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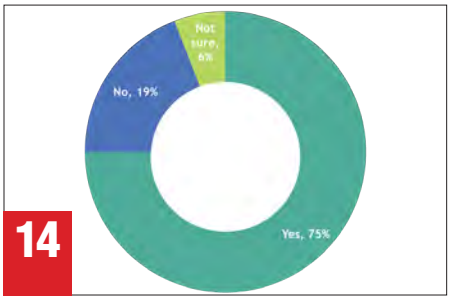

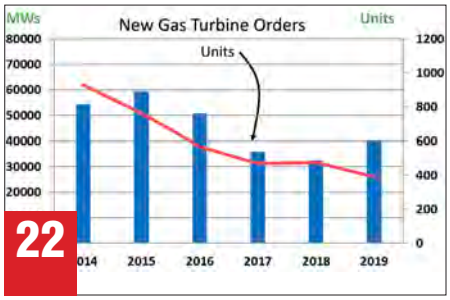

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INTERESTING TIMES

We certainly live in interesting times. Our cover story looks into the repercussions of the Covid-19 outbreak and the oil price collapse. It provides predictions about the downturn and how long it might take for normality to resume.

Additionally, it lays out what turbomachinery OEMs, suppliers and service companies around the globe are doing in response. A few are struggling, but many appear to be doing OK.

Most are positive about the future. They have been through ups and downs before and lived to tell the tale. Following events such as the Arab oil embargo, the Iranian hostage crisis, 9/11 or the most recent recession, they managed to come out relatively unscathed. In some cases, they thrived.

Who knows, but another upswing might be right around the corner. The shale oil boom, for example, was a surprising windfall few predicted. And whatever pain and suffering results from low oil prices, they always eventually recover.

In fact, the last major oil price drop in the middle of the last decade prompted the entire industry to eliminate specification bloat and general inefficiency. It took a leaner and more nimble oil and gas supply chain to facilitate the profitable exploitation of shale oil and gas.

Our survey of turbomachinery OEMs, partners and aftermarket support specialists revealed that most companies are wisely trimming costs. But a word of caution: the slashing of marketing budgets may appear sensible in the short term. But it could be disastrous in the long term. If business is slow, it is vital to get the word out in any way possible about your products and services. Failure to do so could prolong any downturn.

“If business is slow, it is vital to get the word out in any way possible about your products and services. Failure to do so could prolong any downturn.”

Good issue

The rest of the issue has plenty to offer. A timely review of gas turbine sales trends highlights some of the problems facing OEMs as well as areas of opportunity.

We also have the first story from our new associate editor Rory Pasquariello. He tackles the microturbine industry with an overview of the various niches where these machines are succeeding.

A story about mitigating failure mechanisms in turbomachinery by Proto Manufacturing addresses how engineered residual stresses can be used to reduce the amount of failures in turbines and compressors.

Siemens presents a novel method of overspeed impeller testing on centrifugal compressors. Sulzer rounds out the contributed section with an informative piece on coatings.

Our columnists, too, continue to maintain a high level of content value. The Myth Busters delve into steam turbine sizing, making the point that oversizing may not necessarily be a smart idea. Turbo Tips provides tips and insight on how to ensure shafts stay in alignment.

Industry events

We had hoped to see many of you at the Western Turbine Users Conference in late March. It was not to be. For a while there, it appeared the Turbomachinery Expo in London in late June would happen. But it was recently cancelled.

Let’s hope the HRSG Forum in Orlando in late July and the Turbomachinery Symposium in September take place. It has been too long since we crossed paths. ■

DREW ROBB
Editor-in-Chief

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T-POINT 2 IS ABOUT TO OPEN

Mitubishi has begun the commissioning of T-Point 2, its new combined cycle power plant (CCPP) validation site at Takasago Works in Hyogo Prefecture, Japan. Replacing the iconic T-Point, the facility will accelerate technology development and enable more robust validation of advanced gas turbines (GTs) such as the 1,650°C JAC model and 1,700°C ultra-high-temperature models.

Like its predecessor, T-Point 2 will be connected to the grid. Commercial operation is scheduled to begin in July 2020. T-Point 2 is expected to a achieve power output of over 566 MW (60Hz), with nearly 64% efficiency, 99.5% reliability and a turbine inlet temperature of 1,650°C.

The new plant features a triple-casing steam turbine (ST), augmenting overall system efficiency through a multiplier effect with the JAC GT. Greater efficiency reduces carbon emissions and heat loss.

Mitsibishi will use the facility to conduct validation of the next-generation 1,700°C -class ultra-high-temperature GTs, ST upgrades, air-cooled condenser technology, generators, and static frequency converters.

Work is underway to install artificial intelligence (AI) technology at T-Point 2. This will be based upon the Tomoni suite of digital solutions. During an 8,000-hour durability demonstration period, Mitsubishi will also be training AI apps, allowing T-Point 2 to eventually become an autonomous CCPP.

Megamie fuel cell-microturbine hybrid at the Hazama Ando Technical Research Institute in

Mitsubishi Power digest

Mitsubishi Power, formerly Mitubishi Hitachi Power Systems (MHPS), has received an order from Hazama Ando for its pressurized hybrid power system, combining a solid oxide fuel cell (SOFC) with a micro gas turbine (MGT). This order for Megamie, was the second such order for a commercial application.

This system has been delivered to the Hazama Ando Technical Research Institute in Tsukuba, Japan and operation has commenced. This system is being used as a distributed power supply system to support a nationally backed project aimed at curbing CO_2 emissions. It uses natural gas as fuel, supplying clean power and heat with low CO_2 emissions. Hazama Ando plans to switch to hydrogen fuel with zero CO_2 emissions in the future. This system will combine cogeneration equipment with sodium-sulfur batteries.

Mitsubishi Power has received an order and begun work on a turnkey contract for construction of new Units 1-3 at the Anegasaki Thermal Power Station (Ichihara City, Chiba Prefecture) operated by JERA Power Anegasaki. This project will replace the existing power station's aging gas-fired steam power generation units 1-4 with three 650 MW-class CCPPs using 1,650°C forced air-cooled M701JAC GTs. The units are scheduled to begin operations in 2023.

The 980 MW Lake Charles Power Station in Westlake, LA has begun commercial operation. This is part of Entergy's plans to phase out its coal-fired oil and older natural gas portfolio. The plant features air-cooled 501GAC GTs.

Mitsubishi Power has concluded a contract to introduce Tomoni, its digital solutions service for the Domo de San Pedro Geothermal Power Station in southern Nayarit, Mexico. This will enable real-time monitoring of the plant's status and performance to improve operation and maintenance, while extending the intervals between regular inspections. The 27 MW plant was built by Mitsubishi Power under an EPC (engineering, procurement and construction).

Charlie Takeuchi of Hitachi

Hitachi

Hitachi has established Hitachi Industrial Holdings Americas to strengthen business in North America. It operates two U.S. headquartered companies, Sullair (air compressors), and JR Automation (robotics). Through such operations, Hitachi will collaborate with other Hitachi group companies to provide optimization solutions. Charlie Takeuchi has been named President and CEO of Sullair, succeeding Jack Carlson, who retired.

Duke Energy's Lincoln Combustion Turbine Station.

Siemens digest

Siemens Energy started the first ever SGT6-9000HL GT at Duke Energy's Lincoln Combustion Turbine Station near Denver, North Carolina. The HL-class is composed of an air-cooled four-stage power turbine and hydraulic clearance optimization for higher efficiency at full load while facilitating immediate restart.

It includes a service-friendly steel rotor design with Hirth serrations and a central single tie rod and a can annular combustion system. The GT's ramp-up rate is about 85 MW a minute. With inspection intervals of 33,000 equivalent base-hours and 1,250 equivalent starts, the unit is designed for reliability and low life-cycle costs.

During first fire, the SGT6-9000HL and the auxiliary systems – including the gas supply, lube oil system, control system and startup systems – worked together as designed. The 402 MW unit ramped up to a pre-determined test speed, and the combustion system ignited.

The machine will continue a four-year testing plan, gradually introducing technologies to achieve the next level of efficiency. The unit will operate in simple-cycle mode under real-world power plant conditions, allowing Siemens to assess and optimize the performance while gaining commercial operating experience.

Siemens Gas and Power was selected to provide three 33 MW SGT-700B GTs for a Long-Term Program (LTP) with Ascend Performance Materials' nylon intermediate and specialty chemicals facility in Decatur, AL. This allows Ascend Performance Materials to retire assets that currently provide process steam for the facility.

The shift to GTs for steam generation is part of Ascend's sustainability strategy to improve its environmental footprint and accelerate growth. The LTP is scheduled for eight years. Siemens Gas and Power will perform all scheduled outages.

The LTP also calls for Siemens Gas and Power to upgrade, at the time of the first inspection, the B-series generators to C-series models (35 MW rating) to operate in a cogeneration application. The SGT-700, with a 6,500-rpm, two-stage uncooled free-power turbine can operate at 50% to 105% of its nominal shaft speed.

It is designed for higher output and efficiency under a range of operating conditions. The turbines will be manufactured in Siemens Gas and Power's Finspång, Sweden plant in time for project commissioning, which is expected in Q4 2021.

Uniper and Siemens Gas and Power signed a cooperation agreement for the development of projects on the decarbonization of power generation and promoting sector coupling. One focus of the planned cooperation is the production and use of green hydrogen from renewable energy sources.

The scope of the agreement also includes the evaluation of the potential of Uniper's existing GTs and gas storage facilities for the use of hydrogen. The focus of the work is to define what role hydrogen can play in the future evolution of Uniper's coal power plants.

Uniper announced it would close or convert its coal-fired power plants in Europe by 2025 at the latest. Uniper's coal-exit plan is instrumental to becoming carbon neutral in Europe by 2035. Uniper has built two power-to-gas plants in 2013, and added a methanization plant.

Siemens AG appointed Christian Bruch, former Executive Vice President of Linde, to be the new CEO of Siemens Gas and Power and CEO of Siemens Energy. Maria Ferraro, former CFO of the Digital Industries (DI), has been appointed CFO of Siemens Energy.

Siemens has received an order for five SGT-800 industrial GTs, including associated auxiliary and electrical systems, for a peak load and backup power plant in Belarus. The new plant will be built at the existing power plant location of the Berezovskaya combined heat and power (CHP) plant in Beloozersk, Brest Region, in the southwestern part of the country.

The order was placed by Brest Republican Unitary Enterprise of Electricity Industry (Brestenergo). It will have an electrical capacity of 254 MW. Commissioning is scheduled for December 2021. The SGT-800 offers between 50-62 MW and is often used in power generation and oil and gas applications. Siemens' complete scope of supply includes the five SGT-800 gas turbines with AC generators and the PCS 7 control system. It also comprises the gas receiving station, along with high-, medium-, and low-voltage equipment.

Emerson acquisition

Emerson has completed the purchase of hydroelectric turbine controls firm American Governor. With expertise that spans the oldest mechanical to the latest digital governors, which regulate hydroelectric turbines, American Governor has headquarters near Philadelphia, and provides services to over 1,500 hydro plants.

New combined cycle plant

Shanghai Electric Group's first combined cycle power plant (CCPP) in Bangladesh has entered into commercial operation. Converted from a 150 MW simple cycle plant, the 225 MW CCPP in Sylhet includes upgrades for reduced emissions and higher thermal efficiency.

Featuring a 100 MW Global Vacuum Pressure Impregnation (GVPI) air-cooled generator, the plant is designed to operate for its entire life without the need for rewedding or retightening its laminated core. GVPI is said to have boosted efficiency from 33% to 55%.

Ethylene threat

At least 6.6 million tonnes (m.t.) per year, or 26%, of Europe's ethylene production capacity is threatened by oil refineries running at reduced rates or ceasing production, according to analyst firm ICIS. Ethylene, produced by crackers attached to refineries, has been hit by collapsing demand for petroleum products including jet fuel. Coronavirus-linked restrictions cut road and air transport, and aviation has largely come to a standstill across the region.

These ethylene crackers may be forced to reduce operating rates or close because they rely mainly on naphtha or liquefied petroleum gas (LPG) feedstocks sourced from the refineries to which they are linked.

Analysis suggests the 6.6 m.t./yr represent about 50% the refinery linked steam cracking capacity in Europe, and 26% of the region's steam cracking capacity. For propylene, 5.9 m.t./yr of capacity is linked, while for benzene the figure is 4.0 m.t./yr. Some 6.5m bbl/d of oil refining capacity is not operating at typical capacity.

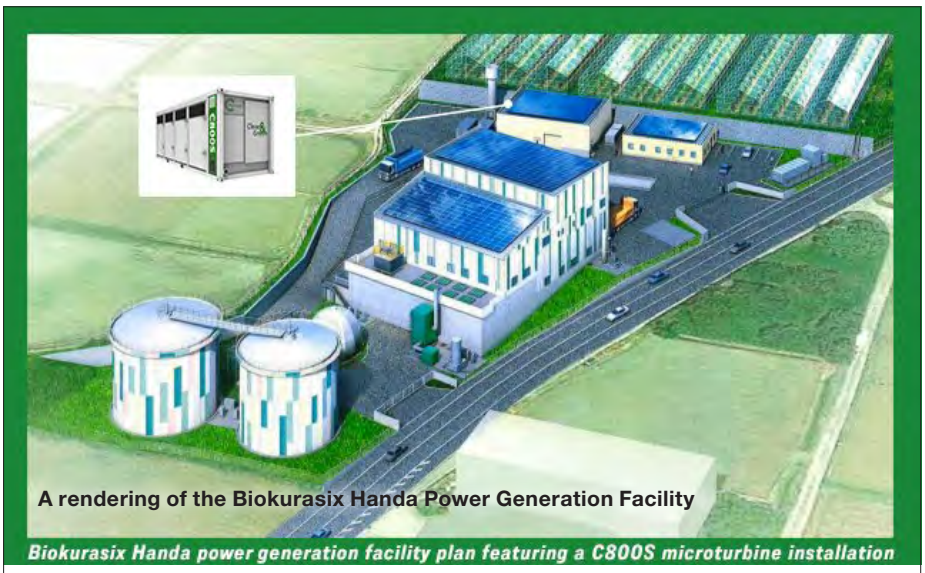
Most stoppages among European refineries are due to reduced fuels demand from coronavirus and associated lockdowns. At least 2.2m bbl/day of Europe's reductions are in place, versus the expected forecast throughput of 12.2m bbl/day.

Digitalized refinery

Texmark's large petrochemical processing facility in Galena Park, TX is engaged in digital transformation. The goal of this Refinery of the Future (RotF) project is to develop, test, and deploy the appropriate Industrial Internet of Things (IoT) technologies to enhance operational functions identified within Texmark's process manufacturing environment.

The project brings together technology partners, such as Hewlett Packard Enterprises, CBT, Aruba, Intel, PTC, National Instruments, OSIsoft, Flowserve, Allied Reliability, SparkCognition, GuardHat, and RealWear.

Analytics software and censored devices are being deployed to generate real-time insights, provide more complete automation and oversight, and reduce the risk of human error. Flowserve, for example, conducted an Industrial IoT pump demonstration. A fully instrumented pump provided data analytics and collaborative tools.



Biokurasix Handa power generation facility plan featuring a C800S microturbine installation

Capstone digest

Capstone Turbine received an order via its Japanese distributor Kanamoto for an 800 kW C800 Signature Series microturbine for a biogas project in Japan. It will use agricultural and animal waste to generate energy for the Biokurasix Handa biogas power generation facility.

It is expected to be commissioned in late 2020. The biogas-fueled 800 kW microturbine will be installed in grid connect mode, which enables the customer to operate with the utility grid in a load-sharing capacity. The facility will produce biogas using a digester to process the organic biomass coming from the city of Handa.

Capstone announced the long-term rental of a 1 MW C1000 Signature Series microturbine for the Permian Basin in Texas. The contract was secured by Capstone distributor Lone Star Power Solutions. Commissioning is scheduled in the fall of 2020.

Capstone received an order for six C65 microturbines from an industrial manufacturer of sorbent minerals in California. The microturbines will be installed in a direct-exhaust combined heat and power (CHP) application at a manufacturing facility in California.

The systems will use natural gas to provide power and thermal energy for the manufacturing process. The microturbine exhaust will go directly into a fluidized bed mineral dryer to reduce the amount of natural gas needed in the burner of the dryer. By using the exhaust energy in the drying process, the microturbines will allow the manufacturer to reduce energy costs, improve plant efficiency, and reduce on-site emissions.

Capstone received an order for an 800 kW Signature Series microturbine to upgrade the City of Roseville, CA, wastewater treatment plant (WWTP). The low-emission C800S microturbine system will help officials meet efficiency and sustainability goals by reducing carbon emission and produce power. Capstone distributor Cal Microturbine secured the order for the digester-gas fueled energy system.

Snam/Rina collaboration

Energy infrastructure company Snam and testing, inspection, certification and engineering consultancy services firm Rina, signed a Memorandum of Understanding to collaborate in the hydrogen sector. The goal is to realize the potential of hydrogen as an energy carrier.

The companies have formed a working group to study and test the compatibility of industrial burners and existing infrastructure already in operation with hydrogen. The group will begin experiments, analysis and technology scouting in various areas involving hydrogen including production, storage and distribution.

Introducing hydrogen into energy networks represents the first step for spreading and developing green hydrogen from renewable sources, while reducing its costs. Green hydrogen is generated by water electrolysis, a process that takes place without CO_2 emissions. In 2019, Snam became the first European company to successfully test the introduction of hydrogen blends into its gas transmission network with a percentage volume of up to 10%.

Yokogawa acquisition

Yokogawa Electric has completed the acquisition of all shares in Denmark-based Grazper Technologies. Grazper developed artificial intelligence (AI) technologies for analyzing images. Its solution allows AI software to run on a field-programmable gate array, a type of integrated circuit. The software employs image-recognition methodologies that have been theorized using algorithms and 3D modeling, and it can be operated with limited computing resources.

Yokogawa aims to leverage these technologies within its businesses and to develop new industrial AI solutions. In particular, by improving the recognition accuracy for moving imagery, it becomes possible to observe the overall environment and context of the whole image, opening up new applications in the security field and for image analysis and robot operations on production lines.

Yokogawa subsidiary, Yokogawa Turkey Industrial Automation Solutions, won an order to provide a control system and field instruments for the Zerger gas-fired power plant in Turkmenistan. The order was received from construction company Renaissance Heavy Industries that is involved in the construction of the plant for Turkmenenergo, the state-owned power utility.

EthosEnergy contract

Turbomachinery operations and maintenance firm EthosEnergy will handle long-term service and repair needs for the gas turbine at a Japanese petrochemical plant. Maruzen PetroChemicals awarded the multi-million-dollar, four-year contract to Ethos.

The contract covers new GT parts, component repair, maintenance and field services for a Frame 6B gas turbine at the facility. Maruzen, founded in 1959, focuses on processing and sales of ethylene, propylene, benzene and other basic petrochemical products, methyl ethyl ketone and other solvents, polyparavinyl phenol and other new materials.

Sundyne acquired

Sundyne, a manufacturer of API-compliant pumps and compressors, has been acquired by private equity firm Warburg Pincus. Sundyne's current management team led by CEO Mark Sefcik, will continue under Warburg Pincus' ownership. Sefcik said all existing channel partner agreements remain in place and all product brand names remain.

Power deals

Total power industry deals for February 2020 worth $5.91 billion were announced globally, according to GlobalData's deals database. This marked an increase of 111.1% over the previous month and a drop of 42.1% when compared with the last 12-month average of $10.2 billion.

In terms of number of deals, the sector saw a drop of 28% over the last 12-month average with 116 deals against the average of 161 deals. In value terms, Europe led the activity with deals worth $2.18 billion.

The top five power deals accounted for 61.9% of the overall value. These were

- Siemens $1.22 billion acquisition of Siemens Gamesa Renewable Energy
- The $1.13 billion acquisition of Abu Dhabi National Energy by Abu Dhabi Power
- JSW Energy's $742.28 million asset transaction with GMR Energy
- The $300 million asset transaction with Glidepath Ventures by Grasshopper Solar
- APG Groep and Aquila Capital's private equity deal with Smakraft for $270.92 million.

ORC system

Turboden has concluded a contract to provide the Meadow Lake Tribal Council (MLTC), representing nine Indigenous First Nations in Saskatchewan, Canada, with an 8 MW Organic Rankine Cycle (ORC) power generation system that uses sawmill residual woody biomass as fuel. The MLTC Bioenergy Centre will use biomass fuel derived from residual wood waste from an adjacent sawmill.

Turboden's binary cycle power generation system has as its core component an ORC turbine, which uses as the boiling medium organic material with a low boiling point. This can include materials such as a fluorocarbon or a hydrocarbon-based material. As a result, this permits the use of relatively low-temperature heat sources such as biomass, factory waste heat, and geothermal energy. The system can generate up to 40 MW of electricity.

The GE 9 HA gas turbine

GE in Poland

GE announced the order of two GE 9HA.01 GTs, along with two STF-D650 steam turbines (STs), providing up to 1.4 GW of power at Dolna Odra at the Polska Grupa Energetyczna Górnictwo i Energetyka Konwencjonalna's (PGE) Dolna Odra Power Plant in the Western Pomerania region of Poland.

PGE's investment in gas-fired power units will provide stability for the long-term operation of the current coal-fired power plant. Commissioning is scheduled for 2023.

The GE-led consortium includes the Polish company Polimex Mostostal, which has been awarded the EPC contract for the new units, together with the contract to build the full underground infrastructure.

GE factories in Elblag and Wroclaw in Poland will also produce equipment for the project. The order also includes an additional 12-year service contract with GE.

GT exhaust standard

The International Organization for Standardization (ISO) has published a new standard "ISO 21905:2020 Gas turbine exhaust systems with or without waste heat recovery," based on the work carried out by the ETN Exhaust Systems Working Group.

The objective was to bring together operators facing similar problems, as well as exhaust system designers and external expertise and support, who could address the problems by developing a common standard for the design, construction and operation of gas turbine exhaust systems.

In the first phase of the project, the group with Equinor, Total and Shell carried out a gap analysis, uploaded an index to facilitate the creation of the standard and collected material. The group focused on an exhaust systems standard incorporating Waste Heat Recovery Units (WHRU) equipment, to be followed by a later version based on Heat Recovery Steam Generators (HRSG).

SHAFT ALIGNMENT

AND ITS EFFECTS ON TURBOMACHINERY

BY AMIN ALMASI

Shaft alignment is the process of aligning two or more shafts to within a tolerated margin. It is a critical requirement for turbomachinery trains before they are put in service.

Shafts are in alignment when they are colinear at the coupling point, i.e., the rotational centerlines of two mating shafts are parallel and intersect. In other words, they join to form one line.

When this is the case, the coupled shafts theoretically operate like a solid shaft. Any deviation from the aligned or colinear condition results in abnormal wear of turbomachinery components, such as bearings, shaft seals and the shafts. Proper alignment reduces power consumption, vibration and noise, as well as helping to achieve the intended life of turbomachinery and its components.

The goal of alignment procedures is to obtain a common axis of rotation during operation for two coupled shafts. This is particularly important for high-speed, high-power units. Although some flexible couplings might allow for a tiny amount of misalignment, correct alignment remains critical for shafts with flexible coupling.

Shaft alignment can change due to factors, such as operational variation and thermal movement. These can cause movements of components, rotor assemblies and shafts, leading to misalignment.

It is important for final turbomachinery train alignment to compensate for actual operating conditions as machinery often moves after start-up as the result of wear, thermal differences, dynamic loads, and support or structural shifts. These factors should be considered and compensated for during the alignment process.

Tools used to achieve alignment may be mechanical, optical (laser shaft alignment) or gyroscope-based. Before shaft alignment, the foundation should be checked and verified.

Alignment is usually accomplished through corrections, such as shimming or moving a component. Both angular and offset alignment should be performed in two planes.

This is accomplished by moving other components to align the shaft(s) with the rotational centerline. Too often, alignment operations are performed randomly, and adjustments are made by trial and error, resulting in a time-consuming procedure.

The use of alignment tools and procedures that take thermal movements into account is a mandatory requirement for turbomachinery operating at extreme temperatures.

Simplistic versus 3D

Since shafts exist in three-dimensional space, misalignment can occur in any direction. It is best to break three-dimensional space into vertical and horizontal planes and to describe the specific amount of offset and angularity in each plane simultaneously at the location of the connection or coupling.

Thus, there are four specific values of misalignment needed to accurately express alignment, two offsets and two angularities. A traditional single limit of perhaps 50 microns is a simplified expression of misalignment used for ordinary machinery and basic alignment exercises. For a thorough investigation, all four components should be considered and verified.

The conditions of misalignment should be described at the location of the coupling: it is at the shaft connection that harmful machinery vibration and forces are created whenever misalignment exists. The magnitude of a misalignment tolerance or the desired alignment quality should be expressed in terms of these offsets and angularities or any other suitable 3D method.

Additionally, the size, geometry or operating temperature of turbomachinery should be considered in its alignment. Vibration and the resulting efficiency loss due to misalignment of shaft centers depends on shaft speed and the details of the coupling or type of connection.

Note that bearing load increases with misalignment. As a rough indication, bearing life decreases as the cube of the load increases, i.e., doubling the load will shorten bearing life by a factor of eight.

Do not forget to take into account thermal movement as a factor in alignment. Aligning center-to-center without paying attention to thermal movement can often lead to misalignment during operation and consequent failures.

The use of alignment tools and procedures that take thermal movements into account is a mandatory requirement for turbomachinery operating at extreme temperatures, whether cold (cryogenic machinery) or hot.

Different criteria have been used related to alignment and allowable misalignment. As a rough indication, limits between 40 and 55 microns have been specified and used. ■

Amin Almasi is a Chartered Professional Engineer in Australia and U.K. (M.Sc. and B.Sc. in mechanical engineering). He is a senior consultant specializing in rotating equipment, condition monitoring and reliability.

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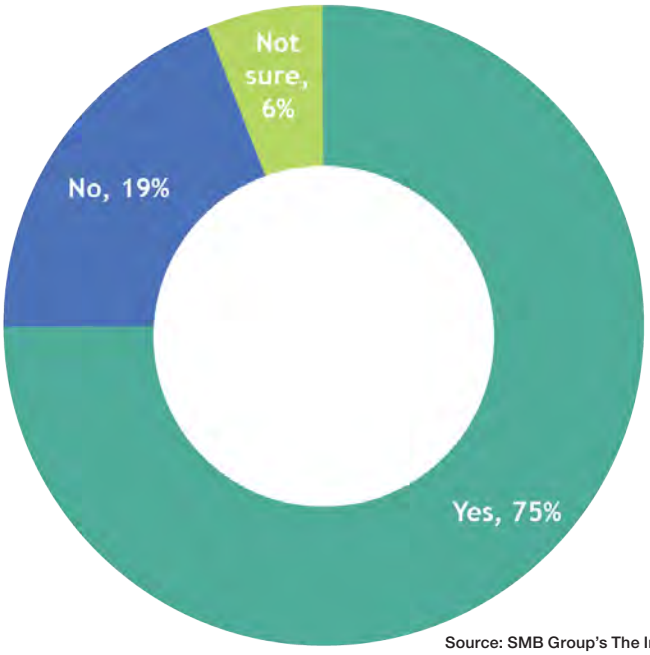
Responses to the question, "Has the Covid-10 virus negatively impacted your business?"



Source: SMB Group's The Impact of Covid-19 on SMBs Study, 2020

COVID-19

HOW THE TURBOMACHINERY INDUSTRY IS RESPONDING TO CHALLENGING TIMES

BY DREW ROBB

Beyond sectors such as Liquefied Natural Gas (LNG) and pipeline compression, the gas turbine marketplace has not been thriving of late. But everything turned on its head in the first quarter of 2020 due to two factors:

- The Covid-19 outbreak
- A precipitous crash in the price of oil.

Government officials around the world brought business to a halt in an attempt to slow the spread of the virus. While most turbomachinery companies and suppliers continued to operate, they faced postponement or cancellation of orders, and severe financial strain.

In tandem with the pandemic, oil producers jostled over output quotas. The resulting supply glut sent oil prices southward toward $20 a barrel.

A downturn, therefore, is inevitable. Casualties are likely, especially among the ranks of the many small business suppliers, service companies and specialists that support the industry. It is also possible that a few mergers and acquisitions may be in the cards among the larger players. That often happens after a downturn.

Experts, analysts, supply chain managers and OEMs including Siemens Gas & Power, Elliott, Man Energy Solutions, Atlas Copco Gas & Process, Baker Hughes, SoftInWay, Doosan Škoda Power, Capstone and LA Turbine are responding to the crisis in various ways.

"We're in for a rough patch but turbomachinery technology isn't going anywhere," said Valentine Moroz, SoftInWay. "The turbomachinery industry is well positioned to weather this storm as it is a critical part of our everyday lives."

Immediate repercussions

There is no escaping some of the immediate repercussions of recent events. A survey of business leaders in the U.S. by business consultancy PwC revealed that 67% are considering the deferment or cancellation of planned investments. Some 2% are looking to make cuts in cybersecurity and privacy budget. Another 53% plan to reduce spending on IT, and 25% may scale back digitalization programs.

Chief Financial Officers (CFOs) are particularly worried about cash liquidity and a potential global recession. The good news is that 61% of CFOs think they can return to business as usual within three months, according to PwC.

18% consider it more likely to take six months. But due to fear that 2020 revenues will be lower than expected, 81% are engaged in wide-ranging cost reduction measures. 26% have laid off or are planning to lay off workers, and 44% have furloughed workers or anticipate doing so.

Half are hesitant about attempting mergers at this time, but the other half intend to forge ahead with ongoing plans. It largely boils down to cash availability. Those that have money in the bank see the potential for aggressive action as the going rate is falling for potential acquisition tar-

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gets in power and oil & gas. Almost 40% of respondents plan to engage in supply chain reorganization, which includes a heavier reliance on local sourcing.

Another report by market research firm IHS Markit found 75% of companies are already reporting some kind of supply-chain disruption due to the coronavirus. Some 938 of Fortune 1,000 companies said they have a tier 1 or tier 2 supplier that has been affected. 44% of companies surveyed admitted to not having a plan to deal with the disruption.

Some predictions place the global economic damage from recent events at $2.7 trillion. Others have speculated that it will rise as high as $12 trillion.

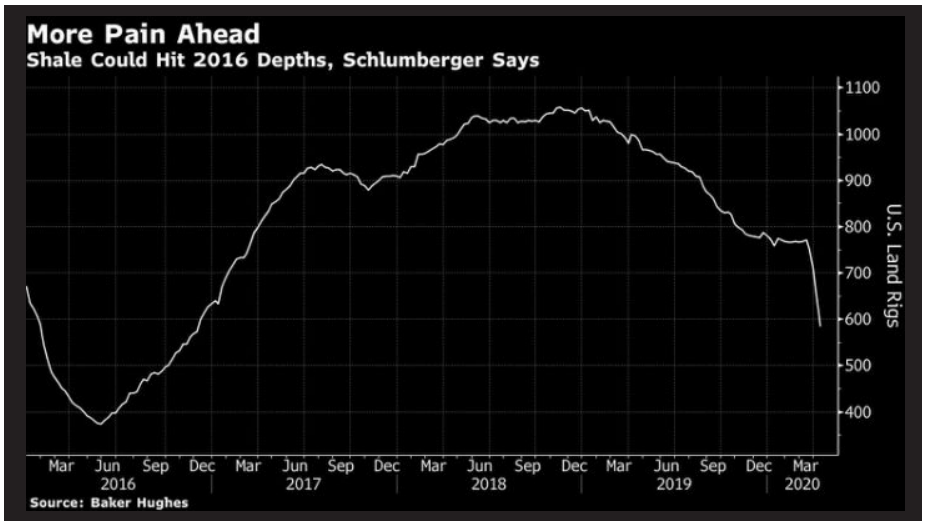
The oil & gas sector has an even more challenging situation due to the crude oil price per barrel hovering around $20 to $25. Such lows have not been approached since late 2001. That has placed a squeeze on the U.S. shale industry. Small drillers are struggling. Production is being ramped back. The boom days are over in some regions.

"Businesses of all sizes are feeling the pain of the pandemic," said Laurie McCabe, an IT and business analyst at SMB group.

Her survey of organizations of 2,500 employees or less, highlighted that 75% of businesses are negatively affected by the crisis. Among those, however, smaller companies have generally been hit the hardest. Those with fewer than 20 employees are most likely to experience extreme hardship.

"Many of these companies lack the cash flow and capital necessary to see them through an extended period of reduced or no sales," said McCabe. "38% of companies with 1 to 19 employees report that Covid-19 is having an extremely negative impact on their businesses."

More than half of small and mid-sized businesses (SMBs) have already or are planning to lay off salaried employees, or reduce their hours. Worried about preserving capital, they are slashing spending on non-employee goods and services by an average of 37%.



Lower rig counts mean pain for smaller operators in hard-hit U.S. shale plays.

This is a big problem for the business world in general, and in particular for power generation and oil & gas. These small businesses supply many of the goods and services that larger players rely on.

SMB Group said that Covid-19 is negatively impacting business in 75% of SMBs. 19% have not experienced a negative effect to date, and 6% are not sure. Close to two thirds believe revenues will drop by 30% or more over the next six months.

While all industries have been afflicted, the depth of impact varies by industry. Personal services, hospitality and manufacturing are taking the biggest hits, with 90% or more of businesses in these sectors reporting a negative impact, said McCabe.

Oil & gas fallout

Oil & gas is especially badly affected. The recent OPEC+ agreement to cut production by 9.7 million barrels per day (mainly from Russia and Saudi Arabia) has done little to arrest the decline of oil prices.

This is having a ripple effect across operations. Industry giants such as Schlumberger and Halliburton have announced furloughs, salary reductions and job cuts.

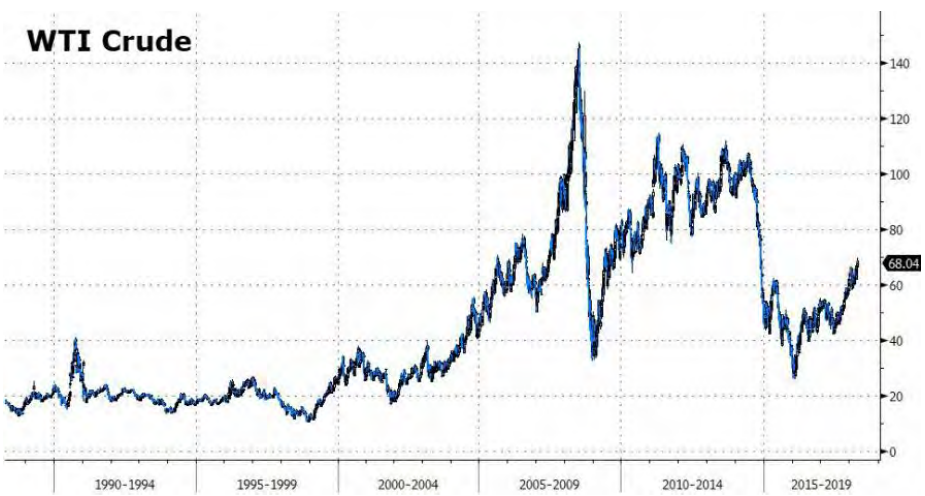
Refineries are coping with a supply glut at very low prices coupled with far lower demand from the transportation sector. Analyst firm ICIS said 26% of the Europe's ethylene production capacity is threatened by oil refineries running at reduced rates or ceasing production entirely.

Ethylene is produced by crackers attached to refineries. But the collapse of demand for petroleum products, such as jet fuel and gasoline means some ethylene crackers may be closed as they rely mainly on naphtha or liquefied petroleum gas (LPG) feedstocks. That could add up to the loss of 6.6 million tonnes (m.t.) per year of ethylene, 5.9 m.t./year of propylene and 4.0 m.t./year of benzene.

Some refineries have scheduled stoppages due to reduced fuel demand from coronavirus and associated lockdowns. As a result, European refineries are producing about 10 million barrels/day right now, which is down about 2.2 million per day compared to the expected throughput according to ICIS.

"The reduction is almost certainly even higher in reality and could be as high as 5 million per day when considering those sites which do not share such information," said Michael Connolly, Senior Consultant at ICIS.

Case in point: Around 40% of Total's refining and petrochemical operations are in France, the U.S., Germany and South Korea. In addition, over 70% of the company's petrochemical plant capacity is based in South Korea, the U.S. and France. Its exposure in Covid-19 affected countries



Crude oil price trends since the late eighties.

makes it susceptible to a fall in capacity utilization over the near term, said data and analytics company GlobalData.

"Total has postponed the restart of the Grandpuits refinery in France, which was shut down earlier for scheduled maintenance, due to lack of demand," said Ravindra Puranik, Oil & Gas Analyst at GlobalData. "The company has also cut production at the Leuna refinery in Germany by around 25%."

However, Total's LNG liquefaction operations look to be less vulnerable to disruption. Similarly, its major exploration and production projects in the Middle East, Norway and Nigeria should not be unduly affected.

Small oil & gas firms may find it tougher to weather the storm. The shale boom would never have happened were it not for hundreds of small companies exploring and drilling for relatively small shale oil deposits.

Such work was not financially attractive enough for the oil majors to carry out. Yet the entire industry depended upon the work of these tiny operators. Unfortunately, there has been a severe drop in general shale activity as shown in rig count. More than a few are filing for bankruptcy, or have had to curtail drilling.

"I don't think we will see a significant decline in the power generation market," said Mathias Scherer André, MAN Energy Solutions. "I remain optimistic about the turbomachinery business outlook for 2020 and beyond."

Pioneer Energy Services is one casualty. After 20 years of operation in the Bakken shale basin, it has ceased drilling there. A plunge in oil prices and the bankruptcy of a major customer in the region meant the closure of its six rigs in the Bakken.

Adding it up across the oilfield services sector, more than 50,000 jobs have been lost since the start of 2019. That equates to nearly 13% of the workforce. Fracking is probably going to face its worst year. Citigroup forecasts that at least half of all fracking work will end by late June 2020 due to lack of viability.

As well as greatly reducing drilling locations, producers are cutting costs by avoiding capital expenditure and even maintenance. Instead of repairing or replacing a faulty pump, for example, some companies are discarding the broken pump and grabbing an old one from an inactive site in an effort to minimize spending.

Power sector

In the power sector, small service shops are the backbone of the industry. These firms are typically composed of industry veterans with decades of highly specialized technical know-how. They are experts in areas such as rotor balancing, outage management, rotor replacement, filtration, maintenance, inspection, emergency repairs, coatings, water washing, chemical treatment, gearing and many other skills. Every one that disappears is a major loss.

Small firms in the Bakken shale play face bankruptcy.

Institutional knowledge, after all, is the backbone of any industry. The Clint Eastwood movie, "Space Cowboys," gives a fine example of the importance of preserving knowledge, even of very old systems. In that film, retired NASA engineers are called back into action as they are the only ones with the know-how to repair an old Soviet satellite that is in danger of crashing. Similarly, the ability to support aging turbomachinery hardware and software must be preserved.

Consider turbomachinery controls. Controls vendors are generally most interested in selling, updating and servicing their latest software and controls. They may continue to service models dating back a generation or two. But after that, they sometimes withdraw support.

Parts become difficult to obtain and maintenance becomes a challenge. Several small suppliers make a living serving the needs of facilities that continue to use aging controls. The individuals that make up these businesses were often those who helped develop these controls – or spent decades at large organizations servicing such systems.

But it is not just small firms. Midsized and large suppliers in most regions are also noticing repercussions. The German association for the mechanical engineering industry (VDMA) asked almost 1,000 member companies about current operations. Supply chain disruptions are particularly prevalent in Italy (75%), Germany (55%), China (51), France (36%) and the U.S. (25%).

"The situation in China and South Korea seems to be easing slightly," said VDMA chief economist Ralph Wiechers. "In addition, many mechanical engineering companies report a significant increase in orders from Chinese customers."

But the fallout among German engineering firms is rising. In a two-week period in April, the number noting supply chain disruptions rose from 60% to 84%. Almost half said this amounted to serious disruption.

Across the board, turbomachinery vendors have taken seriously the restrictions imposed by government authorities. They have been cleaning and sanitizing their facilities rigorously, and going to great lengths to protect their workers, their suppliers and their customers.

MAN Energy Solutions

MAN Energy Solutions has not witnessed any major decline in orders for turbomachinery so far. However, Mathias Scherer André, Head of Sales & Execution Turbomachinery, understands that it would be naïve to believe that the Covid-19 crisis will not affect business.

"Some turbomachinery customers are already reducing their aftersales expenditures on maintenance or overhaul activities," he said. "The current situation and the uncertainty about the future could also dampen appetite for new projects and subsequently weaken the turbomachinery market."

As a result, the company anticipates a business reduction compared to 2019, especially in the second half of the year. The decline in the downstream oil & gas, and the industrial segment is expected to be smaller than in the oil & gas upstream and midstream segment.

"I don't think we will see a significant decline in the power generation market," said André. "I remain optimistic about the turbomachinery business outlook for 2020 and beyond."

MAN's turbomachinery factories are producing at normal capacity, except in India. Remote customer interaction has been made easier by earlier steps taken by the company in digitalization.

Its remote support tool PrimeServ EyeTech is an assisted-reality application. It allows mobile video conferences to be set up via data glasses, or other video-capable terminal equipment like smartphones or laptops.

Technical experts in the MAN Remote Operation Centers or from their home offices can take the customer perspective without having to be on site. This has enabled the company to conduct remote audits, factory acceptance tests, assist remotely with repairs and commissioning.

MAN MRC compressor

In addition, MAN is continuing a strategy to regionalize and decentralize its turbomachinery operations. "Being present in our main markets, close to our customers, has proven to be a valuable asset and key to support our customers when no international travel is possible," said André.

Additionally, the company is building digital tools into its turbomachinery. Examples include its high-speed, oil-free HOFIM compression system that allows for the remote control and unmanned operation for onshore and offshore applications. Its ATU Box (Analytics Telemetry Unit) collects and evaluates operating and sensor data and enables the customer to monitor machine operation around the clock and request advice for remote support.

"Changes in digital habits will outlast the lockdowns that caused them," said André. "Some of them will become the new normal for some business activities."

Siemens

Siemens Gas and Power expects a severe impact in Q2. In the meantime, management has prioritized the safeguarding of employee health & safety, the continuity of the business, a focus on cash and working out how to reduce costs.

In terms of its global supply chain, Siemens thinks the impact will be mainly demand-driven as opposed to suppliers being unable to provide components. But the company is closely monitoring its supplier base.

Gianluigi Di Giovanni, Siemens Head of Power Generation Services Middle East and North Africa, said keeping the lights on is a top priority. The company aims to achieve this in power plants and other critical infrastructure operators using its turbomachinery via Omnivise Remote Services (ORS) which enables the delivery of field service expertise anywhere.

The ORS concept came about in 2015 when a power plant in North Africa was overdue for maintenance. Due to ongoing conflict in the region, Siemens employees were barred from entering the country. It provided training and remote support to successfully complete the outage.

"That experience prompted us to think differently about service, especially how we can use the latest and most secure communications tools," said Di Giovanni. "Containing live audio, video and augmented reality software, ORS enables collaboration with our global network of experts, helping operators monitor, maintain and repair assets."

Capstone

Capstone Turbine is concentrating on near-term earnings. Accordingly, it has expanded its long-term microturbine

The Permian Basin has been one of the most productive shale deposits in the world.

rental fleet with another 1 MW C1000 Signature Series microturbine rented for a site in the Permian Basin.

It is being operated by a large oil and gas company seeking to improve cash flow. Secured by Capstone distributor Lone Star Power Solutions, the microturbine is expected to be delivered later this summer and commissioned in the fall of 2020.

"Like most companies, we are seeing a downturn in new product shipments as a result of the Covid-19 virus pandemic, but that should be offset by the reduction in expenses," said Darren Jamison, President and Chief Executive Officer of Capstone Turbine.

"Capstone's long-term rental program, multi-year service contract business, and distributor support system program all continue to grow according to plan despite the Covid-19 pandemic," said Darren Jamison, Capstone Turbine.

"Capstone's long-term rental program, multi-year service contract business, and distributor support system program all continue to grow according to plan despite the Covid-19 pandemic."

This most recent deal increases the company's long-term rental fleet to 8.6 MW. During fiscal 2020, Capstone's rental fleet revenue grew 230% compared to fiscal 2019. The company intends to expand its long-term rental fleet to 10 MW as part of management's focus to achieve sustainable positive earnings in the June quarter and beyond.

Baker Hughes

Baker Hughes has taken several actions in response to the decline in oil and gas prices and Covid-19. This includes a write down in value of $15 billion from two business units, restructuring to right-size operations for anticipated activity levels

Baker Hughes is deploying digital technology to service turbomachinery.

and market conditions, and a more than 20% curtailment in net capital expenditures for 2020 compared to the previous year. But it reports liquidity of $3 billion.

In its most recent earnings call, the company cited orders of $5.5 billion for the first quarter of 2020, down 20% sequentially and 3% year-over-year. Revenue reached $5.4 billion, down 15% sequentially and down 3% year-over-year.

"Despite a volatile macro-environment driven by a significant decline in oil prices and the Covid-19 pandemic, we produced solid results in our Turbomachinery & Process Solutions (TPS) and Oilfield Services (OFS) businesses and generated over $150 million of free cash flow despite typical seasonal headwinds in the first quarter," said Lorenzo Simonelli, Baker Hughes Chairman and Chief Executive Officer.

"Looking forward, the outlook for oil and gas demand and supply appears equally uncertain, and it will largely be driven by the pace of economic recovery from the Covid-19 pandemic and the supply response that ultimately materializes."

The company's massive turbomachinery manufacturing, assembly and testing facilities in Italy remain open. That's where the TPS segment conducted the first ever remote string test to ensure the engineering, functionality and performance of turbomachinery prior to installation.

This test replicates actual site conditions. Every component is validated to ensure functionality and performance. This includes a mechanical running assessment as well as the measurement of equipment vibration and bearing temperatures at full speed and full load.

The test was done on the first compression train for the Venture Global Calcasieu Pass LNG project using virtualization technology to connect 21 people in five cities to facilitate, run and observe the test. The 10 m.t./yr Calcasieu Pass LNG project employs a process solution from Baker Hughes that uses mid-scale, modular liquefaction trains. After manufacturing and testing, these units are shipped to Cameron Parish, Louisiana.

TPS also secured six contracts to supply turbomachinery for three floating production, storage and offloading (FPSO) units for offshore Brazil. This includes a combined cycle solution with high-pressure compression. Supply includes LM2500+G4 gas turbines, steam generators and turbines, electric motor-driven compressors and related turbomachinery equipment.

The company's Turbomachinery Training Centre has had to shift from onsite training onto virtual training for industrial turbine operations for LNG plant operators. One customer in the Russia and CIS region received two webinars on turbine operations from lecturers based in Italy. Each class lasted five days.

Further remote services harness remote collaboration tools, such as smart helmets, smart pads, smart phones, and remote-monitoring centers in Florence, Houston and Kuala Lampur. This enables the company to provide virtual site assessments, remote inspections, spare parts remote assessments, remote monitoring of running units and technical outage support.

Robert Radimeczky of Atlas Copco.

Atlas Copco Gas & Process

The Covid-19 situation has impacted the turbomachinery business of Atlas Copco Gas & Process, according to company President Robert Radimeczky. "Due to looming uncertainty, investment in our industry is coming under scrutiny as companies are looking to conserve cash," he said. "With Capex strongly decreasing, orders are affected."

He cites economic projections that global GDP and national GDPs will shrink by at least 1.5% to 2% this year. But a delivery and order backlog from 2019, and manufacturing and delivery cycles of about a year mean that the company does not foresee many immediate issues.

"In case business activity does not resume to normal levels in Q3 and Q4, we expect to experience a deeper impact in 2021," said Radimeczky. "Our supply chain has been cooperative in achieving high utilization of our factories."

He envisions companies in the industry localizing more production facilities as well as their supply chains. Digitalization of processes can also help to speed processes, along with remote monitoring and diagnostics.

LA Turbine

Danny Mascari, President of turboexpander manufacturing and servicing company L.A. Turbine, reported that most new projects in the proposal stage have been placed on hold. Engineering work has continued for newly sold projects. But delivery timelines have been extended.

"We are seeing an increase in activity for international project work," said Mascari. "Our aftermarket equipment repair, evaluations and field service work remain active."

He expects to see more budget cuts and, in some cases, new equipment spending may be frozen within the midstream and downstream sectors. In contrast, he predicts companies will start making more aftermarket investments to maintain, upgrade, repair and service existing turboexpander equipment, especially within the midstream sector.

"This is a time to reassess company goals, eliminate the superfluous, and place greater focus on core competencies, and the delivery of those products, services and expertise," said Danny Mascari, L.A. Turbine.

Mascari said it is especially important to be responsive to customer needs.

"We have endured whirlwinds of uncertainty before and understand that damage and casualties will result," he said. "This is a time to reassess company goals, eliminate the superfluous, and

LA Turbine ARES turboexpander.

Daniel Prochazka, Doosan Škoda Power.

place greater focus on core competencies, and the delivery of those products, services and expertise."

Doosan Škoda Power

Doosan Škoda Power reports that the Covid-19 situation and related government measures mostly impacted its on-site services and construction operations, which are, to a large extent, temporarily suspended.

Since the Czech Republic is under an effective lockdown including closed borders, onsite technicians and sales representatives are grounded until the authorities decide it is safe to travel again.

"We have been able to maintain uninterrupted manufacturing production to minimize the impact to our projects," said Daniel Prochazka, Chief Operational Officer of Doosan Škoda Power.

"We are doing our best to keep our supply chain working as well as possible, so the manufacturing process in our factory in Pilsen can continue without major interruptions. To achieve that we had to review our sourcing plan for the main components to avoid delays on deliveries from the most restricted countries."

He has some concern about the development of several ongoing and future projects which rely on governmental subsidies. He hopes this support will be maintained.

Like many in the field, recent events have made him realize that a sizeable portion of global business can be operated and managed remotely. Prochazka believes there is likely to be increased market demand for remote control systems for power plants in the future to ensure continuous operation during a crisis.

Elliott

Elliott Group's business has been designated as essential and is exempt from orders to close operations. Its two main equipment factories in the U.S. and Japan are open with many non-manufacturing personnel working from home. Field service crews remain available and on call.

In China and Italy, Elliott facilities were closed but have since reopened. Service locations around the world in Singapore, Lachen (Switzerland), Abu Dhabi and other parts of the world are working alternative schedules to protect the well-being of employees and their families while continuing to address customer needs.

SoftInWay

Valentine Moroz, Chief Operating Officer at turbomachinery design and R&D software vendor SoftInWay, has noted definite impact in terms of order timing. He works with turbomachinery OEMs, aftermarket services providers and end-users, and sees each segment reducing expenses.

"We're in for a rough patch but turbomachinery technology isn't going anywhere," he said. "The turbomachinery industry is well positioned to weather this storm as it is a critical part of our everyday lives."

With many in the industry joining the unemployment ranks, SoftInWay has launched a campaign "No Turbomachinery Engineer Left Behind". The mission is to provide free software and E-learning resources to engineers across the world who lost their job.

For its customers, the company created flexible payment and financing options. But it does not plan any major shifts in strategy. It is strengthening the alliances it has forged with companies such as Avio in Italy, and Siemens Digital Industries Software in the U.S.

As companies cut head count and senior engineers retire, Moroz foresees heavier use of virtual design and simulation, digital twins and the use of artificial intelligence. With fewer hands on deck, companies are going to need intelligent simulation software and technology to make up the difference.

History repeats

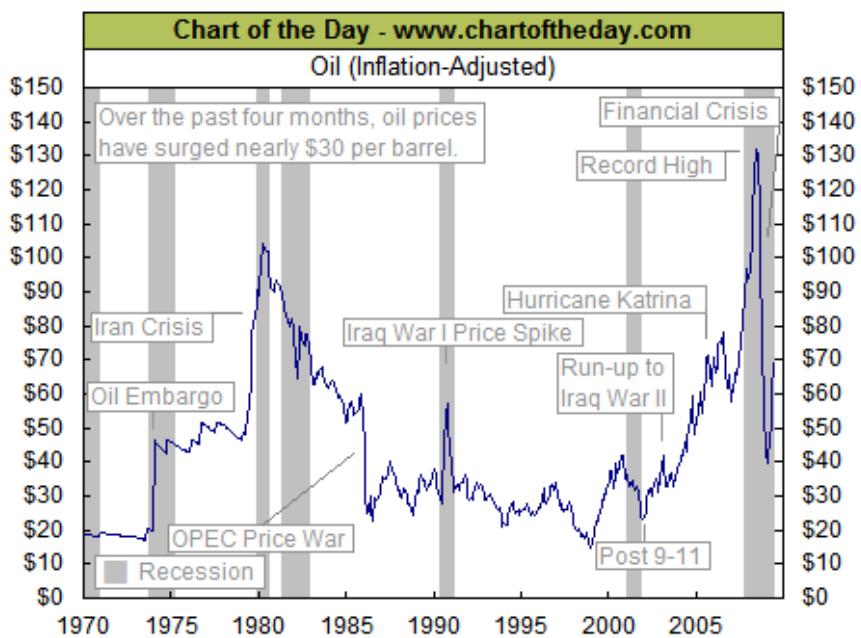
Some historical perspective on current events is in order. Market crashes and recessions have happened before. A quick review of the last fifty years reveals:

- The Arab oil embargo and the Iranian hostage crisis in the seventies
- An oil price collapse during the eighties
- The Gulf War and sustained low oil prices through the nineties
- 9/11, the Enron bankruptcy and financial market turmoil in the 2000s
- A recession in the middle of the last decade.

In between there have been purple patches too:

- 1978 Public Utility Regulatory Policies act (PURPA) opened the door to non-utility power producers and cogeneration
- Late nineties experienced an unprecedented boom in gas turbine generation sparked by deregulation.
- Shale oil & gas expansion over the past decade.

The next few months promise to be interesting. But oil prices will eventually revert. And as technology evolves and alternative fuel sources emerge, the vast amount of know-how resident within the industry will develop new ways to harness turbomachinery and propel it into the future. ■

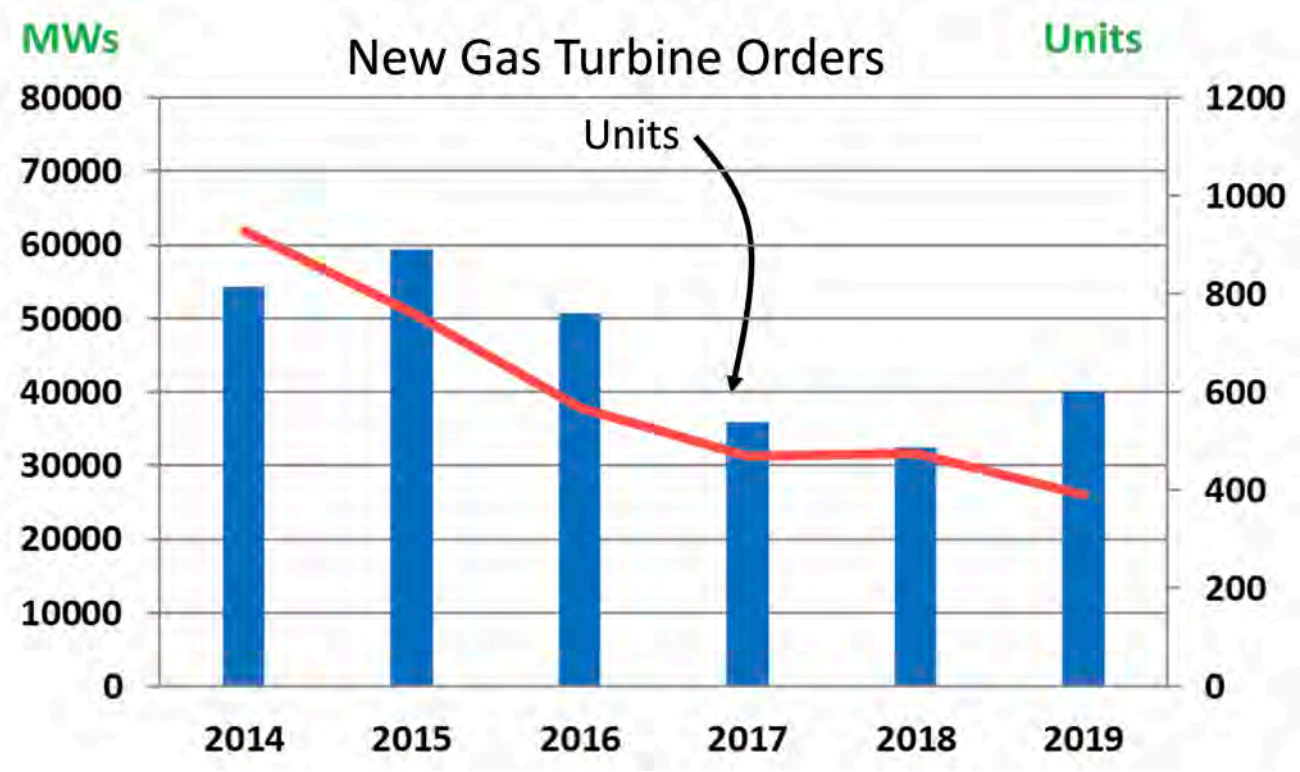


Oil price fluctuations are nothing new.

GAS TURBINE MARKET

PLENTY OF BAD NEWS BUT ALSO SOME GOOD NEWS

WRITTEN BY DREW ROBB



Courtesy of Dora Partners & McCoy Power Reports.

Just as we were about to hear some better news about the gas turbine market at the Western Turbine Users Conference, the world was turned on its head by the Covid-19 inspired shutdown (see page 14). In parallel, a price war erupted between Organization of Petroleum Exporting Countries (OPEC+) members Saudi Arabia and Russia resulting in a precipitous crash in the price of oil.

No one knows yet the extent that these events will impact orders and revenue. What is becoming clearer, though, is the that various parts of the turbomachinery landscape will probably be affected in different ways. Orders for some small gas turbines are likely to rebound faster, such as the GE LM2500 and its variants, as well as various models within the Solar Turbines portfolio. At the high end of the market, orders for advanced class machines may not languish for too long. GE, Siemens and Mitsubishi will continue to fight for orders in this category. However, many mid-sized machines may struggle unless new markets open up.

The best opportunities for turbomachinery business appear to be in LNG, pipelines, flaring, methane reduction, and especially aftermarket and maintenance.

Recovery

By all indications, it looked like the gas turbine market had finally begun a recovery in 2019. MW orders were up for the first time since 2015. Overall, though, we had seen a 39% drop in MW orders and a 65% slump in unit orders since 2012. Compared to 2018, last year saw a rebound of 23% in MW orders, but a decline of 18% in unit orders. Tony Brough of analyst firm Dora Partners assigns that jump mainly to coal retirements prompting coal-to-gas switching.

"Two disruptive global events will likely result in significant market turbulence to the gas turbine business," said Tony Brough of analyst firm Dora Partners.

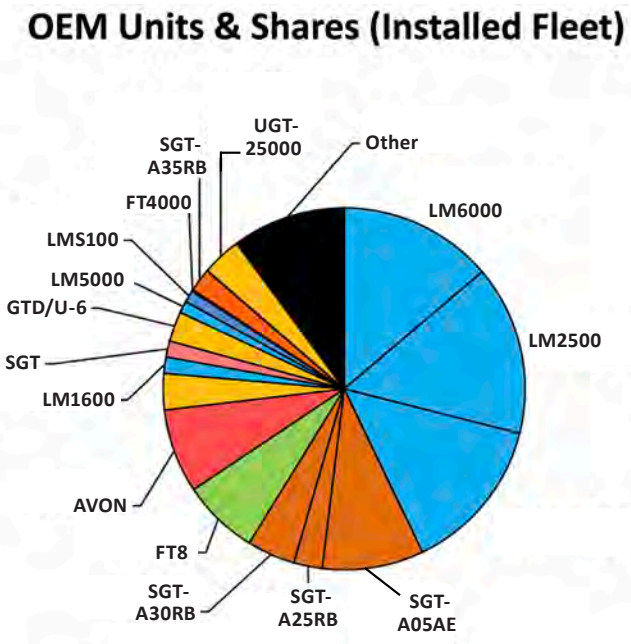
The first of these is friction between Russia and Saudi Arabia concerning a mutual oil production collaboration policy. This caused oversupply at a time of dramatic downturn in demand, driving the price of oil to an 18-year low of close to $20 per barrel.

The global coronavirus pandemic then induced a major reduction in consumer demand, as well as temporary business closures to comply with mandatory social distancing. Both events are exerting an adverse impact on global GDP.

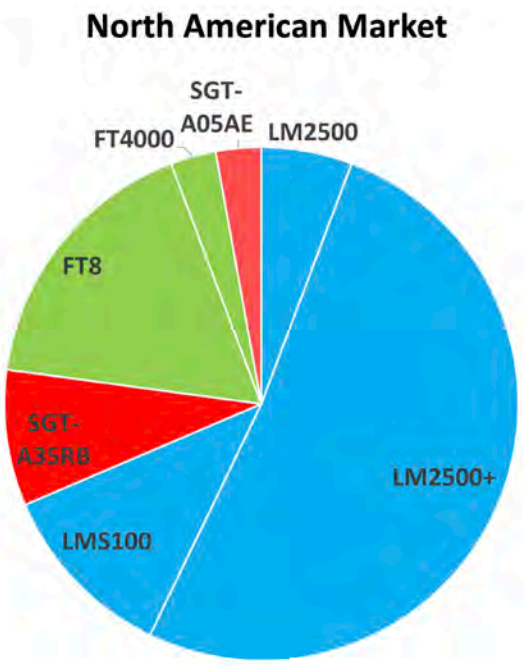
Dora Partners, therefore, predicts that new gas turbine orders will experience a big reduction primarily due to delayed project execution. The amount of the drop remains to be seen. Analysts forecast a downturn in aftermarket products and services, but demand from unplanned maintenance may help.

"Historically, cash conscious business leaders restrict maintenance spending when major market turbulence occurs," said Brough. "But there will be some spot increases in maintenance activity, primarily due to opportunity taking of underutilized equipment during the current market turbulence."

Dora Partners estimates a fall in unit orders as high as 70% this year in oil & gas and 50% in the electric power gener-



The number of units installed among the various aeroderivative fleets showing the extent of LM2500 family dominance. Courtesy of Dora Partners & McCoy Power Reports.



Aeroderivative orders in 2019 for North America. Courtesy of Dora Partners & McCoy Power Reports.

ation sector compared to what was expected. Project delays, deferments and cancellations will add up over the year.

Although it is hard to predict the length of time needed for recovery, Brough guesses the power sector will take two years to rebound and oil & gas will take three years.

Small turbines

For the purposes of this article, we are defining small as being less than 40 MW. It includes a large number of aeroderivative models including the LM2500. This sector has been doing relatively well.

"The small turbine market has remained steady mainly due to orders from the oil & gas segment, not utility power generation," said Mark Axford, Principal at Axford Turbine Consultants.

The LM2500 and its variants comprise by far the largest aeroderivative fleet in existence. Over the past five years, they account for 38% of all aeroderivative units ordered, according to Dora Partners. This machine is favored for oil and gas mechanical drive applications over other units due to its reliability, and the availability of trained personnel and aftermarket providers servicing these models, added Brough.

"There has been steady and robust demand for the GE LM2500 and LM2500+ primarily for compressor drive and LNG plants," said Axford.

This is helping to maintain GE's dominance in the aero market although its share slipped from 66% of all aeroderivative units in 2018 to 47.6% in 2019. Part of the reason for the drop from GE was a hefty order book for Russian firm UEC which has a virtual monopoly on the burgeoning Russian commonwealth pipeline business. UEC captured 40% of aero unit orders in 2019, though Dora Partners does not expect this number to be sustained as the number was inflated by unusually large pipeline orders.

Siemens comes next with an 11.3% share. It offers a wide range of aeroderivatives including the SGT-AO5AE, SGT-A25RB, SGT-A30RB, SGT-A35RB, and the SGT-A45TR. These are primarily destined for oil & gas sites.

Rounding out the aeroderivative market is PWPS with 3.2% share, down from 4.5% in 2018. The FT8 (30 MW) has been the company's top seller over the past five years, though PWPS have made inroads into the 40 MW to 70 MW segment with the FT4000.

When industrial gas turbines are included, Solar Turbines sells the most small units overall. Axford said the Solar Taurus family in the 5 MW to 7 MW range is doing well. Along with the LM2500 family, they are favored by the oil and gas industry. But the recent crash in oil prices means capital budgets for 2020 are being pared back and new projects delayed. This will reduce GT orders during 2020 in this segment.

Midsized turbines

The 40 MW to 100 MW segment is currently dominated by the Siemens SGT-800, according to Dora Partners.

"The SGT-800 is an efficient (almost aeroderivative-like) unit, with excellent dry low emissions capability on both gas and liquid fuel," said Brough. "That unit is taking market share from aeroderivatives and is also well accepted for cogeneration use."

He believes this turbine category is likely to begin to win orders for renewable offset i.e. as the total MW capacity on the grid gains more renewable sources, the variability of available MW-hours rises. Something has to fill the gap when renewables are not producing and power is in demand. Over the last 10 years, that gap filler has mainly been turned-down coal plants and non-baseload large industrial gas turbines (E- and F-class gas turbines). But coal plant retirements are speeding up, large industrial gas turbines are increasingly moving toward baseload, and renewables keep coming online.

"The need for new, more flexible supply is going to increase, and aeroderivatives are an ideal solution," said Brough. "But now it may be 2021 or 2022 before we see it."

The LM6000, however, appears to be struggling. It captured only 6.5% of aeroderivative market share over the past five years. While it consists of an impressive fleet of more than 1,100 units, it is no longer gaining many sales. Axford predicts additional pressure on mid-sized gas turbines due to accelerated industry adoption of battery storage during 2019.

"The installed cost per MWH of battery storage continues to fall," he said. "I am pessimistic about the future of the GT market for simple cycle peaking and balancing power as a greater fraction of this need is likely to be fulfilled by battery storage."

He conceded, however, that smaller

combined cycles will be a better match for the grid in some international markets than the typical 500 MW to 1000 MW combined cycle power plant (CCPP) that accounts for the majority of MW orders these days. Axford believes that smaller CCPPs plants will probably be built using 40 MW to 60 MW gas turbines. But he sees a bleak future for GTs with older technology in the 60 MW to 180 MW range. Most future orders for such machines, therefore, are likely to be for replacement units at existing plants rather than new power plants based on E-class and F-class technology.

Large turbines

2019 appeared to mark a turning a point in terms of increased MW orders after three consecutive down years. But 2020 is now unlikely to continue this trend. The various OEMs have been jockeying for dominance in various parts of the market. GE has historically been number one in MW orders but in 2018, MHPS moved ahead in the large gas turbine space (over 200 MW).

Axford said GE reasserted its top dog status in 2019 due to orders for its HA series GTs. "GE regained a clear position the top gas turbine provider worldwide in 2019," said Axford. "Market worries about technical problems relating to GE HA class machines seems to have been rectified."

Axford believes GE, Siemens Gas & Power and Mitsubishi now have comparable advanced GTs in the 250 MW to 400 MW range. Therefore, business will be won by the seller with the best combination of installed cost, guaranteed efficiency and long-term cost of maintenance. Not surprisingly, all three OEMs push hard to bundle long-term maintenance contracts with the initial equipment sale.

Summary of opportunities

There is no escaping the fact new gas turbine orders are going to have a difficult year. The most dramatic reduction is likely to be in unit orders. though MW will take a significant hit, too.

But with every problem comes opportunity. Let's review some of the opportunities that may be out there.

Maintenance: Large capital expenditures may be put on hold. But maintenance spending is likely to soften the blow. This will manifest in several ways. Actions previously put off due to production necessity are likely to be scheduled now that demand has softened. And with some orders postponed for new turbomachinery, plants will have no choice but to attempt to gain more life out of existing units. That adds up to more focus on maintenance, upgrade requests and component replacements.

"A downturn in aftermarket products and services will be dampened by unplanned/urgent maintenance of equipment," said Brough. "Historically, cash conscious business leaders restrict maintenance spending when major market turbulence occurs. There will be some 'spot' increases in maintenance activity, primarily due to 'opportunity taking' of underutilized equipment during the current market turbulence."

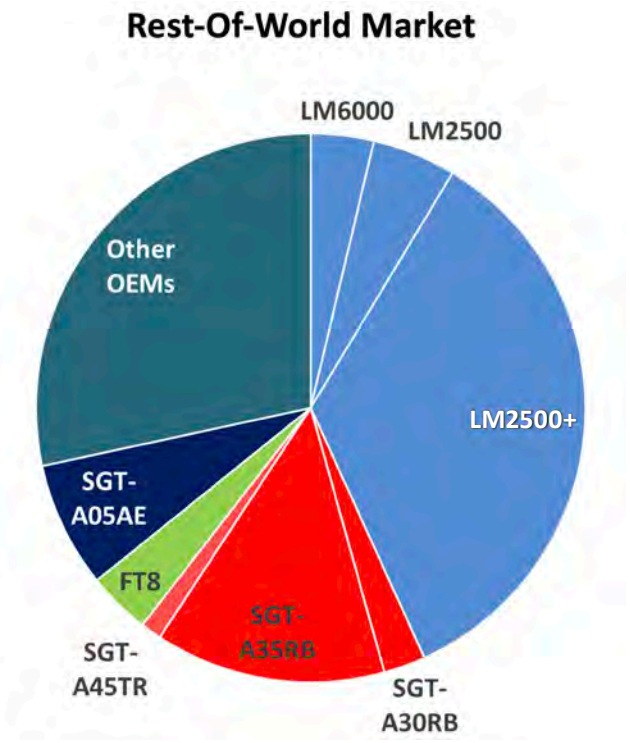
LNG: As covered in our March/April cover story, LNG has been a primary source of good news of late. This market may take a hit, but the difficult part has largely been accomplished – the establishment of the necessary infrastructure in terms of liquefaction trains, terminals and transportation. LNG may struggle somewhat but its rebound is likely to be rapid. There will likely still be plenty of business for anyone building, supplying, maintaining or servicing LNG facilities.

"The delivered price of LNG has fallen substantially as numerous LNG export terminals have come online," said Axford. "This means LNG will be a more affordable fuel both near term and long term. This will be especially important in countries that do not have an indigenous supply of natural gas or pipeline infrastructure. The growing supply of affordable LNG is good news for all sizes of gas turbines."

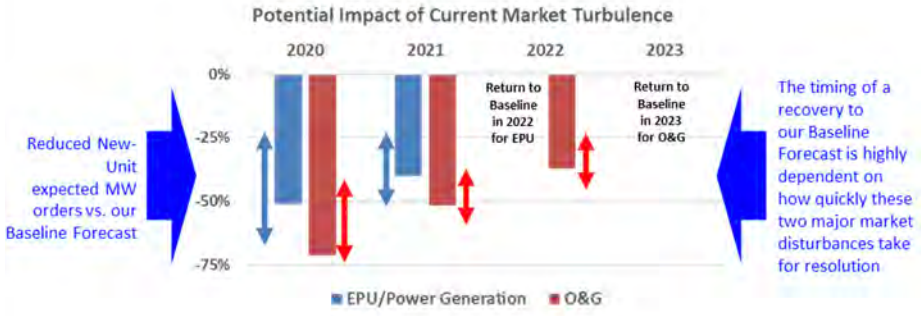
Pipelines: Axford and Brough noted that one of the strong areas for gas turbine sales is pipeline compression. This trend is expected to continue. Pipeline construction may slow, but will ultimately continue.

Flaring: Environmental groups are hounding oil & gas drillers to eliminate flaring of excess gas. Anyone coming up with an easy way to transform flaring into on-site power generation has a large potential market. The sizing and pricing have to be right, and units probably need to be easily transportable. But there is a worldwide need to curtail the practice of flaring.

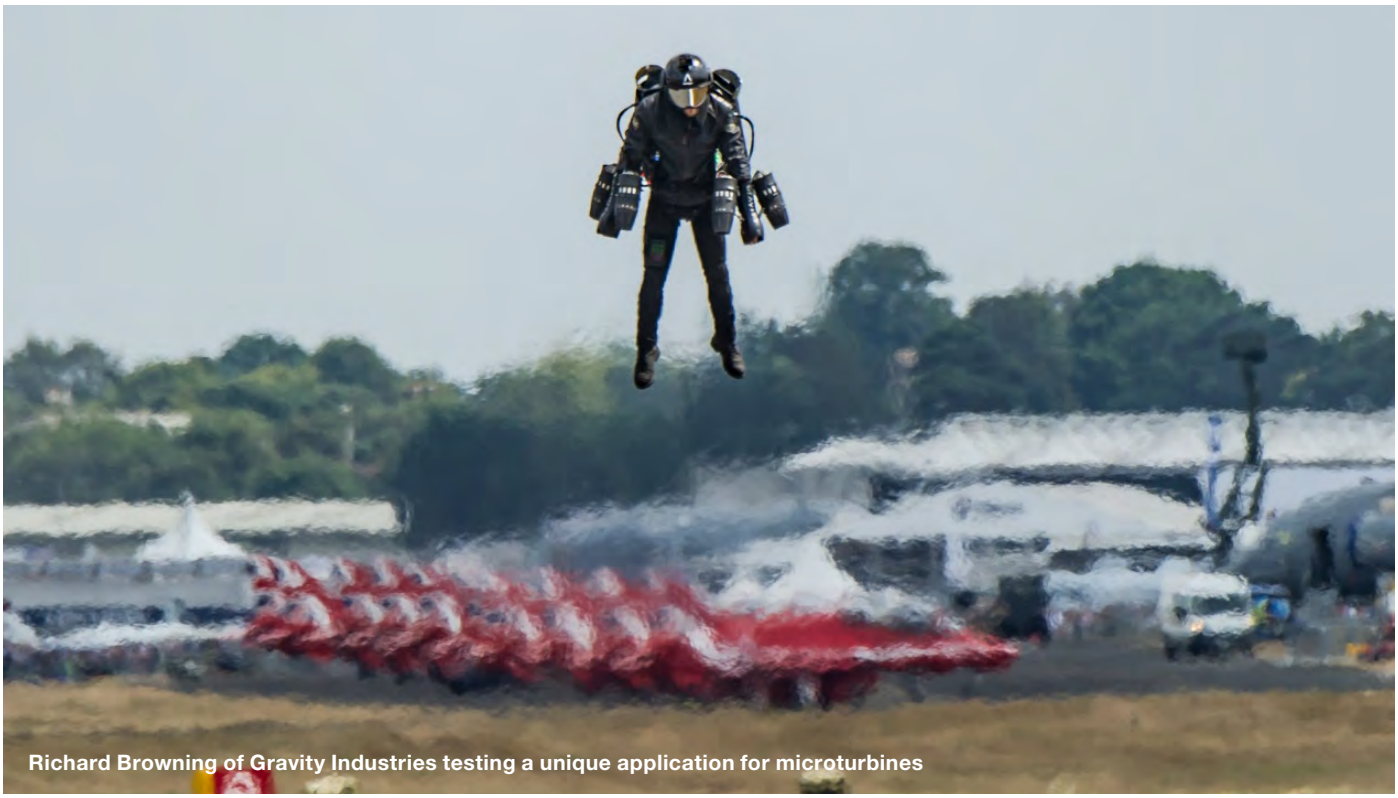
Methane reduction: Flaring and venting of natural gas are just one facet of the methane emission challenge. Pipelines, valves and other components suffer from methane leakage. Solutions that address these problems will find demand as oil & gas companies are under pressure to greatly reduce methane emissions. ■



Aeroderivative orders in 2019 from outside of North America.
Courtesy of Dora Partners & McCoy Power Reports.



How low can the market go? (EPU = electric power utility).
Courtesy of Dora Partners & McCoy Power Reports.



Richard Browning of Gravity Industries testing a unique application for microturbines

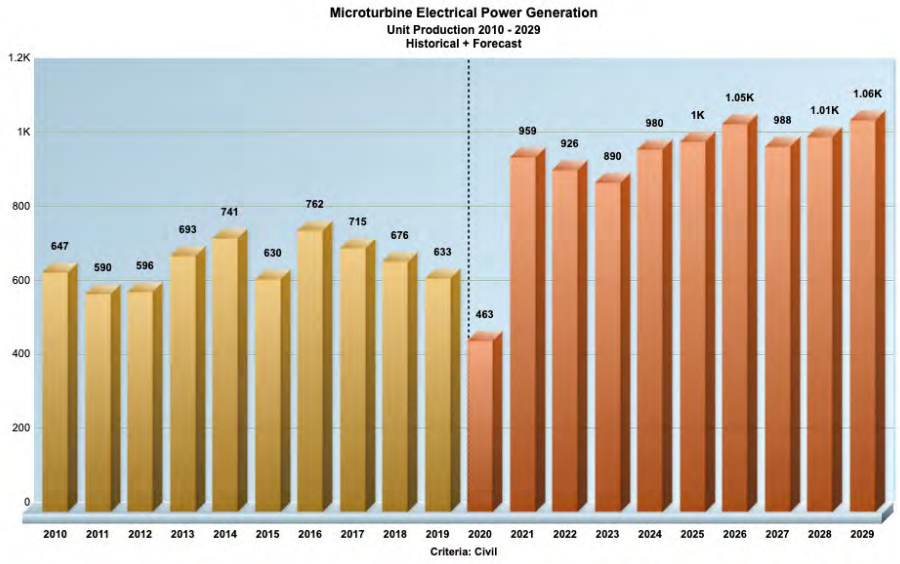
MICROTURBINES: FINDING THEIR NICHE

APPLICATIONS INCLUDE POWER GENERATION, MARINE, CHP, COOLING, AND TELECOMMUNICATIONS

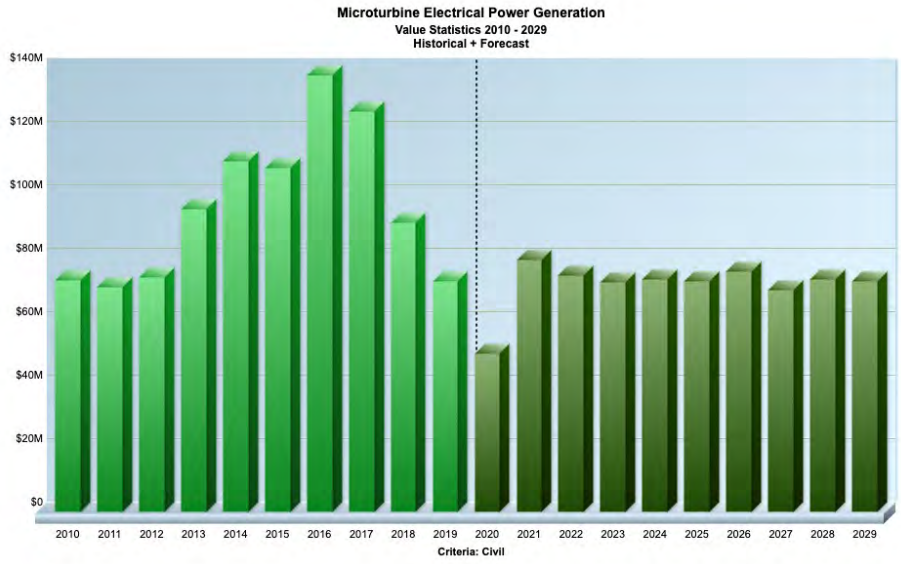
BY RORY PASQUARIELLO

Hovering four meters above a closed airfield, former British military intelligence officer-turned entrepreneur, Richard Browning, is as close to a real-world Tony Stark (of "Iron Man" movie fame) as it gets. His arms face down at an acute angle, each strapped with two microturbines in addition to one on his back. Hot exhaust screams, propelling him upward. Movement of his arms to the left turns him right, and vice versa. He lands a few minutes later, out of gas.

As owner of Gravity Industries, Browning isn't preparing for an existential threat to humanity as he would if this were the Marvel Universe. Nor is Gravity ever likely to be a market leader in microturbine sales. Capstone still holds this mantle (with more than 60% market share), followed by FlexEnergy. Combined, they make up 95% of the market, in terms of value. Mitsubishi Power is another microturbine innovator. And recent entrants include Bladon, Micro



Annual unit production of microturbines. Courtesy of Forecast International.



Annual value of microturbine orders. Courtesy of Forecast International.

Turbine Technologies, UAV and Aurelia.

The consistent trend in the microturbine space is that the technology is growing more powerful, more fuel-versatile and more compact. This is leading to greater creativity, expanding the possible applications for these machines.

Microturbines are capturing some market share from reciprocating engines for combined heat & power (CHP), and are finding some opportunities in distributed energy generation. Additional niches include waste-to-power, hybrid fuel cells, pumps in natural gas fields, propelling small boats, refrigeration, telecommunications, range extenders for electric vehicles and for military vehicle fleets in remote locations.

Market trends

In the short term, the microturbine market is expected to suffer slightly through 2020, then recover to a steady annual total of approximately $70 to $80 million through 2029, according to Forecast International.

Unit production will suffer this year. But Forecast International projects a jump from the range of 600 to 750 per year to between 900 and 1,050 from 2021 to 2029. This leap is partly attributed to two European companies, Bladon and Micro Turbine Technologies (MTT), entering the market.

Bladon's niche is telecommunications. Its clients include providers of cellular service in remote areas, such as parts of Africa and Australia. Its 12 kW MTG series microturbine runs on natural gas and can be monitored remotely. The company claims to reduce site visits by 90% and fuel costs by 30% compared to diesel counterparts. The microturbine is quiet, registering under 65 dB. It complies with stringent European standards for diesel engines.

According to data from Forecast International, Bladon should produce around 2,400 units through 2029, making up about $33.36 million in production value over that period. That equates to a market share of 4.67%.

MTT's EnerTwin produces 3.2 kW of electricity for home and business application. It has heat as the primary output and electrical power secondary. MTT said it can operate as a stand-alone system, in a cluster of several systems, or in combination with one or more conventional boilers. The system currently runs on natural gas. However, new applications are under development that would demand the use of new fuels. The EnerTwin is currently being certified for use with liquefied petroleum gas (LPG) for use in areas without natural gas infrastructure, for example.

Forecast International predicts that MTT should sell around 2,450 units through 2029. That adds up to $19.6 million in value and a 2.74% share of the microturbine pie.

Aurelia, a Finnish company backed by university research, claims to have developed the most efficient microturbine to date (more than 40%). The A400 combines multi-spool and recuperated/intercooled features. Aurelia's main target markets are small and medium-sized commercial and industrial end users that require electrical power and heat for their processes, as well as those who require steam or cooling.

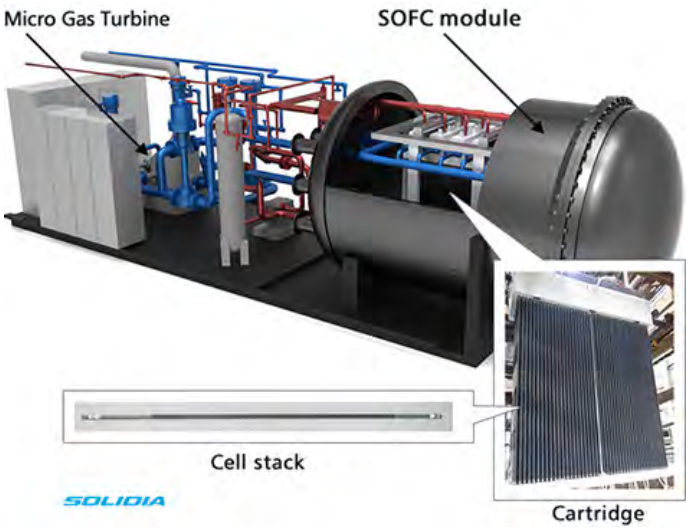
Mitsubishi Power, formerly known as Mitsubishi Hitachi Power Systems, is also making major advances in microturbine technology. Its Megamie concept combines a microturbine and solid oxide fuel cells (SOFC) to produce 250 kW using natural gas, biogas or hydrogen. The first commercial Megamie unit was installed in Tokyo in 2019 and powers numerous shops and offices.

The basic concept works well, but cost remains a barrier. The company plans to increase cell output density, enhance material quality, simplify production processes and collaborate with business partners to optimize the supply chain. A 1000 kW is in the planning stages.

Meanwhile UAV Turbines military-grade Micro-Turbogenerator System is

Bladon MTG series microturbine

Aurelie A400 microturbine



Mitsubishi Power Megamie

aimed at on-demand electrical power generation. Its machines range from 3 kW to 40 kW and address the problem of generating electricity on-the-go and in high altitudes (the higher the altitude, the thinner the air, the lower the power efficiency).

"Mobility is becoming a significant motivating factor for our military; to be portable and nimble in the battlefield," said Fred Frigerio, UAVT's Senior Vice President of Engineering. "They are interested in things that can be handled by two, three or four guys in a truck or a Jeep."

In addition, UAV has demonstrated the Monarch 5 turboshaft engine, which powers a Northrop light fighter jet. It can now run on natural gas, extending its potential into ground emergency and standby power generation for both onsite and remote areas. UAV has been courting clients such as FEMA and the U.S. Department of Homeland Security. These quiet generators can produce up to about 30 kW.

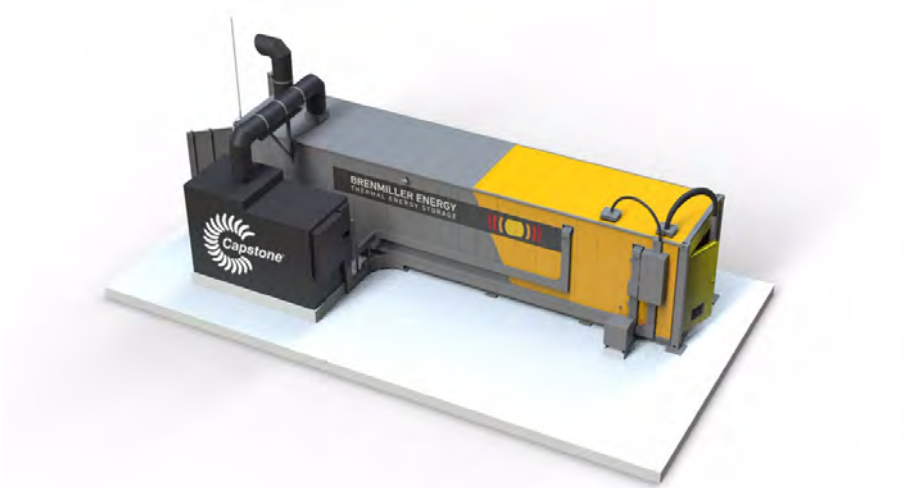
Market leaders

Despite all of these new kids on the block, Capstone and FlexEnergy are expected to maintain their dominance in the coming decade. Capstone's microturbine technology has newfound applications in the marine sector (work boats, cargo ships, commercial vessels and luxury yachts) and as range extenders for electric vehicles (transit buses, class 7 and 8 work trucks). It has found success with a scalable microturbine architecture. Need more power? Stack another Capstone C-series onto the last. They can operate on a variety of gaseous or liquid fuels including natural gas, associated gas, LPG/propane, flare gas, landfill gas, digester gas, diesel, aviation fuel and kerosene.

The company offers microturbines ranging from 30 kW to 1 MW in electric power output, which can be deployed in arrays up to 10 MWs. The Signature Series product line was developed based on a C200 (200 kW) engine and can be configured into 1,000 kW, 800 kW and 600 kW packaged solutions. An added benefit of the technology is the ability to capture the exhaust and use it to make hot water, steam, chilled water, and in some cases directly in a process. The C1000S has been deployed at places such as an Italian food manufacturing facility, a waste water treatment plant in Pennsylvania and a pharmaceutical manufacturing plant in California.

Capstone sells between 400 to 700 microturbines annually, with its most popular being the C65 and the C200, by total megawatts sold. The C250 (250 kW) is under development.

The U.S. and Europe remain primary markets for CHP and oil and gas midstream projects. But the company has noticed an uptick of adoption in Latin



Capstone Microturbine Driving a Brenmiller bGen Energy Zero Carbon Thermal Storage Unit

America, Africa, Asia and the Middle East. The company is expected to sell 3,840 microturbine units through 2029, accounting for a $520.57 million production value and 72.8% market share for that period, according to Forecast International.

Like many manufacturers, costs are expected to drop as volumes increase. Collaboration opportunities are also opening up. Capstone is working with a company named 247Solar to create a zero-emission solar-powered microturbine. Another partnership with Germany's B+K aims to utilize wood waste to generate superheated air to create a renewable, thermal powered microturbine. Additionally, Capstone is partnering with the New York Power Authority and Brenmiller Energy on a thermal energy storage project for Purchase College, State University of New York.

"Our microturbine will directly pipe low emission exhaust gas into a Brenmiller bGen zero carbon thermal storage unit so it can extract and store the heat until it is needed," said Darren Jamison, Capstone Turbine President and Chief Executive Officer. "The system represents an alternative to battery storage with potentially greater discharge durations,"

A C200R microturbine will be utilized in a CHP application to support Purchase College's physical education building, displacing the aging district heating loop in the central heating plant and providing baseload electricity. This is projected to save the college about $100,000 per year while reducing the facility's carbon footprint.

Capstone sees the younger generation's demand for clean energy as a window to greater profits in the future.

It is not alone in this sentiment. FlexEnergy, which bills itself as a clean-tech company, focuses on the creation of energy with near-zero emissions. It acquired the Energy Systems business of Ingersoll-Rand in 2011 and by extension, its MT250 microturbine product line. It now offers a family of systems that operates on a range of fuels.

The company's bread and butter remains oil and gas, its largest market since 2015. Its most popular unit is the 333 kW Flex Turbine series GT 333S. It converts flare and waste gases and tank vapors from oil and gas operations into electric power. The company has doubled its output of machines over the past five years. According to data from Forecast International, FlexEnergy is expected to sell 407 units through 2029, making up a $123.9 million production value, while accounting for 17.3% of the market.

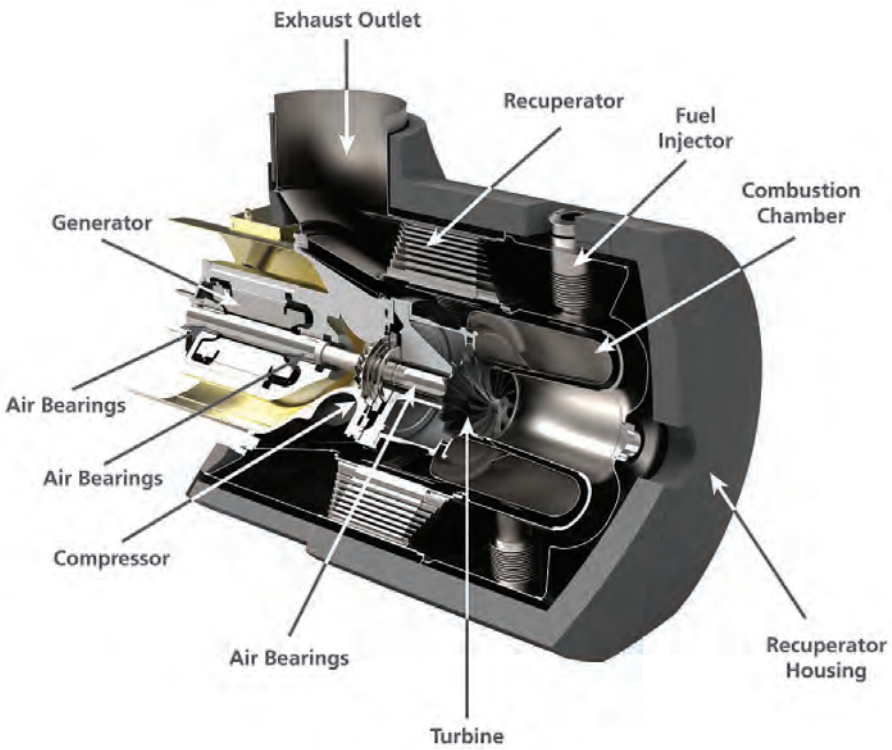
Doug Baltzer, Chief Commercial Officer at FlexEnergy said that after oil & gas comes the manufacturing sector. To boost sales, he said that local utilities can play a big role by supporting on-site generation, among other factors.

"The equipment needed to satisfy utility interconnections is the toughest barrier for us to grow sales and keep costs down," said Baltzer. "Our ability to handle a wide range of new fuels such as synthetic natural gas could boost growth in new markets."

Challenges remain

Innovation in battery storage and renewables represent a competitive challenge to microturbine OEMs. Batteries remain expensive, but costs are dropping steadily. The microturbine market also has also been strong in areas that produce flare gas or stranded gas. With shale play production slashed in light of the fall in oil prices, immediate demand there may suffer.

"In many cases, renewables are less expensive in terms of levelized cost of electricity (LCOE) than their turbine counterparts," said Carter Palmer of Forecast International. "The use of turbines for peak demand (i.e., supplementing renewables) is still an attractive option." He believes microturbines will ultimately keep their niche and are well-positioned to expand it. ■



Capstone C30 microturbine cross-section

MITIGATING FAILURE MECHANISMS

ENGINEERED RESIDUAL STRESSES CAN BE USED TO LESSEN TURBOMACHINERY FAILURES

BY JAMES PINEAULT

When failures occur in turbomachinery, they typically result from one or more mechanisms. This may include fatigue, environmentally assisted or stress corrosion cracking, creep rupture, erosion and foreign object damage.

In many cases, the residual stress levels present in the component play an important role in either extending life with favorable residual stresses or diminishing it with unfavorable ones.

Since residual stresses are introduced in practically every step of turbomachinery machining and fabrication processes, their effects must be considered, understood and managed to maximize component life and performance.

By controlling or introducing engineered residual stresses, premature failures can often be mitigated, and the service life of components extended. Accurate quantitative measurement of residual stress in components is necessary to achieve this goal.

Stress corrosion cracking

Stress corrosion cracking (SCC), also known as environmentally assisted cracking, is sometimes characterized as stress-assisted, grain-boundary oxidization (SAGBO) in high-temperature applications. It is a major source of potential failures in the power industry, as well as in process industries, pulp mills, storage vessels, and even aircraft structures.

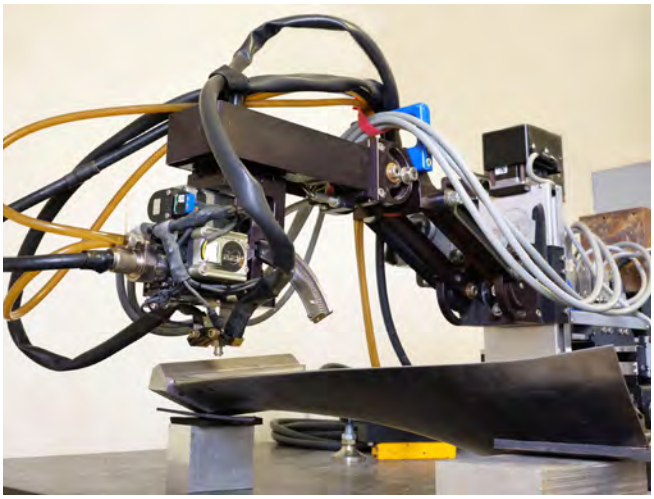
Sustained tensile stress (resulting from the superposition of residual and applied stresses) above a material's SCC threshold is the main component of the stress corrosion cracking triangle (Figure 1).

Other factors are a susceptible material and a slightly corrosive environment. SCC is characterized by selective intergranular corrosion whereby multiple cracks initiate and eventually propagate.

The most obvious solution to SCC is to change the environment. However, that is rarely possible. The addition of a coating can, in principle, break the SCC synergy by sequestering the material from its environment. But this is often impractical or only a short-term solution if the coating wears or degrades over time.

Another approach is to change the material to one less susceptible to SCC. That can be either expensive or unfeasible. Thermal stress relief can be used to help reduce the magnitude of tensile residual stresses to levels below the SCC threshold.

However, if heating reaches the annealing temperature, as would be required to effectively stress-relieve the component, heat treatment itself may negatively affect the desired material's mechanical properties. Heat treatment is, therefore, only a partial solution in many instances.



Measuring residual stress on a turbine blade via the x-ray diffraction technique

Often, the only effective solution to the SCC problem is the introduction of compressive residual stresses. A variety of stress management methodologies can be used to impart compressive residual stresses into a component.

This can include peening, rolling, expanding and their variants. Some are typically applied at the time of fabrication e.g., shot peening, laser shock peening (LSP), cavitation peening and rolling.

Others can be applied in the field on components already in service (e.g., ultrasonic impact treatment (UIT), flapper peening and split-sleeve cold expansion (Cx). SCC synergy can be broken if the compressive residual stresses imparted are sufficient to overcome the sustained in-service applied stresses and keep the total magnitude of stress below the SCC threshold.

Quantitative residual stress measurement methods, including x-ray diffraction (XRD), can be used to characterize the stress state of components that may be susceptible to SCC either before or after they have been put into service.

This helps verify that a compressive residual stress of sufficient magnitude has been installed (one that overcomes any in-service applied stresses so that the total residual stress level remains below the SCC threshold).

Take the case of ground and shot-peened Ck45 steel (Figure 2). Residual stress measurements via XRD were used to compare the effects of grinding and shot peening on the surface and subsur-

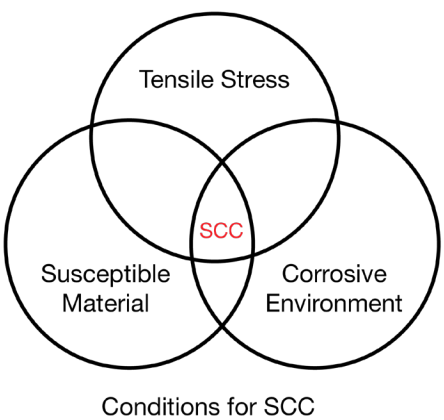


Figure 1: Synergy is required for stress corrosion cracking to occur

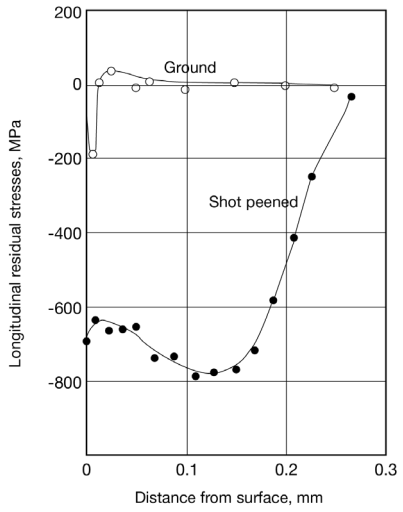


Figure 2: Residual stress vs. depth profiles for ground and shot-peened Ck45 steel

face residual stress state of a component prior to being placed into service. This indicated that the residual stress of the component became more compressive after being shot peened.

Fatigue

When turbomachinery components undergo cyclic loading, they can become susceptible to high-cycle fatigue (HCF) or low-cycle fatigue (LCF). In cases of LCF failures, the in-service stress exceeds the cyclic elastic limit of the material.

LCF is characterized by cumulative fatigue damage associated with failure occurring in the range of 10^4 to 10^5 cycles and multiple cracks in highly stressed areas. Residual stresses can evolve with

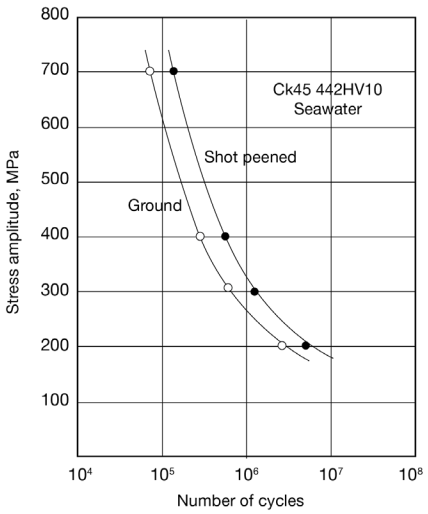


Figure 3: Bending fatigue S-N curves for Ck45 steel tested in sea water. This illustrates the positive effect of shot peening on fatigue life

cumulative fatigue damage and can be monitored periodically at predefined inspection intervals to assist in assessing component condition.

It has been demonstrated that LCF life is sensitive to changes in residual stress. A 5% to 10% difference in stress can result in a 50% difference in lifespan. Thus, errors in the representation of total stress have a profound effect on life if residual stress is not considered.

The longer fatigue lives, as in the case of HCF, failures generally initiate at precise stress-concentration sites with cracks propagating from a single initiation. Residual stresses remain constant until close to the end of a component's life; thus, an understanding of the residual stress state at the start of life is critical.

The ways in which surface and near-surface residual stresses have impacted fatigue-life underscore the importance of studying surface treatments and manufacturing processes. If reliable fatigue-life estimates are to be made (for example, via fracture-mechanics predictions), it is necessary to accurately characterize the residual stress fields.

Fatigue life can be extended and failures mitigated by the introduction of engineered residual stresses via a variety of processes, including Cx, LSP, shot peening, cavitation peening, burnishing and UIT (Figure 3).

Such treatments should be optimized for specific application to maximize effectiveness. By obtaining accurate information about the in-service loading spectra, material properties, component geometry, and residual stress fields, more reliable life-assessment and fracture-mechanic predictions can be made.

Erosion and creep should also be considered. The interaction of liquids or particles in the gas path of turbomachinery can result in the erosion of certain components. The loss of material due to erosive impacts can compound into a loss of cross section, the formation of pits, and eventually, the formation of micro-cracks at the surface.

In combination with cyclic loading, the stress concentrations at a crack tip may provide sufficient energy for fatigue cracks to initiate and propagate. Steam turbine blades that operate at relatively high temperatures can be especially susceptible to erosion resulting from the exfoliation of tubing scales in the system or from liquid droplet erosion.

Understanding and managing residual stresses at susceptible locations, such as the leading edge of a blade, can assist in delaying or mitigating the initiation of fatigue cracks where erosion damage is present and presumably unavoidable.

By increasing the effective depth of compressive residual stresses at these locations, tolerance to damage can be improved. In such cases, deeper-reaching engineered residual stress may be required as the allowable material loss increases. However, conventional shot peening alone may be insufficient, and deeper compressive layers may need to be introduced via LSP or UIT.

Creep

Creep is the tendency of a solid material to move slowly or deform permanently under the influence of persistent mechanical stresses. This process can be accelerated with increasing temperature. Over time, creep may result in a fracture via creep rupture.

High engineered compressive residual stresses ahead of crack tips delay creep crack initiation and increase creep initiation life. Conversely, high tensile residual stresses due to unmanaged fabrication processes can promote creep crack initiation and decrease the time to crack initiation.

Residual stresses have little or no effect on creep crack growth rates. Therefore, surface and near-surface residual stresses are the most critical when engineered residual stresses are introduced to prevent or delay their initiation.

Since deeper-reaching compressive stress processes, such as LSP or UIT do not impart the highest compressive residual stress at the surface, a double-peening process may be desired for two reasons.

It provides the maximum compressive stresses at and near the surface, as well as providing deeper-reaching compression. Double-peening treatments can be optimized and their effects maximized by measuring residual stress post processes.

Once optimal engineered residual stress fields have been established and formally defined, they can be monitored and audited over time to confirm that components have been correctly processed by a given supplier.

The selected methodology of measurement must be accurate, quantitative and suitable for surface, near-surface and subsurface residual stresses to account for both crack initiation and propagation considerations in life modeling and analysis.■

James Pineault is Lab Manager at Proto Manufacturing in Oldcastle, Ontario, a company specializing in XRD equipment and measurement services. For more information call +1 519-737-6330 or visit protoXRD.com

OVERSPEED IMPELLER TESTING

FOLLOWING THESE GUIDELINES CAN AVOID TRIPS AND FACILITATE SUCCESSFUL TESTING PER API 617 STANDARDS

BY MARK KUZDZAL AND MARTIN MAIER

Impeller overspeed testing is essential to ensuring the safety and reliability of centrifugal compressors. To meet API 617 requirements, compressor impellers must be individually balanced and oversped to 115% of the maximum continuous operating speed (MCOS) for one minute.

A centrifugal compressor was recently manufactured for hydrogen recycle service in a continuous catalyst regeneration (CCR) process. During overspeed testing, certain compressor impellers exceeded the overspeed machine vibration limit, resulting in trips.

After further investigation, it was suspected that this event was the result of an inertia dominant resonance condition occurring when the ratio of the polar moment of inertia and transverse moment of inertia approaches a value of one.

Polar inertia (Ip) is the inertia calculated relative to the longitudinal axis. Transverse inertia (It) is the inertia calculated relative to the diametral axis. In the limiting case, for a thin circular disk the ratio of polar-to-transverse inertia is 2.0. This ratio for a solid sphere is 1.0.

Testing process

The centrifugal compressor had a radially split, beam-style, five-stage, straight-through design (Figure 1). A steam turbine was used to direct drive the compressor at 5,026 RPM. The impellers were balanced to API 617 8th Edition (ISO 1940/1 G0.67). This was accomplished before each run in the overspeed machine.

The overspeed machine used for testing can be outfitted with various mandrels (fixtures or shafts that retain impellers when mounted on the spindle of an overspeed machine) to accommodate different sizes of impellers and speeds. The machine continually measures vacuum pressure, speed, and vibration during the test. The latter is measured with a proximity probe.

Figure 1: Photo of a centrifugal compressor for hydrogen service

The unit is designed to trip and shut down when a maximum vibration of 8.0 mils is reached. This is referred to as 100% full scale (FS) amplitude. The machine uses rolling element bearings with a squeeze film damper bearing in series. A key phaser was added to enable rotor dynamics analysis investigation. A 150 HP (112 KW) main drive motor is connected to the mandrel via a belt drive.

The shafting is oriented in a vertical direction, and a 'bumper' bearing is located on the bottom of the machine. The mandrel is manufactured so that a pin is located at the bottom of the mandrel. During mandrel installation, the pin fits inside the bumper bearing with a 0.020-inch (0.51 mm) clearance. This limits the motion of the mandrel and impeller in the event of excessive vibrational amplitude.

Historically, it has been the practice at Siemens to use the same mandrel on a given testing job for both balancing and overspeed of an impeller. As a result, the mandrel must be designed to the length of the overspeed machine and be capable of withstanding the bending moment of the impeller mounted on the machine during balance. This can result in a rotor system where the ratio of the polar (Ip) and transverse moment (It) of inertia approaches a value of 1.0.

The manufacturer of the overspeed machine provides operational guidelines based on these parameters. It states that Ip/It ratios between 0.70 -1.20 should be avoided due to the likelihood of high vibration.

Initial testing

During initial overspeed testing of the 3rd stage impeller of the compressor, the rig tripped out due to high vibration at a speed of approximately 4,800 RPM. The impeller was run with a multi-piece, built-up mandrel with the impeller shroud facing upward. The overspeed requirement for the impeller was 5,780 RPM.

Figure 2: The overspeed test pit. The mandrel assembly is positioned on the cart (far left), which is rolled under the overspeed machine where it is fastened to the spindle. It is lowered into the pit, and a vacuum pump evacuates the chamber to minimize the power required to drive the impeller and heat generation associated with windage.

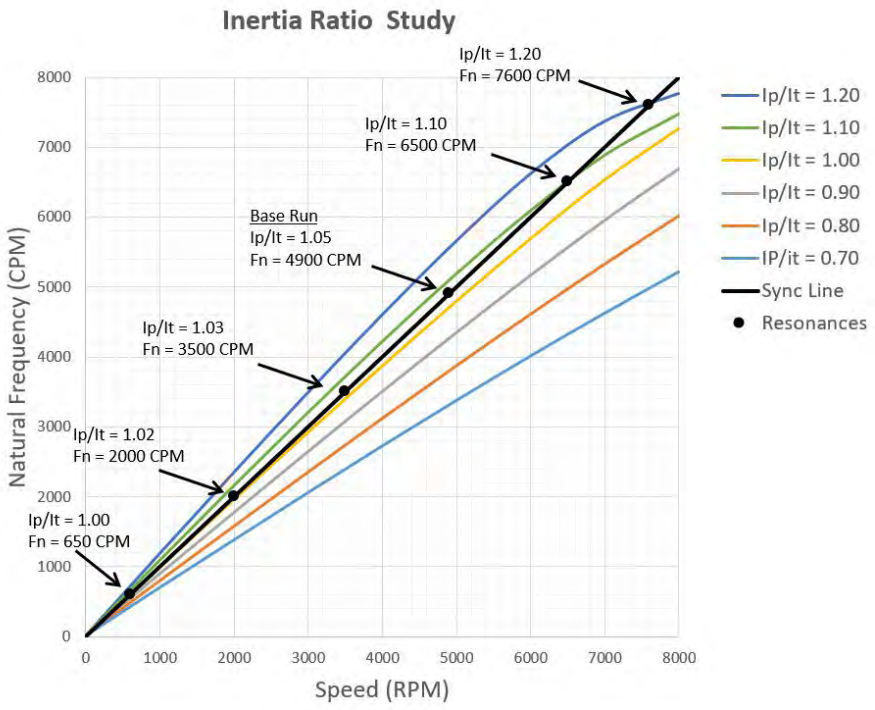


Figure 3. Damped Eigenvalue Plot for mandrel assemblies showing curves for Ip/It inertia ratios ranging from 1.20 - 0.70. The resonance frequencies (intersections with the synchronous speed line) change rapidly as the inertia ratio is reduced from 1.10 to 1.0, so this region should be avoided. For inertia ratios below 1.0, the resonance frequency is in the 100 cycles per minute (CPM) to 300 CPM range.

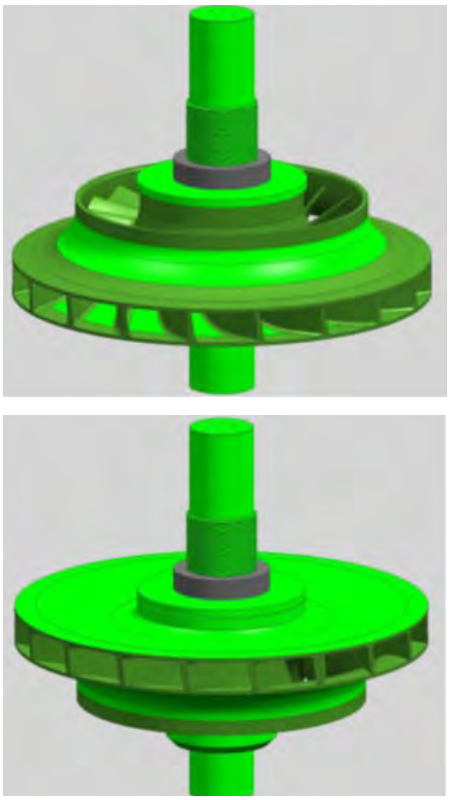


Figure 4. Impeller shroud facing up (left) and impeller shroud facing down (right).

Vibration exceeded the classic speed-squared trend relationship. This indicated that the increase in vibration was the result of more than just the system's response to a fixed amount of unbalance.

A static bump (or ring) test was performed immediately following the test with the mandrel suspended vertically in the overspeed machine. This was done to determine if there was a resonance in the vicinity of 4,800 RPM. However, it was later discovered that it was not responsible for the observed vibration excursion.

Further investigation looked into whether the vibration trip event was the result of an inertia dominant resonance condition, as the Ip/It inertia ratio was outside the recommended operating limits documented in the overspeed machine operator's manual. In this case, the Ip/It inertia ratio was 1.05. It became evident that it was necessary to understand the phenomenon more clearly to determine the best way of addressing it.

Theoretical basis

An inertia study was performed. The separation distance between the disks was varied to change the transverse inertia and associated Ip/It ratio. It is evident that the natural frequency for inertia ratios close to 1.0 is sensitive to small variations in modeling, boundary conditions, and assumptions. For this reason, operation at inertia ratios between 1.0 - 0.95 should also be avoided.

Two different approaches were explored to address the vibration issue and successfully achieve overspeed. The first involved the possibility of accelerating rapidly through the resonance with the existing mandrel design.

A parametric study was performed to determine if it was possible to accelerate (and decelerate) through this mode at such a rate to prevent the vibration from building to unacceptable levels. The rationale being that the greater the acceleration rate, the less time the system could absorb energy and amplify.

Inertia Ratio of Rotor Assembly	Action	Discussion
Ip/It > 1.20	No issues anticipated	
1.15 < Ip/It ≤ 1.20	Detailed CAD Evaluation	Accurate value for Ip and It required to confirm ratio is above 1.15.
1.10 < Ip/It ≤ 1.15	Rotor Dynamic Analysis	May be possible if target speed is relatively low.
0.95 < Ip/It ≤ 1.10	**Avoid**	**High Vibration Possible**
0.90 < Ip/It ≤ 0.95	Rotor Dynamic Analysis	Results will be subject to error due to modeling inaccuracies and uncertainties relating to the boundary conditions
0.80 < Ip/It ≤ 0.90	Detailed CAD Evaluation	Accurate value for Ip and It required to confirm ratio is below 0.90.
Ip/It ≤ 0.80	No issues anticipated	

Disclaimer: This suggested guideline was developed based on experience with a single application tested in a specific overspeed machine recognizing that other applications utilizing different test equipment may produce different results.

Figure 5. Inertia ratio guidelines.

This was not feasible due to the practical limits of the overspeed machine and levels of residual unbalance present in the mandrel assembly.

The second approach involved modifying the mandrel inertia ratio to shift the resonance outside of the range of operation. This was determined to be the best route forward. To avoid disruptions to the production schedule, two modification options were pursued simultaneously.

The first option, which was associated with a shorter lead time, involved installing a flywheel on the existing mandrel to increase the inertia ratio above 1.20. The second was to redesign the mandrel to a one-piece component with an inertia ratio below 0.70. Doing so, however, would result in longer lead time.

Flywheel testing ultimately proved to be unsuccessful due to problems associated with repeated vibration during start-up and shutdown. However, during testing, it was noted by shop personnel that, in some instances, impellers ran better when they were mounted with the shroud facing downward. As the newly designed mandrel was not yet available for testing, this suggestion was noted and tested. The flywheel was then removed, and the impeller mounted on the existing mandrel with the shroud facing downward (Figure 4).

With the impeller shroud facing down, the rotor assembly successfully reached overspeed. One factor that may account for this result is the Ip/It inertia ratio. It increased from 1.05 to 1.13 after flipping the impeller. Another factor is the residual unbalance. It may have shifted closer to the mandrel's center of gravity. Rotor dynamic calculations indicate that if the unbalance shifts by a little as 1.0 inch (25.4 mm), such that it coincides with the mode's pivot point, the system response is virtually eliminated.

Eventually, the second (preferred) option could be implemented, as the new mandrel was manufactured and available for use for overspeed testing of the 2nd stage impeller. The new mandrel was designed such that the Ip/It inertia ratio of the mandrel assembly was reduced from 1.13 to 0.68. All subsequent impeller overspeed tests were successful with the new mandrel.

High shaft vibration

In centrifugal compressors, therefore, an inertia dominant resonance condition can occur. This results in high shaft vibration when the ratio of a rotor system polar moment of inertia and transverse moment of inertia approaches a value of 1.0. Impeller overspeed testing is a likely place for these inertia values to converge.

Attempting to balance out this resonance condition or accelerate rapidly through it has a low probability of success and can result in equipment damage. This is mainly based on the torque transmission limitation of the belt drive system to both accelerate (run-up) and decelerate (brake) the mandrel assembly, especially with large impellers. Suggested guidelines are available to assess the level of risk when operating near this resonance condition (Figure 5).

The probability for success when operating near the 0.95 < Ip/It <1.10 inertia ratio range improves if the following guidelines are observed:

- Align the center of gravity of the impeller close to the pivot point of the rigid body mode. The pivot point is near the CG of the mandrel assembly. This will help to reduce system response. installing the impeller on the mandrel with the shroud facing down resulted in a successful overspeed run, albeit not conforming to the overspeed machine manufacturer's Ip/It guidelines.
- Confirm that the component fits are sufficient to remain engaged to maintain concentricity throughout the speed range.

Our analysis shows that the observance of these suggested guidelines promotes successful overspeed testing per API 617 standards. ■

Mark Kuzdzal is the R&D Head for the Advanced Components and Methods group at Siemens Gas and Power, the global energy business of the Siemens group. Siemens.com/energy

Martin Maier is a Principal Rotor Dynamic Analysis Engineer at Siemens Gas and Power. *For more information, "A Resonance Condition Encountered in a Shop Overspeed Machine Due to Inertia Effects: The Theoretical Basis and Practical Experience," 48th Turbomachinery Symposium by Maier, M., Barnes, T., Frier, S. Kuzdzal, M., 2019.*

SPECIALIST COATINGS

BY GARRET HAEGELIN

Industrial gas turbines rely on specialized coatings to deliver continued performance and reliability. Renewing these protection systems is an important part of the routine maintenance schedule. Quality is dependent on the expertise of the refurbishment team and attention to detail down to the microscopic level.

Industrial gas turbine coatings require an array of application methods that involve specific processes and equipment. High velocity oxygen fuel (HVOF), plasma, arc wire, combustion, air spray and chemical vapor deposition (CVD) are all used in the refurbishment of components.

Coatings also have slightly varied bonding properties with different substrates. It is essential to understand the conditions required to achieve a perfect bond. Furthermore, the remaining range of properties of the finished coating must be sufficient for the application.

For example, the hardness value is an indicator of the proper application of wear coatings while surface roughness will have a major impact on flow efficiency. By inspecting the microstructure and mechanical properties of the coating, it is possible to verify that it was applied to the required specifications and will provide all of the expected benefits in operation.

In every refurbishment project, the right process foundation is essential to long-term success and durability. This involves detailing the equipment and parameters as well as the coating properties required, such as its tensile strength, microstructure characteristics, hardness and surface roughness.

In many cases, coatings are applied as one of the final stages of a larger repair project. It is important to make sure all prerequisite steps have been taken to ensure the substrate is properly prepared for application. A sound substrate is essential for optimum performance.

Pre-coating checks

Most of the superalloys used in gas turbine components develop oxidation and corrosion while in operation. It is essential that any of these contaminants are removed completely, including any remnants of the previous coating. The presence of any intermediate layer between the substrate and the new coating will likely cause bonding issues.

However, care should be taken when grit blasting or blending, to minimize any removal of the original substrate. To identify any remaining areas of oxidation or residual coating, components are heat-tinted. If contaminants remain, the process repeats until suitable results are achieved.

Once intermediate layers are removed, further processes may be required. In some cases, the component's microstructure needs to be prepared in terms of applicable heat treatments. These processes should be performed prior to application to ensure the coating is not subjected to anything outside of its previously qualified specifications.

Similarly, the component may need to be dimensionally altered. The thickness of the newly overlaid coating will affect the final dimensions of the component. In many situations, it will be necessary to remove some base material or adjust geometric profiles to facilitate additional thickness.

Final pre-coat quality control checks should be completed, including dimensions, flow checks and inspections for defects, using penetrant if necessary. Coatings will only bond properly if there are no gaps or cracks in the substrate; any such flaws will cause rapid deterioration of a new coating.

It is also possible that the part came into contact with contaminants, such as oil, machining fluid and non-destructive evaluation (NDE) penetrant fluid. They must be removed via chemical or thermal means in the degrease process. After that, extreme care must be taken to ensure contaminants are not re-introduced to the substrate as this could jeopardize bonding.

Next, grit profiling roughens the target surface, creating an anchor-tooth pattern for the coating to mechanically bond to. Care should be taken to use virgin grit and not re-used grit to prevent contamination.

Industrial robot arms controlled by positioning software provide consistent application. If done properly, they provide a leap forward in quality control and consistency when compared to manual processes. Once applied, the base coat in some cases requires heat treatment.

Following any heat treatment process, it is essential that an NDE is completed to ensure that no voids opened during the heat treatment process. This will typically be a penetrant inspection using red dye or even fluorescent dye to detect even the slightest defect.

When applicable, a top coat, typically a thermal barrier coating (TBC), is applied in a similar quality-controlled manner as the bond coat. After this application, it is important to carefully remove overspray and polish the coating so it meets the specified surface roughness. The final quality inspection should identify any areas that may need minor repairs and confirm all the required specifications have been met.

Following the coating inspection, test fitting or dimensional checks should be performed to ensure the coating has not pushed the dimensions of the component out of specification. If a third party is being used, they should be involved with this process. For components with cooling channels, any change in flow rate can lead to decreased turbine efficiency, overheating of components and even failure.

Therefore, it is critical that flow checks are performed once more to ensure coating, grit or any other foreign matter has not caused the component's cooling air to flow below its specified rate. During these post-coating processes and any further handling of coated components, ensure that the coating remains protected and in pristine condition until the component is reinstalled. This is particularly important for brittle TBCs. In all cases the performance of gas turbines is dependent on the proper application of specialized coatings. ■

Extensive preparation is required to ensure specialized coatings bond properly with substrate materials.

Garret Haegelin is HICoat Division Superintendent at Sulzer. For more information, visit Sulzer.com

IMPROVING COUPLING RELIABILITY

Chuck Sakers, Couplings Technology Leader, Kop-Flex, at Regal Beloit discusses torque monitoring, the importance of coupling reliability, and how to gain more value from existing couplings.

Tell our readers briefly about Regal Beloit

Regal is a manufacturer of power transmission products as well as electric motors, electrical motion controls and power generation equipment. It is headquartered in Beloit, Wisconsin and has engineering, manufacturing, sales and service facilities throughout the world. The company is comprised of three operating segments: Commercial and Industrial Systems, Climate Solutions and Power Transmission Solutions.

The Kop-Flex brand has served the turbomachinery industry for more than 50 years, offering services and solutions like High Performance Disc 2.0, Perceptive Technologies and the Powerlign torque monitoring system. Kop-Flex delivers solutions for oil and gas, power generation, and aerospace and defense in the turbomachinery space. In addition, Kop-Flex offers a full range of coupling products that serve the metals, pulp and paper, and heavy industry markets.

What trends are impacting couplings?

Data demand has exploded for data and information about how couplings are designed and selected, how they are manufactured, how they operate, how they are maintained, and how they are serviced. The coupling industry is catching up with the rest of the world in the data revolution.

Just like you and I track our orders from Amazon and get regular updates during the process, customers are looking for the same easily accessible live data for couplings. The procurement team needs quick access to product information to make purchases. Project managers are looking at Gantt charts to understand more about the process and status while couplings are being designed and manufactured. Installation and maintenance teams always need access to manuals and service experts. Our Kop-Flex team is building a complete digital customer experience (DCX) to support these goals.

How about the hardware side?

We have been gathering data from couplings that allows plant operators to make smarter maintenance decisions by monitoring performance trends with our Powerlign torque monitoring system. In addition, our Perceptive Technologies group uses an array of torque monitoring solutions for online monitoring, predictive maintenance and failure analysis. This includes the use of augmented reality tools.

Also, there is definitely a trend to have spares for all critical equipment. This is a lesson often learned after a field issue. Having that spare coupling on hand without having to transport parts across the country or the globe, ready to use, minimizes downtime. Many customers have purchased a spare to install at the next turnaround. They send the main coupling back to our Kop-Flex team for recertification.

What is your coupling recertification service?

Disc and diaphragm couplings are not a 'wear item' like the seals in a turbine or compressor, which can cause a decrease in equipment performance and are typically replaced on a time-based schedule. Most high-performance couplings are designed to be maintenance-free.

If they are operated within their rated capacities, they can outlast the equipment to which they are connected. To maximize production, each asset, critical or not, should have an appropriate maintenance strategy that is followed, audited for effectiveness, and adjusted as necessary to ensure reliability.

However, equipment upgrades, shifting foundations, process changes, environmental factors and handling can push the coupling outside of its design operating envelope. The recertification service allows end users to evaluate couplings and conduct repairs, if necessary, during scheduled downtimes to prevent unplanned outages. Recertification is targeted at the API 671/ ISO 10441 market, but is available for most coupling types.

Kop-Flex has been recertifying couplings for over 15 years and services more than 150 couplings per year. The team does a full teardown and inspection of each component. They replace components as needed with new parts made to the original drawings and design standards. Recertification restores couplings to a like-new condition for about half the cost of a replacement.

What other products might our users be interested in?

The Kop-Flex Powerlign torque monitoring system allows users to minimize emissions and fuel costs by tracking performance trends in connected equipment. This system can be purchased new with couplings or retrofitted to existing Kop-Flex or other brand couplings.

We also offer a Max-C resilient coupling that provides damping for applications with shock loading or cyclic torques. The Max-C can be mated to disc or diaphragm couplings to tune the drive train. They are frequently used on synchronous and variable frequency drive motors.

What products do you have in the pipeline?

Our teams are always working to provide optimal solutions for the most challenging applications. We have a great focus on providing lightweight, cost-effective and highly reliable solutions for the industry.

There are some exciting ideas in the pipeline, and a lot of the ideas are spawned from our Perceptive Technologies team. They are working directly with customers to understand new challenges that arise in the field and finding unmet needs. The beauty of this team is that they support our whole Regal Power Transmission Solutions business. So, we get a lot of benefit from cross-pollination of ideas and economy of scale from other industries that we serve, like food and beverage and HVAC.

What is the company doing to cope with the current slowdown?

Regal is committed to supporting its associates, customers and communities through the Covid-19 pandemic. It is a rapidly changing situation, and we are working diligently to maintain focus and support essential business while making the best decisions for safety. ■

TURBOMACHINERY WEBCAST REPORT

BY RORY PASQUARIELLO

Several industry events were recently cancelled such as the Western Turbine Users Conference, the Offshore Technology Conference and the Turbomachinery Expo. In response, industry professionals have taken to webcasts to share their skills and technical knowledge.

In partnership with industry leaders, Turbomachinery International Editor-in-Chief, Drew Robb, hosted two online workshops: "Digital Reliability: 24/7 Real-Time Machinery Diagnostics," on April 15 by Dynamics Scientific, and "Turbomachinery Lifecycle Management: The Future Will Be Remote," by Siemens Energy on April 30.

All webcasts are available to view at turbomachinerymag.com.

Digital reliability

The mission of Dynamics Scientific is to research, develop and promote the technology of Safe Resource-saving Operation and Maintenance of Machinery of hazardous industries (SROMM-Technology). The system creates real-time monitoring system for the automatic diagnostics of machinery at industrial sites to prevent malfunctions, failures or breakages, and to reduce the risk of accidents, fires and downtimes during any machinery lifespan.

In his presentation, Andrey V. Kostyukov, PhD, President of Dynamics Scientific, offered tips and information to operators, managers and maintenance teams on how to gain a clearer picture of each machine's health in real-time. The webinar zeroed in on the reliability of equipment in process facilities and how to achieve optimal reliability through real-time monitoring of vibration.

Existing solutions such as protection or condition monitoring systems are focused on confining consequences, not preventing breakdowns. Distributed Control Systems (DCS) show the failure, and perhaps advise the operator to perform an emergency shutdown to minimize the consequences of equipment failure. However, DCS does not identify the fault at an early stage of degradation and take urgent actions to eliminate it. If the protection system alarms, the breakdown happens.

Additionally, condition monitoring systems generally require an expert to interpret. Without this interpretation, the operator may not understand what should be done to prevent an impending failure. That's why most breakdowns and accidents generally happen either during the night or weekend shifts; an expert is not on duty at the facility.

The COMPACS-Net platform from Dynamics Scientific allows refineries and other facilities to see information about every unit within the system.

Kostyukov presented the company's COMPACS system, which uses artificial intelligence (AI) and digitalization to enable process facility teams to obtain real-time feedback on the health of machinery. The goal is the detection and elimination of the root causes of failures and bottlenecks without the need for operators to become experts in areas such as vibration analysis.

For example, COMPACS discovered that 11 machines out of 200 at one facility generated 80% of maintenance orders. By digging into the reasons behind the failures at those specific units, the reliability of the facility was greatly improved.

In one case, an exhauster was causing problems. Initial maintenance actions addressed tightening screws and alignment. However, those repairs did not yield the desired result. Further analysis found impeller imbalance. When it was dynamically balanced, vibration decreased. Normal operation resumed.

The COMPACS system assists facility operators to achieve safe resource-saving operation and maintenance of their machinery. It empowers them to reach desirable outcomes in safety and uptime and achieve digital reliability.

Turbomachinery lifecycle management

Limitations on travel and spending and the advent of social distancing have made it clear that there is a bright future for remote turbomachinery lifecycle management. Remote witness testing, remote performance monitoring and diagnostics and remote field service are growing in acceptance in the industry.

Hundreds of rotating equipment operators worldwide are already employing Siemens-provided remote lifecycle management services. They are realizing benefits such as: greater operational visibility and manageability with lower maintenance costs and fewer repairs; improved safety and security of their personnel, assets and the environment; more uptime and availability; and better utilization and ROI on their capital assets.

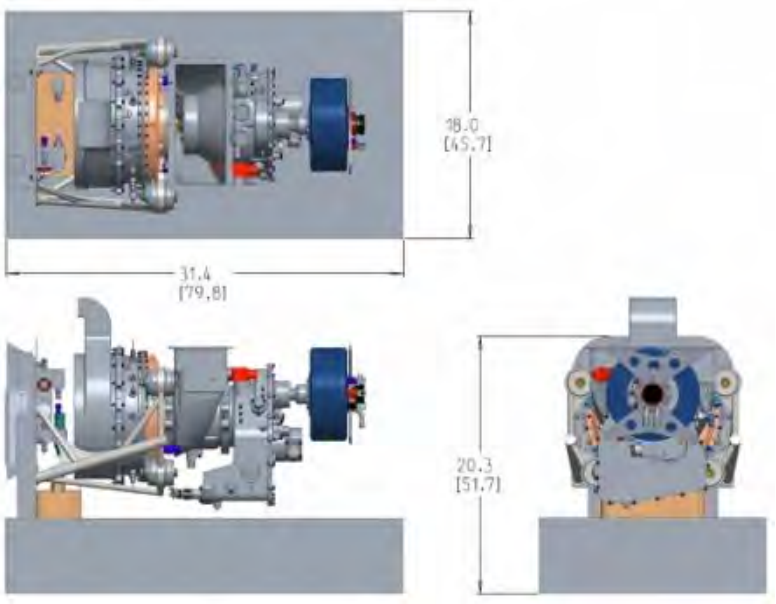
Webinar presenters from Siemens Gas and Power included Carmen Garibi, Oil and Gas Head for Industrial Cyber and Digital Security; Scott Tackett, Director of Pipeline Compression Sales, Americas; and Michael Dollinger, Project Development Manager for Digital Products. They discussed the challenges of remote management and introduced the Siemens Remote Diagnostic Service (RDS). RDS supports proactive and reactive technical support from afar.

Additionally, the implementation of Siemens RITA (Remote Inspection and Testing Acceptance) software enables remote troubleshooting. Remote guidance offers access to experts that can provide over the shoulder support and communication to on-site person via secure video collaboration equipment. Users of this technology can expect increased uptime and productivity via more rapid problem solving.

You can watch a replay of these and other turbomachinery webinars at turbomachinerymag.com. ■

Siemens Remote Diagnostic Service supports proactive and reactive technical support as well as remote expert troubleshooting.

UAV Monarch 5 turboshaft engine



Microturbine

UAV Turbines (UAVT) said its Monarch 5 turboshaft engine can now run on natural gas, which could extend its application beyond flight into ground emergency and standby power generation for both onsite and remote application areas. With minor engineering changes, the Monarch 5 engine can be adapted to clean energy fuel sources such as natural gas and hydrogen.

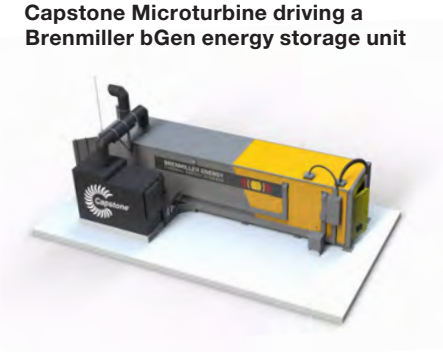
UAV Turbines' miniaturized microturbine technology targets applications such as hard-to-access remote weather stations, oil fields, telecom towers, construction sites, emergency field teams, stationary first responders and military vehicle communications. The Monarch 5 has a power output of 20 kW, thermal efficiency of 17.2%.

In an aero-engine, the load is predictable and the unexpected transients are small. But an electrical load can change fast and in large amounts without warning. Additionally, shock loads in ground power generation use are larger than in aero-engine use, particularly in a moving, off-road vehicle. There are also issues related to inlet air filtering as ground-level air can contain higher particulate contamination.

Reciprocating engines often beat microturbines in efficiency in low power ranges. However, a gas turbine prime mover is preferred where fuel cost is not the driver, but compactness, weight, low maintenance, low vibration, and multifuel dominate the requirements. Those applications tend to be things like emergency response where portability and multifuel are important, and remote emergency power where reliability and low maintenance requirements would be important. Supplemental power for ground vehicles where the available space is restricted would be another application.

Uavturbines.com

Capstone Microturbine driving a Brenmiller bGen energy storage unit



CHP energy storage

Capstone Turbine is developing new energy storage technology in partnership with the New York Power Authority (NYPA) and Brenmiller Energy. This is being done for Purchase College, State University of New York (SUNY). The project received a grant from the Israel-U.S. Binational Industrial Research and Development (BIRD) Foundation to investigate low-emission thermal energy storage as a means of increasing the efficiency of standard combined heat and power (CHP) systems.

The microturbine will directly pipe low emission exhaust gas into a Brenmiller bGen zero carbon thermal storage unit, which extracts and stores the heat until needed. The system represents an alternative to battery storage with potentially greater discharge durations.

Capstone distributor RSP Systems secured the order for the C200R microturbine that will be used in this CHP application. The cogeneration system will be installed to support the College's physical education building, displacing the aging district heating loop in the central heating plant and providing baseload electricity. It is projected to save the State University of New York about $100,000 per year while reducing the carbon footprint.

Capstoneturbine.com

E-Pulse pumps

The Enerpac series of E-Pulse hydraulic pumps combine performance, durability and convenience. A high-efficiency, 0.85 hp direct-drive motor offers a six-piston block design that provides even flow and smooth operation of tools.

There is a choice of five valves. Flow at rated pressure is 32 cubic inches/minute with a maximum operating pressure of 10,000 PSI. Other features include a 24V DC power regulator, built-in thermal protection, a 20-ft. pendant cord on the torque wrench pump and a 10-ft pendant cord on the other four pumps.

Smart controls enable the motor to maintain constant power and provide higher flow than traditional one-half horsepower pumps, and an adjustable speed control provides precision as needed.

Enerpac.com

Enerpac E-Pulse hydraulic pumps.

AI-based data acquisition

Yokogawa Electric has released artificial intelligence (AI)-enabled versions of the GX series panel-mount-type paperless recorders, GP series portable paperless recorders and GA10 data logging software. These are components of the Smartdac+ data acquisition and control system.

AI functionality includes the future pen, a function that enables the drawing of predicted waveforms. This helps users identify and correct problems before they cause disruptions in production operations.

Yokogawa is also releasing a new CPU module for the e-RT3 Plus edge computing platform that is environmentally robust and compatible with the Python computing language. The Smartdac+ system is a product in the OpreX Data Acquisition family, and the e-RT3 Plus is part of the OpreX Control Devices family.

New components of the SMARTDAC+ data acquisition and control system by Yokogawa

Yokogawa.com

Displacement transmitter

In condition monitoring, the measuring chain from sensor to alarm information is traditionally a complicated, expensive path with lots of wiring, signal conditioning and data conversion through a number of systems. The displacement sensor for monitoring shaft vibration is one example of this. Accordingly, Brüel & Kjær Vibro (B&K Vibro) has developed the DT-12x series to fulfill the need for economical displacement transmitters with simplified installation.

The DT-12x is a series of fully integrated, loop-powered displacement transmitters that offer a solution for shaft displacement, and vibration monitoring for a wide range of industrial machines. A fully integrated transmitter is one that combines the driver (oscillator) and signal conditioning electronics (vibration monitor) into the sensor itself.

This simplifies installation by eliminating the need for a driver, vibration monitor and protective housing. A DT-12x transmitter can be directly connected to a DCS or PLC using its standardized 4-20mA output.

As it is loop-powered, its 4-20 mA signal is not affected by long wiring distances, voltage drops or noise. This further simplifies installation when connecting to a DCS or PLC as only two wires have to be connected in the current loop.

In addition to 4-20 mA outputs, there are buffered output wires for transferring voltage signals to portable monitoring instruments for analysis and data storage. The transmitters have several mounting configurations are also built for harsh industrial environments.

Bksv.com

Affordable electric motors

Most electric motors rely on rare-earth minerals such as neodymium and dysprosium for their magnets to produce their required torque. Linear Labs HET motor uses affordable ferrite magnets instead of rare earths to produce high efficiency and torque over the full speed range. This is accomplished due to the motor's ability to use more magnetic surface area than other radial or axial flux motors.

With the HET's stator surrounded on all four sides there is claimed to be almost zero flux leakage compared to competitive motors, creating ample torque from ferrite magnets and making obsolete the need for rare or expensive minerals.

Unlike most electric motor producers who depend on materials sourced from specific regions, the HET motor does not suffer from supply-chain constraints. All raw materials and components are locally accessible and available around the globe.

Linearlabsinc.com

MYTH: STEAM TURBINE POWER – GO BIGGER

Engineers have a tendency to overdesign and oversize rotating equipment. In past articles, we discussed the impact of unnecessary oversizing for compressors and gas turbines. But in terms of performance and cost, the steam turbine (ST) is most impacted by unnecessary oversizing.

For those not familiar with STs: Steam generated in a boiler enters the turbine at an inlet and chest area and flows through parallel governor valves. The flow is distributed by a flow ring, allowing for partial admission before it enters the control stage.

Subsequently, steam flows through several impulse or reaction stages to extract energy efficiently and leaves through a back-end stage. All of these stages consist of stationary and rotating blades. STs can have side streams. Their discharge pressure can be a defined backpressure or the pressure at the steam condensation temperature.

STs designed for API 612 applications must provide 10% margin above the rated driven equipment power with the lowest possible steam demand. This, as well as the desire to build in safety and degradation margins, often leads to oversizing.

It also reduces the efficiency at normal operating points. An ST driving a compressor must be able to produce at least 110% of the rated power at steam conditions coincident with the minimum inlet, and maximum exhaust temperature and the pressure conditions specified.

An example: The boiler could be dropping off, and the main condenser losing vacuum while the plant process is still trying to maintain 110% of the compressor-rated condition at rated speed. What does this mean for the various components and their sizing?

Inlet & Steam Chest Area

To meet design velocity limits entering the ST, all operating points must be considered, including the rated power at worst case conditions. This maximum flow case coincides with the minimum inlet condition, which has a higher specific volume, resulting in the need for a larger inlet flange and steam chest area to pass the flow at or below inlet velocity limits. This increase in volume area raises the internal surface area, which produces larger hoop stresses, requiring increased wall thickness and other structural design challenges.

Governor Valves

When designing the governor valve opening scheme for a multi-valve ST, it is preferable for the normal operating point (or guarantee point) to be on a valve point to reduce throttling losses.

The valve point is when the valve is almost completely open and immediately before the next valve is about to crack or lift from the valve seat. To meet the rated operating point, the governor valve opening schematic must be modified to ensure all valves can pass the required rated flow at minimum conditions to make the turbine-rated power. This change in opening creates a throttling condition for the normal operating points, reducing the ST's front-end efficiency.

Control Stage

To mitigate governor valve throttling losses at normal operating points, flow distribution must be improved by manipulating the area in the nozzle ring to provide a distribution favoring a valve point.

This is accomplished by increasing the nozzle height, thereby forcing a lower arc of admission. Additionally, the throat opening can be increased, which moves the velocity triangles away from optimum design and often requires adjusting blade angles.

In both cases, this creates a larger pressure ratio on the control stage and an increase in active arc losses for normal operating points. The larger pressure ratio produces higher dynamic blade stresses from nozzle wakes and partial admission stimulus when entering and exiting the active arc. This requires more robust staging that reduces operating efficiency.

Back-End Staging

A large change in flow rate can have an impact on the volume flow area needed in the condensing section of the LP staging. Since the ST starts with the lowest available inlet steam conditions, this reduces the energy that can be extracted by increasing the exhaust pressure.

Thus, the flow required to make rated power becomes substantially larger. Meeting the required flow rate requires changes to the design of the back-end stages. For example, the last stage will either need to be gauged open or its height increased.

But either option negatively impacts efficiency. A taller blade height also increases centrifugal and bending stresses. Alternatively, gauging open the nozzle and bucket passages reduces stage efficiency.

The impact of these parameters varies based on the type of machine, the power balance and operating conditions. Oversizing is different for straight-through condensing, back-pressure, or extraction- and induction-type turbines. Straight-through turbines are impacted across all design conditions, which can result in flow requirements up to 60% above the guarantee condition.

For an extraction turbine, impact splits performance losses in each section. Extraction/induction machines can see front-end flow oversizing requirements from 10% to 30%, and back-end flow oversizing from 30% to 50%. Clearly, this negatively impacts efficiency. A performance drop of more than 5% is not uncommon.

It is sometimes appropriate to conservatively oversize power margin per API requirements and account for future degradation. But oversizing an ST usually results in an exponential increase in hardware costs and a significant reduction in design performance efficiency. (Adam Neil of Elliott Group significantly contributed to this article). ■

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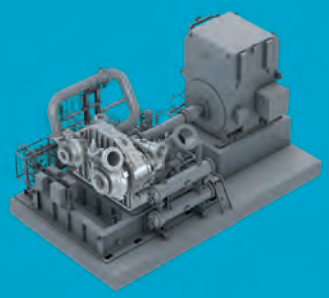

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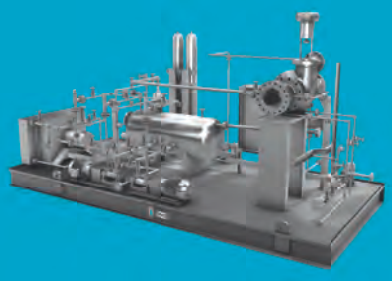

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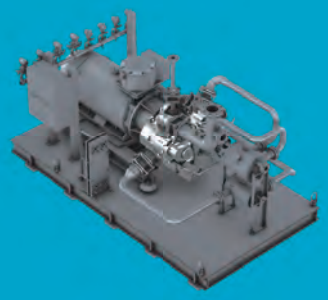

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