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HYDRAULIC MOTION VS. ELECTRIC MOTION

AN HONEST COMPARISON FOR THE RECORD

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FLIGHT SIMULATOR MOTION BASES

Servo Kinetics, Inc. has been a major player in the hydraulic industry aftermarket since its inception in 1978, with its primary focus on the remanufacturing of individual hydraulic components, such as pumps, fluid motors, cylinders and various other hydraulic devices. While component remanufacturing is the largest segment of our operations, systems design and operation has always been part of our service base since our inception. For Servo Kinetics, the area of flight simulation operation and maintenance has been the primary source of our systems work. It is the hydraulic motion platforms used on ground based flight simulators that has provided systems work that fits well within the capacity of our experience and workforce.

Servo Kinetics, over the past 35 years has garnered a sterling reputation from both the commercial and military simulator motion platform sectors as the "go to" firm that provides the highest quality, cogent, test documentation and on time delivery at an acceptable cost. For example: over a 24 year period, Servo Kinetics has overhauled and/or upgraded NASA Houston's space shuttle simulator three (3) times.

The majority of simulator motion platforms come to us from both military and commercial operators. Through our sales calls on customers in both sectors, we are made aware of changes that are being planned in terms of new motion platforms out on bid or changes associated with adding a new simulator that may be electrically powered.

When our sales staff hears the words "electrically powered", they start to become very concerned. After all of our years of maintaining and upgrading motion platforms one might ask, "Are we biased in favor of Hydraulic Motion Platforms" ? The answer "of course we are", but not totally because we believe hydraulic is superior to electric, but rather that they are pretty much equals when flight simulation performance is considered, with neither having a major advantage over the other. The major problem for us, comes from the claims that are made about the electric simulation system being a major new advancement in the technology. This is not the case: in fact it is merely a different method of solving the same problem but with an entirely different and more complex set of technical difficulties to overcome. Thus, having its own set of generally high cost technical trade-offs (draw backs). Servo Kinetics clearly feels that the electric sales approach by electric actuator manufacturers avoids a true and accurate comparison of all aspects of the two systems. And this is primarily due to them selecting "only" the very small differences in a performance based comparison and not a total evaluation of "all" operational, maintenance and repair aspects. Of course, some proponents feel "change for the sake of change" is a reason enough as if to say 70 years is enough; even though these "Hydraulic" systems have been operating two to three times longer than they were originally designed for.

A Look At The Past:

Over the past ten to fifteen years, there has been much fan fare and "salesmanship" information provided about electric motion platforms attributes. Very little, however, has been said about the advantages of classic hydraulic systems. The following is intended to expose the myths of each system and put them on an equal comparison basis. It should be noted that of the various motion platform systems available in the market place, each, may have application advantages due to the characteristic of a particular design. Hence, the following analysis and comments are intended for applications where it is necessary to "lift and hold" payloads for extended periods of time as well as accelerating and decelerating that payload while being held in such an elevated condition. Of primary concern are motion platform systems designed primarily for flight simulation and similar applications.

Promoters of electrical powered motion platform systems have repeatedly stated that electrical systems consume less electrical power. Let's see if this is true by considering the requirements of a specific example. For simplicity, let us assume an example where it is necessary to lift and hold a 20,000 lb payload for long periods of time. Note: this is a common condition for flight simulators and similar applications where accelerating and decelerating dynamics are small but large excursions of the platform are important. Such applications typically use six (6) linear actuators in a hexapod arrangement. As a matter of historic note: the LINK company started building such systems in the late 1940's, into the 50's with more than 220 units by the 60's and 70's. The following example is typical of the above referenced conditions, assuming the following typical "Flight Simulator" level conditions:

Simplified Typical Motion Platform Example:

Payload = 20,000 lbs

Acceleration Required = 1g

Max Velocity Req'd = 20 in/sec

Hydraulic Acceleration Power Required = **60 HP**

System Design HPU Size = **100 HP** (Typical Sizing)

Accumulator Size = 3-10 Gal

Motor/Pump Eff. = **85%**

Max Operating KW = **87.8 KW**

Power Rqm't (Center-No Motion)= **11.2 KW**

Electric Acceleration Power Required = **60 HP**

System Installed Motors: 6@60HP = **120 HP**

Motor Eff. = **95%**

Max Operating KW = **94.3 KW**

Power Rqmt (Center-No Motion)= **47.1 KW**

As you can see from this very simple example, the installed power requirement is 20% more for an electric motion platform system, and very importantly, consumption is greater. The most telling issue is when the motion platform is operational at mid stroke position, with no motion being commanded. In this case the hydraulic valves simply close and the HPU's swash plate throttles back allowing the HPU motor/pump to spin at a very low energy consumption rate. The electric unit, on the other hand, must continue consuming energy equal to the entire weight of the payload, and, heating up. Also, in this case the hydraulic system generates very little heat (approximately 3.2 tons of air-conditioning required to dissipate the heat generated) while the electric unit generates considerable heat (approximately 13 tons of air-conditioning required) that must be rejected. This "heat rejection" cost is almost never mentioned by those promoting electrical systems, however it is critical because in electrical systems, this heat is rejected "in the space" that the motion platform is located; typically in the "people" space. Hydraulic systems however, reject the much smaller amount of heat, typically in a remote mechanical room space. This is not a minor concern, since greater air flow and cooling are required in the "people" space that results in a more "uncomfortable" inhabited space. The bottom line is that electrical system utilized in "motion platform" applications consume significantly more energy than hydraulic systems.

Overload Capacity:

Both electric and hydraulic motion platforms are typically designed for a specific application where the payload is clearly defined. Should the payload "increase" appreciably, say by 20%, an electric system may not function adequately due to overloading. Electrical systems are highly dependent on the sizing of the electrical motors, either DC or brushless AC systems and their ability to be over-loaded. It is quite simple, electric platforms are "sized" for a much narrower band of operation; beyond that band and the platform will fault. Typically, the only solution in these cases is to order a new, larger motion platform.

A hydraulic system, on the other hand, can accommodate a much wider range of operating parameters. Typically, a properly designed hydraulic system can be "overloaded", up to 50% or more and still operate effectively. Certainly, you do not get something for nothing; if you increase the operating pressure to handle larger pay loads, then you must re-stroke the HPU so as to not over load the motor. In such a case you would give up some "dynamic performance" for the ability to handle the larger payload. Additionally, by simply replacing the HPU with a larger unit, it is possible re-obtain the performance criteria. The main point to be made here is that if all of the components are designed and sized correctly, it is possible to operate a hydraulic system far beyond its original "customer defined" specification limits. For manufacturer's of motion platforms, this is unfortunately a common problem; i.e.; the customer asks for a system to be designed for an 8,000 lb payload and ultimately puts 12,000 lbs on it. An electrical system would, in this case, need to be replaced, while a hydraulic systems wide operating latitude can allow operation with proper adjustment.

PERFORMANCE:

In terms of obtainable accelerations and velocities, assuming equal design criteria; both hydraulic and electric system are comparable. Conceptually electrical systems should have higher resolution capability since most of these systems utilize encoder, resolver or similar feedback systems. In reality, however, manufacturing tolerances coupled with design and assembly tolerances relegate the true resolution to that comparable to hydraulic systems which use both digital and analog feedback systems depending on the manufactures design. Theoretical and actual accuracy, and, resolution for electrical systems is misleading. Digital accuracy relative to computer programming and theoretical computation can be far different from the actual accuracy once machining and fabrication tolerances are taken into account. Hence, at best, hydraulic and electric systems accuracies are comparable.

A second issue that is almost never mentioned, is the problem associated with "loosing" communications and/or interruptions with the control system and its affect on the physical hardware. Where digital systems are used; typically electrical systems, loss of power or interruptions in communications result in a system that looses it orientation unless more sophisticated and complicated control logic is required. Hydraulic systems, which typically use analog feedback systems always have "one foot on the ground". The actuator extension, hence, attitude of the analog system is always available and known; it does not lose its spatial orientation. This is important for installations where frequent power outages are the norm. Loosing orientation is of major concern particularly in applications where very heavy payloads are elevated and power is lost or an E-STOP condition is initiated.

DURABILITY/RELIABILITY:

Hydraulic systems, by far, have proven to be significantly more durable. Many of the older hydraulic motion platform systems have been in operation for over sixty years with virtually all of the same equipment in place. Control and computer systems have changed and been upgraded, but the physical hardware in most instances is original. Other than servo-valves, there is essentially only one physical moving part in each actuator; the piston/rod combination. Essentially there are no other moving parts. Baring the HPU, which is typically located remotely, noise from the actuators amounts to a very low level smooth "swishing" sound. In virtually all applications, any sound emanating from the system is masked by surrounding noise levels. Developments in servo-valves over the years have made them very reliable and durable; with operational lives greater than thirty years in most instances.

Electric motion systems have been in operation for approximately ten to fifteen years. During that time, several have been replaced with hydraulic systems for many dead weight bearing applications. The number and type of components in electrical actuator designs is of major concern. The present primary designs use either lead screw, ball screw or roller screw mechanisms. All of these utilize a multitude of components to effect the rotary to linear motion. Combinations of multiple planetary rollers, a generous number of roller balls and wearing lead screws comprise the design features for the various mechanisms. All of these need proper and typically generous amounts of lubrication. Also, at high speeds the roller screw and ball screw designs result in significant noise emanating from the number of loaded moving parts, unless, significant measures are taken to dampen the inherent noise. Component wear is of major concern. The combination of multiple small heavily loaded mechanical parts is a recipe for metal-to-metal contact and wear. These designs, although clever, are not "simple" in their approach to converting rotary motion to linear translation.

INSTALLATION:

Electrical systems require high voltages to be brought to the motion platform system actuators, within the personnel space. Special precautions need to be taken to make sure such systems are safe and meet national and code requirements. Hydraulic systems, however, only require the high voltage service to be brought to the remote HPU location only. It is common for the hydraulic HPU to be located in a remote location under tight control. Hence, only low control voltages are required at the motion platform directly.

Hydraulic systems require pressurized hoses run to each of the actuators under servo-valve control. Typically system pressures between 1000 psig and 1500 psig are used. These pressures are easily and safely handled by two-wire-braid hoses commonly rated for pressures in excess of 3000psig. Leaks are virtually a thing of the past with modern SAE' O-ring, JIC and other fitting configurations. Similarly, hydraulic oils can be replaced with "food grade" mineral oils in situations where required. The depiction of modern high performance hydraulic systems being comparable to that used in commercial and industrial equipment is misleading. Modern hydraulic systems do not have the leaking and rupture problems associated with low cost implement equipment.

SIMPLICITY/COMPLEXITY:

Hydraulic systems are quite simple: actuators, servo-valves, controller and computer. Hydraulic actuators are designed to absorb the total system energy, in case of a "worse case" run away conditions. This is accomplished via the use of built-in cushions at either end of the actuator stroke. This very simple cylinder design feature is built into the cylinder to protect against all control, electrical and hydraulic failures. Essentially, when any condition of failure occurs, i.e.; computer, controller, electrical, servo-valve and even operator error, results in failure; the cushions built into the cylinders will protect both the motion platform and the payload from damage.

Electrical systems, on the other hand, typically rely on a combination of "switches" and control logic to protect the system. Many electrical systems rely on a "braking" system to violently stop the motion. Although these can be effective in their implementation, programming and additional complexity results in a much higher installed cost and potential for system failure that can result in damage to either the motion platform or payload. It should be noted that if all of these backup electrical systems fail, the actuator will simply slam into one of the hard stops with instantaneous lock-up of the actuator. This is typically a binding jam that requires mechanical means to unlock unless more complicated systems and equipment are added to limit the deceleration to reasonable limits.

MAINTENANCE:

Hydraulic systems typically require maintenance approximately every 1000 hours of operation. This usually amounts to checking the HPU filter, lubrication (depending on the manufacturer) and general clean up and verifying performance responses. These "low tech" system checks are quite easy to maintain with standard maintenance techniques and personnel. Such systems have been in operation for many years with minimal maintenance.

Electric systems, on the other hand, typically require lubrication approximately every 80 hours of operation, along with checking of power wiring and a multitude of limit switches, control logic verification and encoder/resolver operational checks. Their reliability is predicated on the proper functioning of a combination of components arranged in a "series" arrangement. Any one of the monitored components will result in the system being halted, hence increasing down time and its associated expense.

OPERATING NOISE:

Hydraulic actuators utilized in the equipment space are extremely quiet with sound levels under 50dbA. Of significant importance is the issue of hydraulic system noise associated with the HPU. This is typically addressed by locating it remotely from the motion platform. This is advantageous for two main reasons: Reduced noise, and, controlled and reduced heat rejection.

Electric motion platform systems can be noisy due to the many small moving parts in the actuators as the result of their particular design. There is a significant "rushing" sound that is very distinct and may or may not interfere with the programmed content on the moving deck. This can be of particularly concern in "flight simulation" applications.

OIL REQUIREMENTS:

Hydraulic units can either use standard hydraulic oil, or food grade oils when necessary. Note: food grade oil has been used in food processing applications for nearly one hundred years with no adverse effects. In fact, food grade oil, if boiled to kill any bacteria, can be consumed with no adverse effects (not recommended) other than lubrication of your intestinal track. Hence, the “fear” of oil and leaks are no longer of major concern.

Unfortunately, and in most cases erroneously, the promoters of electrical systems point to oil as one of the major reason for selecting electrical systems due to some questionable set of theoretical environmental constraints. This is a misconception of the systems involved. Motion platforms and their hydraulic components are “NOT” to be equated with a typical industrial or farming hydraulic applications. Motion platform hydraulics employ only the highest quality components, fittings, materials, oils and control systems. The cost of an industrial hydraulic cylinder, for example; might be $60.00; a comparable servo -system actuator would be $1000.00 for the same payload capability. Similarly, the fittings and connections for servo quality systems commonly utilize JIC and SAE connections which virtually protect against leakage. Industrial and farming systems commonly use “pipe” fitting connections, which are at best poor. Pipe fittings are poor, not only for hydraulic systems but for “home” applications as well. Hydraulic systems, when designed and installed properly do not leak and are not of major concern, and, can be installed in a very compact package.

SAFETY:

Depending on the design concept, hydraulic systems are inherently safe, particularly when E-Stop conditions are encountered. Hydraulic systems can be very easily designed to either lock-in-place, or, soft settle during E-Stop conditions and power outages. This is accomplished by either stopping the command to the servo-valve, or providing either a control voltage to the servo-valve or using a separate abort valve. Different manufactures use differing schemes.

Electrical systems, on the other hand, are typically designed to “lock” in position when an E-Stop command is initiated. Also via use of more expensive and complex battery backup schemes for providing power during E-Stop, “slow settle” requirements can be achieved. All of this is at additional cost and complexity of the control system logic. These systems are “critical” to electrical systems which if not addressed properly for all potential failure cases, can result in an immediate retraction collapse of the actuators due to the higher efficiency mechanical designs.

CLOSURE:

The intent of this analysis has been to show that there are several advantages of hydraulic systems in lieu of electrical systems. Advantages range from simplicity, durability and versatility to safety. The author’s twenty five years of experience in building both hydraulic and electric motion platforms is the culmination obtained, which is the basis of this comparison and analysis.

It is critically important that when considering the purchase of a custom motion platform, to listen very carefully to what is being offered by all manufacturers; consider the application in detail and do not dismiss hydraulic systems out-of-hand because of misleading statements. Ask the offering party to demonstrate each system for your review. Only then, can the advantages of each and every system be evaluated.

George Kokalis and Servo Kinetics, are extremely honored to have co-authored this article with;

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All technical and scientific conclusions were provided by Dr. Sarnicola

Servo Kinetics, complete simulator services are accessible at www.servokinetics.com