DOWNHOLE PUMP VISUALIZATION AND DATA ACQUISITION

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ABSTRACT

A novel image acquisition system has been developed that will enhance our knowledge of downhole pumps. This system, comprised of a video camera, digital frame grabber and image processing routines, has been integrated to the downhole pump test fixture at the University of Texas at Austin where in the past pressure at various point of interest around both the standing and travelling valves have been recorded.

As the images and pressure information have been recorded at the same exact time, one can now look at the picture of the pump to see the actual valve movement for each interesting 'blip' on the pressure plot.

The outcome of this research can be beneficial in better understanding of downhole pumps, improving the life of downhole pump, and eventually reduce the cost of operation and maintenance of downhole pumps.

INTRODUCTION

Downhole pump actions has in the past been investigated in various ways. As the pump is located remotely at the bottom of the well, pump movements / actions were initially predicted by pressure data that was recorded at the surface. To have a better observation of the pump actions, this pump can be brought to the surface and installed over a clear transparent wellbore, made of clear acrylic tubing, where the pump action and fluid movement can be investigated. Petroleum Engineering Department of the University of Texas at Austin fabricates this test fixture and equipped with a data acquisition system to record several pressure data from various points around the pump as a function of time.

To record the pump movement, a video grabber system has been integrated with the data acquisition system such that the two information, digital data and video, are interlinked to each other so any data that generates curiosity to the observer also brought the specific video frame to the screen.

EQUIPMENT

Sandia System developed the original data acquisition system. This Sandia System is a very powerful and fully configurable data acquisition system. The number of active channels and the channel configuration can be defined independently as required. Each channel can have its individual calibration stored in a file for a quick system launch. Figure 1 shows the configuration panel of the Sandia System.

The objective of the project is to integrate this Sandia System with an off the shelf video camera and a video grabber card. As the Sandia System was developed under LabVIEW programming environment, it is very fit to utilize a video grabber card that can be driven under LabVIEW. IMAQ (Image Acquisition) PCI-1411 board was selected as the video grabber board for the project as this board can digitize at full video speed of 30 fps (frame per second), and has an S-Video input for good video quality input. This board also has the provision to generate or receive external trigger that can be used to synchronize with other data acquisition boards.

PROBLEMS ENCOUNTERED

Two problems were encountered during the during the integration process. The **first** problem was even though the video grabber by itself can digitize at 30 fps, the whole system went to a very crawling speed when both the video grabber and the original data acquisition board were active. The second problem was the images were not synchronized to the acquired data.

The first problem, trying to stream images at full 640 by 480 pixels to disk only managed around 12 fps, far from our intended speed of 30 fps. One way to increase this imaging speed is to reduce the frame size but we will risk loosing some information that might be important for analysis. Another method to increase the imaging speed is to create a continuous ring buffer where the data can be written as fast the image is available and then this image is moved to disk at the available disk speed. When the writer reaches the end of the buffer, the writer loops back to the first one hoping that by this time the first image has been taken out and written to the storage file. This mechanism allows for parallel reader/writer processing. As the writer runs at nearly 30 fps and the reader runs at approximately 10 fps this method will eventually fails as the writer laps the reader, and hence corrupting the data. One solution to prolong the occurrence of this data corruption due overlapping is by increasing the ring buffer size. Unfortunately, due to limited physical memory available in the computer, the maximum ring buffer gave only around 20 seconds before the data got corrupted. Currently the solution is stream direct to disk.

The second problem that was encountered was the lack of synchronization between the acquired images and the pressure data. The first solution shows that the pressure and image acquisitions were not synchronized. The data sets were aligned at the start of acquisition but became misaligned as the test progressed. The second solution was to use the available external trigger port on the video grabbing board by triggering at 30 Hz and then route this signal to the trigger line of the data acquisition board. Unfortunately individual samples from data acquisition (DAQ) board cannot be triggered, and only the start of acquisition could be triggered. Hence after the first trigger is received the DAQ board is running independently from the video board. Another solution that was tried was to feed the external trigger to the DAQ board thorough the digital line, instead through a cable as the previous method. A different problem was encountered this time as the system slowed down drastically due to PCI bus contention. This PCI (Peripheral Connection Interface) bus is the "data highway" between the CPU and all of the plug-in boards. It took about five minutes to view the images in the slideshow after the end of the image capture and stream to disk. The final solution for this synchronization problem was to remove all hardware triggering mechanisms. The algorithm that is used now is a software-timed model that allows a higher degree of correlation between the instantaneous pump images and transducer data.

To fully describe the synchronization solution, the entire system can be divided into two parallel but asynchronous processes - the image acquisition and the transducer data acquisition. To ensure synchronization, both processes must begin at the same time and have identical sampling rates. Ensuring that each process sample the data at nearly the same time was fairly straightforward using this software-timed model. The first step is to configure the transducer acquisition process to acquire a single data point per channel with each call to its data read function, AI Read. Then a single buffer in memory to hold the acquired images is configured. When the software is started the system begins acquiring data; the primary acquisition code calls IMAQ Copy, which acquires a single image from the camera into the image buffer in system memory. If the image is not fully transferred from the camera, this function will block the system's execution until the image is ready. Then, immediately after returning from IMAQ Copy, AI Read function is called to acquire a single point of transducer data per channel. The acquired image and transducer data is then streamed to disk.

The execution loop then iterates, and another set of data is acquired. As the camera's frame rate is 30 frames per second, the IMAQ Copy function can not run faster than 30 Hz, and because AI Read function must wait until IMAQ Copy function returns, both processes are guaranteed to sample at the same rate of approximately 30 Hz.

However, if the amount of time required to stream image and transducer data to disk exceeds 33 ms (the period of a 30 Hz sampling rate), the system will miss image frames and the acquisition rate of the entire system will slow down. As the streaming time required to disk is directly proportional to the image size, reducing the acquired images will improve the saving to disk procedure. During the initialization phase, the program asks the user to select a region of interest (ROI) on the image to be recorded and discard any extraneous area around the subject of testing. This effectively reduces the image size; the number of bits copied into our system buffer and subsequently streamed to disk.

Using these techniques and a reasonably sized ROI, a transfer rate of 30 Hz can be easily achieved, hence a full-motion video acquisition system. Further analysis shows that the image and transducer data is very tightly correlated to each other. The maximum expected error is a skew of **33** ms (one frame period) between image data and transducer data. Overall, the system is capable of providing a tight integration of the two data sets.

DATA ACQUIRED AND ANALYSIS

Figure **2** shows the slideshow program where a user can pull up a file, see the acquired pressure data and images. A slider is provided on the program to select a particular point in time and view the respective video image to the computer screen. Using **this** slider the user can "jog" back and forth over the data set to view the images and the corresponding transducer (pressure) data, shown as a vertical line on the plot. The captured image shown in this screen capture shows a travelling valve at fully closed condition. Further down in time when the same valve is at open position is shown in Figure 3, and the transducer data shows that the pump is on the downstroke phase with positive pump barrel pressure. At the transition from fully seated to fully open, the travelling valve made a fluttering movement as can be seen on the early part of the pump barrel pressure (the square wave shaped plot), and also can be seen on the captured images.

A case of pumped-off condition **is** shown in Figure 4. The pressure inside the pump barrel is not rising instantaneously but in a gradual form, due to the period where gas above the fluid inside the pump barrel recompresses. The captured image shows a fully seated travelling valve. As soon as the pressure inside the pump barrel exceeds the discharge pressure, travelling valve opens and stream of gas exits. Figure 5 shows the open travelling valve and the exiting gas. Also shown in Figure 5 the pressure data on an expanded time axis, to better see the crossover of the pump barrel pressure to the discharge pressure. Figure 6 shows the standing valve of a pumped-off pump. This figure shows, in an expanded time-scale, the pump barrel pressure that is less than the intake pressure. Also shown is the standing valve image with the valve in open position and gas bubbles moving into the pump barrel.

This integrated image and conventional transducer recording system is ready to be used for further study on downhole pumps, and this system has a huge potential in helping on improving the understanding of downhole pump mechanism and responses. This system can also be implemented on other moving systems where a correlated captured image and transducer data is required.

CONCLUSIONS

1. A system that integrates the conventional pressure data recording system for downhole pump with visual images has been developed.
2. Current commercial desktop computers are barely capable in handling both the acquired images and transducer data. Several compromises had to be implemented for a full-motion image and data acquisition system.
3. As each image requires a considerable size of memory, a big physical memory is a major requirement.
4. Pressure data can be correlated with valve behavior, such like the fluttering on pressure due to ball valve vibration during the seated to unseated and unseated to seated transitions.
5. In a pumped-off condition, the movement of gas can be seen on the captured images and the time of movement correlates very well with the recorded pressures.
6. This integrated image and conventional data acquisition system has a big potential for future studies of downhole pumps.

REFERENCES:

"NI-IMAQ Users Manual", National Instruments, May 1999.

"NI-IMAQ Function Reference Manual," National Instruments, May 1999.

George, Shinoy and Graf, Christopher; "A real-time LabVIEW-based video image capturing system," final project report, The University of Texas at Austin, August 2000.

Figure 1 - Configuration Panel of the Sandia System - Each channel can be configured according to the input signal, assigned to a name and also has the provision to disable without having to delete from the list.

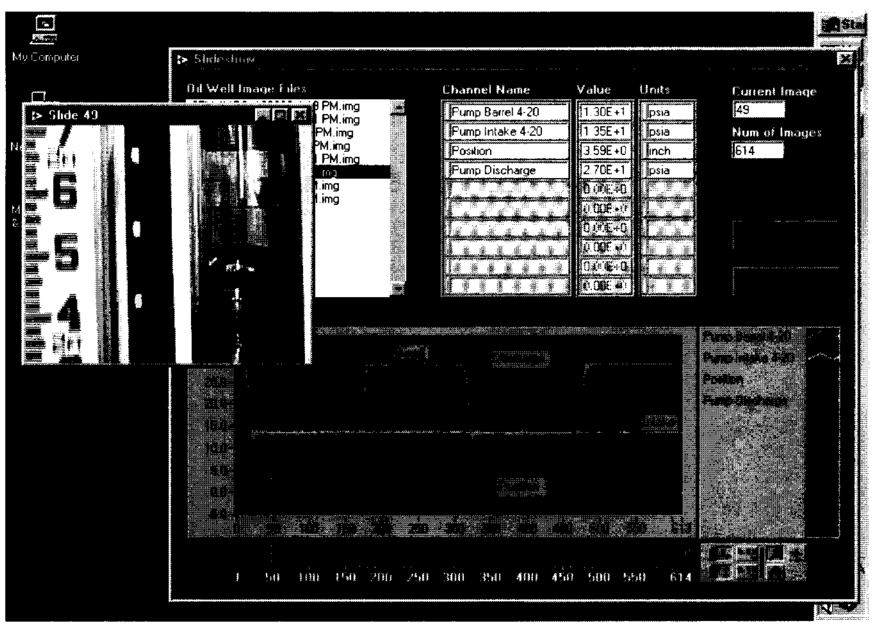

Figure 2 - The Slideshow Program Where the User Can Pull Up a File, See the Acquired Data, Scroll Over to Find a Specific Point in Time, and Observe the Corresponding Image - This screen capture shows travelling valve at fully closed condition.

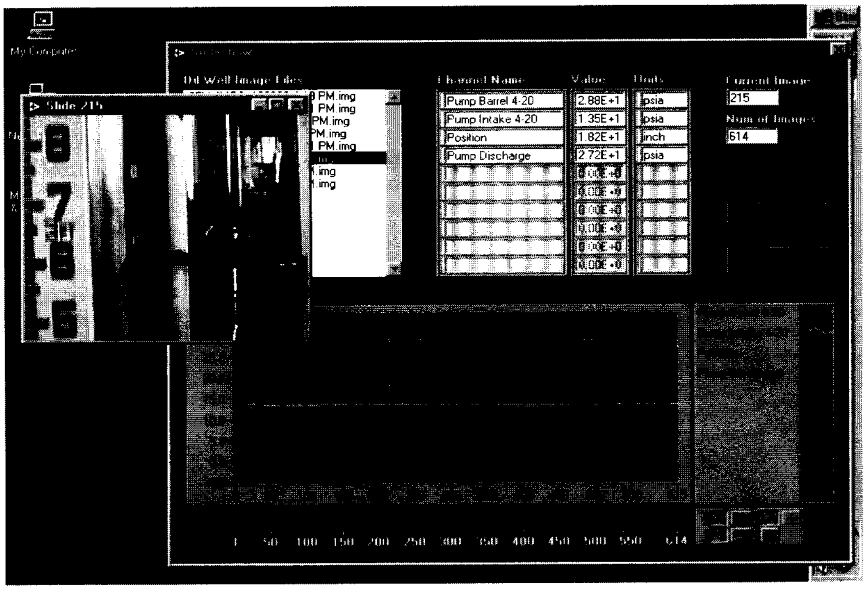

Figure 3 - The Image of a Fully Open Travelling Valve of the Same Data File at the Downward Stroke -The square wave line is the pressure inside the pump barrel. As shown on the screen capture pressure inside the pump barrel increased as the downward travel began and then the travelling valve started to open, fluttered for several milliseconds and then stabilized.

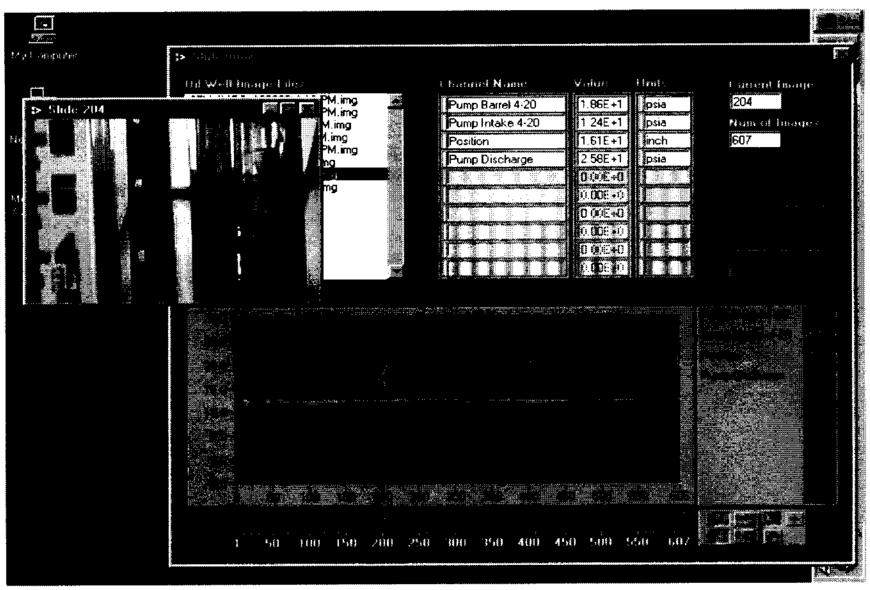

Figure 4 - This screen capture shows a pumped off condition. The pressure inside the pump barrel is not rising instantaneously on downward stroke but in a gradual manner while the gas space above the fluid inside the barrel is recompressed. The vertical cursor shows this condition while the corresponding image shows the travelling valve still in fully seated position.

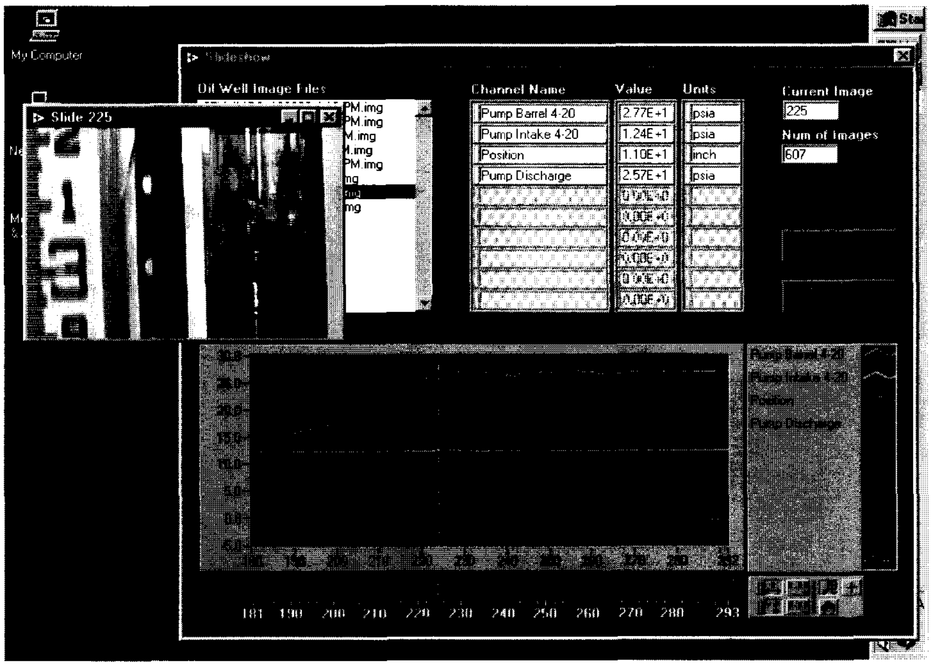

Figure 5 - As soon as the pressure inside the pump barrel exceeds discharge pressure, travelling valve opens and gas streams out as seen on the captured image. Note that the time axis in the pressure plot has been expanded to observe the exact pressure behavior at travelling valve opening of this pumped off condition.

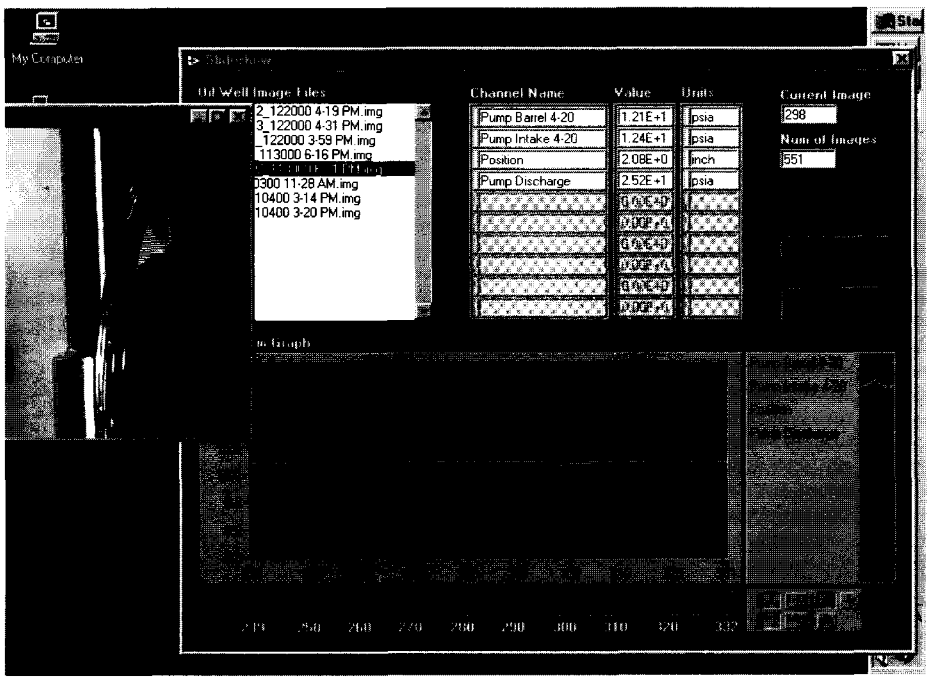

Figure 6 - Another Observation of a Pumped-Off Condition - This is the standing valve when pressure in the pump barrel is less than the intake pressure. The captured image shows gas bubbles streams over the standing valve. Note that the time axis has also been expanded for clarity.