Developing pioneering and environmentally friendly compressor technology

An interview with

Ahmed Kovacevic (Director at PDM Analysis Ltd)

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PDM Analysis Ltd develops, markets and supports SCORG™ – a specialised software for the design and analysis of positive displacement screw compressors, pumps and motors. Their focus is on supporting industry and academia with software tools and services, for easy and accurate insight into the performance and design of screw machines. Their innovative solutions have led to better designs with significant improvements in reliability and efficiency.

PDM Analysis is led by Professor Ahmed Kovacevic. Dedicated to the development of design excellence in academia and industry, Prof Kovacevic teaches, researches and collaborates with industry in numerical modelling, analysis and design of Positive Displacement Machines. He is the director of the renowned Centre for Compressor Technology and the chair of the International conference on Compressors and their Systems at City, University of London. We spoke to Prof Kovacevic to find out more about the wide ranging benefits of their innovative technology.

How does SCORG work?

SCORG is a unique software for analysis of positive displacement rotary machines like screw compressors, expanders and pumps as well as gear pumps, G-rotor and vane machines. SCORG was originally developed at City, University of London's Centre for Compressor Technology and since 2014 is commercialised through a spin-off company from the University, called PDM Analysis Ltd.

Positive displacement machines are used to either increase pressure of a gas or vapour when energy is applied to drive the machines or inversely, to reduce pressure and extract energy from the pressurised gas or vapour. Screw machines are formed by two or more counter rotating helical shaped rotors, surrounded by stationary casing, that create volumetric changes to the fluid as it moves through the moving rotors. That fluid volume is generally of a complex shape which could be difficult to describe mathematically.

With SCORG, we pioneered a technique to represent these complex volumes by a numerical mesh which can be used to calculate gas or vapour pressure, temperature and velocity within this complexly shaped working domain and from that to calculate performance of the machine in the form of power and flow rate. This is achieved by applying computational fluid dynamics principles built in a variety of commercial numerical solvers using the numerical mesh created by SCORG. But this is just a part of the story. To design an efficient screw machine designers require a tool which can quickly and reliably inform them on the potential effects of design changes on the performance and reliability of the machine. SCORG is the tool which enables designers to perform this task quickly and accurately.

What benefits can be derived from accurate insight into performance and design of screw machines?

About 20% of electrical energy generated in developed countries is used for compression. Screw compressors play significant role in industrial compression systems like oil and gas, refrigeration, air conditioning, air compression, food and pharmaceutical and others with the global market of screw machines reaching $11 billion by 2021. There are almost two million new screw compressors manufactured every year. They consume vast amount of energy and even small improvements in their performance will make a difference on reducing environmental impact and carbon footprint.

Standard analytical tools still used by many screw compressor manufacturers could not give full details of pressure, temperature and velocity distributions within such machines which are required for efficient design.

In about 87% of all screw machines, oil is injected in the compressor to cool, seal and lubricate the machine. Oil screw compressors are normally cheaper and smaller than oil-free compressors but they consume more energy and pollute the environment with residual oil. It is therefore paramount to understand how the amount of oil can be minimised and if possible completely eliminated from the compressor system.

In the remaining 13% of oil free compressors, which do not have benefit of cooling the gas by oil injection, reliability is a significant issue. This causes oil free compressor systems to be very expensive and this is the main reason why these highly sought oil-free compressors are still not used except in exclusive areas like food and pharmaceutical where oil is strictly prohibited.

By better understanding the physics of temperature increase, heat transfer and influence of heat on compressor elements, it would be possible to increase the share of oil-free machines in the market and further reduce impact of compression on the environment.

How is the performance prediction calculated?

Requirement related to performance predictions may differ from one designer to another. Some may be interested in quick and reasonably accurate overall performance of a compressor or expander for which lower order models like multi-chamber thermodynamics could be used. Others may be interested in understanding the details of internal flows and their influence on the machine performance for which 3D computational fluid dynamics is the right tool to use. But there is also a group of users who might be interested in the performance of a complete system like, for example, a refrigeration system. In that case combined multi-physics approach may be required to integrate performance of a compressor and other elements of the system like heat exchangers, pumps, piping, and so on. SCORG allows all these means of performance calculations to be performed. Moreover, it simultaneously enables structural analysis which will then give the information on robustness and on reliability of the machine and its system. Functions of SCORG that lead to required performance predictions are as follows:

1. SCORG allows design and modification of the profile of rotating elements which is the key driver for satisfactory compressor performance.
2. All geometry and physical aspects of the machine are generated within SCORG to provide inputs into proprietary chamber modelling tool built in SCORG. The same geometry values could be used within SCORG to integrate other commercial multi-physics solvers (for example GT-Suite of Gamma Technologies). This allows modelling of a complete system.
3. SCORG generates numerical meshes which can be used with virtually any commercial and open access CFD solvers (like Simcenter STAR-CCM+, Ansys CFX or Fluent, Symerics MP or Open Foam).
4. The performance predictions obtained by any of the previous three methods could be integrated through SCORG to calculate deformations of machine solid elements and solid-fluid interaction.

How important is the presentation of data to the overall success of SCORG?

It is very important to extract desired information which could lead to the design of better machinery or detection of issues which may occur during the operation of a screw machine. By knowing the behaviour of the system and being able to visually represent these results in the form of graphs and 3D graphics, designers get a chance to understand how their machines may become more reliable and efficient.

SCORG was conceived about 15 years ago on the back of my PhD at City University of London which pioneered methods to represent complex working domain shapes in screw machines by structured numerical mesh generated by analytical transfinite interpolation. That allowed use of 3D computational fluid dynamics which was never before used for analysis of screw machines. This in turn gave an opportunity to understand internal flows in detail and has led to improved designs. Adequate representation of calculated results is key for success in design.

What are the key functions that differentiate SCORG from other simulation software providers?

Since 2013, about a decade after the first version of SCORG, a few companies started to develop their own software which could perform some analysis of screw machines. Some of them are using exactly the same configuration of the mesh as first proposed in SCORG but generate the mesh using numerical instead of analytical methods implemented in SCORG. Their resultant meshes are of similar quality, but the time required to generate it and computational effort are significantly larger than by using SCORG. Meshes which they generate could be used only with their proprietary CFD solver while meshes produced by SCORG enable use of virtually

any CFD solver known today in the market. Some other providers of modelling software concentrate on lower order models which have only limited use but are quick ways of estimating performance. SCORG is the only software in the market offering a holistic approach to design of screw machines by enabling use of lower order multi-chamber thermodynamics modelling as well as high fidelity 3D CFD.

However, the biggest difference between SCORG and others is that SCORG was developed by the group at City who design screw machines for industry for more than 30 years and have implemented our IP in hundreds of screw machine designs. The continuous development of SCORG is done with one aim in mind; to allow designers including our group to implement latest findings from the fundamental and applied research that we do by using the software which we design to support our work in design of these machines. This is the unique combination in the market place which gives confidence to the users of SCORG that they will implement the latest state of the art in the design of their machines.

Who can benefit most from utilising SCORG's innovative products and services?

SCORG is used by screw compressor and pump manufacturers in their R&D departments for development of new efficient screw machines and for improvement of their existing machines. The companies operate in many different industries including air-conditioning and refrigeration, air compression, oil and gas, transport, pharmaceutical, food etc. The number of companies which use SCORG is growing every year and many novel ways of applying their machines are evaluated by SCORG. SCORG enables R&D engineers to design efficient machines faster and with confidence. But, this directly benefits their companies who increase turnover and profit and become leaders in their niche areas.

In recent years, the interest for screw machines is quickly increasing which triggered many universities to start studying screw machines. Universities and research centres greatly benefit by using SCORG which is now often used as a tool in educating postgraduate students in this area. These are just some of the users but the benefit is much wider. I am the Chairman of the Organising Committee of the renowned International Conference on Compressors and their Systems held every two years at City, University of London. The conference attracts a large number of industrial and academic participants interested in compressors and many of them come to attend the short course on CFD in Positive Displacement Machines which we organise alongside the conference traditionally held in September every odd year. In 2019, we had 55 participants in this short course from more than 35 institutions, all of them interested to hear about latest developments in modelling of screw machines.

Are there any notable recent case studies or examples of excellence you can share with us?

There are many cases where use of SCORG resulted in great benefits for our customers. Many of them cannot be mentioned due to confidentiality but I can mention few success stories. Howden Compressors is a screw compressor manufacturer based in Glasgow, Scotland, who were the first in the world to produce a screw compressor in 1938. They started using SCORG in 2008 and it helped them to design machines which have made a great success in the market. For example, in 2012-13 they supplied just short of 100 largest oil injected screw compressors for a gas gathering project in Australia for production of liquid natural gas (LNG). More recently, based on modelling results produced in SCORG, they designed their largest screw compressor ever. Just now they are completing the design of their new oil-free machines where SCORG was used to conceptualise the machine.

Is there anything else you would like to add?

Close collaboration of PDM Analysis Ltd and City, University of London is a great example of how fundamental research performed at university can be implemented in industry and benefit society. The Centre for Compressor Technology at City, where we originate from, has celebrated its 25th anniversary in February 2020. We are very proud that SCORG is now widely accepted as the leading solution for design of screw machines and that it has been used in almost all corners of the world. Our next target for this spring is to allow wider use of SCORG on virtual machines. With City, we will continue to support our customers and advance compression technologies of 21st century.