

## Safe and Clean Rubber Reclamation Technology Using Continuous Screw Devulcanizer

Vulcanization is a process where polyisoprene (natural rubber) is mixed with sulphur at a relatively high temperature and the resultant 3-dimensional cross-links of C-C, S-S and C-S bonds are extremely difficult to separate back to their original forms, thus giving vulcanized rubber its unique properties for high stress applications like tyres.

However, the same thermosetting properties that make vulcanized rubber an excellent material for making tyres also make them non-biodegradable and difficult to recycle. Thus finding a way to reverse the vulcanizing process and allowing the resource to be reuse has become a most pressing ecological challenge in recent years.

This reversion process called devulcanizing attempts to selectively break or delink the S-S and C-S rings, and longer chains are formed, giving the devulcanized crumb rubber or reclaimed rubber better viscoelasticity properties.

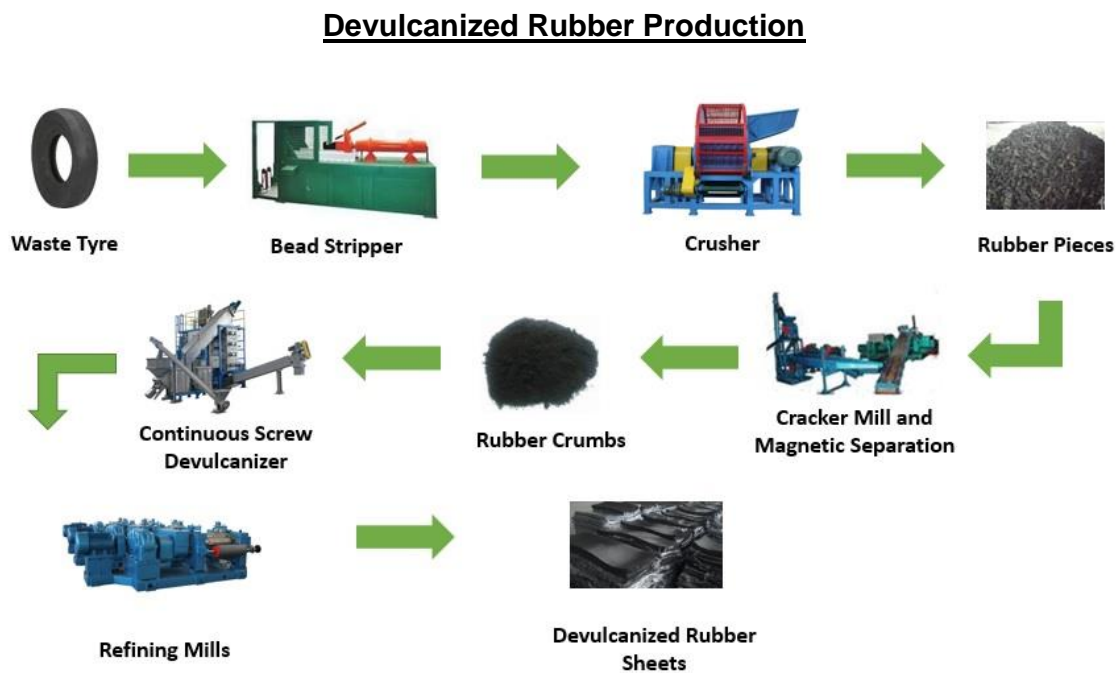
However, rubber devulcanization technology has not enjoyed much development since Charles Goodyear received his US patent for vulcanizing rubber in 1844 because of one or more of the following reasons:-

- 1) operating at very high (and unsafe) pressure – up to 4 MPa (40 Bar);
- 2) operating at a very high temperature – up to 300°C;
- 3) subjected to extremely large shear forces, requiring high power consumption ;
- 4) requiring to supply a special form of energy, e.g., ultrasonic and microwave radiation;
- 5) subjected to a mixture of highly toxic reagents, catalysts and/or promoters;
- 6) highly polluting to the environment due to discharge of water containing toxic oil and heavy metals and sulphur dioxide and carcinogenic dioxins into the air;
- 7) requiring an unusually long processing time, even for partial devulcanization of cured rubber or elastomer; and
- 8) only capable of devulcanizing the surface of rubber crumbs.

## Devulcanized Rubber Production

Bead is removed from tyre by a bead cutter, and the casing is fed to a crusher to be cut into pieces of 50 – 80 mm. Steel wire from beads is separately removed by a bead grinder. The tyre pieces are crushed in a cracker mill to loosen the rubber from the steel or nylon; steel and nylon fibres are removed by magnetic and nylon separators, and rubber crumbs of 5 – 28 mesh are sieved out by vibrating screeners.

Crumb rubber is devulcanized, and after devulcanizing could be used as it is or is further processed in refining mills to produce reclaim rubber sheets of required tensile strength and elongation.



## Conventional vs New Devulcanizing Systems

The conventional method of delinking is done in a devulcanizer where high pressure of up to 4 MPa and temperature of up to 300°C is required, and water is used as a medium. This process has its inherent safety risk due to the high pressure employed. Energy consumption compared to output is high, and product consistency is difficult to maintain. Furthermore, discharge of waste water and noxious fumes is injurious to health and pollutes the environment.

Maxlink's new thermo-mechanical devulcanizing technology, using the patented continuous screw devulcanizer operating at atmospheric pressure, consumes relatively less energy, and is much safer and eco-friendly because the process does not require high pressure and steam, hence no waste water is discharged and little fumes emitted. Rubber reclaiming plant using this equipment would meet the most stringent environmental requirements.

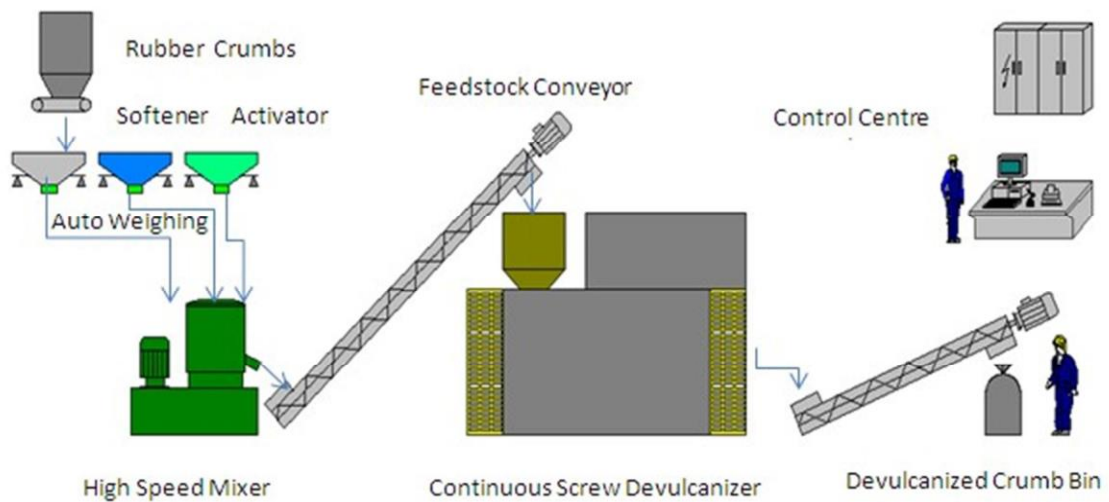
High Pressure Dynamic Devulcanizer (Old System)	Continuous Screw Devulcanizer (New System)
High pressure – 2 to 4 MPa (20 - 40 Bar) High temperature – 220° to 300°C	Operates at atmospheric pressure. Pressure vessel safety inspections not required. Meets all standard safety requirements.
Steam heating – 2 ton/hour Boiler required – 800 Kcal	Thermal heating (hot) oil or electromagnetic induction used. No boiler required.
Water used in process. To produce 1 ton of rubber, 250 lit of water is required, and hence 250 lit of effluent is discharged.	No water is discharged to pollute environment.
Devulcanizing – 3 hour/batch. Loading and unloading – 3 hour/batch. 3 – 4 operators required for process.	Continuous feeding of raw materials. Only 1 operator is required for fully automatic line, saving labour costs.
Production capacity – 3.5 to 4 ton/day.	Production capacity – up to 8 ton/day. Output doubled.
Power consumption – 230 to 260 kw/ton.	Power consumption – 20 to 30% lower energy consumption.
End products still at high temperature, and may burn during storage.	End products cooled to less than 60° C – no fire risk.

The above comparison is based on equivalent production capacity of 6 m<sup>3</sup> for each system.

## MSD-10 Continuous Screw Devulcanizer



## Continuous Screw Devulcanizing Process



## Eco-friendly

Using Maxlink's eco-friendly technology, end-of-life tyres can be recycled 100% with no residual waste and minimal emission to the atmosphere. The tyres are first completely crushed into rubber crumbs, steel and nylon fibres, and the rubber further processed in the patented MSD-10 continuous screw devulcanizer. Water used in the process constitutes less than 5% of the feedstock and is re-circulated, whereas in other systems water content may be higher than 25% and will be discharged after each production batch, causing runoff of toxic oil and heavy metals into our ground water. Sulphides released from the devulcanizing process are trapped in gas scrubbers to prevent noxious smoke escaping into our atmosphere.

Maxlink's pioneering status in odourless devulcanized rubber manufacturing is acknowledged in the industry; this technology has allowed wider usage for products made from it, like antistatic mats used in cleanrooms and office environment.

This clean and green technology has been approved by the Chinese government in the world's largest rubber consuming market as the technology of choice to replace the older systems.

## Safety

The Maxlink continuous screw devulcanizer operates safely at atmospheric pressure as opposed to the conventional dynamic devulcanizer which requires 2 to 4 MPa (20 – 40 Bar) pressure to work.

Rubber crumbs are water-cooled to around 60°C before being discharged from the screw devulcanizer, as opposed to older systems where the rubber is still at high temperature when discharged and fires from self-combustion may occur.

Materials used in process conform to REACH standards and using them would not be injurious to the health of workers or users.

## Efficiency

Maxlink solutions are designed with a high degree of automation and energy-saving to reduce manufacturing costs and consumption of valuable resources.

Equipment and operation throughout the production line were designed with the objective of saving labour. Materials are moved between work stations by conveyor systems – belt, screw, bucket and pneumatic types are all being employed.

The Maxlink continuous screw devulcanizer is computerized and only requires one operator compared to 3 or more for the other systems. It uses electromagnetic induction for heating which saves energy consumption and lowers maintenance cost.

The refining line in Maxlink’s system configuration is also highly efficient, requiring only 2 operators to run the entire line, reducing manpower requirement by 60 – 75%.

These 3 key advantages of the continuous screw devulcanizer – eco-friendly, safety and efficiency – have addressed the main concerns pertaining to usage of the older systems.

**Benefits**

Maxlink’s devulcanized rubber is used mainly for 3 reasons – as a source of rubber hydrocarbon or carbon black, or as a process aid. It generally contains about 50% rubber and 20% carbon and is less expensive than the virgin materials it replaces, and requires less mixing time and power consumption when processed. Thus, its prime benefit is cost reduction.

**Grades of Devulcanized Rubber Produced:-**

Product	Tensile (MPa)	Elongation(%)	ML[ (1+4)100]
Odourless Reclaim Rubber	7 – 9	220 – 330	75 – 85
High Tensile Reclaim Rubber	10 – 12	300 – 380	65 – 75
Standard Reclaim Rubber	7– 9	220 – 330	75 – 85

As a processing aid, the benefits that Maxlink’s devulcanized rubber offers include:-

- a) shorter mixing times
- b) lower power consumption
- c) lower heat build-up
- d) lower thermoplasticity
- e) minimum reversion
- f) better dispersion
- g) lower swelling and shrinkage
- h) higher cure rate
- i) lower deformation
- j) better aging
- k) improved tackiness

## Applications

The devulcanized rubber crumbs can be used as it is or further milled into reclaimed rubber sheets of the required tensile strength and elongation. Devulcanized rubber is sold at a third to half the price of natural rubber, and is a low-cost material for making many rubber products. For products requiring better viscoelasticity, devulcanized rubber could be a more suitable material than natural rubber.

Devulcanized rubber is used in the manufacture of:-

- a) tyres
- b) tyre retreading materials
- c) tubes and flaps
- d) shoe soles
- e) conveyor belts
- f) bitumen binders for asphalt pavement
- g) sports and playgrounds
- h) railway sleepers and crossings
- i) adhesives
- j) water proofing materials
- k) Portland cement
- l) other rubber moulded products.

China leads the world in the production and consumption of reclaim rubber, using 4 million tons or equivalent to the weight of 88 million truck tyres or 440 million passenger tyres in 2013.

In 2013, the Chinese government has enforced regulations to stop the operation of polluting rubber reclaiming plants and encouraged them to switch to the new safe and non-polluting technology or install air and water treatment systems. In 2014, the government has also directed the rubber industry to stop the usage of materials containing carcinogenic hydrocarbons, like coal tar and certain grades of pine tar, and to comply to REACH standards in manufacturing. China has taken the lead to make tyre recycling a green and sustainable commercial activity.

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