TDF: the fossil fuel alternative

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Escalating fossil fuel prices, an increased competitive environment and the pressure of more stringent environmental regulations remain primary concerns for the cement industry. However, there is one variable that most cement plants can control directly: their thermal energy costs. With coal still being the number one natural resource used in cement manufacturing facilities worldwide, its substitution by end-of-life tyres is not only environmentally sound, but will also help increase a cement plant's sustainable competitive advantage.

Figure 1: CM Tyre TDF SYSTEM – processes passenger car and SUV tyres into a 50mm clean cut chip at a rate of 10-12 tph

Tyre Derived Fuels (TDF), which is an umbrella word, comes in various shapes, forms and costs. The most common ones used for co-processing in cement kilns are: whole tyres, tyre chips and crumb rubber. Since fewer kilns can co-process whole tyres effectively and as crumb rubber is more expensive, a middle of the road solution is the use of tyre chips. Key factors involved for co-processing tyre chips include:

- Physical properties of the tyre chip: chips must be precisely cut and as free as possible of protruding wires.
- Location and the timing of introduced chips
- Sulphur, alkali and chlorine balances
- Ability to prepare a different raw material mix, at the same or lower cost
- Handling or injection equipment: tyre chips cause equipment to wear. A reliable handling and firing system needs to be designed for your specific application.

There are no general guidelines for operating technique, since the above functions are highly dependent on individual cement kiln design and requirements. The only barrier for co-processing tyre chips in cement kilns is the economic feasibility compared to other alternatives. All the others can be overcome.

Current practice

Cement kilns worldwide account for over 50 per cent of tyre chip use. They are ideal for disposing of TDF as high temperatures ensure complete burnout of organics, which controls the formation of dioxins and furans, a primary concern in solid waste combustion.

In addition, the cement production process can utilise the iron contained in the tyres steel beads, belts and ply. A 10kg automobile tyre typically contains 1kg of high-grade steel. The iron can partially substitute the Fe_2O_3 requirement in the raw meal mix. In given quantities, these components do not change the quality of the cement. Some cement producers may even want to remove the steel from the tyres and recycle it at the high current scrap market values.

Moreover, no special equipment for emission control is necessary, although it is always recommended to have continuous emissions monitoring in place. There is not really a need to convert or adapt the pollution measuring and control devices, except in the case when a kiln is running with higher CO levels, especially when one operates ESPs. But before even thinking about modifying or replacing a

filter, through a good process optimisation assessment, many process issues can be alleviated, making room to more efficiently co-process tyre chips.

Common pitfalls

Although the co-processing of large amounts of TDF as an alternative fuel has been successfully demonstrated, many cement kiln owners still struggle to derive measurable benefits from its substitution for a number of underlying reasons, such as:

- Lack of drive, commitment and a good dose of optimism. Co-processing is not a trivial side activity. It requires a firm top-down approach with a clear goal.
- Not enough market knowledge for cement producers to position themselves as the best alternative between the waste tyre market and their kilns.
- Insufficient practical combustion experience. They will struggle to successfully co-process volumes that matter, while trying to maintain clinker capacity and maintain or reduce emissions.
- Poorly prepared TDF, along with inadequate handling systems.
- Cement producers should resist the temptation to buy off-the-shelf TDF handling systems, until their needs have been properly identified. Sluggish feed has to be prevented at all cost.

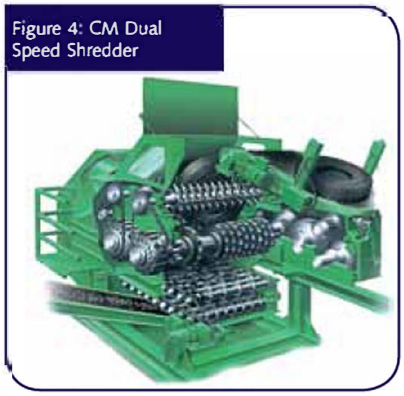
Figure 2: poor quality rubber chip

Figure 3: a CM tyre shredder produces a 50mm clean-cut tyre chip, ideal TDF for cement kilns

Tyre chip quality and preparation

As with any other alternative fuels, physical and chemical balance is crucial. One of the main reasons tyre chips become a handling nightmare and affect the bottom-line is when the tyre chips become entangled from the protruding wire and create a 'bird's nest' (see Figure 2) which will make it virtually impossible to properly control the required amount of heat input and not upset your kiln. Therefore, clean cut chips, produced with a reliable shredder (see Figure 3), will eliminate the uneven heat distribution of tyre chips when they are introduced into the kiln.

Figure 4: CM Dual Speed Shredder



A clean-cut, consistent chip size is essential when producing TDF that is being fed into a cement kiln. Close knife-to-knife tolerances and superior knife materials are the two contributing factors to producing cleanly cut chips from whole tyres with no loose or exposed wire (see patented knife systems panel).

CM manufactures tyre recycling equipment systems designed specifically for reducing whole tyres into clean-cut nominal tyre chips which have become the solution both in cost savings and increased production for cement companies (see Figures 1 and 4).

In addition, CM has several variations for turnkey zero waste, steel reclamation equipment systems featuring the CM2R

Farmer supports Asia Cement

New Zealand discards between four and five million tyres a year. Until now, those tyres have been discarded all over the countryside, tossed away onto farms, or dumped along roadways, riverbanks and other rural properties creating serious fire hazards and mosquito infestations. Over the years, many of these tyres found their way onto Owen Douglas' farm and after decades of losing the battle with illegal dumping, he decided to make it his mission to find a way to responsibly eliminate the tyre piles littering his land and his country.

Owen concluded that the best way to rid his country of all the tyre piles and all future tyre disposal was to shred the tyres for TDF and he set up his new venture as Tyre Disposal Ltd. At this time, he was also having conversations with the team at CM. They chose to investigate the options for potential markets for Mr Douglas and contacted Chris Aum, sales manager for e & Resources of Korea and CM sales representative for Asia. Chris was able to arrange for Owen to meet with the group at Asia Cement, located just outside of Seoul to discuss the opportunity.

Early last year, the meeting took place and in less than 15 minutes Asia Cement eagerly agreed to take as much TDF as Tyre Disposal Ltd could produce and ship. With this agreement now in place, Owen placed the order with CM for a CM Dual Speed Tyre Shredder a rugged two-speed, stage-one processing system built for reducing whole passenger car, SUV and tractor trailer tyres into 50mm (2in) clean cut tyre chips at a rate of 8-12tph. The agreement with Asia Cement is to ship 1000 20ft containers of 50mm tyre chips (20,000t) to Korea annually.

After a lengthy trans-global ocean voyage, the shredder landed in the Port of Tauranga in late January and was delivered to Owen Douglas. Shortly after arrival CM field technician, Ziggy Kotlarczyk travelled to Tauranga to oversee the assembly and start-up of the CM and to provide training in operations, maintenance, and safety procedures of the CM tyre shredder for all Tyre Disposal employees.

and 4R Liberator for this application as well.

CM has been building whole tyre reduction systems since 1982 and has installations in place at many of the largest cement companies, including Lafarge, Holcim, Cemex, Sapphire Energy Recovery, Ltd, Geocycle, Asia Cement and Cimpor. All of these companies are actively receiving end-of-life tyres at their facilites and processing on site.

Currently, CM is working on an installation for YTL Cement Co, the shredder company's first installation in Malaysia. It is installing a Dual Drive Single Speed Tyre Shredder in the autumn. CM also has an order for a Dual Drive Tyre Shredder for Dundee Tyres Ltd in the UK which also produces TDF for the cement industry.

Inside the kiln

As shown in Table 1, over 80 per cent of a tyre is carbon and oxygen, which accounts for its rapid volatilisation and high heat value. Nominal wire tyre chips contain approximately up to 33GJ/t, where sub bituminous coal contains only between 27-29GJ/t.

Tyre chips can be completely combusted in a cement kiln. The combination of high temperatures (1450-1500°C), a positive oxygen atmosphere and a long gas and tyre chip residence time (4-12secs at the elevated temperatures) assures the complete combustion. With an average sulphur content of 0.5-1.5 per cent, it is on par or less than most coals and petcokes. In terms of substitution, when co-processing tyre chips, a kiln operator can reduce coal by 1.25t for every 1t of tyre chips used. As far as emissions, tyre chips and TDF in general, are known to help reduce the NO_x levels up to 30 per cent, if injected in the right spot under optimised conditions.

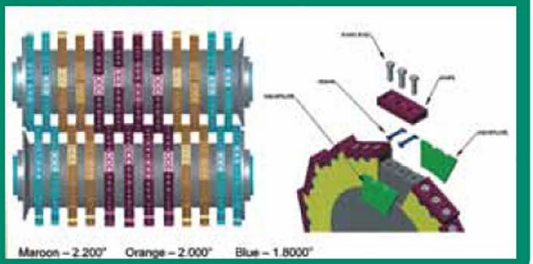
Patented knife systems

The success of CM as a leader in tyre reduction systems for the cement industry is that all CM Shredders feature the Holman™ patented knife system designed for extremely close knife tolerances which result in tyres being cut cleanly with a minimal amount of exposed wire thus, eliminating clogging or slowed delivery to the kiln.

CM shredders feature patented knife design systems designed for extremely close knife tolerances which result in tyres being cut cleanly with a minimal amount of exposed wire. A variety of knife configurations are available, including two standard designs:

The Multi-Stack utilises multiple width knives in the same machine, allowing worn knives to be sharpened and reused. Knives are used a total of three times – thus reducing knife costs by 200 per cent.

The Double-Stack system has taken CM's proven Holman knife design and adapted it to stay sharp longer and to process larger tyres with less horsepower. By placing the knives side-by-side or by 'double-stacking' they can be operated until worn, then removed and repositioned for a second use without regrinding them. The side-by-side design results in less energy consumption and allows the knife to be utilised a total of six times – reducing costs by 300 per cent.



From a process perspective, certain rules need to be taken into consideration to ensure success:

- As a non-linear rule, the smaller the chip size the higher the substitution rate can be. However, a 25x25mm chip size is about the smallest size that can be produced efficiently with shredders. It is key, though, to have a short and strong flame with sufficient momentum. If one doesn't have a multi-channel burner with the ability to adjust axial and radial settings, other solutions exist to emulate the desired effects.
- Via the main flame, the temperature, oxygen, micro mixing and time are far in excess of what is needed for complete combustion, even with the strong organic bonds. The hydrocarbon chains in TDF are similar to the ones in coal, hence as easy to break and volatise. As proven, additional mixing, or the creation of an accelerator, could be beneficial for calciners.
- For long kilns, the chips need to be blown to the back of the burning zone to minimise impact on quality and SO_3

Table 1: chemical composition of tyres vs coal

Fuel element (%)	*TDF*	*Coal*
Carbon	83.87	73.92
Hydrogen	7.09	4.85
Oxygen	2.17	6.41
Nitrogen	0.24	1.76
Sulphur	1.23	1.59
Ash	4.78	6.23
Moisture	0.62	5.24

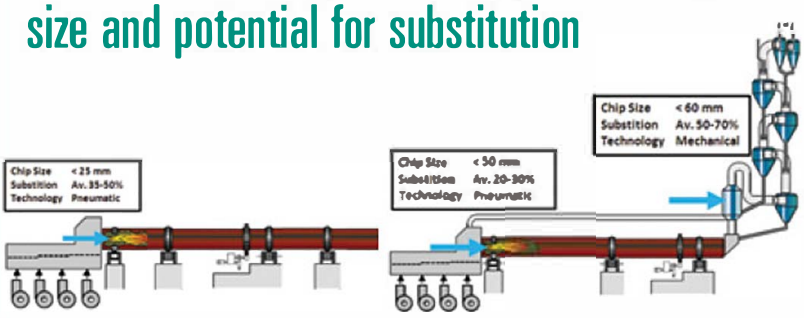
cycles. Ideally, the injection pipe should be located above the main burner, at a 5-10° angle, so the main flame can carry the chips further and start the volatilisation prior to the chips striking the load. Injection velocity of 50m/s should be the goal.

- If one has a precalciner, injecting the chips in the vessel over the main flame is preferred. For a preheater on the other hand, the main burner is preferred.
- Finally, the impact of raw materials on SO_2, CO, VOC, DIFs needs to be fully understood and tracked, prior to co-processing any chips.

Unless you are prepared to try and maybe achieve satisfactory results by trial and error, a careful kiln assessment is advised to determine the current pyro-processing conditions, which will result in the selection of the best injection location, among other key aspects. To achieve higher substitution rates, it is highly recommended to perform MI-CFD modelling prior to envisioning expensive modifications to the kiln systems.

At least 60 per cent of the kilns worldwide do not operate under optimum process conditions. If one decides to co-process tyre chips under those conditions, there is a high risk that production levels will be affected. In its experiences, Alterros has found that after putting the kiln system through a fitness test, using qualified process engineers, production levels can be increased, along with reaching healthy co-processing rates.

Depending on the kiln system, the following rules of thumb apply with regards to chip size and potential for substitution



Korean order for CM Dual Speed Shredder

CM Asia, managed by sales manger Chris Aum of e & Resources of Korea recently completed the installation of a CM Dual Speed Tyre Shredder for Osung Resources in Korea. This stage-one machine is designed to process whole passenger, SUV and truck tyres at a rate of 8-12tph. The CM Dual Speed is configured to produce a 50mm tyre chip to be used as TDF and sold to a local cement plant in Daegu located on the Korean peninsula.

Daegu is a large city with a population of over 2.5m people and Osung is planning to process 20,000tpa to support recycling efforts for this region. Osung's president is already a pioneer in the waste plastic treatment field and is currently the president of the Waste Plastic Association in Korea. He employs more than 50 workers and now plans to acquire another factory to process end-of-life tyres in another largely populated region and strives to be the top tyre recycler for all of Korea. CM has several installations currently in operation throughout Korea.

Potential for co-processing TDF in developing countries

The potential in Africa, China and Latin America is just as big as in any other countries, possibly even more. Often, no regulation (and if so, lack of enforcement) really exists in developing countries, so tyres are a liability. It boils down to the cost of the alternative though. It is better if legislation is in place to promote the beneficial re-use of TDF through co-processing. This being said, the lack thereof shouldn't stop the establishment of projects, as long as it makes economical sense.

As a matter of fact, from a competitive landscape perspective, co-processing is usually the best solution around, as no recycling programmes exist (and recycling is higher up the waste management hierarchy than co-processing).

Does it pay?

In evaluating current market prices worldwide, coal is selling anywhere between US$60-140/t. The current average price per tonne of 50x50mm nominal recycled tyre chips for 2019 was US$24/t. Assuming a coal cost of US$100/t and a delivered chip at US$25/t, a quick calculation shows that replacing 20,000tpa of coal, can save your company a recurring US$1.8m per year!

In certain cases, additional benefits can be found as the iron in the tyre chip can help displace traditional iron-containing materials or additives, which usually come at a cost.

Conclusion

Co-processing tyre chips as an alternative energy source can not only lower costs in a sustainable manner, but will have a direct benefit on the community. Unsightly tyre piles are a known fire hazard and can also collect water, which in some countries is the perfect breeding ground for mosquitoes and the associated diseases they transmit.

In some parts of the world government incentives are available for using alternative energy solutions and will work with a facility to incorporate the process.

To have a successful tyre chip programme, do not neglect the other facets of the supply chain, which is the supply and logistics of delivering whole tyres to the shredding facility. A full assessment of the waste tyre market, supply chains and current kiln operations will determine how tyre chips can create lasting benefits for your company, stakeholders and your environment.