FES/BarDyne Technology Transfer Publication

#5

Dr. Ing T. Hong, P.E.
President
BarDyne, Inc.
Stillwater, Oklahoma U.S.A.

Ming-Yuan Tsuei
China Steel Co.
Taipei, Taiwan R.O.C.

HyPneu—Computerized System Problem Identification and Analysis

Abstract

The design process has changed significantly as the computer age evolved. The days when a design engineer develops a system through trial-and-error are rapidly coming to an end. The one factor which as slowed the evolution of the design process has been the availability of a computer program which can run on a personal computer and analyze a complete engineered system. Many times an engineered system will include hydraulic, pneumatic, electronic, and mechanical components. These components interact to produce the overall system performance. However, software has not been available which can handle such a diverse array of system components. Therefore, problem identification and analysis of systems have evaded the analytical stage of system design to become painfully evident in the hardware stage.

This paper presents a computer program called HyPneu which can analyze a complete system. In addition, HyPneu will permit the engineer to design a system at his desk on his personal computer. Once the program has been explained and described, real world systems with performance problems will be analyzed using HyPneu. The problems will be revealed and possible solutions will be predicted.

Introduction

The design and troubleshooting of a fluid power system is, many times, the most critical part of the machine development process. In the performance of an airplane as well as that of a backhoe, the most noticeable system outputs are a function of the operation of the hydraulic system. For example, if the hydraulic cylinder is too small for the application, the pressures may be very high, the system will move very rapidly, and may not move the anticipated maximum loads. If the pump is too large or too small, again the system will not function adequately. These are the types of problems that can occur in engineered systems.

Nearly all the systems with which an engineer must deal with are dynamic in nature. This means that the output of the system is as much a function of time as it is the size of the component. When a problem arises in the operation of a dynamic system, steady-state analysis will seldom permit successful identification of the problem, and certainly will provide little help in arriving at a solution. It has been the experience of the authors, that

This paper was presented at the Symposium on Steel Production Technology in Taiwan during November, 1993.

trouble shooting a fluid power system is about 70% problem identification and 30% problem solution.

In today's environment, the fluid power systems engineer is being required to evaluate systems which will perform many tasks at a much faster rate than ever before. This creates a dilemma which must be answered by providing the engineer with more powerful tools. It is totally unacceptable to force the trouble shooting or problem solving process of a fluid power system to be accomplished through trial-and-error effort. A more powerful tool is available—the computer. However, the computer can not be useful without adequate software and personnel.

In the early days of computer implementation in the problem identification and analysis arena, the engineer was required to be intimately familiar with fluid power components and systems. In addition, he needed to be a mathematical genius and a computer expert. Therefore, computer based problem identification has been slow to be applied to fluid power system trouble shooting. Moreover, fluid power systems many times involve diverse technical disciplines. For example, in a hydraulic system, the input to the system is normally some type of engine or motor which includes mechanical and/or electrical elements. The output may include gears, linkages, etc. In addition, the output may be used in a feedback circuit which will usually encompass instrumentation, logic elements, and controllers. Such a complex interaction among system elements makes the implementation of system models on a Personal Computer (P.C.) very challenging.

This paper will present a computer program which will unify the various technical disciplines permitting the identification of problems as well as the analysis of complete engineering systems on a personal computer. In addition, the implementation of the computer software is discussed. The overall use of this program will be demonstrated through the presentation of several case studies.

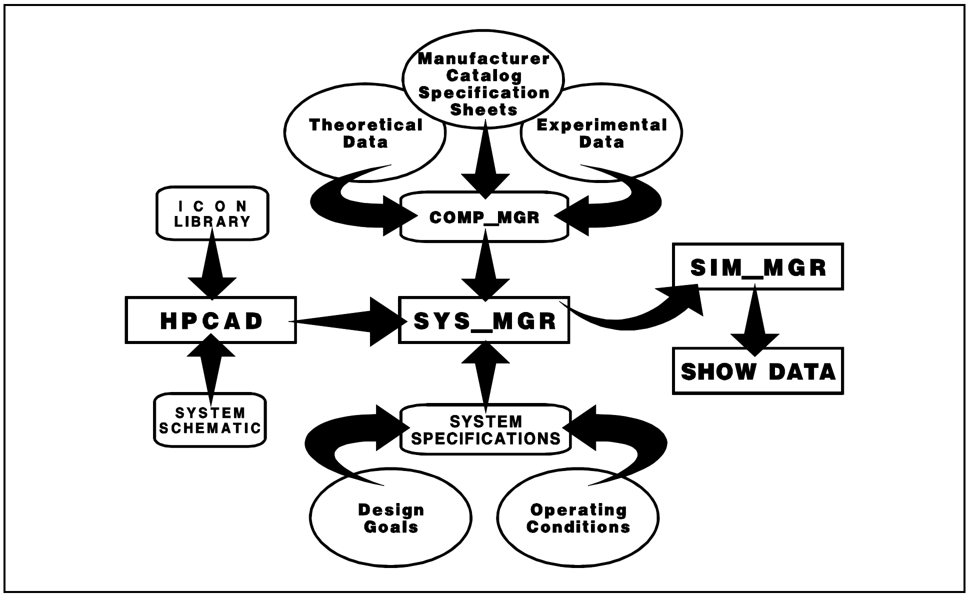
HyPneu Implementation

HyPneu[1][2] is a computer program which has been designed as a tool for system designers to utilize in the development of engineered systems. The scientists who are responsible for the HyPneu software recognized the fact that the lack of adequate software had significantly slowed the design process. In order to provide sufficient help, this software had to successfully handle such components as hydraulic, pneumatic, electronic, and mechanical—all in the same system. The final feature which was required involved the need for each engineer to perform system design, problem identification, and analysis at his desk on his own P.C.

HyPneu consists of two primary sections. The first section is used to thoroughly describe the system. When a designer is concerned with problem identification and analysis, it is necessary to first describe the system. This is accomplished with a subprogram of HyPneu called HPCAD where a complete schematic is entered. The second section is called HPMGR and is used to build component databases, manage the components used in the system, accomplish the simulation, and display the results.

A flow chart for the HyPneu program is shown in Fig. 1. As can be seen in the figure, HPCAD includes a comprehensive icon library of hydraulic, pneumatic, electronic, mechanism, and instrumentation components. Once the schematic of the system is complete, the computer knows what kind of components are included in the system and how they are connected together. As the user moves from HPCAD to HPMGR, each port connection is evaluated to insure compatibility (make sure a hydraulic node has not been erroneously connected to a pneumatic port).

Figure 1
HyPneu Flow Chart



In HPMGR, there are three major sub-divisions. As shown in Fig. 1, these divisions are called SYSMGR (System Manager), SIMMGR (Simulation Manager), and SHOWDATA (Display Results). The system manager provides all specific component data through the component manager, as well as the system specifications. The simulation manager provides options relative to the simulation parameters and algorithms, while the SHOWDATA allows manipulation of the format for the display of the results.

For the technically trained person, this program is an extremely valuable tool. To illustrate one possible use, consider a hydraulic system where one particular hose has a very short life. Most knowledgeable trouble shooters will quickly deduce the probability of high pressure surges, particularly if the hose failure occurs during one of the system transients. However, why such a pressure spike exists and the optimum solution to this problem can be both time consuming and expensive. When HyPneu is available, the engineer merely describes his system to the computer in terms of the schematic and component data. Then the system can be simulated and the magnitude of the pressure surge can be evaluated. Through the use of the P.C., several solutions can be analyzed in a very short time period. If this analysis effort leads to the inclusion of an accumulator to absorb the pressure spike, the location and parameters of the accumulator can be determined quickly, and easily through the use of HyPneu.

Simplicity is one of the unique features of HyPneu. The component models used in HyPneu are primarily based upon information which can be obtained from the component manufacturers catalog or from simple performance tests. The philosophy behind this approach lies in the fact that detailed information concerning the internal parts of a component are seldom available to the hydraulic users. In addition, research and development has shown that the use of such information is not necessary in accurately simulating the performance of a system. For example, the information of a pump normally provided by the manufacturers is shown as in Fig. 2. Note that the key parameters are volumetric efficiency, mechanical efficiency, delivery, and pressure. HyPneu uses these attainable parameters to quantify the pump model. Therefore, HyPneu is capable of accepting any practical data from designers, manufacturers, and users. The fact that this computer program relies on readily available performance data to describe the system components means that it is both simple to use and accurate in its analysis.

Figure 2
Typical Pump Performance Data

Case Studies

The versatility and simplicity of the HyPneu program are a result of many years of experience and research by BarDyne's staff, involving the design, analysis, and trouble shooting of engineered systems. It is not possible in the short space provided by this paper to completely or even adequately describe all of the basic details of the HyPneu approach. However, the following case studies will illustrate a few of the many industrial application which have been analyzed and diagnosed using this unique software package on a P.C.

Case Study No. 1

Shock loading on a hydraulic system can be a very serious factor. Hydraulic systems are designed to be very stiff so that response and precision are good, and therefore, the effects of shock loads will be multiplied and can cause catastrophic failure. The peak pressures encountered during shock loading can not be calculated using steady state techniques and, in fact, many dynamic simulation programs will not produce a satisfactory analysis of this situation.

An industrial example of a system which must absorb significant shock loading is the thickness control system in a rolling mill[3]. Such a system normally consists of force controls on two very large rollers. When the steel is processed (or bite-in) through the rollers, the sudden force trying to seaprate the rollers will cause a severe shock load in the force control system. If the system can not absorb this shock extremely high pressures will result.

The rolling mill example is used to illustrate HyPneu's capability in a shock loading application. A shock force generator (CTT) and a mass (SM1100) represent a shock load on both the top and bottom roller cylinders. In Fig. 3a, such a system is shown schematically.

It can be seen by the curves of Fig. 3b that by using only a relief valve to protect the pump and cylinder from the shock loading, the pressure will peak very high and experience a low value excursion. This situation can cause hose and cylinder failure. However, the use of an appropriately sized and located accumulator will greatly improve the system performance. The performance of the system using a 10 liter and a 50 liter accumulator is also shown in Fig. 3b. This is a perfect example of a diagnostic analysis revealing the presence of a large pressure spike and the solution to this problem by the addition of an accumulator.

Figure 3a
Shock Absorption
System Schematic

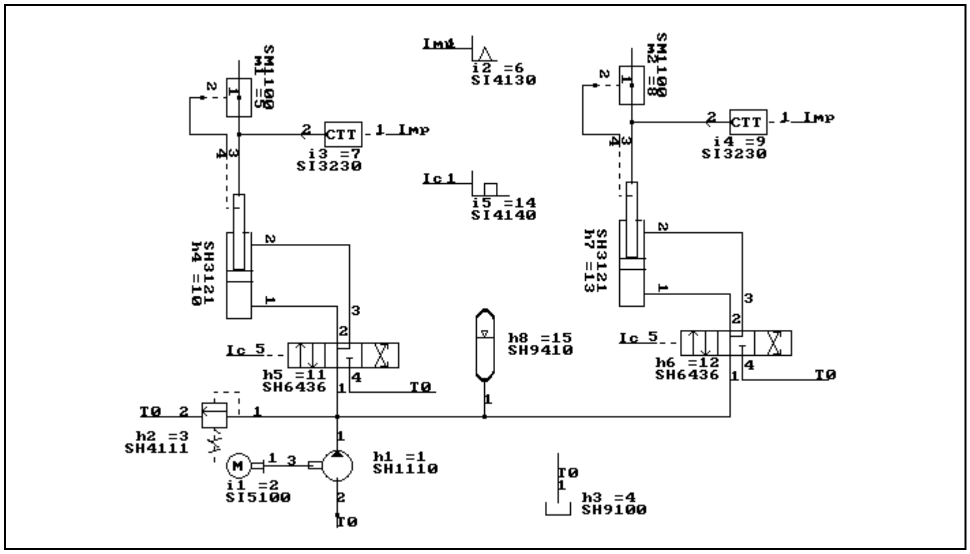
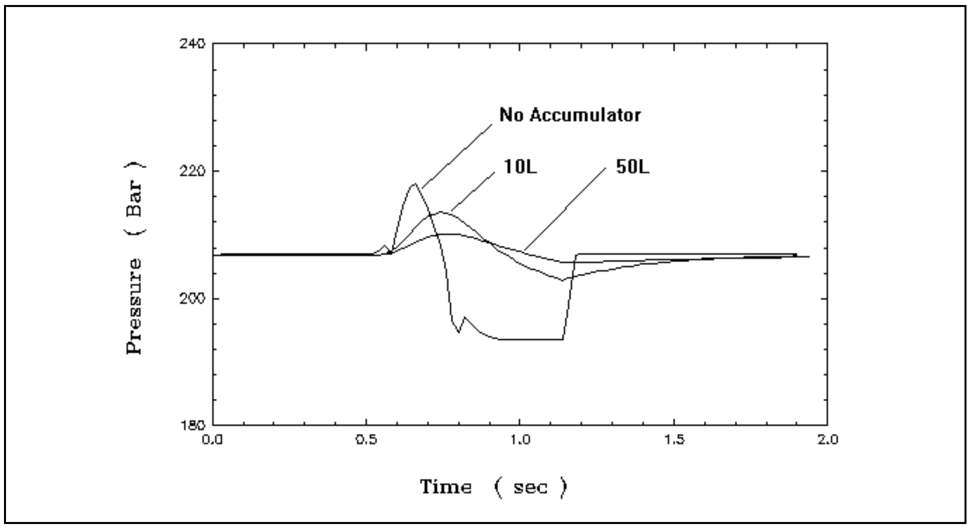


Figure 3b
Shock Absorption Analysis



Case Study No. 2

This case involves the use of HyPneu to analyze and diagnose the performance of a newly designed pilot operated relief valve. As can be seen in Fig. 4a, the system used to evaluate this relief valve consisted of an ideal pump which produced 225 gpm at 1800 rpm, the relief valve, and a system load valve. It should be noted that HyPneu uses generic elements such as a poppet valve (SH5540) for the main stage, a spool valve (SH5530) for the pilot stage, and orifices (SH5510) for restrictions, to build the relief valve model. All of these generic models are available from the HyPneu component data base, therefore, programming is not required. The user only needs to input the basic parameter information (such as the diameter of the orifice) concerning the models. This prototype relief valve was evaluated through simulation at two different sets of conditions with the operating pressure set at 1000 psi (70 bars). Condition one is where the system load valve is closed slowly from 0.1 seconds to 0.2 seconds. Fig. 4b shows the flow rate and the system pressure under these conditions.

The purpose of the first set of conditions was to study the stability of the valve under a slowly changing input. The second set of conditions consisted of closing the system load valve very quickly (instantly). The system pressure versus time trace for this second condition is shown in Fig. 4c. The purpose of the second evaluation was to ascertain the amount of overshoot which the relief valve would permit. It should be noted that the operation was fairly stable under both inputs. However, the overshoot was greater than 200%. This is extremely valuable diagnostic or trouble shooting type of information. A system which is designed for a working pressure not to exceed 1000 psi (70 bars) can seldom last very long with pressure spikes to 3000 psi (210 bars) without hose and fitting failures as well as other component degradation.

Figure 4a
Relief Valve Schematic

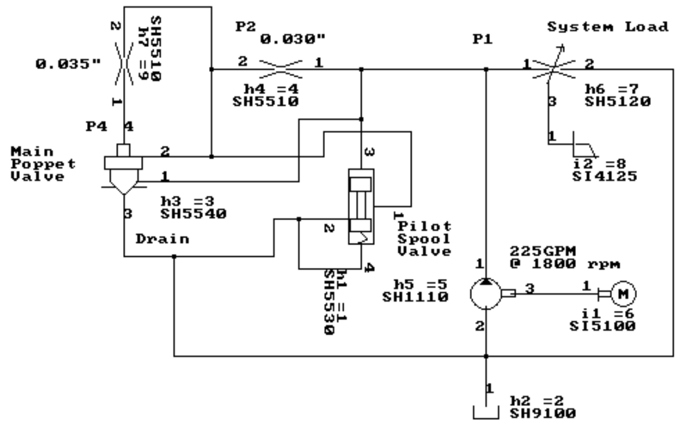


Figure 4b
Relief Valve Performance Load
Valve Closed Gradually

Case Study No. 3

This example demonstrates the manner in which HyPneu can be used to evaluate the overall efficiency of a hydraulic system. From a diagnostic point of view, such an evaluation would be a logical approach in determining the cause of high system temperature. Included in the HyPneu models data base are models called HPH and EFF, which stand for Hydraulic Horsepower and Overall Efficiency, respectively. By inserting the HPH models into the lines at two locations within the hydraulic system and connecting their output to the EFF model, HyPneu will calculate efficiency.

Figure 4c
Relief Valve Performance Load Valve Closed Instantly

This feature is demonstrated by using the cylinder control system shown in Fig. 5a. As can be seen in this figure, the horsepower at the pump outlet and at the cylinder inlet are used in the efficiency determination. The performance of the system (efficiency vs time) as the control valve is opened is shown in Fig. 5b, where line considerations are not included. For comparison purposes, the cylinder control system was modified to include a 0.635 cm 10 meter line (SH9512) between the valve outlet and the cylinder inlet post. The dynamic efficiency of the modified system is shown in Fig. 5c. It should be noted that the overall efficiency of this hydraulic system is dramatically degraded by the inclusion of this small and long line.

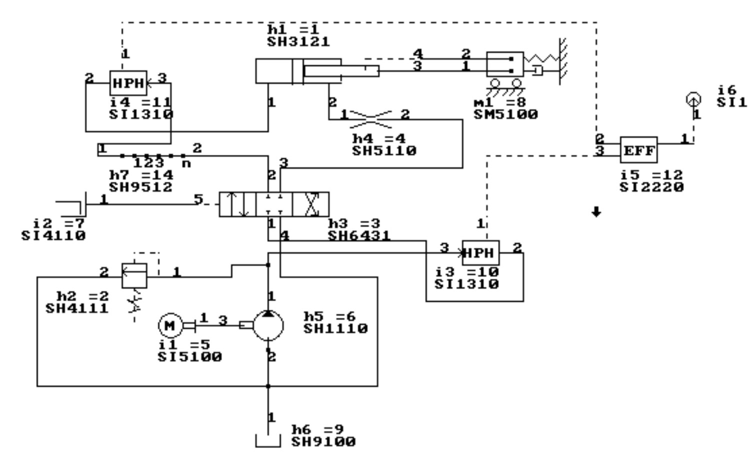


Figure 5a
System Efficiency Analysis Schematic

Case Study No. 4

As any user knows, hydraulic cylinders will encounter an end-of-stroke limitation in their displacement many times during the operation of most hydraulic systems. In fact, a hydraulic system may incorporate several cylinders and some of these cylinders will encounter end-of-stroke, while other cylinders in the system are still moving. Therefore, in order to thoroughly diagnose the operation of a multiple cylinder hydraulic system, it is very important that the analysis approach and software be capable of simulating hydraulic system operation when one or more cylinders reach end-of-stroke during the evaluation period.

Figure 5b
System Efficiency Analysis
Without Line Consideration

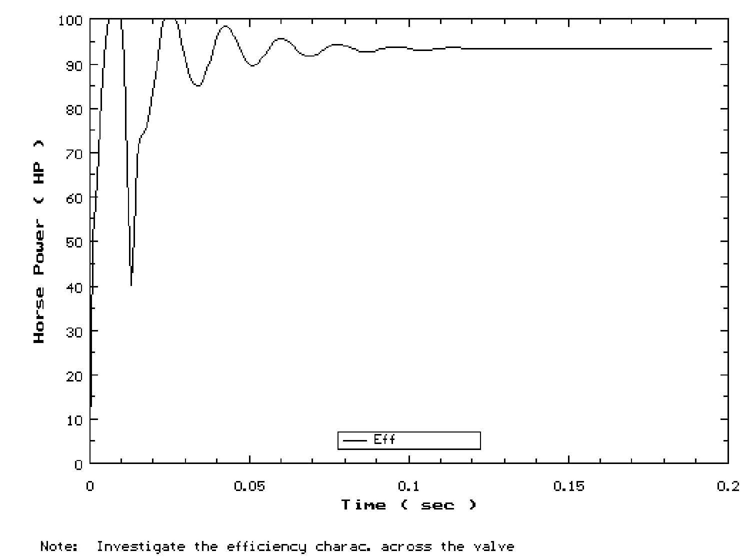


Figure 5c
System Efficiency Analysis
With Line Consideration

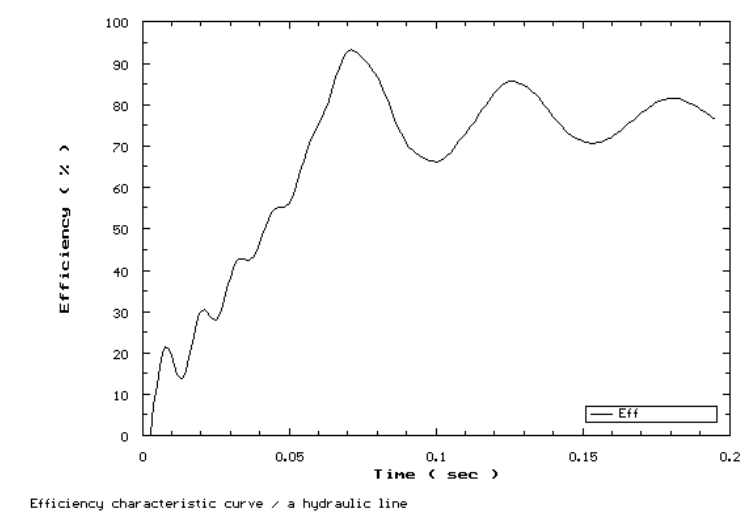


Fig. 6a shows a schematic of a typical hydraulic system which incorporates two hydraulic cylinders. These cylinders are identical in every way except the cylinder on the left has a stroke of 0.1 inches (0.254 cm), while the cylinder on the right has a stroke of 3.0 inches (7.62 cm). Obviously, when the control valve (SH6431) is actuated by the control signal (SI4210), the cylinder on the left will reach end-of-stroke much faster than the cylinder on the right. To illustrate this operation, the cylinder displacement of both cylinders are plotted versus time after the control valve is opened as shown in Fig. 6b. In addition, the cylinder inlet pressure versus time is given in Fig. 6c. It should be observed from this example that while the left hand cylinder reached end-of-stroke at about the 0.075 second point in the simulation, the program continued to simulate system operation without interruption.

Figure 6a
Schematic to Multi-Cylinder Hydraulic System

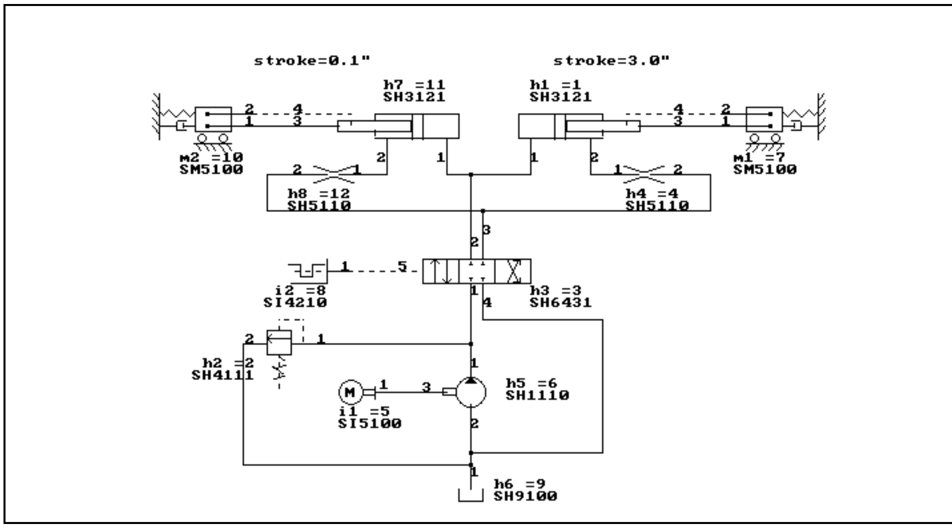


Figure 6b
Cylinder Displacement Curves

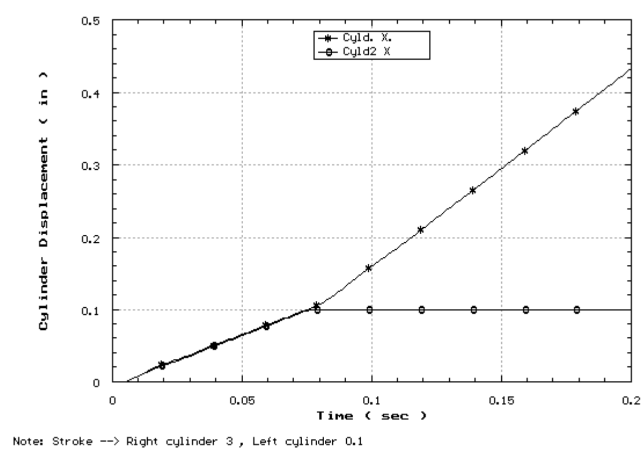
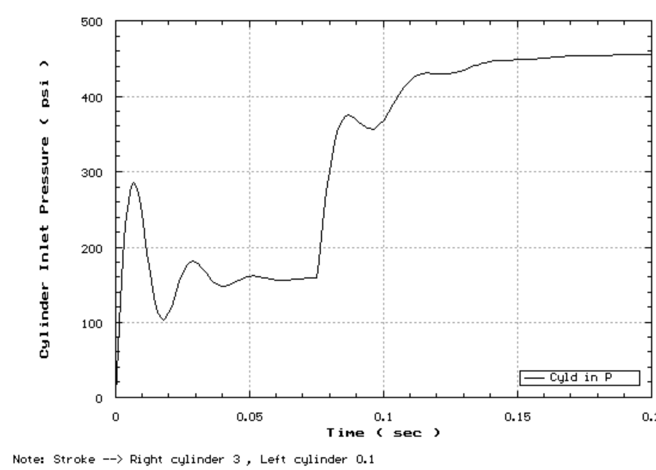


Figure 6c
Cylinder Inlet Pressure



Conclusion

The paper has presented and discussed a computer program which is capable of greatly reducing the time and cost associated with not only system design, but also system diagnosis and trouble shooting. It is very plain that most engineered systems such as hydraulic systems encompass many technologies. Hydraulic, electronic, electrical, pneumatic, and mechanical components are all incorporated in the same system. The individual who must identify and solve problems associated with such systems must have effective tools to do these tasks efficiently. The HyPneu program can provide such a tool for both diagnosis and system design.

The HyPneu program implementation was discussed in order to provide the reader with an understanding of it's organization. However, the entire scope of the software could not be presented in a technical paper. The versatility and simplicity of HyPneu were illustrated using four case studies. These cases represented real world situations which have been successfully addressed by HyPneu.

References

1. "HyPneu Owner's Manual" BarDyne, Inc., Stillwater, Oklahoma U.S.A., 1992.

2. "HyPneu Application Notes," BarDyne, Inc., Stillwater, Okalhoma U.S.A., 1993.

3. Steel Rolling System Schematic, China Steel Co., Kaohsiung, Taiwan, 1988.

