Green Technology Improvements in Solenoid Valves

Whitepaper

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Green products are items that are considered environmentally friendly. This typically involves energy efficiency, renewable energy harnessing, recycling as well as health concerns. To be environmentally friendly, the long and short term environmental impact must be considered. A comprehensive look at a product from its inception to post mortem must therefore be taken.

Solenoid valves are used in a wide variety of applications leading to millions of them being powered around the world. Many of these valves are used to help harness renewable energy. With so many solenoid valves in operation drawing power from electrical grids coupled with the fact that many are used in the renewable energy field, it is only logical to look at the latest Green improvements in solenoid valves. Let us look at the latest advancements in the design and application, the production, and the end of life impact of solenoid valves with respect to the environment.

With the pollution and greenhouse gas production that comes with fossil fuel energy, there is a movement to make energy consuming devices more efficient. With solenoid valves, traditional, non-intermittent duty units would draw between 3.5 watts to 20 watts, depending upon the physical size of the unit. The power draw limitation was typically based on the thermal limitations of the unit due to self-heating. New, lower power options typically draw between 0.5 and 2.5 watts. Usually, a drop in power levels would also mean a drop in ratings and while this can still be the case, much of the performance losses can be gained back with optimization of the solenoid's magnetic circuit.

Low Power Solenoid Valves

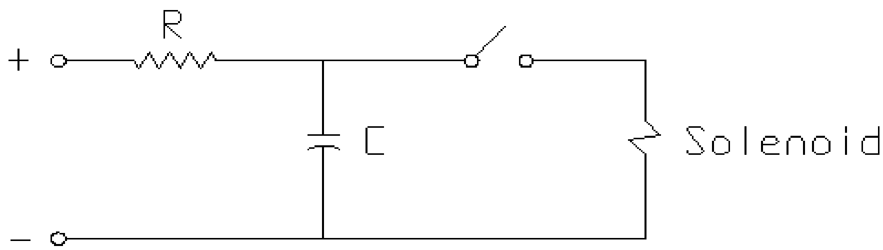
Due to the very difficult math required to just approximately model the magnetic circuit of a solenoid, optimization of a solenoid required iterative lab test process. This trial an error process required the physical machining of prototypes and lab testing. A hypothesis would then be formed and to test it would require another prototype or modification of the existing prototype and then a retest. This process is very time consuming, which limits the amount of iterations possible. Unfortunately there are quite a few variables associated with solenoid magnetics so optimization of all of them was not possible. Fortunately with computers and finite element analysis (FEA), most of this iterative process can take place through computer modeling. Computer modeling is a much more efficient process and has led to a more effective optimization of solenoid magnetic circuits. Coupled with some of the latest magnetic materials with high magnetic permeability, solenoids have become much more efficient. Unfortunately efficient magnetic circuits typically mean tightly coupled. With very tightly coupled magnetic circuits, solenoid valves become more susceptible to having drop out problems (valve shifting states from on to off) due to residual magnetism of the magnetic materials. With the valve shifted into the energized state, the magnetic circuit becomes very tightly coupled. With the circuit tightly coupled, any residual magnetism left in the materials after the coil is de-energized can lead to the pole piece (plunger) stuck in the energized position. For this reason, having the coercive force (Hc) and residual magnetism (Br) (metrics that indicate the level of hysteresis of material) become as important as the permeability. While the proper design of low power valves can be daunting, it is now possible.

No Power Solenoid Valves or Magnetic Latching Solenoid Valves

While low power valves are a nice way to minimize energy usage in a system, the best would be no power. While this may seem inconceivable at first, there are bi-stable valves that require no power to stay shifted in either position. These are latching valves. While a very short pulse of energy is required to change states of a valve, there is no power required to keep the valve in the shifted state. Due to the inherent hysteresis in solenoids (ie. It takes more energy to shift the valve from the de-energized state to the energized state.) if a permanent magnet, or even magnetically hard material (ie. high Br and Hc) are used, a valve can stay in the energized position with no additional magnetic force coming from the coil. To achieve this bi-stable latching function, it is typical to use a permanent magnet in the magnetic circuit. The magnet has a north and south pole so the magnetic flux created by the magnet is either added to the flux generated by the coil or it will buck the flux of the coil. When in the de-energized state (the position that has the magnetic circuit in its less efficient state) it will take both the current in the coil plus the magnet to shift to the energized state. Once there, the magnetic circuit is now more tightly coupled and requires only the force generated by the permanent magnet to stay in that position. To de-energize, the coil can be reversed and allowed to nullify the force generated by the magnet, allowing the return spring to drop it into a de-energized state. Again, the benefit of this design is the lack of outside energy needed to keep the valve in state.

Peak/Hold Circuitry Solenoid Valves

With regards to low power requirements for valves, there is a third alternative aside from low power and latching. The use of peak/hold circuitry can allow the use of full power valves and thus not compromise any ratings, but after the valve is shifted to its energized position, the power fed to the coil can be folded back, thus saving energy. Again, this scenario takes advantage of the hysteresis in the solenoid. While this concept is not new, it also has evolved. Historically, this type of circuit involved a storage capacitor and a bleed down resistor.



With the switch open, the capacitor (C) would charge through the resistor to full input voltage. On switch closure, the stored energy in the capacitor would allow the solenoid to shift states and the holding current would run through the resistor (R). The total impedance would be the resistance of R plus the resistance of the solenoid, thus dropping the total power draw. There are three drawbacks from this approach. First, the capacitor can be quite large to store enough energy to shift the solenoid. Second, there has to be some waiting time to charge the capacitor after the switch is opened before it can close again. And lastly, the power drop through R is just wasted in heat. Fortunately, there are newer approaches that use solid state circuitry that do not have these drawbacks. These circuits typically drive full voltage to the solenoid for a short time to allow it to open and then it goes into a switching mode, chopping the voltage by quickly turning on and off at a rate much faster than a solenoid can respond. The on time vs. off time percentage can then be tailored to dial in the required holding energy.

Renewable Energy

Sun

The other aspect of fossil fuel energy reduction that solenoid valves have a significant role in is renewable energy. Many techniques that are used to harvest renewable energy must rely on solenoid valves to make them viable and efficient. The most popular renewable energy source comes from our sun and there are three primary ways to convert solar energy to a useable source such as electricity. These include photovoltaic cells, steam generation and solar powered Stirling cycle engines. Photovoltaic cells convert solar energy straight to electrical energy. These cells are typically built into panels that face the sun. Solar steam generators use parabolic trough shaped mirror panels that focus solar energy to a plumbing system that contains water. The energy heats the water into steam which is then used to run a turbine connected to an electrical generator. With both photovoltaics and solar steam generators, for the systems to be most effective, the panels or mirrors must be facing the sun. As the sun moves across the sky, the panels need to follow. Unfortunately these devices can be quite large and hence weight can be significant. For these large systems, solar tracking devices often will use hydraulic power to move the panels toward the sun. Solenoid valves would then play a role in controlling the hydraulics.

Solar Powered Stirling Cycle Engines

The Stirling engine approach to converting solar energy to electric energy poses some significant challenges for solenoid valves. The most efficient Stirling engines run on high pressure hydrogen. Solar energy is focused by a large parabolic array of mirrors. The focused energy is used to heat the hydrogen. The hydrogen is also cooled through heat exchangers. Pumping action of a piston can be achieved through this heating and cooling of the hydrogen. This pumping force is then applied to a crankshaft which can apply the rotational energy to spin an electrical generator. Higher temperature differentials between the heated and cooled hydrogen yield higher efficiencies of the system. It is therefore important to keep the hot side of the system as hot as possible but within the safe limits of the materials. Since the solar energy is not constant throughout the day, one way to maintain the highest possible hydrogen temperature is to adjust the system pressure up and down with relation to the amount of solar energy being absorbed. Solenoid valves designed to work with high pressure hydrogen are a perfect fit for this function in an automatic controlled system. The other challenge in the Stirling engine/generator system is speed governing. The Stirling engine/generator set is typically connected directly to the electrical grid. The load that this imparts on the generator is used to govern the speed (RPM) of the Stirling engine. In the event the system becomes uncoupled from the electrical grid, the load is instantly released from the generator which allows the engine to run away (over speed). To control this, the gas management system (consisting of a manifold of solenoid valves) must respond by pneumatically short circuiting both sides of the double acting pistons. This results in a near net zero force acting on the pistons thus keeping the system within RPM limits or ultimately allowing the system to stall to a stop. The particular challenges for the solenoids are to create a short circuit with enough high pressure flow potential to control the speed and to do it with a fail-safe two way normally open valve configuration.

Wind & Hydro Power

Beyond solar, the other popular choices for harnessing renewable energy are though wind power and hydro power. Once again, hydraulic systems are typically used to control both of these technologies. With wind, forces can be quite variable. To optimize and control the speed and power of the system, hydraulic systems can be used to adjust the pitch angle of the turbine blades. Hydraulics can also be used to adjust the yaw angle of the system to keep the turbines perpendicular to the incoming wind direction, thus maximizing wind energy conversion. Like wind energy, many hydroelectric power systems use hydraulic controls to govern the system by controlling water flow to the turbine though the control of wicket gates. Hydraulics can also control water levels in these systems by operating automated spillway gates. Once again, these hydraulic systems rely on solenoid valves to operate and control flow.

Manufacturing

Highly efficient, low power valves as well as valves used in renewable energy systems are a large part of the Green story. However, for a complete cradle to grave picture, the manufacturing of the valves as well as the end of life impact of these valves must be considered. With respect to manufacturing, there are four areas that should be reviewed from a Green perspective. These include waste stream management, industrial recycling, environmental risk mitigation measures and energy usage.

Waste Stream Management

In a manufacturing plant, there can be several different types of waste streams. These can be from rinse water effluent from passivation systems, pickling lines, tumbling systems and plating lines to name a few. These types of systems can also produce hazardous solid waste, typically containing heavy metals. Where these types of processes are performed, continuous monitoring and control must be present or risk of polluting the land and water systems can result. In the US, the federal and local state governments have strict requirements with regard to these systems. Permits with the federal government (EPA) as well as the state governments (DEEP in Connecticut) must be in place. Periodic government audits also occur to verify compliance that the processes are under control and waste stream limits are never breached. Handling of other types of less hazardous waste streams also require documented processes. These include used organic oil absorbents, used rags, spent aerosol cans, used oil, used solvents, and used water soluble cutting lubricants to name a few.

Industrial Recycling

Recycling of products reduces the environmental impact in several ways. There are systems in place to restore spent oils and water soluble cutting fluids. Using these systems reduces the usage and thus the energy required to produce and distribute these commodity items. Other types of recyclable items fall into a category that allow the reuse of items after reprocessing outside the manufacturing facility fall into this category are rags, uniforms, cardboard and paper. Other items fall into a universal waste recycling plan for non-manifested, non-hazardous and non-permitted controlled items such as used light bulbs, light ballasts, batteries etc. By controlling these items, the likelihood of putting potentially toxic product into landfills and having these toxins leach into ground water is eliminated.

Environmental Risk Mitigation

Environmental hazard risk mitigation for manufacturing is also regulated in the United States at the Federal and State levels. Items that require controlled procedures with monitoring and reporting are solvents, organic toxins, spill prevention plans as well as inventory (with limits) on hazardous and some non-hazardous chemicals. While these items keep the likelihood of polluting the local environment to a minimum, actively monitoring the local storm water for verification is also a regulated requirement.

While strict environmental controls are in place to keep the environments safe, another less apparent facet of manufacturing that needs consideration with respect to being Green is the amount of product and energy required to produce the products. Deploying Lean Manufacturing techniques is a perfect fit for becoming a Greener manufacturer. Lean is the relentless pursuit of the elimination of waste in manufacturing hence, through these techniques, more can be achieved with less. Ultimately this leads to less energy, less material which means a smaller carbon footprint to produce the same products.

Finally, the end of life of a product must be considered. Recycling of materials is a great way to minimize environmental impacts. It keeps waste out of landfills by turning certain materials into resources that can be turned into new raw materials. Recycled materials typically need only a fraction of the energy to produce vs. materials produced from basic raw products. While recycling is a great way to be green, much of the products produced still make their way into landfills. Consequently, it is important to consider the materials used in the product as these will decompose and leach out substances into the landfills. In 2006 the European Union adopted RoHS (Restriction of Hazardous Substance Directive) that restrict the use of hazardous materials, particularly lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ether. This directive has since become widely accepted around the world and has since lead to the adjustment of materials used in finished products.

Summary

When considering advancements in Green Technology, understanding the environmental impact of the product from its design inception, its production, its use and finally its end of life must be understood. With the use of solenoid valves so widespread, are good models for understanding the Green implications of a product for its entire life cycle.

ABOUT PETERPAUL

Peter Paul Electronics, founded in 1947, is a premier manufacturer of solenoid valves including high flow, explosion proof, high pressure, plastic, safety and mini valves. PeterPaul configures possibilities from solenoid valves that operate with power as low as 1/2 watt to pressure as high as 5000 psi. PeterPaul is located in New Britain, Connecticut and Fajardo, Puerto Rico. High quality design, innovative research and product development set PeterPaul apart from other manufactures. Continuous improvement is in the fabric of the company on all levels with people having years of experience, dedication and pride.

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