BILSING AUTOMATION®
SET THE PACE!

THE DEFINITIVE GUIDE TO
CARBON FIBER

bilsing-automation.com

INTRODUCTION

The global composites market size is expected to reach $160.54 billion by 2027[1], expanding at a CAGR of 7.6% over the forecast period. The growth of this market can be attributed to the increasing demand for lightweight materials, which is well-known in industries such as wind energy, automotive and transportation, and aerospace and defense. In addition to being lighter in weight, composites can provide structural strength comparable to metallic alloys. In the transportation industries, this leads to improved fuel efficiency and improved performance, as well as recyclability.

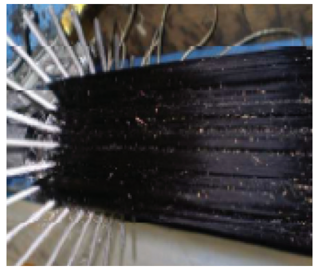
What is not as well-known, however, is the fact that carbon composites are just as well-suited to the automation industry where these materials can be used to create lighter, stiffer parts that feature better damping qualities. Composite materials can contribute to equipment that runs faster with higher accuracy and reliability; all of which leads to improved productivity and part quality.

In 2005, Bilsing Automation initiated a program to create tooling products that are lighter, stiffer and more harmonically stable. This led to our development of a range of high modulus, graphic carbon fiber profiles that provide a complete gripping and transporting solution from the point of component contact back to the handling device. These profiles have shown to improve operations in press transfers, robotic, plastic part extractors, manual lift assists and NAAMS frames for automotive body shop operations.

This brochure will provide detail on the Bilsing carbon fiber products, helping create a foundation for investing in this technology.

- Carbon Fiber Technology
- Carbon Fiber Characteristics
- Carbon Fiber in Automation Applications
- Bilsing Carbon Fiber Real World Performance

WHAT IS CARBON FIBER COMPOSITE?

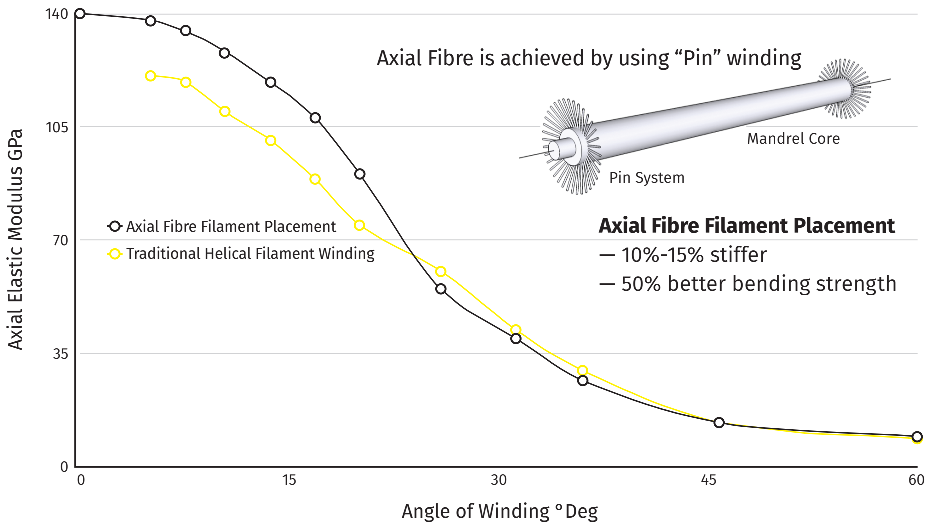


A composite is a material which is produced from two or more constituent materials. These materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements. Composites are usually made of a thermoset resin such as an epoxy, reinforced with a fiber component. Automation or machine-building applications use a Pitch carbon graphite fiber, made from refined coal tar pitch, a by-product of steel production. This has a higher tensile modulus of 640 GPa to 760 GPA as compared to PolyAcryloNitrile fibers typically used in aerospace and automotive applications. Once the resin-fiber combination is cured with heat, it results in a material with a high strength-to-weight ratio.

Composites need properties in more than one direction in order to be useful. They are made by layering the fibers in the plane oriented to the predicted stress directions. This is a benefit to composite structures as they can be optimized in the direction of the imposed loads.

Cylindrical-type carbon fiber (Cf) components used by Bilsing are made using filament winding technology where the fiber takes the form of a 'continuous string', impregnated with resin, wound at an angle around a cylinder and then cured.

This approach allows more laminate to be applied to the highest performing longitudinal (axial), transverse (across) and shear (+ 45°) layers. which works well for plate, beam and tube.



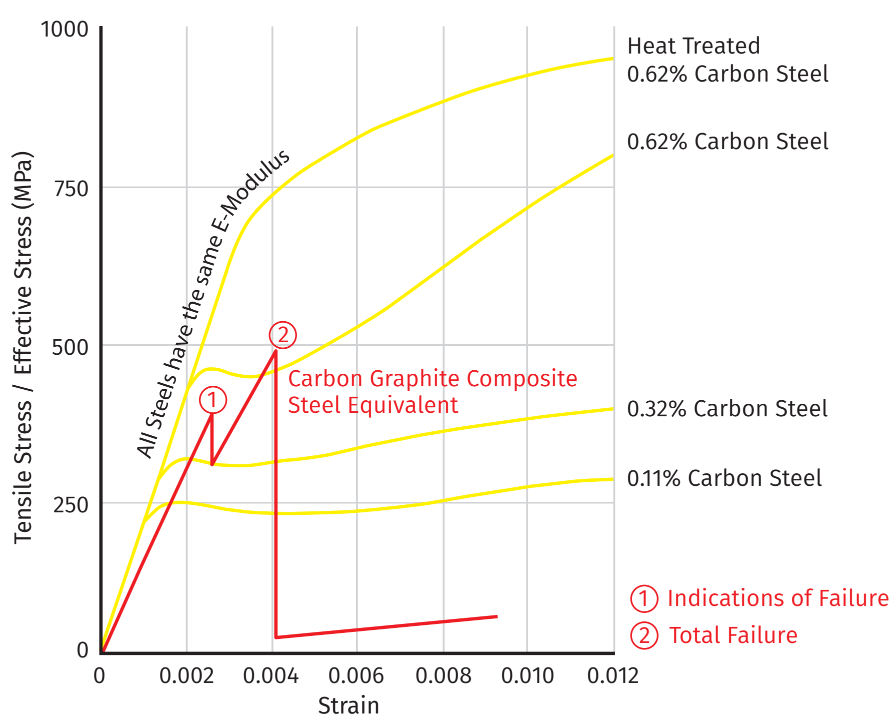
[1]Grandview Research, Composites Market Size Worth $160.54 Billion By 2027

Bilsing partners with leading engineered composites company Compotech on our Cf products. Compotech has perfected its own version of filament winding, referred to as axial fiber placement. This technique improves resistance to bending loads by winding the fibers along the length of the cylinder, rather than around its circumference. This aligns all the fibers in the axial direction, enabling more fibers relative to the volume of the material. This combined filament winding and axial fiber placement technology produces beams 10 to 15% stiffer in the axial direction, with 50% greater bending strength, compared to conventional filament-wound beams.

COMPOSITE CHARACTERISTICS

Composite materials are anisotropic with differing properties in each direction whereas metals are isotropic and have the same properties in all directions. Additionally, and interestingly, the material characteristics of composites are created at the same time as the component is made.

Composites made of pitch fiber can offer twice the stiffness of steel, while exhibiting about the same strength. However, should the thickness of the "steel equivalent" composite can be increased by 30%, i.e. 6mm > 8mm, the same stiffness is achieved, but the weight of the composite is still only 25% the weight of steel.



Mass: Carbon composites are generally 4x lighter than most steels: The density of steel is 7.8 kg/m3 whereas the density of graphite damping composite is between 1.4 and 1.8 depending on composition.

Damping: Damping is up to 20x better than steel when damping material is included in the composite. The inclusion of damping material will reduce the composite e-modulus, but it is still similar to standard steels.

Stiffness: E-modulus of a graphite layer in the direction of the fiber can be over 400GPa using 760GPa fiber. A quasi-isotropic "steel equivalent" laminate will have an e-modulus of 150 GPa in both X & Y directions; hence the need to use 1.3x the thickness to maintain the equivalence of 210 GPa steel.

Strength: The maximum strength of a "steel equivalent" composite is about the same as the yield point of standard steel at about 385 Mpa.

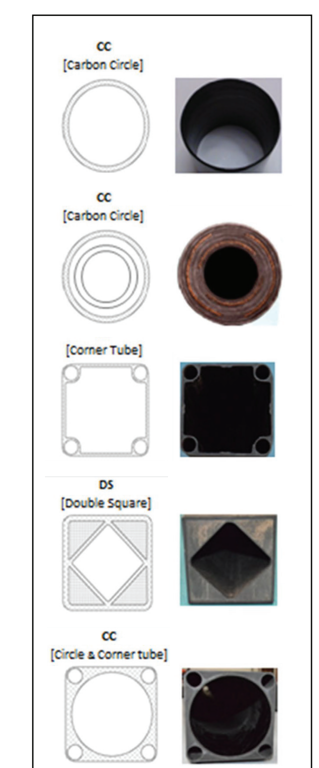
Failure: Composites do not have a yield point. Composites can micro-crack in the matrix at about 75% of ultimate load; think of this as the composite equivalent of a yield point. However, unlike steel, the e-modulus does not change and the stress/strain curve is a straight line until failure. Composites fail in compression or the compression side of bending at about half the tension failure stress levels.

COMPOSITES IN AUTOMATION APPLICATIONS

There is great opportunity for the use of fiber reinforced composite materials in automation applications where they can offer significant productivity, quality and lifecycle cost benefits. However, composites in this sector have been relatively slow, which is likely due to a natural reluctance to change from what is perceived as established methods of manufacture to a new way of machine design and construction.

Bilsing has invested significant time and research into the development of lighter, stiffer and more harmonically stable tools made from high modulus, graphite Carbon Fiber (Cf). Potential composite tooling applications include crossbar beams, loading and unloading beams, destacking beams, panel loading T-Beams, and tooling supports for the body shop pressroom – including hot forming, injection molding, assembly and more.

Bilsing produces a series of round, square and conical composite tools as well as custom profiles for specific customer needs, which can be powder-coated to any color. Additionally, special dampening layers are added to many of the Bilsing applications making the tooling even faster and more precise.

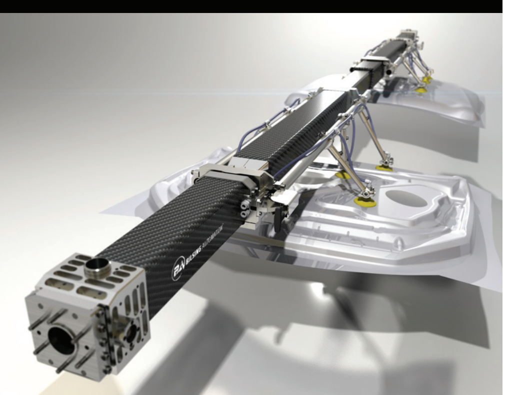


REAL WORLD RESULTS

In general, there are many advantages to using composite materials for machine components that are in motion. Lower mass and higher stiffness means a higher natural frequency. Higher damping properties result in less vibration and more accuracy. Less mass means less energy is required for accelerating and decelerating. The following examples illustrate how all of these benefits can work together for improved output.

PCD Tubes

These machined carbon tubes, used as holding tubes in a variety of tooling applications, are typically made of a combination of standard modulus fiber and high modulus carbon fiber where clamp strength and high axial stiffness are required. These tubes offer almost the same deflection properties as steel, yet are 1/5 the weight. Compared to aluminum, the PCD tubes weigh significantly less yet offer an average of 2.3 higher stiffness.



Cross Bar Profiles

One of the most used profiles in the automotive automation industry is a cross bar for press lines. The data here is based upon a typical baseline profile of 100mm square profile typically in lengths of 4.5-5 meters.

To compare mechanical properties of steel, aluminum and carbon fiber, we used a profile with the same cross section of 100x100mm with 8mm wall thickness in each material.

As shown the diagram below, the stiffness of Bilsing profile is slightly higher (lower deflection) than the steel profile and significantly higher than aluminum. From a mass point of view, the linear density of the steel profile is 23kg/meter; aluminum. 8.2kg/meter and the Bilsing composite profile 5kg/meter.

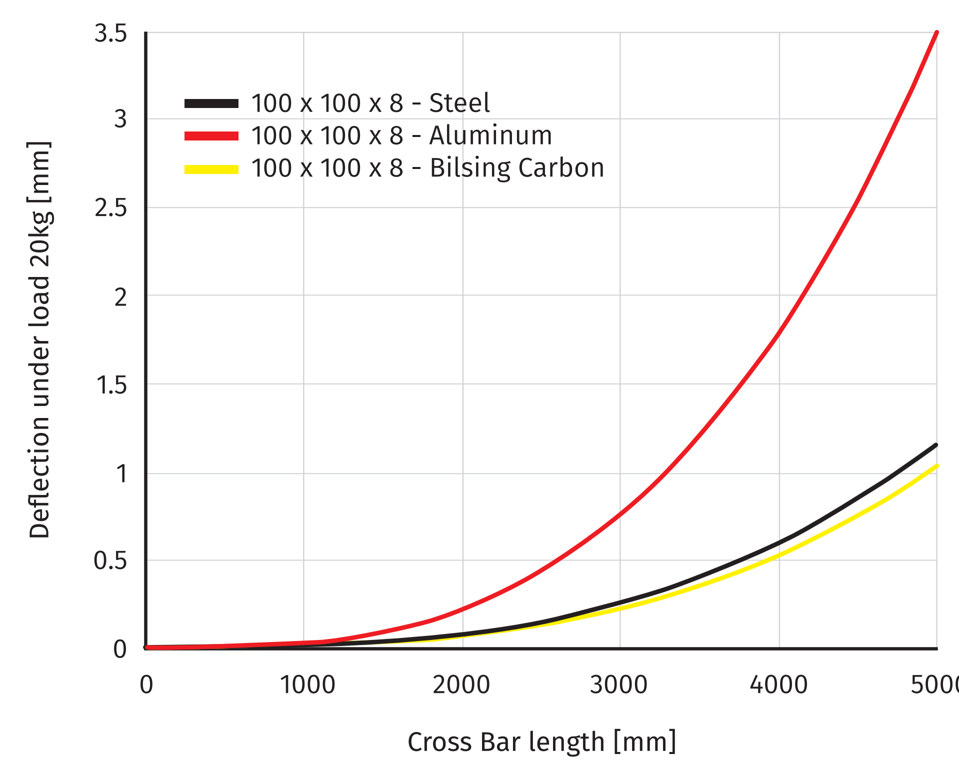
Result: A lighter weight, stiffer profile means more payload capacity. For a 5 meter long cross bar, the carbon profile is 10% stiffer than steel and 40% lighter than aluminum (aluminum 42kg vs. 25kg in carbon => extra 17kg of payload which can be used).

PCD Tube Comparison with AL and Steel

OD	ID	Wall Thick.	CARBON		ALUMINUM		STEEL	
			Weight	Deflection	Weight	Deflection	Weight	Deflection
(mm)	(mm)	(mm)	(kg/m)	(mm)	(kg/m)	(mm)	(kg/m)	(mm)
20	16	2	0.18	2.34	0.31	6.21	0.89	2.10
25	20	2.5	0.27	1.09	0.48	2.54	1.39	0.86
25	16	4.5	0.46	0.78	0.78	1.80	2.28	0.61
25.4	18	3.7	0.39	0.87	0.68	1.88	1.98	0.64
38.1	30	4.05	0.7	0.22	1.17	0.45	3.40	0.15
40	35	2.5	0.45	0.26	0.80	0.55	2.31	0.19
40	30	5	0.88	0.14	1.48	0.34	4.32	0.11
60	50	5	1.38	0.04	2.33	0.09	6.78	0.03
63.5	55	4.25	1.26	0.04	2.14	0.08	6.21	0.03

Weight and deflection comparison of same-dimension carbon fiber, aluminum and steel tubing.

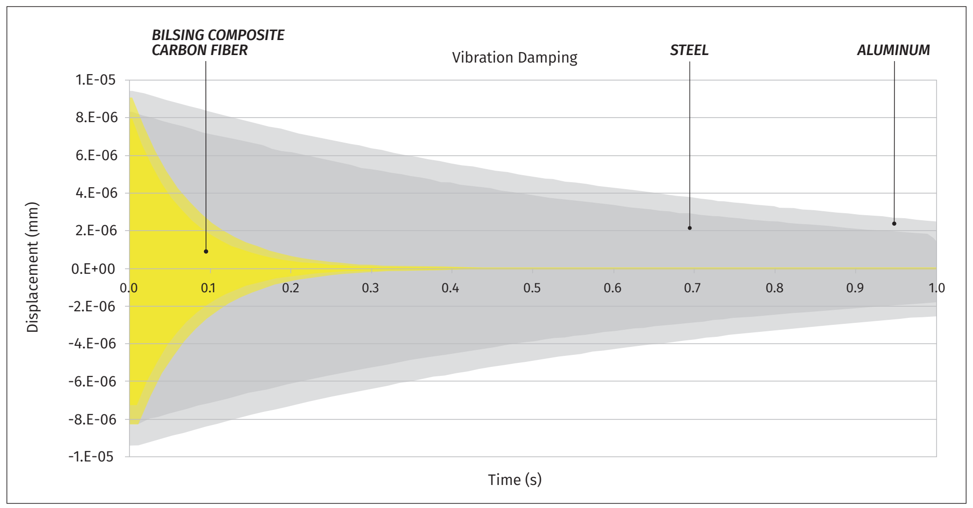
Square Tubing Comparison



T-BEAMS APPLICATIONS

Similar positive results can be seen in Bilsing Cf T-Beam applications. These beams are 70% lighter than steel and 25% lighter than aluminum solutions, as well as being dimensionally smaller. The material properties of Cf reduce vibration and deflection so that tools settle more rapidly and with higher precision, allowing for a smaller press opening during the stamping process. This allows users to make productivity gains of up to 20%.

Faster Settling Time



Linear Part Transfer

In transfer press operations, it's critical that the pressroom automation solutions be able to keep up with the stamping process. The KUKA Cobra solution, developed in partnership with Bilsing, is a packaged solution designed for the transfer of single or double parts between presses with gaps from 5.2m to 8.5m. The benefits of lightweight, yet stiff, carbon fiber tooling are enhanced even more by the system design to offer faster component entry and exit, a lower profile that shortens cycle times, and highly dynamic kinematics enabling the Cobra transfer system to reach speeds of up to 18 SPM for payloads of up to 60kg.

HYDROFORMING APPLICATION

Situation: An automotive hydroformer was manufacturing a tubular part for an engine cradle weighing about 20 lbs. in a line featuring a hydraulic pre-form press and hydroforming press integrated with five robots. The baseline tooling was aluminum with a rotation device mounted on the leading end of the end effector. Two blanks were handled by a common tool; the first was picked and placed for cleaning and lubrication and the second was placed into the die cavity following lubrication.

Although it was a two-cavity die, the robot could only load one component at a time due to the combined weight of the parts and end effector. While one part was set in a nesting station, the robot would select the second part for lube using a separate gripper. The weight of the tooling was also affecting the robot efficiency and cumbersome for the operators during changeover.

Solution: A switch to carbon fiber provided a lighter, stiffer alternative to the aluminum tooling. In order to achieve the same strength of carbon fiber, the wall thickness of the aluminum tubing would have been doubled, increasing its weight even more, yet still not achieving a comparable stiffness to the composite tooling.

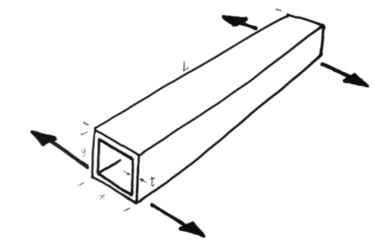
Because carbon fiber made the overall tooling so much lighter, the robot could now handle additional part weight. Another advantage was a 6-second reduction in cycle time representing an overall improvement of 15%. And part consistency and process repeatability improved due to the harmonic stability of the Cf tooling creating less 'bounce' on the robotics.

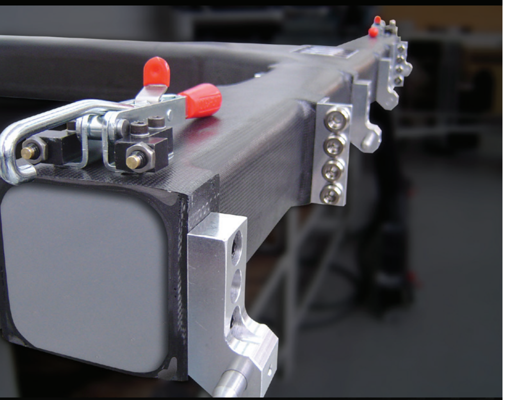
Further process improvements included increased ergonomics, especially when it came time to change tools. With aluminum, changing one end effector was a two-man job. With carbon fiber, two men help to help guide the end effector to its nest, but it's light enough for one man to carry. Carbon fiber is easier to guide into place because of its rigidity and it's less likely to damage magnets and other parts during changeover.

Another benefit was a reduction in downtime when recovering from a robot crash. Aluminum is prone to breakage, so in the event of a crash, it would break or bend the tool, not only affecting the main part, but also other parts. Should carbon fiber break, there are no bend issues. If you do have a crash, there is little clean up. Typically, one half snaps off while the other half is still held in the clamp and there is no dust as in aluminum.

ENERGY COST COMPARISON

An often-overlooked benefit of composite tooling is the energy savings it can yield. Although it's true that carbon fiber beams require a higher up-front investment than either aluminum or steel, the significant energy savings still provides a better return over the life of the tool. Results are shown below from a Compotech study comparing steel, aluminum and carbon fiber beams of the same stiffness.





Design of Beam			*Carbon Graphite Composite*	*Aluminum*	*Steel*	
Width of beam	x	mm	300 mm	400 mm	300 mm	Select dimensions to achieve the same stiffness
Depth of beam	y	mm	300 mm	400 mm	300 mm	
Wall thickness of beam	t	mm	6.95 mm	17.90 mm	14.25 mm	
x section area	area	mm^2	8.1467900E+03	2.74E+04	1.63E+04	
Area	A	m^2	0.0081 m^2	0.0274 m^2	0.0163 m^2	
Length of beam	Lbeam	mm	6.0 m	6.0 m	6.0 m	
Density	Rho	Kg/m^3	1,400 Kg/m^3	2,700 Kg/m^3	7,850 Kg/m^3	
Mass of beam	M	Kg	68 Kg	443 Kg	767 Kg	
Price / Kg		€/kg	200 €/Kg	12 €/Kg	4 €/Kg	
Material Price			13,687 €	5,318 €	3,069 €	
Machining			1,000 €	1,000 €	1,000 €	
Price / kg			214.6 €/Kg	14.3 €/Kg	5.3 €/Kg	
Price of beam		€	14,687 €	6,318 €	4,069 €	
2nd Mom. of Inertia	I	mm^4	1.17E+08 mm^4	6.67E+08 mm^4	2.22E+08 mm^4	
E Modulus	E	GPa	400 KN/mm^2	70 KN/mm^2	210 KN/mm^2	Same stiffness
Make the stiffness the same	EI	KNmm^2	4.67E+10 KNmm^2	4.67E+10 KNmm^2	4.67E+10 KNmm^2	
Move the Beam						
Equipment load on beam	Load	Kg	80 Kg	80 Kg	80 Kg	
Average acceleration	Accel	m/s^2	5.0 M/s^2	5.0 M/s^2	5.0 M/s^2	
G Force	G	G	0.5 G	0.5 G	0.5 G	
Length of motion	Lbed	m	6 m	6 m	6 m	
Time to 1/4 cycle	Qtime	s	0.77 sec	0.77 sec	0.77 sec	
Time for complete cycle	Time	s	3.10 sec	3.10 sec	3.10 sec	
Peak velocity	Accel*Time	m/s	3.87 m/s	3.87 m/s	3.87 m/s	
Force to accel. & decel.	ML/T^2	Kgm/s^2 ...N	742 N	2,616 N	4,236 N	
Energy (Work) for 1 cycle	ML^2/T^2	Kgm^2/s^2 ...J	8,906 Nm	31,392 Nm	50,829 Nm	
Energy requirement greater than Carbon Composite				22,486 Nm	41,923 Nm	
Energy Requirements						
System efficiency			90%	90%	90%	
Cycles per day			9,295	9,295	9,295	
Energy per day			26 kWh	90 kWh	146 kWh	
Energy per year			6,388 kWh	22,515 kWh	36,456 kWh	
Energy cost per year			958 €	3,377 €	5,468 €	
Carbon Composite saving per year				2,419 €	4,510 €	
Drive System Cost						
Power required...	ML^2/T^3	Kgm^2/s^3	3.194 kW	11.258 kW	18.228 kW	
Multiple of power required				3.5	5.7	
Estimated cost of drive system	quote from bosche		3,500 €	5,500 €	7,000 €	
Drive system purchase saving				2,000 €	3,500 €	
Total Cost / Year Over	***3***	***Years***	***7,020 €***	***7,317 €***	***9,158 €***	
			Carbon Composite Cheaper by	***4%***	***23%***	

3600000	***0.15***	***250***	***8***
Joule / kWh	***€/kWh***	***Days / Year***	***Hrs / day***

LIFECYCLE

In independent laboratory tests comparing steel, aluminum, and carbon fiber at 1,000,000 cycles with approximately 350 lb. force of tension and compression loaded, Bilsing carbon fiber beams proved to be lighter and more robust than aluminum, yet stronger than steel beams of the same size.

An added benefit of the Bilsing T-Beam is its modular design, which enables users to simply change out components instead of having to replace the entire unit should a component break or need to be changed out.

Higher productivity means more parts out the door, which means more money for users. The annual productivity payback achieved by composite tooling over its lifespan includes:

- Faster operating speeds and higher productivity
- Less vibration and more rapid damping
- Heavier load handling capabilities on the same line
- Lower energy consumption and lifetime operating costs
- Easy assembly for structures needing bolted connections

ENVIRONMENT AND SAFETY

Composite materials are safe to use as well as recyclable. Unlike steels and some aluminums, epoxy composites do not corrode and are impervious to fluids as long as any cut sides are sealed. Bilsing's composite tooling, manufactured with temperature-resistant glue, can operate in a wide range of temperatures, from -40°C (-104°F) to 700°C (1232°F), making these carbon fiber beams well-suited for hot forming operations.

In terms of environmental impact, unwanted composite is chopped and the matrix burned off to recover energy trapped in the chemistry. Short fibers are used for reinforcement in injection molding or concrete while other recycling processes can convert the material back to its basic elements.

NOTES

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ABOUT BILSING AUTOMATION

Bilsing Automation is a leading supplier of industrial tooling solutions, specializing in automated tooling and material handling systems with over 30 years' experience in automotive stamping and bodyshop applications, as well as developing material handling solutions for injection molding, fabrication, packaging, hydroforming and non-automotive applications. The company is focused on providing optimum product performance that results in cost reductions, supporting the customer through planning, design, engineering, assembly and commissioning. Bilsing Automation also offers 3D digital simulation and on-site training as part of its service offerings.

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