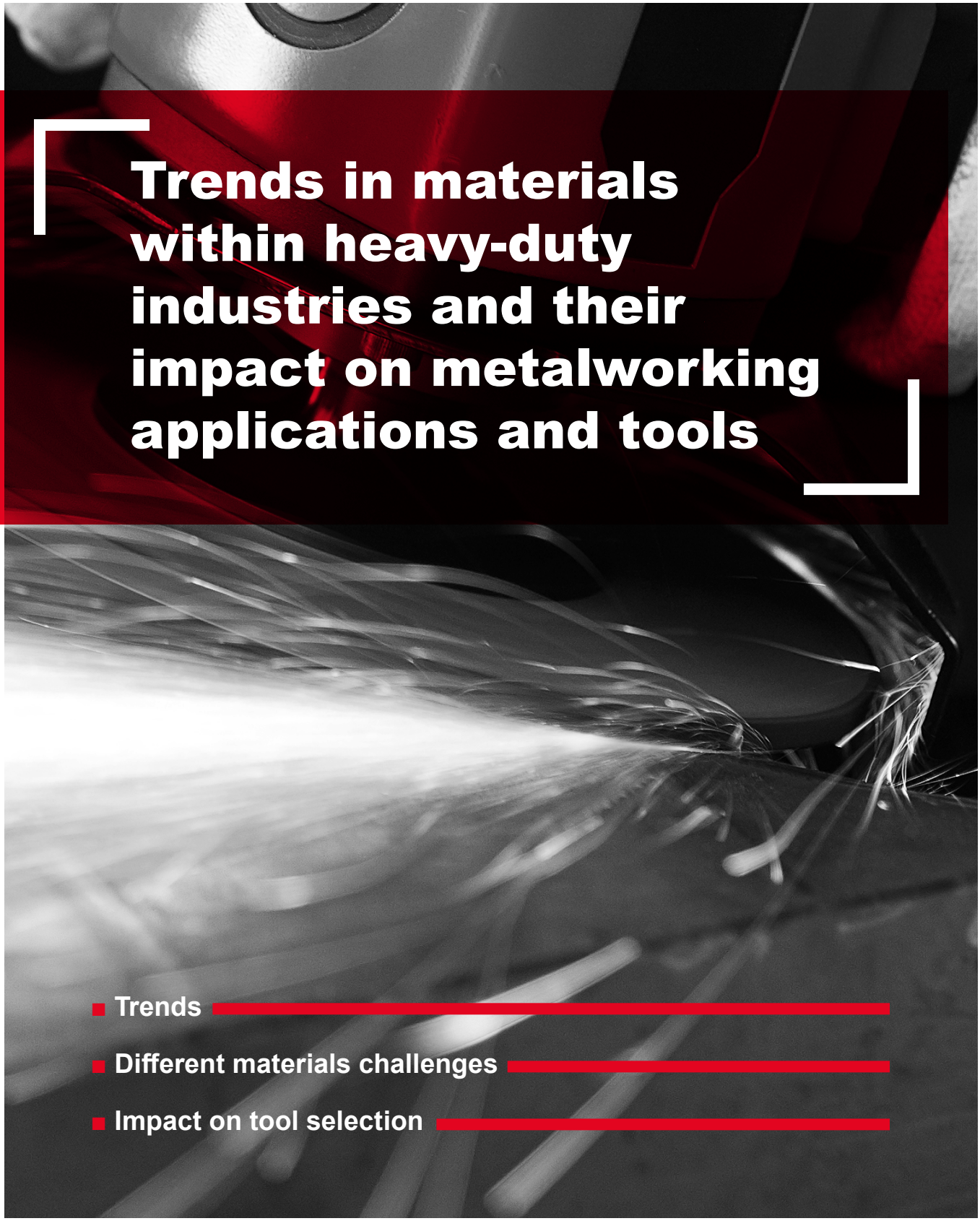
Trends in materials within heavy-duty industries and their impact on metalworking applications and tools



- Trends
- Different materials challenges
- Impact on tool selection

Chicago Pneumatic

INDEX

The ⓘ indicates that you can learn more about the related topic in our Expert Corner, our online knowledge hub. Please refer to our appendix for the links.

EXECUTIVE SUMMARY

Metalworkers and manufacturers in all types of industries want to increase productivity.

The transportation and machinery industries, in particular, are embracing the use of new materials to meet growing demands for lightweight, stronger components or those with increased corrosion resistance. For example, stainless steel, aluminum, and even composite materials are being used in what are traditional steel applications.

However, working with these materials presents various **challenges** to the operator and their tool during the different fabrication and casting processes such as surface preparation, weld seam removal and finishing. The materials' inherent mechanical and thermal properties mean they behave in different ways to each other when ground or sanded for instance, and therefore there are different requirements from the tool.

Having an understanding of how the material acts when worked on and knowing which tool will deliver the best results in terms of **performance and safety is essential for increasing efficiencies.** This white paper explores the current trends for materials and gives insight into the challenges associated with each material. The paper goes on to outline recommendations for which tools are best suited to the many different materials and applications and considers other factors that contribute to **increased productivity.**

Enjoy your reading!

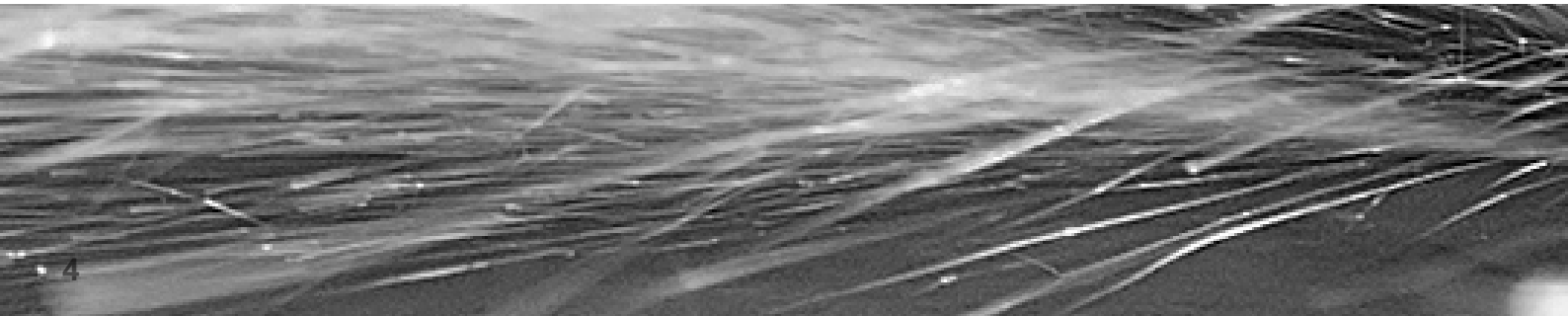
1. TRENDS IN MATERIALS WITHIN HEAVY-DUTY INDUSTRIES

Steel has long been used in traditional heavy industries including transportation and machinery for its excellent mechanical and tensile properties.

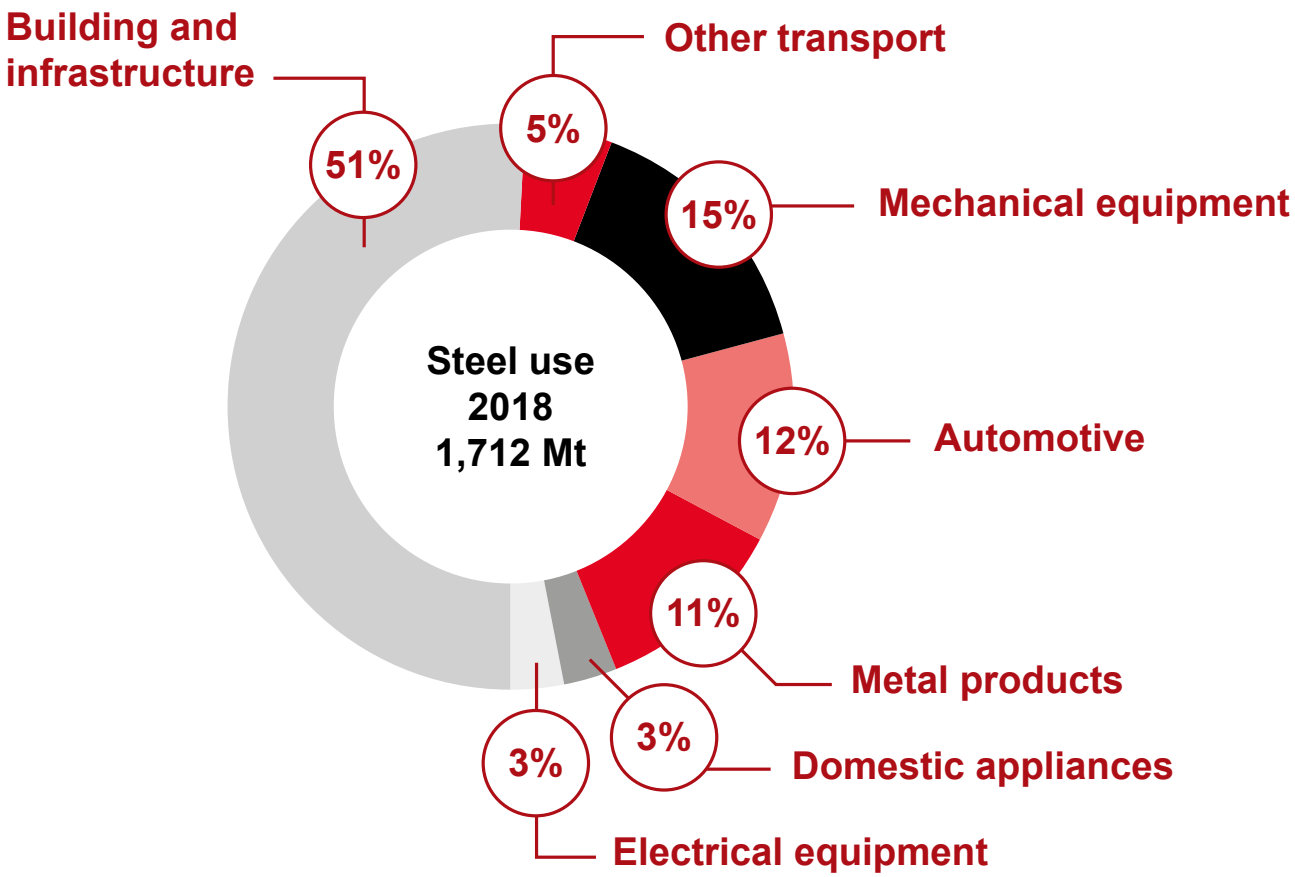
The material is durable, strong, UV-resistant, affordable, and 100% recyclable.

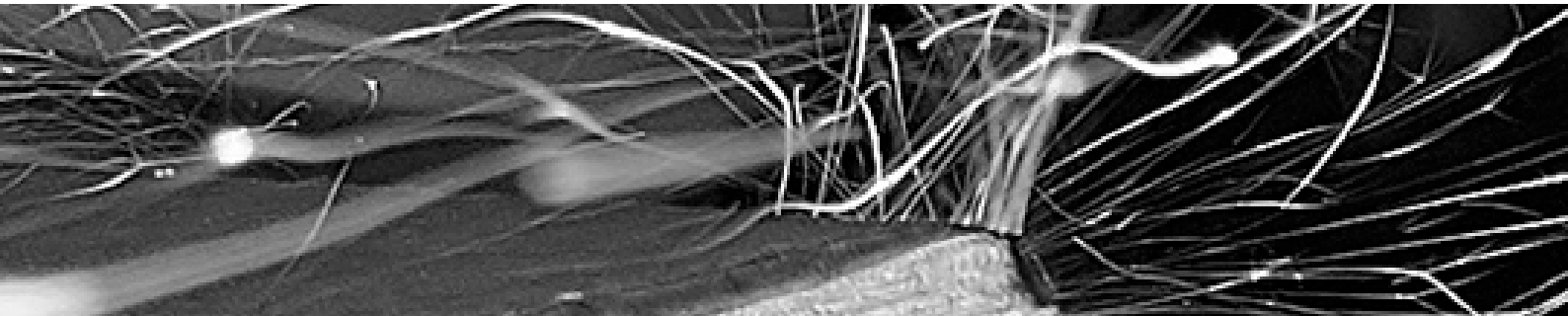
According to the World Steel Association, there are more than 3,500 different grades of steel in use.

In the last 20 years, 75% of these have been developed[1] and new generations of steel continue to be designed.

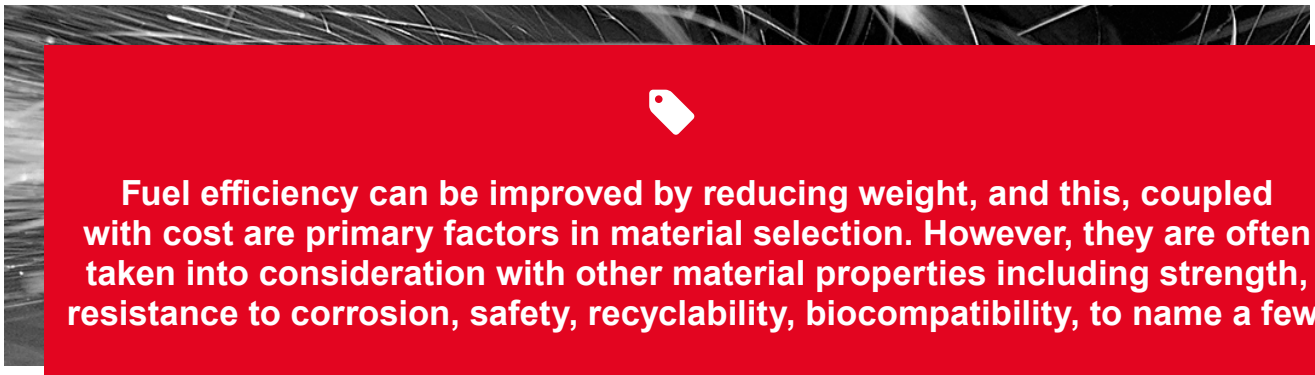


In 2018, the amount of steel used in the world reached 1,712 Mt, distributed as the graph shows[2]:





However, major demands on the transportation industries for increased fuel efficiency and reduced CO_2 emissions, and pressure on the machinery industries for overall cost reductions and improved efficiency, mean that engineers are exploring the use of other metals and materials. Stainless steel, steel alloys, aluminum, titanium, and composite materials are being introduced and adopted in a host of heavy-duty applications such as in rail, marine, machinery and off-road vehicles.

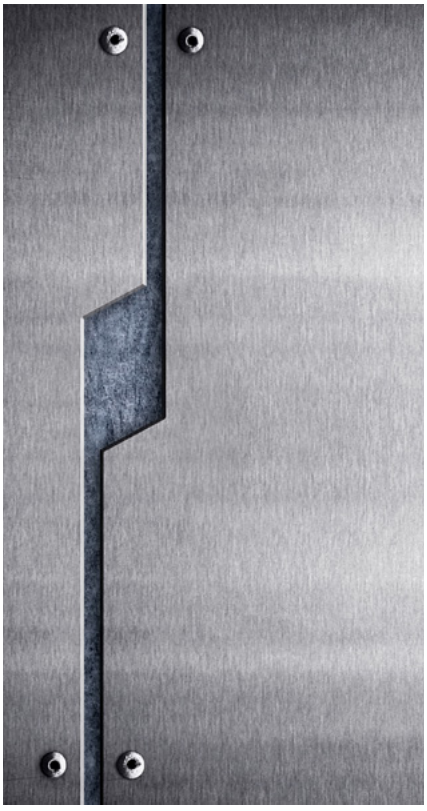


Fuel efficiency can be improved by reducing weight, and this, coupled with cost are primary factors in material selection. However, they are often taken into consideration with other material properties including strength, resistance to corrosion, safety, recyclability, biocompatibility, to name a few.

Steel is tough with a density of 7.85 g/cm³, but it is also relatively inexpensive and remains preferred in industries where cost-efficiency and strength are more important than weight.

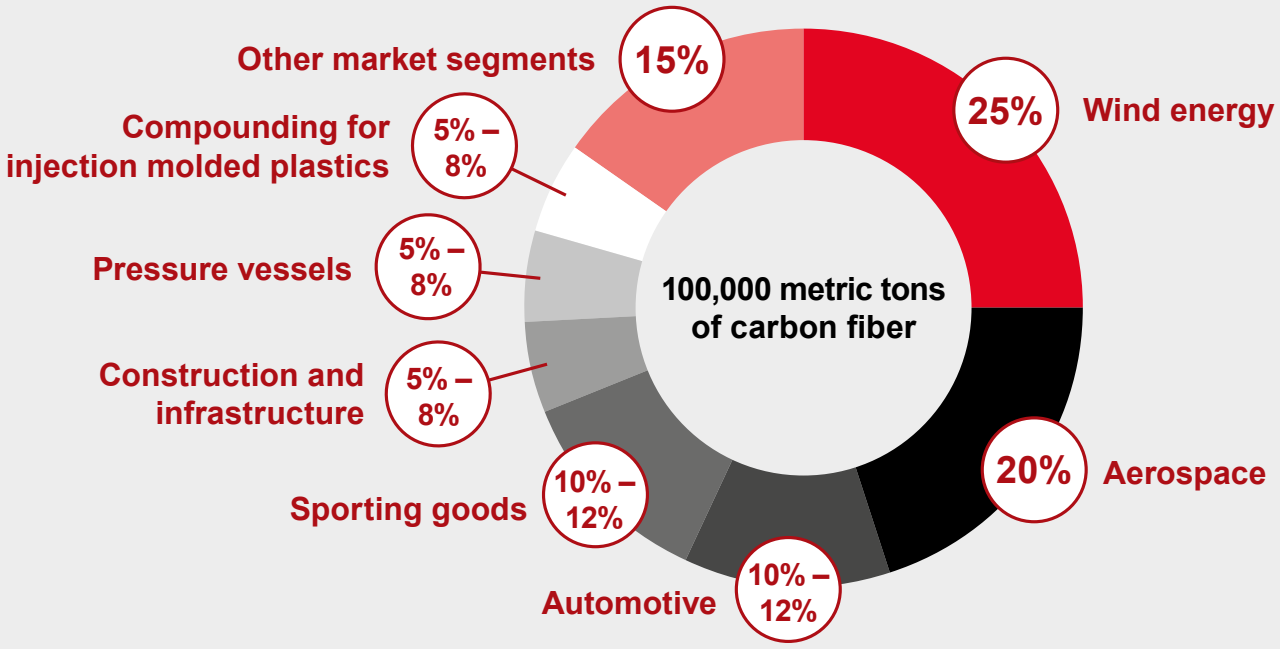
Advancements in **aluminum** technology have made it increasingly durable and lightweight (1/3 the density of steel at 2.7 g/cm³) plus it is resistant to corrosion. The growth in the global aluminum market is driven by development in the transport industry as well as technological advancements in aluminum manufacturing technologies and processing equipment[3].

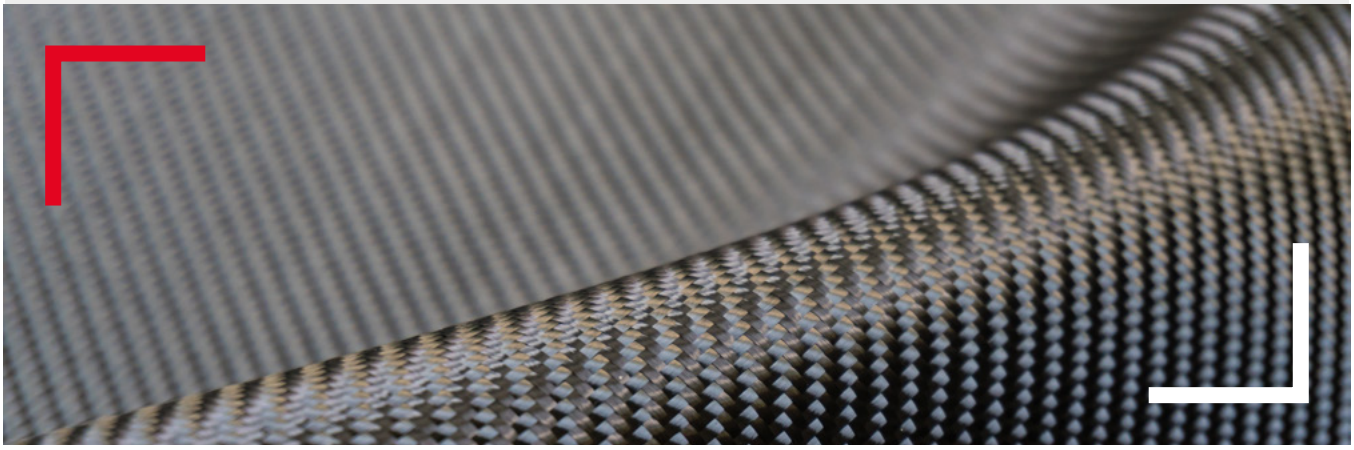
Titanium is considered a superior combination of high strength and low weight ratios when compared to steel, but its high cost is limiting its application for traditional heavy industry. As such, titanium tends to be reserved for use in higher-budget applications in the aerospace and defense industries. Its biological compatibility also means it is being adopted in the medical industry.



Fiber Reinforced Polymer composites (FRP composites) are chosen for components because of their relative stiffness and strength. The materials have a high strength-to-weight performance, which leads to lower weight, and more efficient structures.
For example, carbon-fiber-reinforced composite can be five times stronger than 1020 grade steel while having only one-fifth of the weight. Aluminum (6061 grade) is much nearer in weight to carbon-fiber composite, though still somewhat heavier, the composite can have twice the modulus and up to seven times the strength[4]. However, composites are also more costly than steel and are reserved for technological breakthroughs.

A state of the industry report in Composites Manufacturing Magazine highlighted that in 2019, demand for carbon fiber globally totaled approximately 100,000 metric tons[5]. The market continues to grow at 10 to 12% per year and the approximate breakdown of carbon fiber used by markets' segments are as chart 2 indicates:



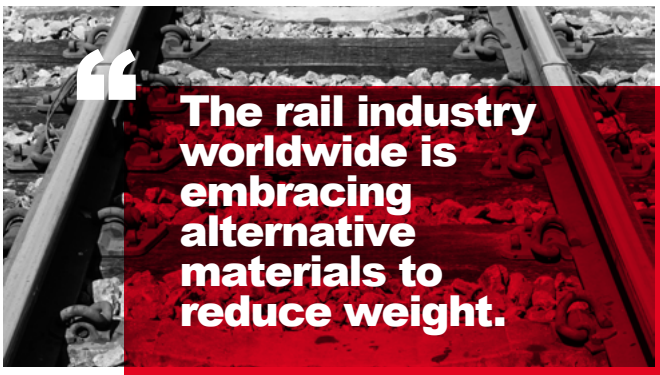


Below is a more detailed look at materials used in the transportation and machinery industries:

TRANSPORTATION

■ Rail

Reducing weight while maintaining safety are key in rail. While steel is still an important metal for tracks since it is the most reliable and therefore the safest, the rail industry worldwide is embracing alternative materials to reduce weight – particularly in carriages. Aluminum and FRP composites are being used in a host of applications such as trackbeds, gantries, vehicles / modules, interiors, lineside furniture and platform systems.



The aluminum alloys used in lightweight high-speed rail have lower density compared to steel (without compromising on strength), as well as excellent formability and corrosion resistance. As such, the main advantage of aluminum over steel is securing lower energy consumptions in high-speed trains and increased load capacities that can be transported, especially in freight trains. In rapid transit and suburban rail systems, where trains have to make more stops, significant cost savings can be achieved as less energy is needed for acceleration and braking if aluminum wagons are used. Lightweight trains, coupled with other similar procedures can reduce energy consumption by up to 60% in new wagons[6].

The combination of aluminum with composites can achieve further weight savings. For example, the Korean Tilting Train Express uses CFRP sandwich structures with an aluminum honeycomb core, which reduces the vehicle mass by 3.9 tons[7].

■ Shipyards

Focusing on reducing weight during shipbuilding is paramount. Cargo ships are one of the most popular methods of transporting goods, but also a significant source of emissions. The less the ship weighs, the less fuel it consumes, reducing pollution.

In shipbuilding steel plates are traditionally welded together to fabricate ship hulls. Modern steel plates have been designed with much higher tensile strengths than their predecessors, making them much better suited to the efficient construction of large container ships. A plate is available with a designed resistance to corrosion, ideal for building oil tankers. Such steels make possible much lighter vessels than before, or larger-capacity vessels of the same weight, offering significant opportunities to save on fuel consumption and hence CO_2.

Steels will still be the dominant bulk material in ship structures since it is presently the most economical solution, but there will be an increasing appetite for FRP composites to replace steel in selected applications. The use of polymer matrix composites can offer lightweight, stronger and tougher materials that do not corrode. Next-generation resilient mount materials will be explored to actively reduce the noise and vibration released from machinery[8].
In some applications, such as naval vessels, FRP composites also allow for the integration of multiple functions, for example, structural performance with thermal and radar signature reduction[9].

MACHINERY

■ Process equipment

Cost, reliability and efficiency are the three major drivers with process equipment found in chemical plants, petrochemical plants, refineries and power stations, and this is especially true of heat exchangers. The two main materials used in this application are stainless steel and aluminum and they are equally effective.

Aluminum has a thermal conductivity which is approximately four and a half times higher than stainless steel and it is the cheaper of the two materials.

However, stainless steel's strength, durability and high resistance to corrosion have resulted in it being a favorable choice for heat exchangers, and they tend to be better value in the long run.

■ Off-road vehicles and machines

Off-road vehicles burn a large amount of fuel and create more carbon emission compared to normal vehicles, as they require a large amount of power to operate, so in this application **reducing weight while maintaining safety** is vital.

High-strength steel and aluminum have been the biggest beneficiaries of weight reduction efforts in North America over the past decade, gaining 6% and 3% of vehicle mass, respectively.[5]

One area that aluminum is increasingly being applied is to wheels on commercial heavy-duty vehicles. Aluminum wheels are typically three to four times the cost of traditional steel wheels, but the wheels weigh less and are also proving to be more durable and tougher than steel – particularly in the mining and logging industries. Despite the higher upfront cost, they are proving more cost-effective in the long term.

2. WORKING WITH DIFFERENT MATERIALS AND THE CHALLENGES THEY PRESENT

It is clear to see that metals are a dominant material used within heavy industries. This section explores the different metal working processes, and the challenges the various metals present, especially in material removal applications.

There are two major metal working processes – casting and fabrication. Material removal is an integral part of theses metalworking manufacturing process and determines the overall quality of a finished product.

FOUNDRIES AND CASTING PLANTS

In foundries and casting plants, molds are made, and metals are cast into various shapes by melting them and pouring into the mold. Key applications for material removal in foundries include:

- **Mold manufacture**
- **Fettling – degating and surface cleaning**
- **Weld seam removal on cast parts**
- **Finishing and polishing**

FABRICATION

Fabrication consists of forming, machining, joining and finishing raw materials such as plates, tubes, or castings.
Essentially, the fabrication process shapes raw material into semi-finished or finished products.
Key applications for material removal in fabrication include:

- **Machining: drilling, chamfering, or sawing**
- **Surface preparation: metal plate chamfering**
- **Weld seam removal and weld cleaning**
- **Finishing and polishing**

Steel and steel alloys

Key applications for steel and steel alloys are mainly related to fabrication and the welding process, both before and after welding. Before welding, tools such as grinders are commonly used or surface cleaning and chamfering, whereas cutting tools are used for cutting. After welding, grinders are typically used for weld seam removal and to prepare the surface for painting. Cutting and drilling tools are also used.

The key challenge of working with steel and steel alloys is that removal tasks can take a long time, and the process risks becoming inefficient and costly. The tools that give the best results tend to be heavy – often between 3kg to 5kg – but they become arduous when used for any length of time, in some cases, workers may have to grind for 5 hours a day in a harsh environment with metal particles in the air. On occasion, it can be tough to find employees for the most difficult jobs.

Another challenge is the inherent corrosion properties of the material. It can be difficult to prevent rust and achieve and maintain a good surface finish for painting.

Tips

1. ***For tough jobs which require a lot of grinding it is important to use an appropriate abrasive. Zirconium oxide (or zirconium alumina as they are also known) abrasives are hard wearing and provide excellent performance over a longer lifetime.***
2. ***Consider the material removal method. Is grinding really the best option, or would cutting be more efficient? If ingates can be removed close to the surface with a cutting tool, that would minimize the amount of grinding required and the associated time, ultimately improving productivity.***

Stainless steel

Stainless steel is often used in containers, pressure tanks and pipes, the key material removal applications are weld seam removal, grinding, and sanding and polishing the final part.

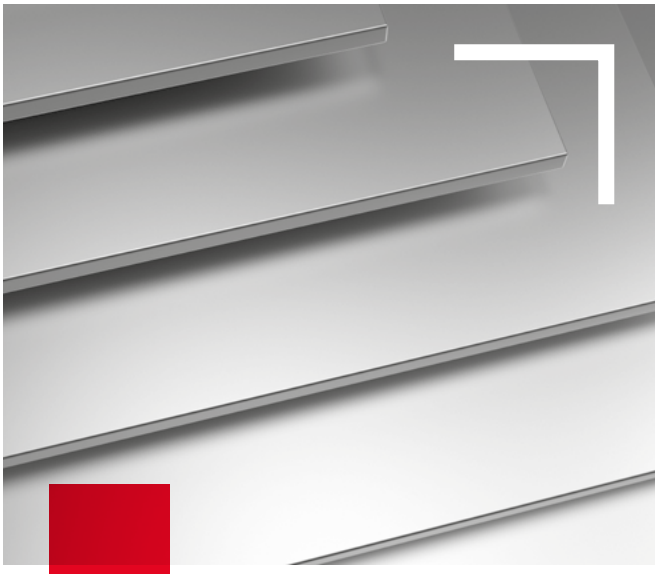
However, stainless steel has a lower heat conductivity than steel and other iron materials, and as a result gets hotter locally when worked on. Operators need to be extremely careful when working with stainless steel because the parts are often thin and there is a high risk of damaging the metal product.

Since care and attention is required, the grinding process can often slow down the whole production flow, and there are often quality remarks on the surface finish of the completed part.
It can be a challenge to keep the processes on carbon steel and stainless steel separated and operators frequently use a tool with a “contaminated” abrasive from a non-stainless task on a stainless one. This ultimately damages the stainless-steel product.

Tips

1. ***Use a low speed tool, less than 4000 rpm, this will help avoid overheating.***
2. ***Allow extra care and time for the job and be prepared for it to take longer.***
3. ***Use abrasives appropriate for the task and keep the steel and stainless-steel abrasives separate.***
4. ***Flap discs with a finer grit are best for softer operations and provide a better finish. All angle grinders, angle and pistol die grinders can be used with flap discs.***

Aluminum



Key material removal applications with aluminum include fettling of castings, surface preparation and finishing. Some of the major challenges of working with aluminum are that if material is pushed on too hard, it can result in over-heating, which damages the metal. The grinding wheel also becomes clogged, which slows down the process, and makes it inefficient.

Additionally, when worked on, aluminum produces a fine dust, which can be inhaled by the operator, and is therefore a health and safety risk. The dust is also a potential fire hazard.

Tips

1. *Most standard abrasives can be used at normal speeds. These depend on the size of the disc, for example at 6" a normal speed is 10000 rpm and at 7" it is 8500 rpm.*
2. *Apply sprays and waxes to prevent clogging.*
3. *Consider abrasives carefully. While many aluminum oxides grinding wheels with hard bonds dominate the market, they are not always the best solution; grinding aluminum can be easier with a soft bond and/or a silicon carbide grain.*
4. *Ensure the working area is well ventilated and use dust extraction to protect operators.*

"Because of their structure, FRP composites require a completely different approach."

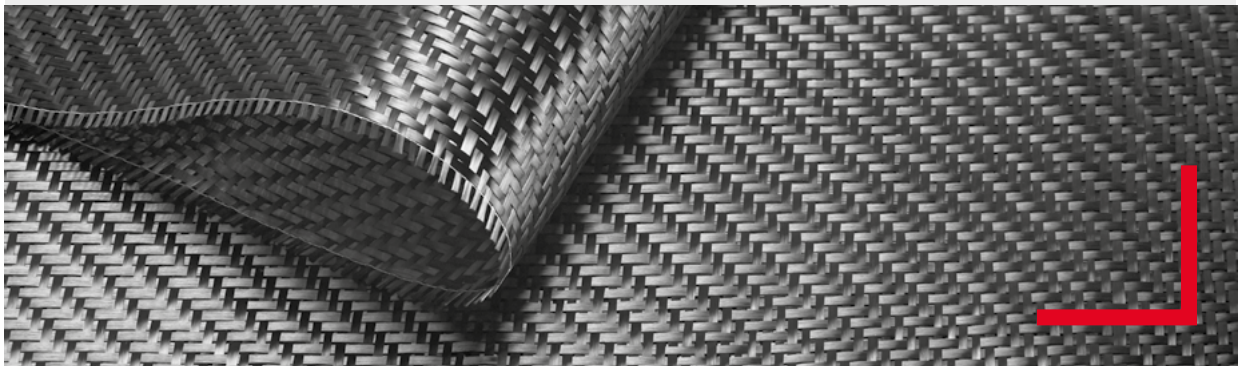
FRP Composites

Fiber Reinforced Polymer composites (FRP composites) are becoming increasingly prevalent within traditionally heavy industry, but because of their structure, they require a completely different approach to material removal. Key applications for material removal include sanding and drilling.

One of the main complexities of working with FRP composites is their heat sensitivity when the temperature is higher than 200°C. Material can melt on the grinding wheel, which makes the job impossible or degrades the quality of the component. Dust from the fibers is also a potential health and safety issue or even a fire hazard. As such, grinding is not the best suited application for FRP composites.

Tips

1. *FRP composites with a low fiber content are easier to grind and sand to an acceptable surface finish. If the FRP composite has more than 70% fiber content, grinding will be tough and result in a lower-quality surface finish than other FRP composites.*
2. *Use a low speed power tool when sanding.*
3. *Use a high speed power tool when drilling (minimum 6000 rpm).*
4. *Dust extraction is a must. There are many different types of dust extraction systems, and the most efficient are portable machines with a hose attachment.*



3. IMPACT ON TOOL SELECTION

All areas of the metal working industry, from foundries to fabrication, are looking to increase efficiencies throughout their processes. Using pneumatic tools that are appropriate to the material being worked on and the application will enable users to work effectively and efficiently to increase productivity. When specifying tools there are a number of considerations to take as outlined below.

Speed

SPEED IS A MAJOR FACTOR TO CONSIDER, AS IT HAS A SIGNIFICANT INFLUENCE on achieving an efficient material removal rate. However, there is no one perfect tool speed for each material as there are many variables that contribute towards the most effective speed. *For example, disc type, disc size, cycle time, wheel life and required surface finish quality, all have an impact on what speed to select.*

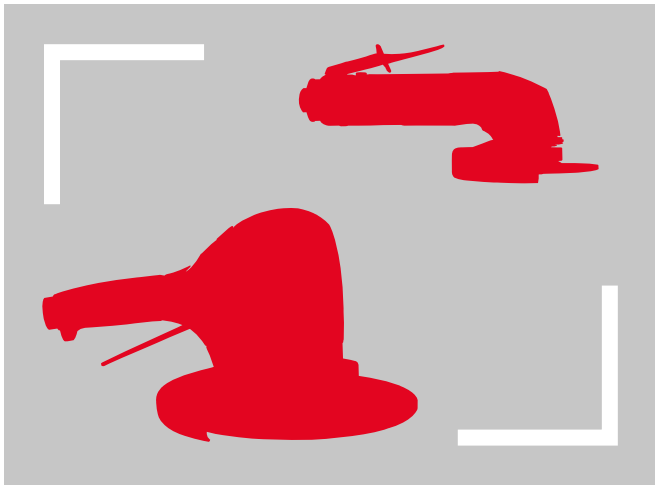
Higher speed is not necessarily better since it can cause local heating in certain materials which ultimately results in clogged grinding wheels, or the material becoming damaged. Operators should refer to their internal processes to determine the right speed to use as it will vary considerably between applications.

Considerations by material type:

Material	General considerations for tool selection
Steel and steel alloys	These materials can be tough to grind, so select powerful tools to be as efficient as possible.
Stainless steel	Depending on the application, it is generally advised to select a low speed power tool because of the material's lower heat conduction.
Aluminum	Aluminum is a very workable material, and as such has no specific demands from tools. In this case, tool selection should be based mostly on variables including safety, speed, performance and reliability requirements.
FRP composite	It is important to use the correct speed and abrasive to achieve the best results and avoid melting the FRP composite onto the abrasive.

Recommendations by application

Cutting, Surface grinding, chamfering, and weld seam removal

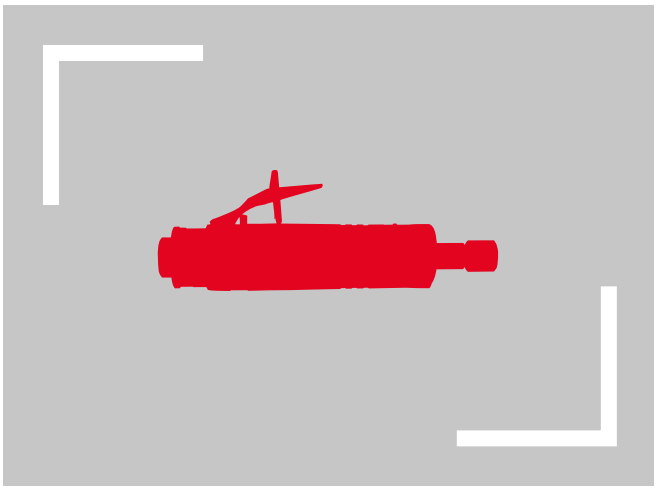


ANGLE AND VERTICAL GRINDERS WORK BEST IN THESE SCENARIOS.

Tips:

1. *Ensure the air pressure is correct. Pneumatic tools require a dynamic pressure of 90 PSI (6.3 bar) to work most effectively. If the pressure is higher than this the tool's lifespan can be negatively affected and there is a risk of disc burst, jeopardizing the operator's safety. To avoid this, it is recommended to use grinders with overspeed shut-off safety functions.*
2. *Pay attention to the abrasive. For example, use grinding and cutting discs that are designed for the job. The disc should be an appropriate size for the tool, right for the material being worked on, and the tool's speed should not exceed the disc's maximum operating speed. Also, the disc should be checked before using it to ensure that it is in good condition; cracked, damaged or expired discs should not be used.*

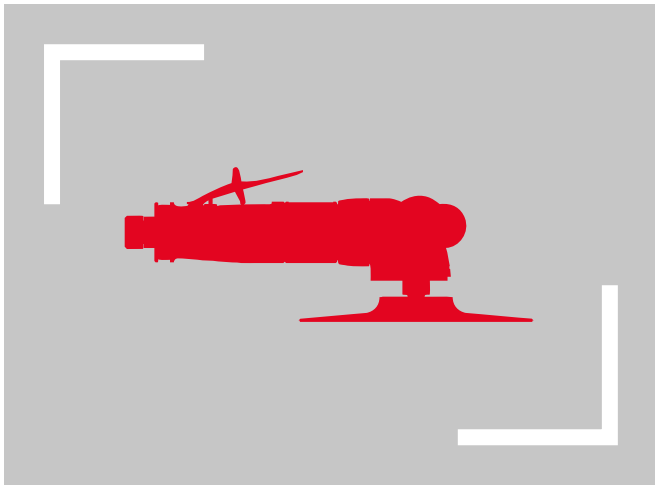
DIE GRINDERS ARE IDEAL SPECIFICALLY FOR CHAMFERING AND WELD SEAM REMOVAL



Tips:

1. *Use the right abrasive depending on the material:*
   - *Carbide burrs on harder materials such as hardened steel, alloy steel or cast iron.*
   - *Mounted points for softer materials such as aluminum and FRP composites because they help to remove less material even if a high force is applied on the tool. So, the piece is not damaged. Mounted points should not be used on harder materials as the mounted points can break and put operators' safety at risk.*
2. *Use a chamfering machine to obtain a good welding edge preparation.*

Surface sanding

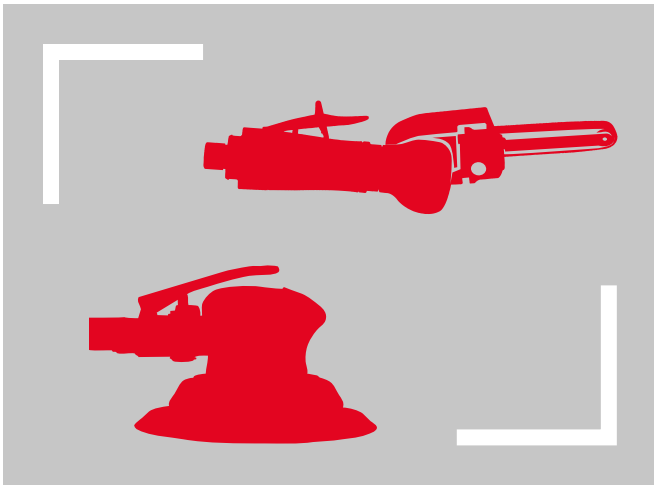


ANGLE ROTARY SANDERS ARE MOST APPROPRIATE IN THIS APPLICATION

Tip:

Use low speed tools (< 4000 rpm) depending on both the material of the workpiece and abrasive. Low speeds are particularly recommended for steel and FRP composite materials.

One example of a tool specially designed for low speed operation is Chicago Pneumatic's CP3550 angle rotary sander.



ROTARY ORBITAL SANDERS AND BELT SANDERS ARE IDEAL FOR FINISHING JOBS.

Tips:

1. *To keep the sanding process clean and contaminant-free consider using a tool that provides true oil-free operation.*
2. *Select orbital sanders with built-in speed regulators to ensure the performance and safety of the tool. The majority of rotary orbital sanders include this feature.*

Chicago Pneumatic's CP7250HCVE orbital sander with central vacuum provides oil-free operation.

Other factors affecting productivity, safety and ergonomics

Some other factors that can make a difference to the productivity, as well as **the safety and comfort** of the user include the tool's power-to-weight ratio, durability, functionality, ergonomics, cost, air line set-up, and product features such as:

SPINDLE LOCKS,

which enable quick abrasive replacement to minimize downtime.

AUTOBALANCERS,

which stabilize a tool and greatly reduce vibration. Since vibrations are minimized, the tools can be used safely for longer periods of time. Abrasive disks also last longer as the contact between the abrasive and the application is optimized. As such, operators do not need to use as many abrasives on a job and they can save associated purchase costs. The use of autobalancers also results in a 15% higher material removal rate than using a tool without this function.

TOOLS WITH DUST EXTRACTION

and ventilated grinding tables. These are mandatory when working with aluminum and FRP composite materials, and a worthwhile investment when working with other metals.

Another aspect to consider for the future is **CONNECTIVITY.**
When working with materials, increasing efficiencies is going to be a dominating factor for tomorrow's operators. Tool manufacturers are looking at developing smart, intelligent tools which will have a major part to play in data management.

CONCLUSION

This white paper has highlighted an increasing number of materials being used to meet the demands in traditional heavy-duty industries including transportation and machinery. For example, new metals and FRP composite materials are providing the much-needed weight reduction, higher strength, and corrosion resistance in finished pieces.

However, for metal workers used to working with certain tools on iron or steel, this can present a challenge as the tools will perform very differently on other materials including aluminum and composite. It can often be difficult to know where to start when specifying tools to work most effectively.

Only by fully understanding the applications and how the materials behave, together with requirements from the tools (e.g. performance, safety ergonomics, etc.), can operators make well-informed decisions on the right tool to help increase the material removal rate, their productivity and ultimately bottom line.

Do you want to learn more or discuss further your metalworking applications and potential tool needs? Our teams of experts are here to guide you.

CONTACT US

CHICAGO PNEUMATIC

Chicago Pneumatic was founded in 1901 and has been providing high-quality power tools ever since. Its tools are designed for everyday use in the most demanding environments and serve customers in the industrial, metalworking, maintenance, oil and gas markets.

At the heart of Chicago Pneumatic are its **people** and they have a **passion** to research, develop, manufacture, and deliver high performing products and solutions that meet customers' long-term needs. Its people are truly experts in their field, providing first class knowledge on how to work with tools most effectively. The company's specialists work closely with customers to fully understand their challenges and requirements so they can recommend the best tool for the application and materials they work on.

Everyday Chicago Pneumatic inspires their customers to become experts on power tools with their Expert Corner, its online knowledge hub. The Expert Corner is aimed at anyone with questions about power tool selection, **performance**, or regulations. It provides new articles every month covering a wide variety of topics as well as videos to explain – in a clear and interactive way - some of the more complex topics. It also features complete downloadable technical guides.

Considering that industrial maintenance professionals working with power tools rely on them to improve their productivity, provide a safe working environment and ensure top quality work, the Expert Corner materials are designed to help managers and operators gain a better understanding of power tools and all subjects related to them.

As a leading manufacturer of power tools, Chicago Pneumatic invests heavily in developing new designs and testing products to ensure it provides the highest quality and safety levels. Chicago Pneumatic also believes it is very important to assist their customers to improve productivity and enhance their wellbeing.

Drawing from its 110+ years of industry experience and knowledge, Chicago Pneumatic is sharing free advice online, such as this white paper, to help power tool users work smarter and safer.

Today, Chicago Pneumatic has a global reach, with offices in more than 20 countries and local distributors worldwide.

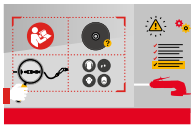
To learn more, visit www.cp.com.

APPENDIX

1 **Worldsteel association, Steel facts –** https://www.worldsteel.org/about-steel/steel-facts.html
2 **Worldsteel association, Steel markets –** https://www.worldsteel.org/steel-by-topic/steel-markets.html
3 **Allied Market research, Aluminium market –** https://www.alliedmarketresearch.com/aluminium-market
4 **Composite UK Trade Association –** https://compositesuk.co.uk/composite-materials/introduction
5 **Composites Manufacturing Magazine, January 2020** http://compositesmanufacturingmagazine.com/digital/2020/CM-issue-january-february-2020.pdf
6 **Aluminum Insider –** https://aluminiuminsider.com/aluminium-use-production-trains-steams-ahead/
7 **Report produced for BSI by Composite UK Trade Association –** https://www.bsigroup.com/globalassets/documents/about-bsi/nsb/standards-strategy-for-light-weighting-in-transport.pdf
8 **Lloyd's Register –** https://www.lr.org/en/insights/global-marine-trends-2030/global-marine-technologytrends-2030/
9 **Materials World magazine, January 2020 - The institute of Materials, Minerals and Mining, Materials World –** https://www.iom3.org/materials-world-magazine/feature/2020/jan/06/assessing-composite-joints-ships

Learn more about pneumatic tools and material removal with our Expert Corner. Find below a selection of related topics:

The secret to productive industrial drilling
https://www.cp.com/en/tools/expert-corner/blog/secret-to-productive-industrial-drilling



Grind safely!
https://www.cp.com/en/tools/expert-corner/blog/grind-safely

Why is a pneumatic grinder spinning too slowly?
https://www.cp.com/en/tools/expert-corner/blog/why-is-a-pneumatic-grinder-spinning-too-slowly

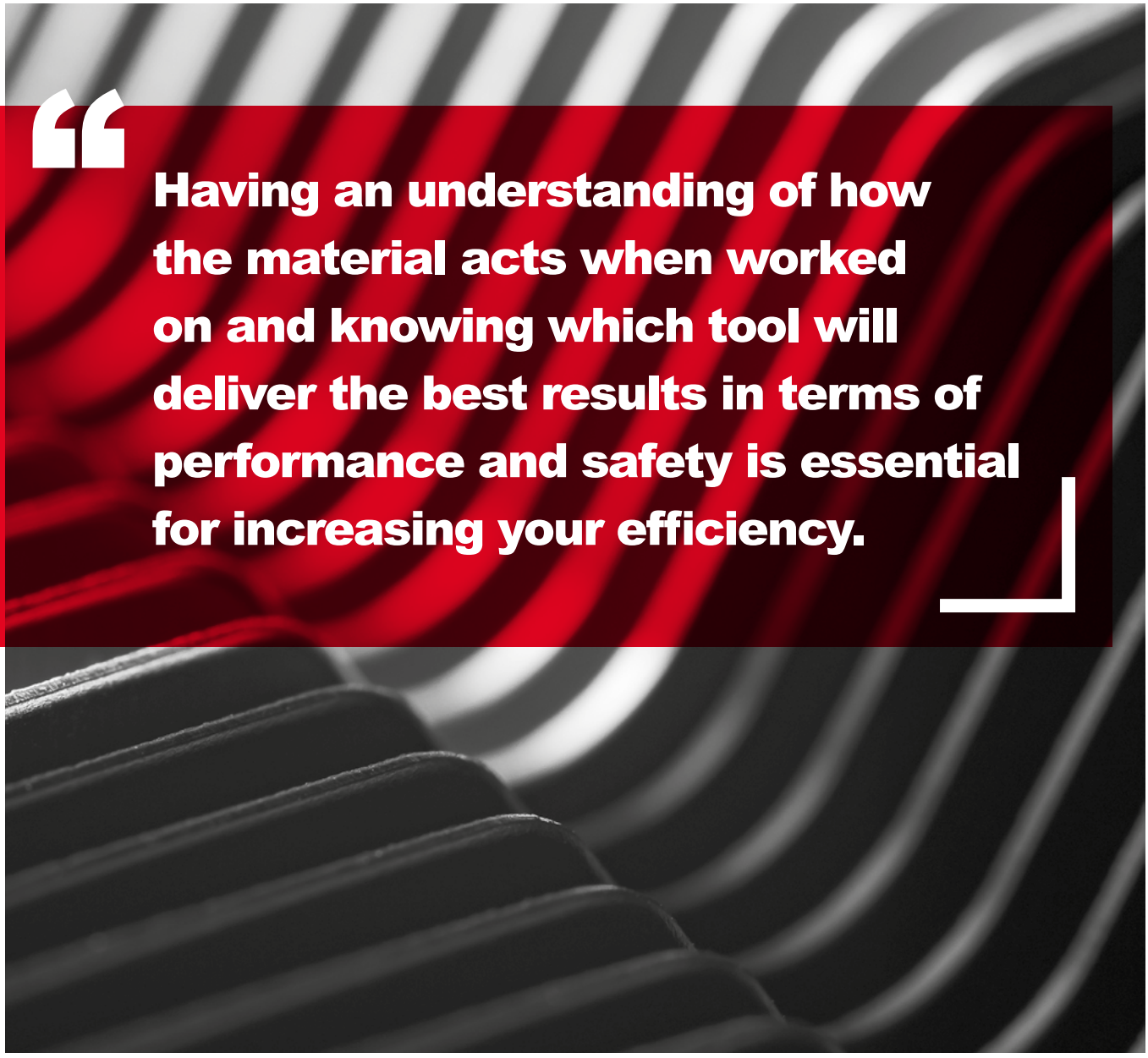
7 simple steps to ensure operator safety
https://www.cp.com/en/tools/expert-corner/blog/7-simple-steps-to-ensure-operator-safety

How do you prevent grinder wheel burst in metalworking?
https://www.cp.com/en/tools/expert-corner/blog/grinder-safety-with-overspeed-shut-off

Limiting vibrations – it's all in the balance
https://www.cp.com/en/tools/expert-corner/blog/limiting-vibrations-all-in-the-balance

Improve Your Productivity With Governed Air Grinders!
https://www.cp.com/en/tools/expert-corner/blog/improve-your-produtivity-with-governed-air-grinders

When to Use Vertical Grinders Versus Angle Grinders?
https://www.cp.com/en/tools/expert-corner/blog/when-to-use-vertical-grinder-versus-angle-grinders



More information on www.cp.com

Chicago Pneumatic