soften, control and allow adjustment of the spring configuration, as well as incorporating some other improvements from other belt support systems. All credit to our client for opting to incorporate a tapered chute on this troughed system. They realised the benefits for spreading skirting related wear and opted to spread this over a greater area. This further pushed Kinder Australia to come up with a completely bespoke system to ensure the dynamic section too followed the tapered shape of the chute.

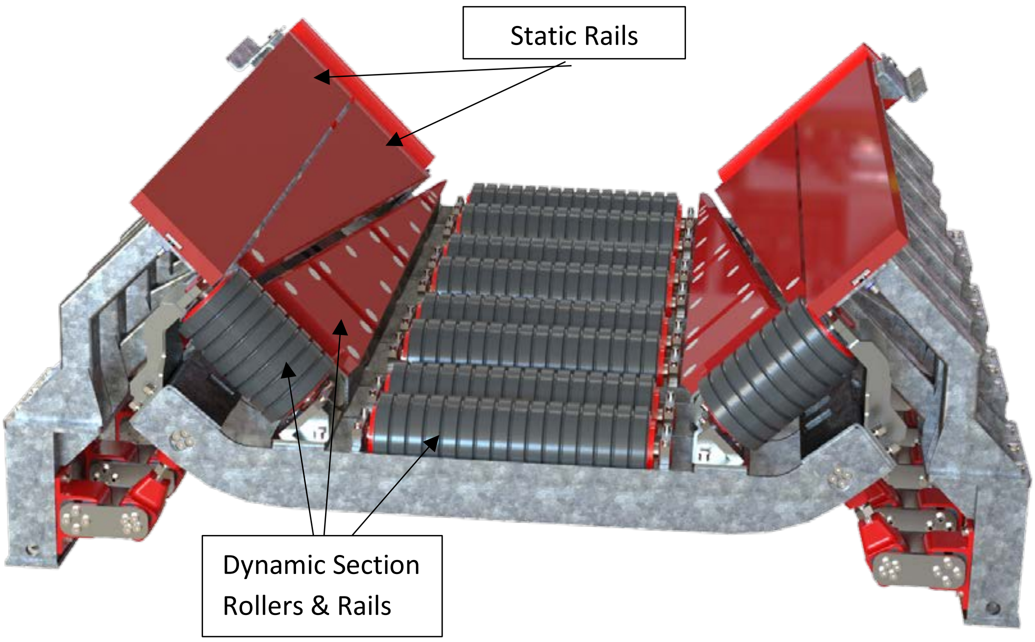

Figure 32 - K-Shield Dynamax® Combi Impact Bed

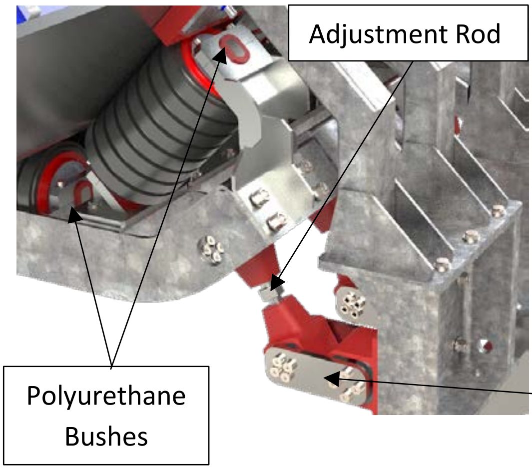

Figure 33 - New torsion spring configuration

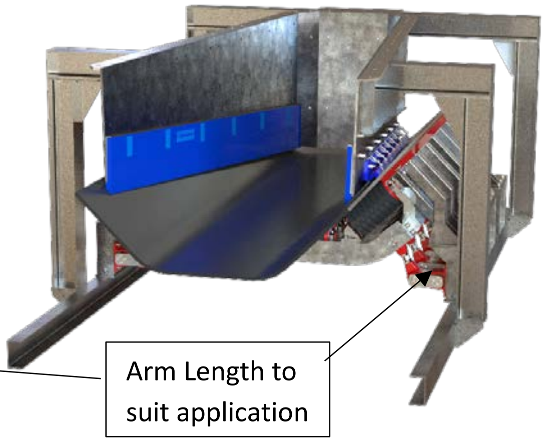

Figure 34 - Tapered chute assembly

Moving away from 'off the shelf' torsion spring assemblies allowed us to control the distance from pivot-to-pivot points, thus optimising dynamic travel for a given impact force. This will allow for any future application to be fine-tuned, within the limits that the packaging envelope allows. It also allowed us to incorporate an adjustment rod, that will allow the ride height of the dynamic section to be maintained over the life of the torsion springs, an issue encountered with the K-Shield Dynamax® Impact Idler (Portelli, 2019). Design incorporations from lessons learnt in other transfer applications include:

- Combi design to take the largest friction forces out of the equation
- Polyurethane isolation bushes incorporated to all impact loaded rollers
- Pre-tension of one torsion spring to further dial in the dynamic system behaviour
- Completely independent dynamic sections to ensure springs are less likely to work together producing a higher (harder) spring rate
- Spring assembly is more open, making build up issues less likely
- Lead in rollers ensures excessive pressure on slider rails will not occur

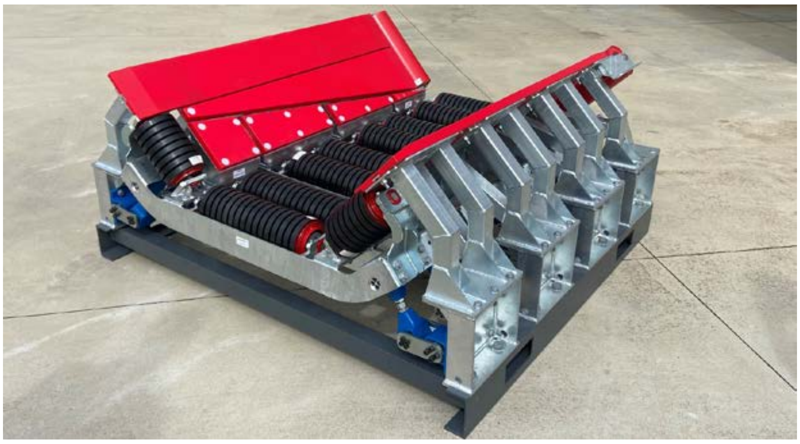

Figure 35 - K-Dynamax® Combi Impact Cradle ready for shipping

Bibliography

Australian Government Bureau of Meteorology. (2021, December). Scoresby, Victoria, Daily Weather Observations. Retrieved from bom.gov.au: http://www.bom.gov.au/climate/dwo/202112/html/IDCJDW3072.202112.shtml

Çengel, Y. A. (2006). Heat and Mass Transfer. New York: McGraw-Hill.

Department of Primary Industries and Regional Development. (2021, May 3). Climate in the Pilbara region of Western Australia. Retrieved from Agriculture and Food: https://www.agric.wa.gov.au/climate-change/climate-pilbara-region-western-australia#:~:text=Temperature%20in%20the%20Pilbara&text=In%20northern%20inland%20areas%2C%20such,%C2%B0C%20across%20the%20region.

Nylacast. (2019, February 01). Nylacast Nylube. Retrieved from nylacast.com: https://cdn-nylacast.s3.eu-west-2.amazonaws.com/nylacast/uploads/2015/08/NylacastNylubeTechnicalData19.pdf

OKULEN. (2013). OK 1000 Technical Data. Ahaus-Ottenstein: Ottensteiner Kunststoff GmBH & Co.

Portelli, C. T. (2019). Reducing Belt Conveyor Transfer Impact Energy Using a Dynamic Idler. 13th International Conference on Bulk Materials Storage, Handling and Transportation (ICBMH 2019), 272-290.

Ptak, A., Taciak, P., & Wieleba, W. (2021). Effect of Temperature on the Tribological Properties of Selected Thermoplastic Materials Cooperating with Aluminium Alloy. Materials.

Wear Systems Solutions. (n.d.). Photo courtesy of WEAR SYSTEMS SOLUTIONS, thanks to Chris Uchtman.