Reducing vibration of cable carriers on high precision machinery

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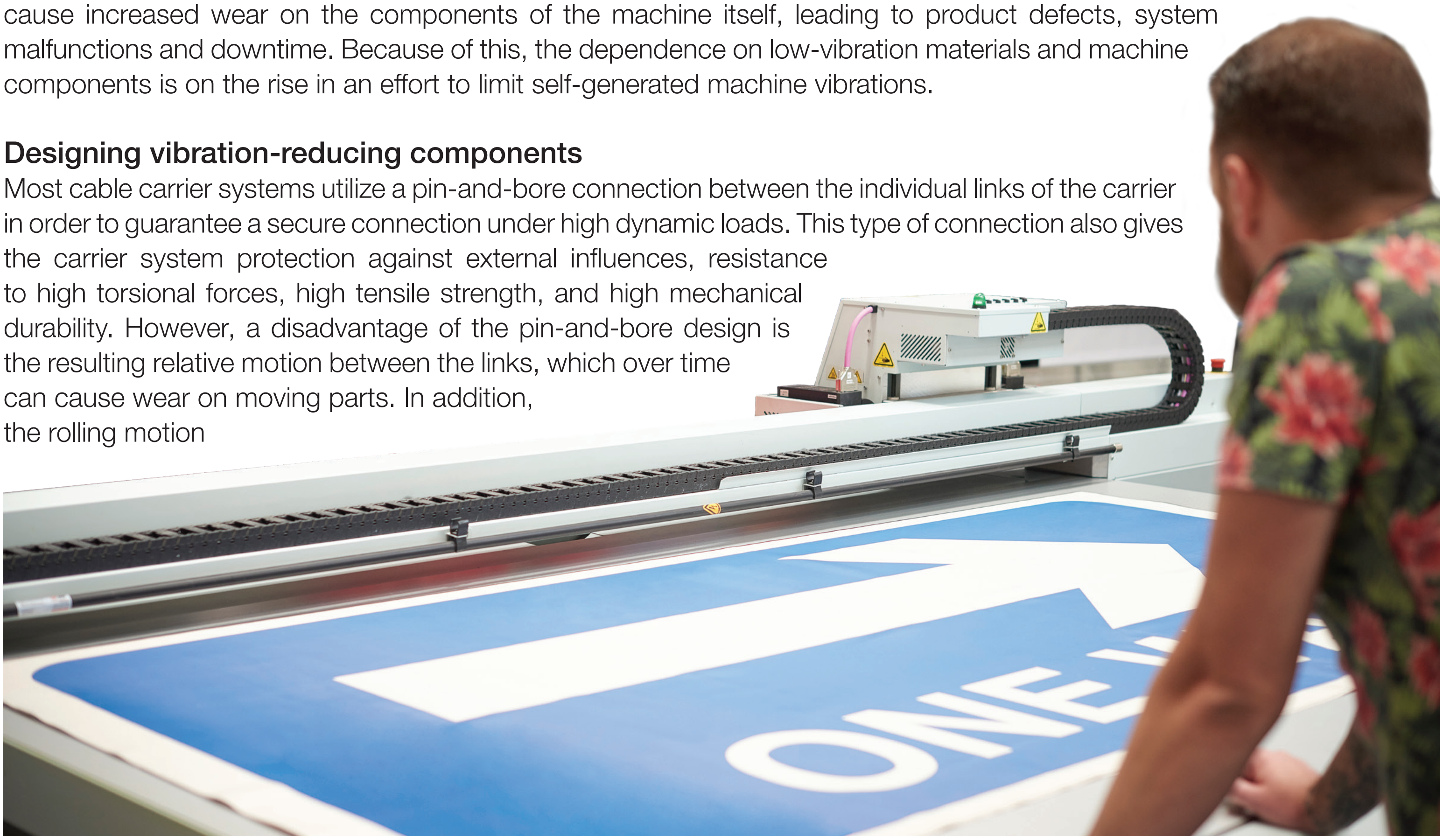
In a wide range of applications customers are demanding increased accuracy and precision from their production equipment. Simultaneously, increasingly complex automation has created an additional challenge, as the vibration of dynamic machine components can significantly increase vibration of the complete system. In a number of industries, including printer design, semiconductor manufacturing and machine tools, cable carrier systems can be a possible source of vibration. Cable carrier systems supply energy, data and other media, and as technology increases, so too does the number of cables and hoses that require guidance. As cable carriers guide and protect cables and hoses throughout the motion of the printer, machine tool, etc., vibration of the supporting structure of the cable carrier can occur, as well as at the moving end or tow arm of the machine. This vibration can negatively influence the performance of a machine once it reaches a certain level. For manufacturers, as well as their customers, factors that limit the capabilities of precision systems must be tackled using cable carrier systems that minimize vibrations and maximize smooth and precise operation.

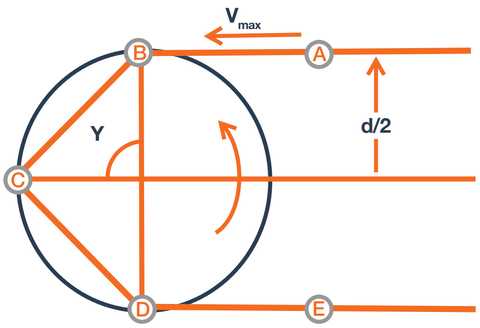
In printing, milling, or other precise tasks, dynamic loads are the typical source of vibration, which can cause chatter on tools and workpieces alike. These chatter vibrations not only decrease the quality of the print, product, etc., but can also cause increased wear on the components of the machine itself, leading to product defects, system malfunctions and downtime. Because of this, the dependence on low-vibration materials and machine components is on the rise in an effort to limit self-generated machine vibrations.

Designing vibration-reducing components

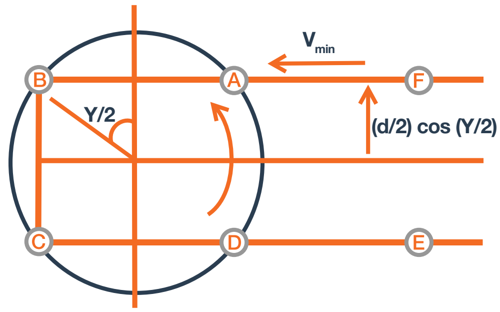
Most cable carrier systems utilize a pin-and-bore connection between the individual links of the carrier in order to guarantee a secure connection under high dynamic loads. This type of connection also gives the carrier system protection against external influences, resistance to high torsional forces, high tensile strength, and high mechanical durability. However, a disadvantage of the pin-and-bore design is the resulting relative motion between the links, which over time can cause wear on moving parts. In addition, the rolling motion



of a cable carrier system exhibits the so-called “polygon effect,” where the chain does not form a smooth rolling motion, resulting in an angular, or polygonal, transition between links. In addition to increased wear, this also results in a “stepping” motion, which can create system vibrations. This can – in a worst-case scenario – result in material failure due to catastrophic resonance. Even in less extreme cases, the vibration caused by the polygon effect results in material wear and decreased accuracy on the workpiece.



chain link position 1



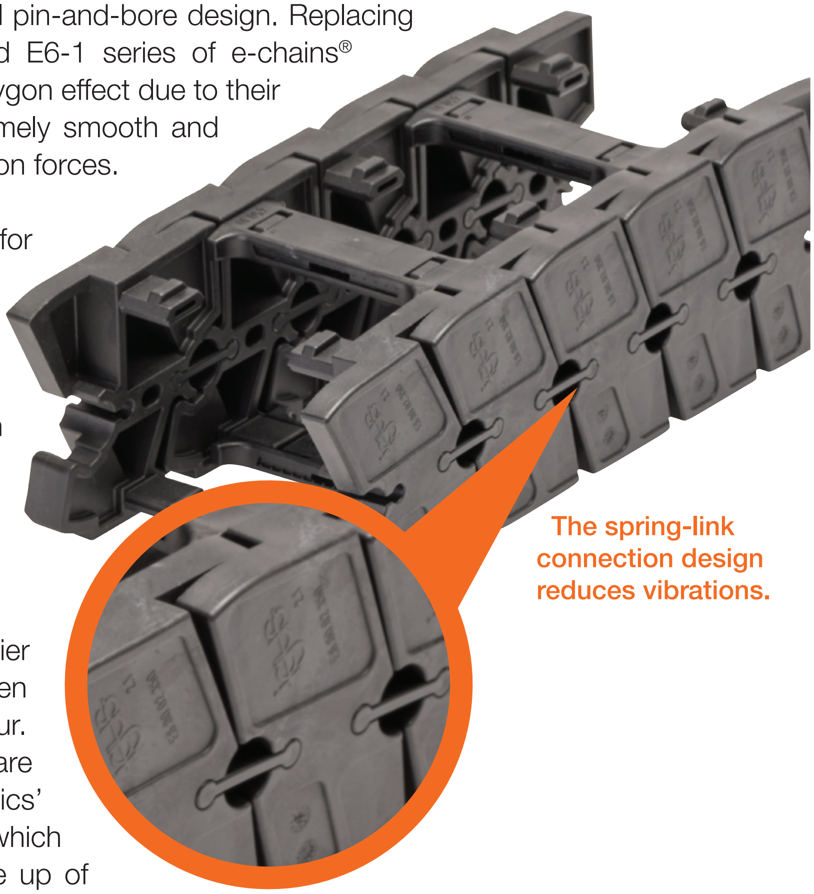
chain link position 2

The polygon effect: visualized

As the chain moves around the curve, from position 1 to 2, the individual links (AB, BC, CD, DE) create an angular motion, changing the height of the system from d/2 to (d/2)cos(Y/2). This height fluctuation creates vibration and a rough “stepping “motion.

To improve upon the design of cable carriers to reduce vibration, most manufacturers rely on a short link pitch to offer smooth, quiet motion. igus® low-vibration e-chain® cable carriers combine a short pitch length with an advanced plastic spring element to replace the traditional pin-and-bore design. Replacing the conventional pin-and-bore design, the E3, E6, and E6-1 series of e-chains® feature a flexible connection element that reduces the polygon effect due to their alternative geometry. This upgraded design offers extremely smooth and nearly vibration-free operation, even under high acceleration forces.

The advantages of this new design were tested for effectiveness in a 220 million cycle test conducted in the igus® test lab. The endurance test was conducted with the E6-29 energy chain system®, with focus on the system’s spring link connection. Throughout the test, the connection was subjected to more than 440 million bending cycles, and based on the results issued from the University of Applied Sciences in Cologne, Germany, no measurable wear or damage of any kind was recorded.



The spring-link connection design reduces vibrations.

Material selection and its impact on vibration

No matter how specialized the design of a cable carrier system, without materials that are properly able to dampen vibrations, damage and eventual failure can still occur. Compared to their metal counterparts, plastic materials are much better at damping vibration forces, due to plastics’ viscoelastic behaviors. The plastic material igumid G, which makes up igus® e-chains®, is a proprietary blend, made up of a reinforced polyamide 6 (PA6) base. Polymer blends like these are also able to dampen vibrations by using the interface between the material’s components (ie: fibers and other structures blended throughout the base polymer) as a mechanism for reducing vibratory forces.

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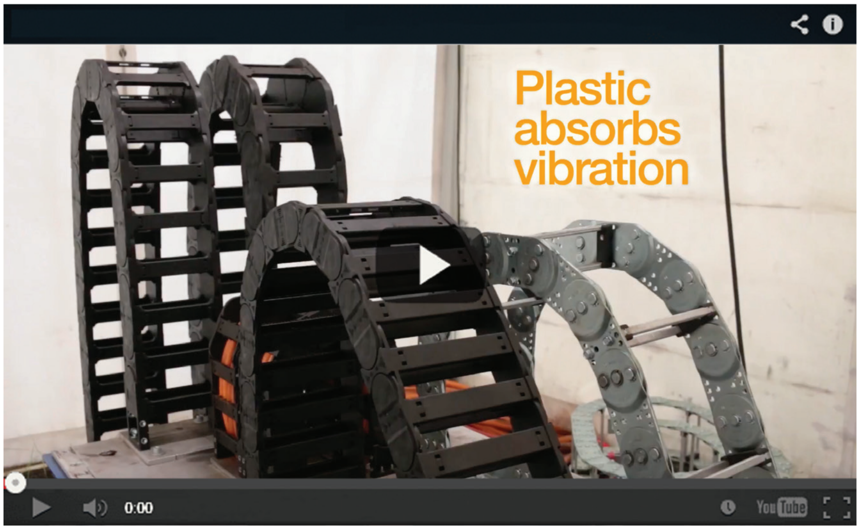
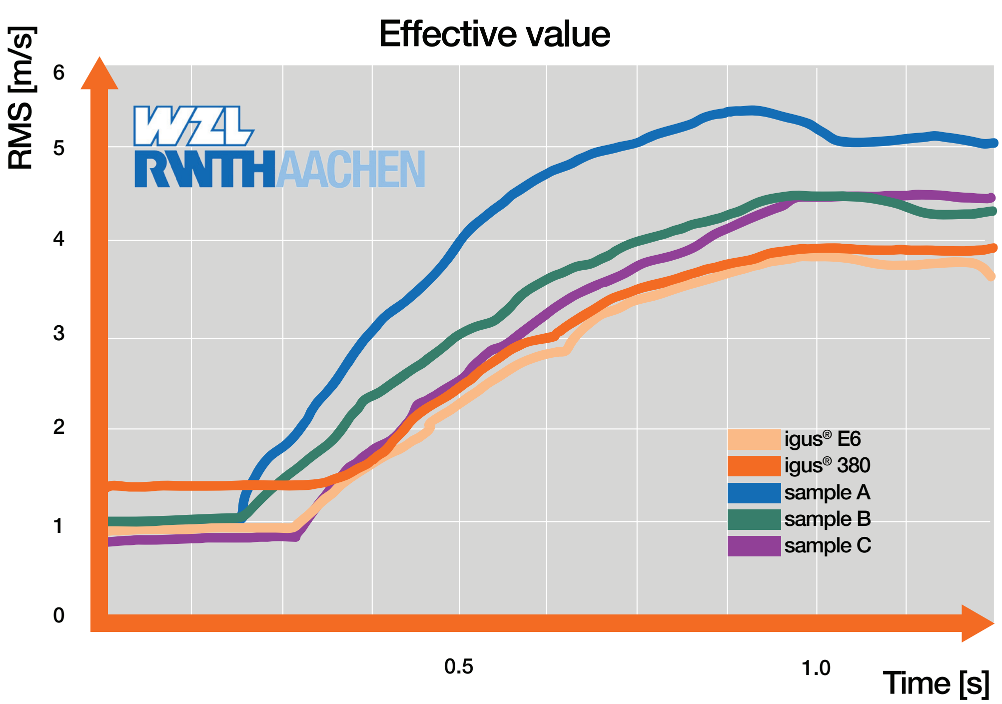


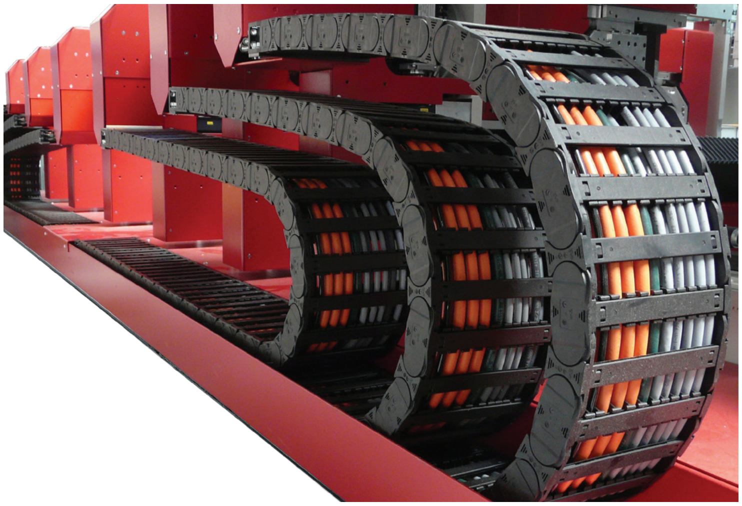
Click to see plastic vs. steel cable carrier vibration tests in action

When compared to metal and other plastic cable carrier options, igumid G offers a much higher ability to dampen vibration forces. Vibration testing was conducted by the IPA Fraunhofer Institute on the material which makes up both the e-chains® and the spring link connection elements. These tests found that the igumid G plastic material offers sound pressure levels of only 37 dB (A), significantly below the values of competitive material options, which has also been confirmed by experts at TÜV Rheinland. In addition to sound pressure testing, these tests showed a range of other material benefits of igumid G, including high levels of corrosion and wear resistance, and compatibility with the maximum quality standards for cleanrooms, ISO Class 1. ESD versions of the material are also available.

Vibration properties case study: e-chain® cable carriers in scientific comparison

A study was conducted by the Laboratory for Machine Tools and Production Engineering at the RWTH University in Aachen, Germany to determine and compare the vibration properties of a range of five cable carriers systems of the same size category. Tested carriers included an igus® E6 and 380 carrier, along with three from competitive manufacturers. The test utilized a base frame and a highly dynamic linear motor drive, with a force of 3,147 lbf (14,000 N). The linear motor moved a carriage attached to the moving ends of the carriers at four different speeds (25, 50, 100, and 200 m/min), and two accelerations (10 and 20 m/s2) over a travel length of 800 mm. Impact of the carrier's vibrations were measured with two accelerometers with sampling frequency of 6000 Hz, that were installed on the moving end and the support trough of the cable carriers. Data was measured separately for the two directions of travel. Sensor generated signals were analyzed in the time and frequency domains. For the time domain, the Root Mean Square value indicated the vibration energy at the measurement location. For all the cable carriers included in the test, the highest levels of vibration were evident on the supporting trough in the direction of the application axis (Z axis), however, the differences in accelerations had no significant influence on the vibration values. According to the test data, of the five carriers tested, the vibration values were lowest for the two igus® e-chain® cable carriers.





The results from these tests demonstrate that the E6 and 380 e-chain® cable carriers from igus® offer ideal performance with respect to vibration characteristics and smooth operation at all travel speeds and accelerations. On average, the measured vibration was 28% lower than competitive carriers. The igus® E6 and 380 demonstrated an effective maximum value of approximately 4 m/s2. In contrast, the cable carrier with the highest levels of vibration exhibited a value of 5.6 m/s2, or ~40% higher than the vibration exhibited by the tested igus® carrier options.

Technology outlook

The new E6-1 series of cable carriers from igus® is the next generation of the E6 series, which in the testing on the previous pages has shown to have the lowest levels of noise and vibration in cable carrier applications due to its material makeup and design. This new generation offers a weight reduction of approximately 30% when compared to the E6 series, and exhibits even lower noise and vibration levels. A shortened pitch and "brake" in the stop dog system reduce the sound pressure levels by an additional 2 dB(A). Optimized geometry makes operation of the E6-1 system very smooth, eliminating the polygon effect almost entirely, even at higher speeds and accelerations.

Another option for reducing vibration on machine tools can be provided via special cable carrier design. An example of this would be creating a nested arrangement of cable carriers, which can dramatically increase milling accuracy in certain cases. These nested systems, like the example shown above, can change the system properties of the machine, and can be combined with additional systems to help minimize or eliminate damaging vibrations. These systems apply external forces to minimize or completely eliminate damaging vibrations via damping or canceling solutions, differentiated into passive and active systems.

Passive systems attain their vibration damping effect by converting the vibration energy to another form. In this circumstance, an additional mass transforms the kinematic energy from the vibration into thermal energy or a relative motion between two other bodies. Active systems employ an external energy supply to create a phase-canceling vibration. Both passive and active systems can effectively compensate for vibrations, but also have a cost impact, as these types of systems are typically only available as a customized one-off solution and cannot be transferred to other machinery. The economic use of these types of adaptive solutions is not always viable for the price-sensitive machine tool market; therefore, the primary effort in research and development for vibration-reducing systems going forward should focus on identifying and reducing the component sources of vibration.

Summary

As the demands for process accuracy for a range of applications increases, the need for technical advances to reduce vibrations also grows. An important element of a successful strategy is to improve the operational smoothness of energy supply systems in dynamic applications. New solutions, such as the polymer spring link connection for igus® e-chain®, can significantly contribute towards realizing the objective of attaining a low-vibration machine tool. While other solutions are available, the lowest cost option to create a low-vibration system is to integrate low-vibration machine components.