ASME PROCESS INDUSTRIES DIVISION

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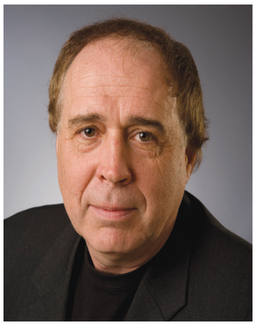
Process Industries Division (PID)

Editor: Qubo Li, Ph.D.

Winter 2012

MESSAGE FROM THE CHAIR



by Dr. Steven B. Beale, Fellow ASME and IMechE

Process Industries Division is one of the oldest divisions in the ASME; founded in 1934, it currently has 1,119 primary, 1,837 secondary, and 3,916 tertiary members, and has spun off a number of other ASME divisions over the years. It is my privilege to serve as chair of PID and my thanks go to all members of the Advisory Board, current members of the Executive Committee, Technical Committee members, and especially to ASME staff, as well as all members of the PID for their continuing support and hard work on behalf of our division. Our commitment is to foster PID activities and membership and to ensure its growth into the future. All members of the Executive and Technical Committees are, by definition, volunteers, and we are always on the lookout for new members with time, energy, or ideas, willing to make a difference to advancing PID goals and activities. Please feel free to contact me, or any of the EC members, at any time, with your thoughts and ideas, including articles for future newsletters: It is only through the active participation of the membership that we can continue to adapt and evolve into the ever changing engineering scene.

Our main activity continues to be participation in the ASME International Mechanical Engineering Congress, which this year is being held in Denver Colorado, from November 11-17. We are actively participating in two different tracks: Track 1 Energy Water Nexus, and Track 9 Advances for Process Industries. In the latter area, two of our technical committees are organizing sessions; the Compressor Technologies committee, chaired by Prof. Abraham Engeda, and the newly revamped Heat and Mass Transfer Systems (formerly Heat Exchangers) committee, under the stewardship of Dr. Hal Strumpf. In addition we have papers in Sustainable Technologies, an activity initiated by former EC chair, and member of the PID advisory board, Prof. Ahmad Fakheri. The Energy Water Nexus is an entirely new ASME activity and PID is proud to co-sponsor technical sessions related to desalination, a special session on 'blue energy' (electric power from salination differences), as well as water power, and water reuse. In addition PID personnel will be participating in a discussion sponsored by the ASME Centre for Research and Technology Development, on Water Management Best Practices.

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WOVEN WHEEL COMPRESSOR TECHNOLOGY

By Qubo Li, Ph.D.

Water Vapor as Refrigerant

Compressing water vapor as a refrigerant has been a dream for decades since water vapor is a good refrigerant from several perspectives: environmentally friendly, nontoxic and non-flammable. Besides these, as a green refrigerant, it has zero ozone depletion potential (ODP) and zero global warming potential, which means there are no risks associated with using water vapor as refrigerant in the future. Another main advantage of using water vapor as refrigerant is that it is a natural substance: it can be obtained for free and is readily available. Dirty water is easily cleansed and clean water is disposable. Recently, researchers also found that compressing water vapor as refrigerant in a multiple stage compressor offers about 20-30% potential energy saving over conventional refrigerants [1].

Technological Challenges to Compress Water Vapor

Since water vapor provides such high potential over other refrigerants, why do most industrial refrigeration products use R134a instead of water vapor? European countries such as Germany and Denmark have already developed their own water chillers [2]. However, due to technological challenges, such as manufacturing cost to composite impellers as well as specific thermodynamic characteristics of compressing water vapor under vacuum, further development of water chillers have been impeded [3, 4]. Comparing with other refrigerants, water vapor needs relatively high compression ratio as well as low compression pressure. In this case, turbo impellers, especially axial blades, are the choice to achieve such requirements. However, Brandon [4] noticed that high manufacturing cost of multi-stage axial impellers was the main bottleneck and in his study concluded that without substantial and successful efforts to develop low cost high capacity compressors, water based vapor compression refrigeration systems will not be economically attractive comparing with conventional ones. Therefore, how to overcome these technological challenges becomes critical.

Novel Woven Composite Wheel

Recently a novel composite impeller has been designed and manufactured from a technology similar to filament winding, as shown in Fig.1. Filament winding technology is widely applied to manufacture composites since the manufacturing cost can be greatly reduced, automatic manufacturing becomes possible and this saves a lot of labor cost. In this case, by taking advantage of filament winding technology, manufacturing of composite impeller results in extremely low cost production.

Figure 1. Complete layer for endless fiber winding (left) Computer model wound with single endless fibers (center)

In addition, composite mechanical properties to this impeller are also qualified for high speed rotating requirements [5] according to this author's study. It is thus claimed by the authors [5, 6] that manufacturing challenges of compressing water vapor as refrigerant can be solved.

Impeller's Specific Characteristics

Besides competitive low cost compared with conventional impellers, there are several characteristics that make this impeller special: extremely low mass rotor construction. The impeller is made of composite material and thus in many high speed rotating applications, there are no limitations such as high centrifugal stress, the difficulty and cost of containment in the event of a rotor failure, and the significant risk to people in the area. The camber line at the shroud is a circular arc with one dimensional optimized blade angle and the angles of the blade between shroud and inner hub are determined from the pattern, which can be analytically calculated. Special characteristics of this impeller blade have the potential to create serious boundary layer separation problems, considered from the perspective of subsonic fluid mechanics. As previous blade geometry investigation indicates, since this novel impeller blade differs from conventional airfoil, characteristics of this novel impeller blade indicate that only on some specific radius can the expected incidence angle be realized. Because of this, fluid easily separates from the blade during rotation. However, these novel impeller patterns were found to guide and benefit the fluid flow [7].

Multi-Stage Turbo Chillers

Based on the novel impeller, researchers at Michigan State University also advanced specific multi-stage turbo chillers as shown in Fig. 2 [8]. From the evaporator, chilled water at 6ºC is supplied to the air handler cooling coil and returns at 12ºC to the evaporator where it is expanded. As a result of the low pressure in the evaporator, the water evaporates into vapor. The water vapor is compressed by a multistage turbo compressor to the condenser pressure. A compression cycle with seven stages is shown in Fig. 3. Between stages, cooling water from the expansion valve's low pressure side flows into a liquid water extraction controller; according to different pressure requirements between stages, this controller is able to spray liquid water at different pressures and the controller is especially developed for this purpose. In the condenser, the water vapor condenses either by direct mixing with cooling water or by indirect cooling. The condenser cooling water is continuously circulated through a cooling tower for heat rejection to the ambient.

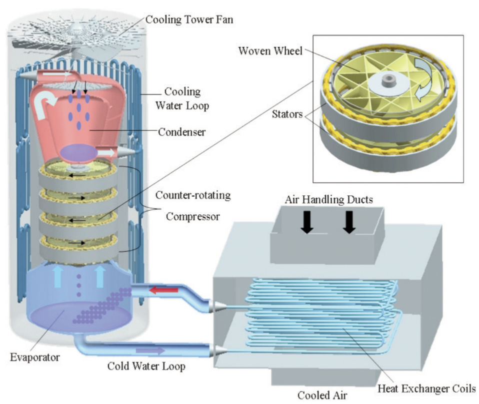

Figure 2. Turbo chiller employing R718 refrigeration cycle

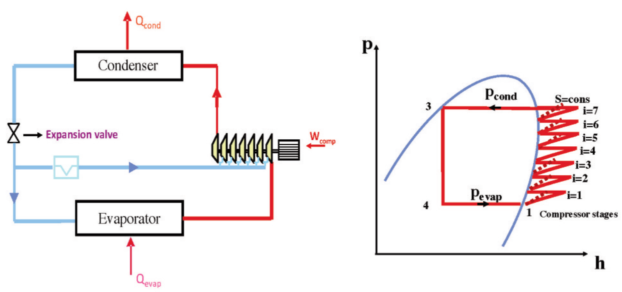

Figure 3. R 718 Vapor compression cycle with seven stage compression

Impeller Aerodynamic Performance

The filament winding technology is capable of weaving several impeller patterns. In order to understand each pattern's performance, computational fluid dynamics (CFD) is used to compare the basic patterns. According to the findings [9], the authors found that compared with the traditional impeller pattern, the specific pattern shown in Fig. 1 has better aerodynamic performance because of the existence of small triangle shapes. To some extent it reduced secondary flow and guided a better flow at the design point.

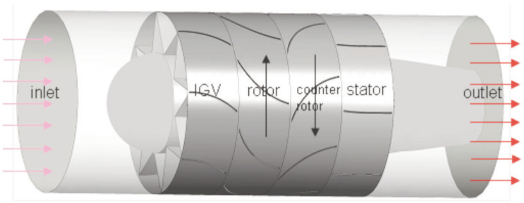

Figure 4. Three-dimensional setup of counter rotating wheels.

A further investigation [10] in a counter rotating stage shows that highest pressure ratio reaches more than 1.3 with an isentropic efficiency as high as 70%. This means that with the designed seven counter rotating stages, compressing water vapor as refrigerant becomes promising. The main advantages of this technology lies in the fact that the manufacturing cost of the composite impeller will not be a problem; possible other applications would extend to water turbine and other renewable related turbo products.

1. *Demiss A. Amibe, Q.L., Norbert Mueller. Multi stage variable speed turbo compressor for enhancing seasonal energy efficiency ratio of air conditioners using R718 as refrigerant. in ASME Turbo Expo 2010. 2010. Glasgow, UK.*
2. *Albring P., A.R., Burandt B., Norbert Mueller, Grundlagenuntersuchungen energierationeller Kreisprozesse mit Wasser als Kältemittel und Erprobung einer Versuchs-Großanlage (Fundamental investigations of energy efficient cycles with water as a refrigerant and test of a full-size test unit), in Abschlußbericht (final report) zum BMBF-Forschungsvorhaben 0326921A. 1999.*
3. *Wight, S.E., Yoshinaka, Tsukasa, Le Drew, Brenda A., D'Orsi, Nicholas C., The Efficiency Limits of Water Vapor Compressors, in ARTI-21CR/605-10010-01. 2000, The Air-Conditioning, Heating and Refrigeration Institute (AHRI).*
4. *Brandon F. Lachner Jr., G.F.N., Douglas T. Reindl, The commercial feasibility of the use of water vapor as a refrigerant. International Journal of Refrigeration, 2007. 30(4): p. 699-708.*
5. *Qubo Li, R.G., Norbert Mueller, Using Filament Winding Approach to Manufacture Composite Impellers for Water Chiller. Journal of Advanced Materials, 2010. 42(4): p. 45-55.*

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From the the chair

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In heat and mass transfer systems, there will be sessions on boilers, cooling towers, thermal and stress issues in heat exchangers, and also a panel session entitled "Game changing Technologies for Next Generation Heat/Mass Exchangers" which is made up of a series of short informal discussion papers. In compressor technology, papers on improving efficiency and innovative designs will be given, along with practical examples of computational fluid dynamics (CFD) for analysis and design of industrial compressors. Other topics considered will be industrial and pipeline compressor control, stall and surge, aerodynamic forces resulting in vibration and noise, and blade design. For sustainable technologies; renewable energy from biomass, emissions reduction, waste management, and energy conservation and heat recovery are among the subjects for presentation. All-in-all this year's Congress looks like it will be a pretty interesting event. We invite and encourage all members of PID to attend our technical and panel sessions at IMECE 2011 in Denver.

PID is committed to enhancing the technical knowledge of our members, providing conferences, workshops, seminars, tutorials, and short courses, for sharing of ideas and expertise, and encouraging research and technology for emerging technical areas in process industries. PID is part of the Manufacturing Technology Group, which in addition to Process Division includes Manufacturing, Materials Handling and Plant engineering and Maintenance. I invite you to visit our web site for further information, **http://divisions.asme.org/pid/**

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Woven Wheel Compressor Technology

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6. *Qubo Li, J.P., Norbert Müller, Thermodynamic potential of using a counter rotating novel axial impeller to compress water vapor as refrigerant International Journal of Refrigeration, 2011. Vol 34, Issue 5, pp1286-1295.*
7. *Qubo Li, J.P., Norbert Müller, Aerodynamic design and CFD analysis of a novel axial compressor, in 40th AIAA Fluid Dynamics Conference and Exhibit. 2010: Chicago.*
8. *Qubo Li, J.P., Norbert Müller, Simulation of fatigue failure in composite axial compressor blades. Materials and Design, 2011. Vol 32, pp 2058-2065.*
9. *Qubo Li, J.P., Norbert Müller, Numerical simulation of novel axial impeller patterns to compress water vapor as refrigerant. Energy, 2011. 36: p. 2773-2781.*
10. *Qubo Li, J.P., Norbert Müller, Design of a novel axial impeller as a part of counter-rotating axial compressor to compress water vapor as refrigerant. Applied Energy, 2011. 88: p. 3156-3168.*

ENERGY IN OIL SAND

By Jeya Kumar

Why Oil?

One main reason is that almost everything we use in our modern living is made, at least in part, from petrochemicals -- materials derived from petroleum!! If all the petroleum, and the products that come from it, were to suddenly disappear RIGHT NOW -- you would be sitting in your chair nearly naked, and the chair would not have much of a cushion. Your pens, combs, radio, TV, calculators, most of your computer, toys, shoes, sporting equipment, most of your car, telephone, floor tiles, lipstick, soap, and food packages would all disappear as well. That is only a small sampling!!

Crude oil has become the world's most important source of energy since the mid-1950s. It is used to make gasoline, diesel fuel, home heating oil, jet fuel, chemicals, and other products such as plastics, fertilizers and pesticides. It is by far the No. 1 energy source, supplying 38.7 percent of the world's demand. (Refer Fig. 1 World Marketed Energy Consumption). Oil meets transportation's unique requirements whereas other sources of energy do not. These requirements are portability, energy density, safety and ease of handling.

Figure 1. World Marketed Energy Consumption, 1990-2035 Courtesy: Independent Statistics & Analysis from US Energy Information Administration- International Energy Outlook 2011.

Formation of Oil Sand

It is believed that the oil sands were formed many millions of years ago when a warm tropical sea covered Alberta. The oil was formed in southern Alberta when tiny marine creatures died and fell to the bottom of the sea. Through pressure, heat and time, their tiny bodies were squished into an ooze which today, we call petroleum (rock oil). In northern Alberta, many rivers flowed away from the sea and deposited sand and sediment. When the Rocky Mountains formed, it put pressure on the land, and the oil, being a liquid, was squeezed northward and seeped into the sand, forming the Athabasca oil sands.

Oil sands are a natural mixture of sand, water, clay and bitumen. At 10 degrees F, bitumen is as hard as a hockey puck. Figure 2. Western Canada Sedimentary Basin Cross Section.

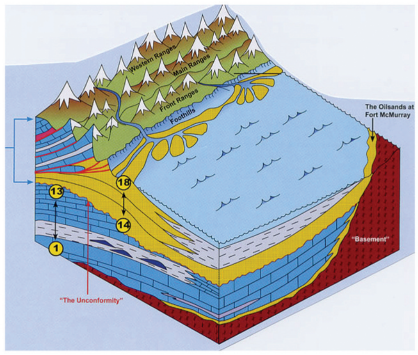

Figure 2. Western Canada Sedimentary Basin Cross Section – courtesy – Ayrton Exploration Consulting Ltd.

Canadian Oil Sand

All sources of energy, developed responsibly, will be needed to meet growth in global demand. Today, half of Canada's crude oil production is from the oil sands. Oil sands development is expected to contribute over $1,7 trillion dollars (170 followed by 10 zeroes!!) to the Canadian economy over the next 25 years. The oil sand currently affects the jobs of 115000 people across Canada.

Canada has the second largest oil reserves in the world – next to Saudi Arabia. Proven reserves are those reserves claimed to have a reasonable certainty (normally at least 90% confidence) of being recoverable under existing economic and political conditions, with existing technology.

Alberta has leased over 26,000 square kilometers of boreal forest for oil sands development, an area equal to the state of Florida. Canada's province of Alberta contains four major oil sand deposits. They are located at Fort McMurray (Athabasca), Cold Lake, Peace River, and Wabasca. There is enough heavy oil in the deposits of Northern Alberta to pave a four lane super highway the entire 250,000 miles (400,000 km) to the moon, with ample to spare for approaches and exit ramps.

The Athabasca deposit covers an area of 16,350 square miles and contains about 114 billion cubic metres of bitumen (a mix of oil and sand). This equals 862 billion barrels of bitumen, of which 33 billion barrels are recoverable by surface mining. The

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deposit is covered by a thickness of overburden consisting of muskeg, glacial tills, sandstones and shales. The oil sand is mineable if the overburden thickness is less than 250 feet (75 metres). Alberta supplies 1.4 million barrels of oil per day to the U.S.

Recovery

Two tons of oil sand are needed to produce one barrel of oil. Oil sands are recovered using two main methods: mining and drilling (in situ). 20% of the oil reserves are close enough to the surface to be mined using large shovels and trucks. 80% of oil sand reserves are recovered using steam, combustion or other sources of heat into the reservoir to warm the bitumen so that it can be pumped out. Out of 175 billions barrels of oil that can be recovered economically in Canada, 170 billion barrels are located in the oil sands.

Mining shovels dig into the oil sand and load it onto huge trucks. The trucks carry the oil sand to crushers. The oil sand is broken up in crushers and coarse material is removed. Hot water is added to the oil sands. The resulting slurry is fed via hydro-transport to the extraction plant. The mixture of oil, sand, and water goes to a primary separation vessel. Thick bitumen froth forms at the top of the vessel and is skimmed off. The bottom clay is sent to the mined out areas and the water at the bottom is sent to a tailing pond. Thick bitumen is sent to upgrading for processing. Upgrading converts bitumen into a lighter, less dense product, using heat to crack larger molecules into smaller fragments.

After the oil sands have been mined, oil is separated from the sand and sent for further processing. Tailings are the left over mixture of water, sand, clay and residual oil. Tailing ponds are large engineered dam and dyke systems. The existing area of tailing ponds is 180 sq km. The total mining footprint covers an area about 0.5% the size of England and 10% of that land has already been reclaimed. There are currently more than 170 square kilometres of tailing ponds in Alberta's oil sands regions requiring reclamation.

Monster Equipment

The use of bucketwheels and draglines for oil sand mining was phased out in the year 2000, in favour of the truck and shovel method and moving oil sand into the refinery by hydro-transport. This six-wheel monster truck (Fig. 3) weighs 260 tons and carries a load of 350 tons in its box that is 20 metres long x 7.5 metres wide. The box can be raised or lowered in about a half-minute and it can hold a Greyhound bus and two pick-up trucks! The tires weigh 4 tons and are 11 feet in diameter. Compare the size of the man to the truck! Weighing more than two 747 air-planes, these trucks are somewhat like driving a house!

Figure 3 Monster Truck – costing approx. $5 million!

Upgrading

Roughly, two tones of oil sand is needed to produce one barrel of oil. Upgrading involves using temperature, pressure and catalysts to break up the complex hydrocarbon chains and reorganizing them. Bitumen is rich in carbon, but poor in hydrogen and often contains other undesirable elements like sulphur and nitrogen. The upgrade process removes carbon and adds hydrogen, replacing unwanted sulphur and nitrogen.

In the upgrading process, bitumen is chemically and physically changed into lighter products that can be easily refined. The two upgrading methods that are currently used are coking and hydrotreating. During coking, bitumen is heated to 500°C to break its complex hydrocarbon molecule into solid carbon called coke (which is very similar to coal) and gas vapours. The gases are funneled into a fractionation tower to be condensed and distilled into liquid gas oils that form synthetic crude oil. In the hydrotreating process, hydrogen is added to the bitumen to bond with the carbon in the molecule, creating more products while also removing impurities.

Upgrading is done in four main processes: coking removes carbon and breaks the large, complex hydrocarbon chains into smaller pieces; distillation sorts the mixtures of hydrocarbon molecules into like-sized components; catalytic conversion help transform hydrocarbon chains into more valuable forms; and hydro-treating removes sulphur and nitrogen, replacing them with hydrogen.

The resulting project is synthetic crude oil, which is then shipped via underground pipelines to refineries across North America; to be further refined into jet fuel, gasoline and other petroleum products.

Energy in Oil Sand

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Greenhouse Gasses

Canada, with 0.5% of the world's population, produces 2% of global greenhouse gas emissions. Oil sands account for 5% of Canada's GHG emissions and 0.1% of global GHG emissions.

37.2 megatonnes is equivalent to 2% of 2008 emissions from the US coal fired power generation sector. That is the same amount of GHG emissions in 2008 from oil sands!

Oil sands crude has similar CO_2 emissions to other heavy oils. With $2 billion earmarked to initiate the carbon capture and storage projects, the five projects are expected to reduce GHG emission by 5 million tonnes annually beginning 2015.

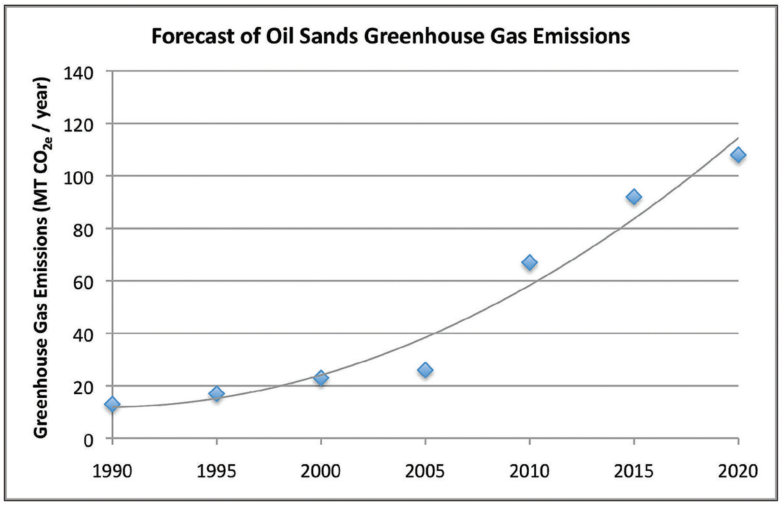

Figure 4. Green House Gas Emission from Oilsands – source- Canada's Energy and GHG Emissions Projections Reference Case March 2008.

Prospect

Economic growth, reduction of emissions, finding alternate sources of energy all have conflicting interest in decision-making. Albert Eintein, noted as well. "We cannot solve these problems with the same kind of thinking, that created them, in the first place." Churchill said it a little differently, "The only thing, that mankind learns from history, is that he does not learn anything." Oil products are more and more in competition with alternative sources, mainly coal and natural gas, both cheaper sources. Production will also face an increasingly complex situation.

By 2020, it is predicted that oil sands production could reach three million barrels per day, and by 2030, possibly even five million barrels, making Alberta a global energy leader. For more information, follow the link and select the topics of interest to you. **http://oilsands.infomine.com/publications/**

Acknowledgement:

Canadian association of petroleum products publications.

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