HEAVY MOVABLE STRUCTURES, INC.

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E-Chain Dynamic Cable Management Systems

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The evolution of dynamic cable management systems

The rise of energy chain cable carriers

Along with the invention of machinery a need arose to have a flexible power cord that could provide power to a moving system. As machinery grew bigger and faster the challenges of handling the cables multiplied and innovation was needed to keep machines running. At first, cables were dragged along the ground. Then they were hung in the loops of a festoon style configuration. Conductor bar provided power and allowed systems to travel farther distances, but had limitations also conveying control signals. Cable reels provided a way to achieve longer distances with power and data, but single composite-style cable solutions did not provide enough flexibility for all applications.

Then there was the conception of the energy-chain. This new cable management product allowed for the guiding and protecting of not just cables, but hoses as well. The energy-chain provided a completely customizable cable management solution made from standard parts. It allows for endless configurations of cables and hoses and can be used in all kinds of environments. It can be used to protect cables in all kinds of motions whether they be linear, three dimensional or even rotational. It is the Swiss army knife for dynamic cable and hose management. The acceptance of the energy chain as a standard has happened in many industries involving heavy machinery already and is slowly making it’s presence known in the Heavy Movable Structures industry.

An overview of old technologies for managing cables and hoses

Droop cable systems

One of the most basic techniques for passing an electrical cable package from a static to a moving structure, droop cables do just that – a heavy, armored composite cable containing power, control and data communication cables pass from land to the moving object. One of the more common multi-conductor solutions for use on bascule, lift and swing bridges, the droop cable can carry a load between 600 and 2000 volts while remaining somewhat flexible enough for routine operation. These cables can be up to 5 inches in diameter and can contain up to 125 conductors. The ability to survive harsh conditions make droop cables an appealing solution for the movable bridge industry, but their heavy weight, lack of guided protection, expensive purchase cost and long lead times can be a real burden for new installations as well as maintaining operation of existing structures.

Festoon systems

Out of a need to supply cabling to a movable structure over a long span, festoon systems were developed using simple components to transmit power, control and data from point A to point B in a simple, managed fashion. A group of basic components keep these systems quite uniform, albeit maintenance intensive. Festoons utilize an I-beam rail to guide the system, wheeled trolleys to ensure the cable

moves with the structure, a saddle system to route and contain the cables, tow ropes and shock cords to pull the trolleys with the moving end of the machine, and cabling. These solutions require greater overhead space to accommodate hanging cable loops, 10-15% of the total travel length designated as storage space, and tend to be mechanically harsh on the cables themselves.

Busbar systems

The busbar system provides an economical solution for supplying local high current power distribution to a movable structure. Most commonly using copper conductor bars to transmit the power feed, the system supplies power through a series of 'shoes' located at the moving structure's tow arm. The system can be easily expanded upon for future growth, but can prove to be difficult to maintain – especially if there are numerous structures operating off a lone conductor bar rail. This solution also lacks an integrated feature that provides data communication. For high voltage applications, specialized technicians may be required to make repairs or modifications to the busbar system. Climate conditions – especially those close to corrosive maritime environments – can heavily impact the reliability of busbar solutions.

Cable reels

Cable reels are large, drum shaped cable management systems used to dispense and coil various types of electrical cables. These reels can range in size depending on the application's cable requirement – typically multi-conductor composite cables with a sizable outer diameter. The drum size is dependent on the length of travel that must be achieved – with longer travels requiring larger, heavy duty motor driven reels. These large reels add significant weight to the structure it is being installed on, and introduces several additional points of maintenance. Slip ring systems, motors, and composite cable replacement are all costly long-term maintenance concerns. In many cases, should one critical conductor within the composite cable fail during operation, the entire composite cable must be replaced at a high cost and generally long lead time.

New technology in tribo-plastics enables the creation of Energy Chain cable carrier systems

Tribology

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. Tribology is highly interdisciplinary. It draws on many academic fields, including physics, chemistry, materials science, biology and engineering.

A quick history lesson from wiki…

"The Jost report"[i] which was published back in the 60's identified the huge cost of friction, wear and corrosion to the U.K economy which was estimated at 1.1-1.4% of the GDP. Despite considerable research since the Jost Report, the global impact of friction and wear on energy consumption, economic expenditure, and carbon dioxide emissions are still considerable. In 2017, Kenneth Holmberg and Ali Erdemir attempted to quantify their impact worldwide.[ii] They considered the four main energy consuming sectors: transportation, manufacturing, power generation, and residential. The following were concluded:[iii]

- In total, **~23%** of the world's energy consumption originates from tribological contacts. Of that, **20%** is to overcome friction and **3%** to remanufacture worn parts and spare equipment due to wear and wear-related.
- By taking advantage of the new technologies for friction reduction and wear protection, energy losses due to friction and wear in vehicles, machinery and other equipment worldwide could be reduced by 40% in the long term (15 years) and 18% in the short term (8 years). On a global scale, these savings would amount to 1.4% of GDP annually and 8.7% of total energy consumption in the long term.
- The largest short term energy savings are envisioned in transportation (25%) and in power generation (20%) while the potential savings in the manufacturing and residential sectors are estimated to be ~10%. In the longer term, savings would be 55%, 40%, 25%, and 20%, respectively.
- Implementing advanced tribological technologies can also reduce global carbon dioxide emissions by as much as 1,460 metric tons of carbon dioxide equivalent ($MtCO_2$) and result in 450,000 million Euros cost savings in the short term. In the long term, the reduction could be as large as 3,140 $MtCO_2$ and the cost savings 970,000 million Euros.

Triboplastics

Triboplastic is the word that was invented to describe injection-molded polymer parts that are tribologically optimized for low wear and long life. The engineers at igus® develop more than 100 new polymer compounds every year and analyze their tribological characteristics in the igus® R&D center in more than 7,000 tests. All results are placed into an extensive material database. Based on this data, it is possible to offer a precise prediction of the lifetime for a part in almost any given application. This has fulfilled the dream of many an engineer: predictable performance that requires absolutely no lubrication.

Energy Chain technology has been tested and proven in other heavy machinery industries

Applications in other industries

Although motion plastics systems are only recently making headway in the Heavy Moveable Structure industry, the technology has been tried and true in various other industries. Some examples of other industries motion plastic systems have excelled at are the:

- Offshore Industry
- Port Industry
- Material Handling Industry
- Steel Industry

Offshore industry

Motion plastics systems are featured on numerous applications in the offshore industry – including some of the harshest environmental conditions faced on the open sea. Energy Chain systems have been tested and proven on equipment such as skidding systems for jack up rigs, pipe handling systems, offshore pedestal cranes, access platforms, top drives, and numerous other types of applications.

Port industry

Port and terminal facilities are another example of an industry that has taken full advantage of Energy Chain systems. Featured on the most prominent equipment in the industry – ship-to-shore (STS) cranes,

rubber tyred gantry (RTG) cranes, rail mounted gantry (RMG) cranes, and automated stacking cranes (ASC), igus motion plastic systems have proven to be a trusted solution for the most demanding applications at a port. Design engineers, equipment owners and operators, and maintenance personnel alike have all realized the benefits Energy Chain systems can offer.

Material handling industry

Bulk material handling applications have also proven to be an exceptionally harsh environment for all types of cable management. Equipment manufacturers and equipment owners have turned to igus' motion plastics for a reliable, lasting solution. Motion plastics offer the ability to convey power, control, communication and data cables in a rotary motion without the use of a slip ring. This ultimately enables equipment owners to operate around the clock without the fear of unplanned downtime for system failures or frequent maintenance.

Steel industry

The Steel Industry is starting to make a comeback and in doing so they are looking for ways to be more efficient and more economical. By utilizing motion plastics, the steel industry is able to accomplish both tasks. Incorporating the motion plastic system with steel facilities cranes, cutting machines, plate finishers and coil transporters, among dozens of other applications has led to less down time and an overall increase in production. With these capabilities, motion plastic systems have become a global partner with hundreds of steel industry facilities worldwide. With the motion plastic systems being in hundreds of industries, in thousands of facilities and in millions of applications it has been put through all type of real world test applications and it has become a tool of choice by so many. With all unknown products there have been some skepticism, trying to buck the trend of industry standards such as festoons and droop cables or bus bars, but no one has been able to argue with the motion plastic system's capabilities once they saw it in action.

Where can Energy Chain be used on Heavy Movable Structures?

Potential opportunities to integrate motion plastics

As cable management solutions have evolved, they have found their way into the heavy movable structures industry in the form of motion plastics systems. There are numerous opportunities within the industry to integrate and benefit from the usage of Energy Chains, such as:

- Lift Bridges
- Swing Bridges
- Rolling Bascule Bridges
- Stadium Roofs
- Kinetic Architecture

Lift Bridges

Lift bridges such as the Portsmouth Memorial Bridge has integrated an Energy Chain system as its primary cable management solution to eliminate frequent breaks and damages to the bridge's cables. With the motion plastics system installed, it guarantees safe cable routing without any untwisting or bending. The Memorial Bridge's operational window was 30"x 14" and had an elevator speed of 4'/sec. It was installed with a 152' of vertical travel that has to endure over 18,500 cycles per year and also contend with the elements of rain, snow and ice.

Swing Bridges

Swing bridges like the Selby Bridge in England posed a unique challenge with a very small operating window. However, the motion plastics system and its uniqueness to have reverse bend capabilities allowed the system to fit inside the petal stool housing and accommodate the 110-degree turning radius that the bridge demanded. The operational window was so restrictive that a custom two-staged rotary application was utilized to ensure that the motion plastic system would fit and be fully operational.

Bascule Bridges

Specific types of bascule bridges can potentially benefit from the motion plastics systems as well. In particular, rolling bascule bridges can integrate a cable carrier inside its trunnion housing to guide cables from the raised to the lower positions of the bridge.

Stadium Roof Systems

Stadium roofs have become extremely fond of the motion plastic systems for not only their performance, but as well as their aesthetics. Motion plastics systems can be found in stadiums all across the world.

University of Phoenix Stadium in Glendale, Arizona

Arthur Ashe Stadium in Queens, New York

Mercedes Benz Stadium in Atlanta, Georgia

Singapore Sports Hub in Kallang, Singapore

The Energy Chain system's ability to fit into smaller operating areas and produce less noise than its counterpart, the festoon systems, gives stadium owners the ability to provide a friendly more eye appealing stadium to their fans.

Kinetic Architecture

Kinetic Architecture such as the independent LED screens found in Victory Plaza in Dallas, TX is another prime application for the motion plastics systems. Regardless of the number of cycles, or the extreme weather conditions the moveable plastic system can get the job done.

As the motion plastic system is starting to make a name for itself in the Heavy Movable Structure industry benefits can be seen all around. From bridges, to roof top stadiums to kinetic architecture the future is bright and the sky's the limit.

The importance of using the correct cable management solution to protect cables and hoses

Mechanical Stresses Caused by Motion

Mechanical stress endured by cables while powering moving machinery is one of the leading causes of cable failure. When cables are installed in a way where they are required to support their own weight or maintain their own bend radius throughout operation, individual conductor breakdown inside of the cable becomes accelerated. Add in other elements such as acceleration and deceleration forces of the system, wind, snow or ice load and you have a prime environment for cable failure. Once the copper stranding breaks down over time, continuity is lost and the cable fails. It is possible to alleviate this mode of failure by integrating guided cable protection in the form of a polymer cable carrier and continuous flex cables. Strain relief clamps used to fix cables at both the fixed and moving end while using a polymer cable carrier to protect the fill package from outside influences ensure reliability in scenarios that commonly cause droop cables, festoons, and cable reel systems to fail.

Abrasion and Wear Caused by Motion

Outer jacket wear on a cable is a result of the cable's exposure to repetitive contact over the same location for a prolonged period of time. The outer jacket of a cable acts as an overall armor to protect the internal conductors from being exposed to the surrounding elements. Once the outer jacket has been worn through, the internal conductors are left exposed and vulnerable to the local environment. Installing cables in a polymer cable carrier ensures the carrier is the item taking the wear as opposed to the cables directly. When installed correctly, the cables will lie in the carrier's neutral axis - meaning the cables are not pushing against the outer radius or pulling against the inner radius. Combine this with a jacket designed specifically to wear against a polymer material, and cable life will be effectively prolonged.

Damage from Outside Forces

There are many environmental factors to consider when determining the best type of cable management for your application. Life expectancy, ease of maintenance, durability, reliability, customer support, and total system price all play a role in selection. The ramifications of downtime or inoperability because of component failure play a vital role in every project's success. Since many instances of damage caused by outside forces cannot be predicted, it is best to ask questions that can be answered prior to your selection – such as parts availability after the solution has been installed, the costs and process required to replace these parts, customer support after implementation, and any testing results that would demonstrate the component has been proven to work in similar environments. For modular systems such as polymer cable carriers, sourcing spare or replacement parts in the wake of a catastrophic event have never been easier. Polymer cable carriers can be broken down to individual links – allowing replacement of specific sections rather than entire systems. Breaking multicore cables down into individual conductors and partitioning them inside of the drag chain makes cable replacement a straightforward and cost-effective task.

Why should designers start considering Energy Chain cable carriers for their projects?

Flexibility in Design from a Time & Delivery Standpoint

It's no lie that cable management is usually the last component designed in on most projects. By this time, space for cable management is limited and the time required to integrate a custom solution is dwindling. Thanks to the modularity of polymer cable carriers, designing and supplying a custom solution from the ground up gives the end user the option of integrating a custom solution on short notice. Working with existing system drawings or on-site surveys as a basis to design around, a catalog full of cable carriers and continuous flex cables provides numerous options for delivering a turn key solution. Delivering a solution that is ready to install as it shows up on-site cuts installation time and costs – a feat every job site strives to achieve when facing a tight schedule.

Safety

Given the proximity to pedestrians, operators, personnel and all those in-between, supplying a safe solution is critical to both the project designer and end user. Various 'classic' solutions leave those near exposed cables and conductor bars little protection from potentially deadly high voltage loads. Polymer cable carriers operate in a clearly defined guide trough system – away from those who may be working or walking nearby. Certain systems can also be outfitted with a top of the line safety feature capable of emergency stopping operation if force loads exceed preset parameters. On projects for the shore power industry, visual and audible cues were also integrated to signal the machine and cable carrier system were in operation. igus® operates the largest experimental and test laboratory for its industries. The testing facility is the beating heart of igus®' industry leading innovations. We test, inspect and develop under real conditions in a 19,000-square foot facility. We test both individual components, complete systems and customer application upon request. All of this is done solely with the objective of providing the best plastic product to our customers.

Cost Savings

When integrating polymer cable carrier technology, it is important to consider the Total Cost of Ownership (TCO) and Return on Investment (ROI) when weighing the usage of competing technologies.

On igus Energy Chains, parts marked for wear are non-existent. This feature alone eliminates the need to purchase said wear parts as well as pay labor costs associated with performing that maintenance. By eliminating routine maintenance, your equipment remains operational for longer periods of time – which translates to higher throughput and increased revenue as a result.

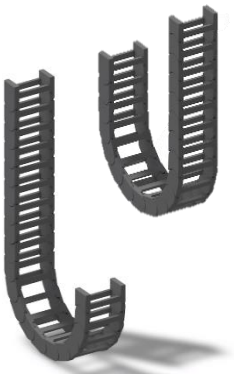
What factors are important when considering an Energy Chain system?

Filling and dynamic considerations

When designing with energy chain systems the most important design consideration is the fill package of cables and hoses. The size of the cables and hoses drive the height and width of the system as well as the bending radius that is needed to properly protect the elements inside. The next consideration is the amount of space where the system will need to operate. These are hard limits that must be considered in the design. Other considerations such as the speed and acceleration of the application can usually be addressed through product and material configurations.

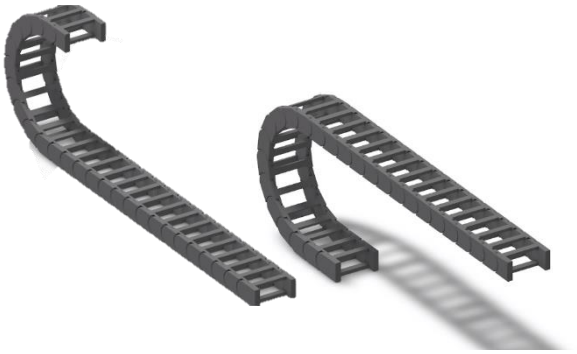
Different types of motion can easily be achieved when designing with an energy chain. Below you will find examples of different configurations.

Table 1 – Types of energy chain motions



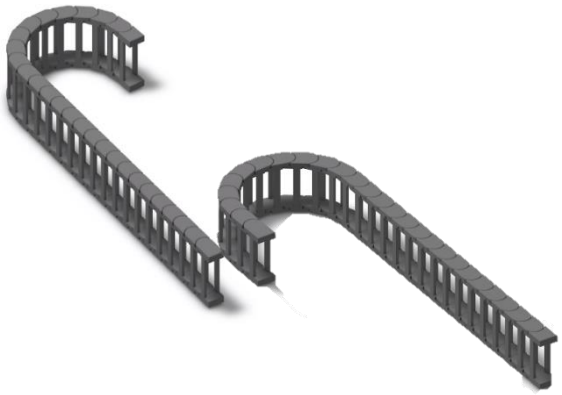
Vertical hanging configuration
Use in Lift Bridges

Vertical standing configuration
Use in Lift Bridges

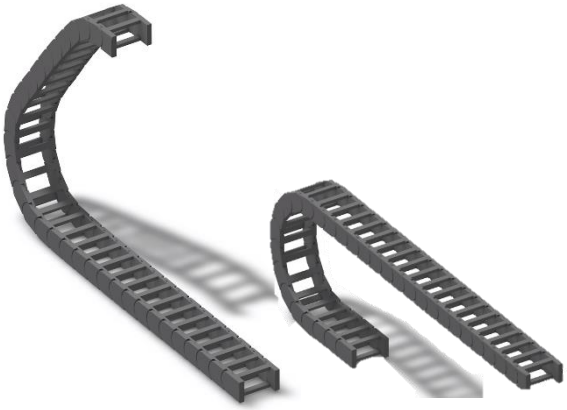


Standard horizontal configuration
Use in dams, roof systems and gates

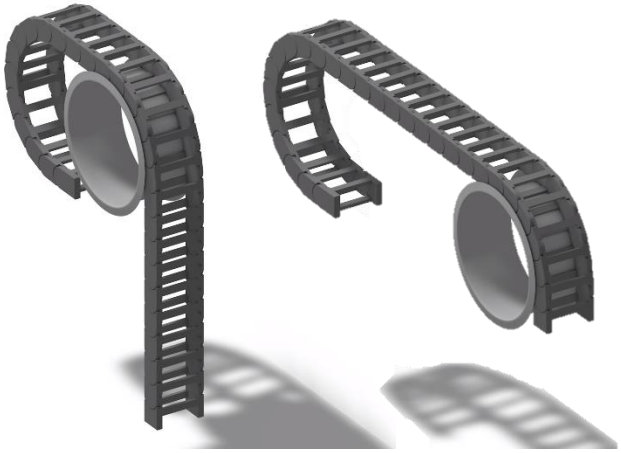
Standard gliding configuration
Use in dams, roof systems and locks



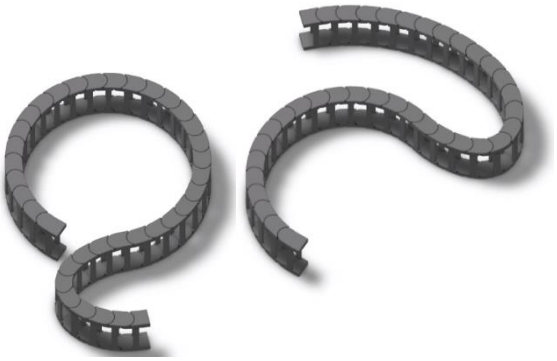
Side mounted configuration
Use in tight vertical spaces



Combined motion X+Z configuration
Possible use in bascule bridges



Specialty Motion configuration

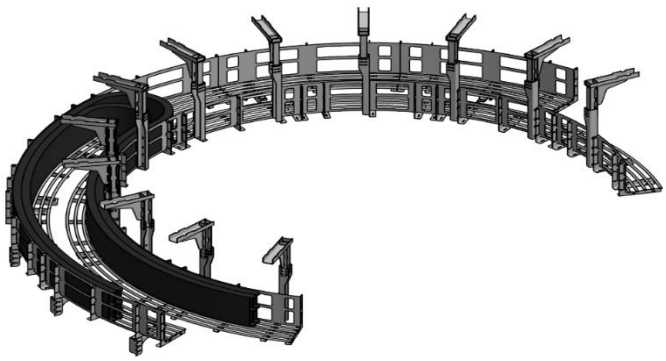


Rotational Motion configuration
Use in swing bridges

Environmental considerations

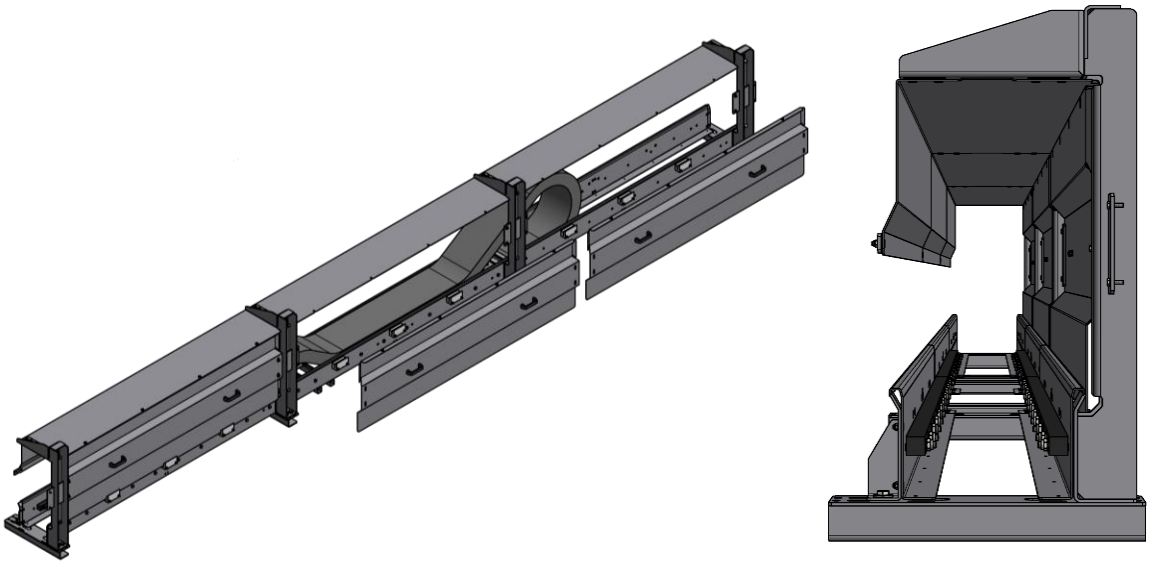
Environmental considerations such as snow and ice as well as heavy debris can be effectively mitigated through the use of different guiding trough styles such as a fully enclosed system or tube style trough that prevents debris from building up inside the guidance system

Trough styles for environmental challenges



Tube style guide trough will allow material to fall through preventing blockages in the chain runway. It is manufactured from heavy duty stainless pipe and provides a rigid structure for the RBR, or Reverse Bend Radius chain, to operate inside in areas of high debris.

Another effective approach is to completely cover the energy chain system protecting it from debris as well as snow and ice.



Material choices

Because of the wide range of triboplastics that are available for use in the manufacture of energy chain components, solutions are readily available for most applications and environments. Tribopolymers have been engineered to withstand extreme temperatures, provide chemical resistance, tolerate high UV exposure and because they are molded with dry lubricants they shed contaminates that would normally cling to grease and oil.

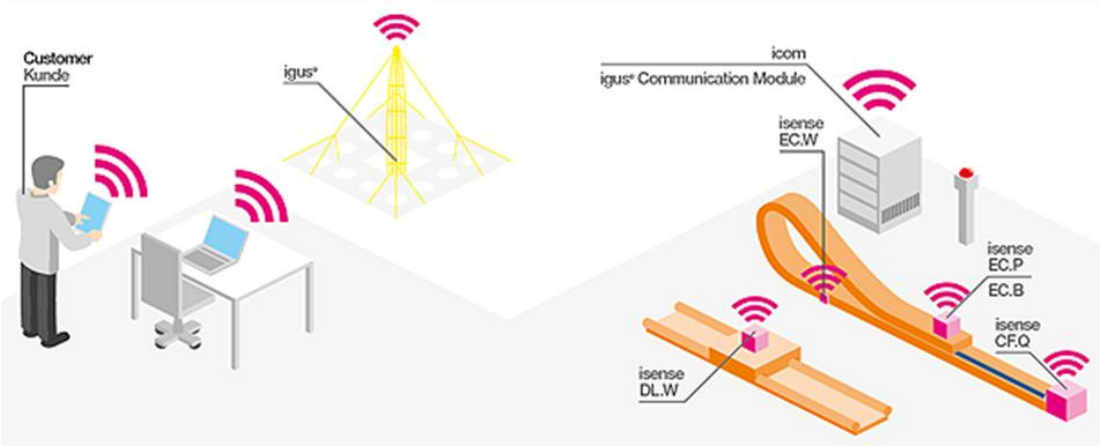
Motion plastics check the boxes for use in heavy machinery industries because they are lightweight, corrosion free, self-lubricating and much stronger than they appear to be. The use of these products creates longer machinery life and energy savings through less friction and wear and creates applications that require less maintenance.

The role of “smart” energy chain cable carrier components in helping enable industry 4.0

Self-monitoring systems

One of the main design principles of the industry 4.0 initiative is moving from sensors and methods that alert of faults and damage *after* it occurs or as it is occurring to methods that will *predict* and prevent failures of systems.

For example, if you have a component on a machine that upon failure creates a stoppage or fluctuation in output or production that can be measured by a sensor you may or may not have enough time to stop the process before it creates damage to either the machine or the product that you are making. In industry 4.0 that same component would be self-monitoring and could tell you that there is either a problem starting to happen or that it is starting to reach it’s end of life and needs to be replaced.



Engineers have started to develop ways for energy chain cable carrier systems to self-report their health status as a preventative measure for costly breakdowns and unscheduled downtimes. There are currently components that measure the performance of these systems, monitoring statistics like push/pull forces on horizontal long gliding energy chain applications while they measure wear and general usage on others.

igus® has developed systems through vast amounts of test and real-world data that allow predictability in the performance and life-time of triboplastic products. This information coupled with active monitoring systems allows for a machine to report that it needs a part to be replaced – before the part is showing signs of failure or affects the performance of the system. With the ability to replace or service parts before they fail, costs and downtime are minimized. Aside from the convenience of knowing when your machine needs maintenance, it is also beneficial for parts and systems that are in areas that are not easily accessible for inspections.

The obvious choice for cable management of the future…

Energy Chain systems

With over 50 years of experience designing and manufacturing tribopolymer cable management systems, time-tested and proven Energy Chain systems numerous industries have chosen to adopt can also benefit the heavy movable structures industry. With successful implementation on industry leading projects, an Energy Chain solution can be realized on almost every application within the HMS industry – no matter how large or small. A safe, reliable, maintenance free solution is only a phone call away. Contact igus today to future proof your design and experience all of the benefits and Energy Chain system has to offer.

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[i] *Jost, Peter (1966). "Lubrication (Tribology) - A report on the present position and industry's needs". Department of Education and Science, H. M. Stationary Office, London, UK.*
[ii] *Holmberg, Kenneth; Erdemir, Ali (2017-09-01). "Influence of tribology on global energy consumption, costs and emissions". Friction.*
[iii] *Holmberg, Kenneth; Erdemir, Ali (2017-09-01). "Influence of tribology on global energy consumption, costs and emissions". Friction.*