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Sampling theorem to periodic non_continuous signal from cavitation of piezoelectric pump

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Abstract: A general means of data processing is a sampling method, in which continuous analog data are measured non_continuously at certain time intervals as digital data, and the median value is ignored. The sampling time intervals are determined by the sampling theorem. Since both valve and no_valve piezoelectric pumps are pumps driven in a vibration form, they send a periodic non_continuous signal to cavitation. The sampling theorem is not applicable to a non_continuous signal. For this reason, the authors developed a method to apply the cavitation in a pump driven in the piezoelectric vibration form as a periodic non_ continuous signal. And a sampling system using this method was manufactured.

Key words: piezoelectric pumps; data processing; sampling systems
CLC number: TH38 Document code: A

1 Introduction

Both valve (1)_(4) and no_valve (5)_(10) piezoelectric pumps are new types of pumps, which are provided with a piezoelectric ceramic actuator as a power source and have a vibration form different from that of a traditional displacement reciprocating or rotary type pump. In this study, note that valve and no_valve piezoelectric pumps may be shortly called piezoelectric pumps. The valve piezoelectric pump finds its widespread applications in medical care, physics and chemistry, and machine tools(3). The no_valve piezoelectric pump receives attention because it has a simple structure, which can be miniaturized, and is applicable to low_cost fluid and micro machinery.

Since pumps of this new type are greatly affected by cavitation, we developed directly observing and recording equipment from a discharge opening window which does not modify a small_size pump structure (11). This equipment handles a data signal as a continuous image on analog videotape. A general data_processing means is a sampling method in which continuous analog data are measured non_continuously at certain time intervals as digital data and the median value is ignored. The sampling time intervals are determined by the sampling theorem (12)_(14).

Since the piezoelectric pump is a pump driven by vibration, it sends a periodic non_continuous signal to cavitation if the process generates cavitation is a target of the signal. The sampling theorem is not applicable to the non_continuous signal.

For this reason, the authors developed a method to apply the cavitation in a pump driven in

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the piezoelectric vibration form as a periodical non_continuous signal to the sampling theorem. Next, we developed a sampling system using this method. At the same time, using this method, we conducted an experiment on the cavitation sampling of the valve piezoelectric pump.

2 Piezoelectric pump

2.1 Structure

The piezoelectric pump is a new type of pump, which is provided with a piezoelectric ceramic actuator as a power source and has a vibration form different from that of a traditional displacement reciprocating or rotary type pump. Fig. 1 shows the structure of a valve piezoelectric pump (3) (4). Fig. 2 shows a typical no_valve piezoelectric pump (5)_(8) composed of a piezoelectric vibrator, a no_valve mechanism (a mechanism replacing a valve), and a pump housing. If a traditional valve is defined as a device, located between the pump room and the outside, which is closed at a moment, there is no moment when a no_valve mechanism (a mechanism replacing a valve) is closed. Note that the no_valve mechanism is provided with a function to increase or decrease a fluid resistance significantly.

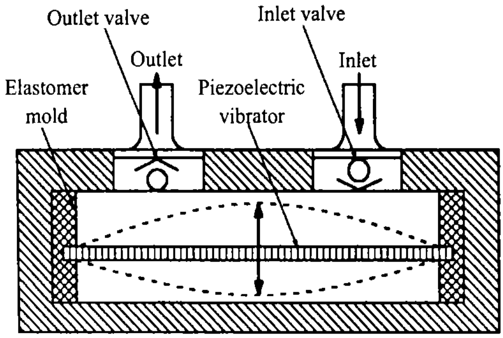


Fig. 1 Structure of the valve piezoelectric pump.

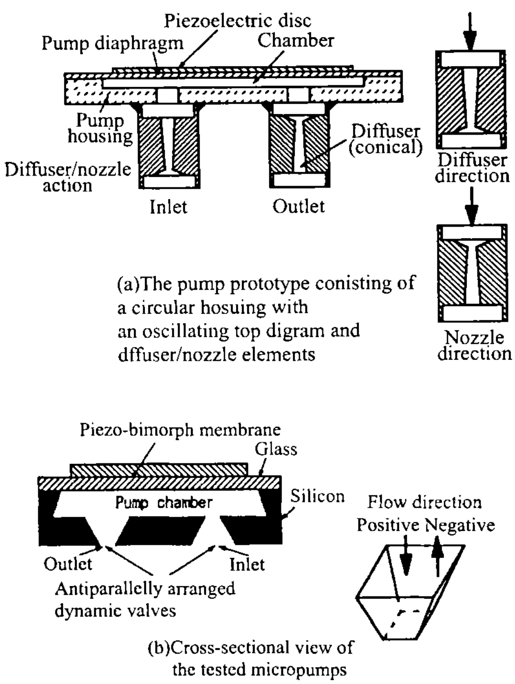
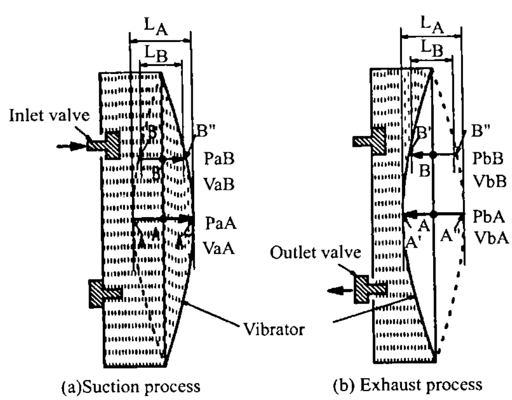


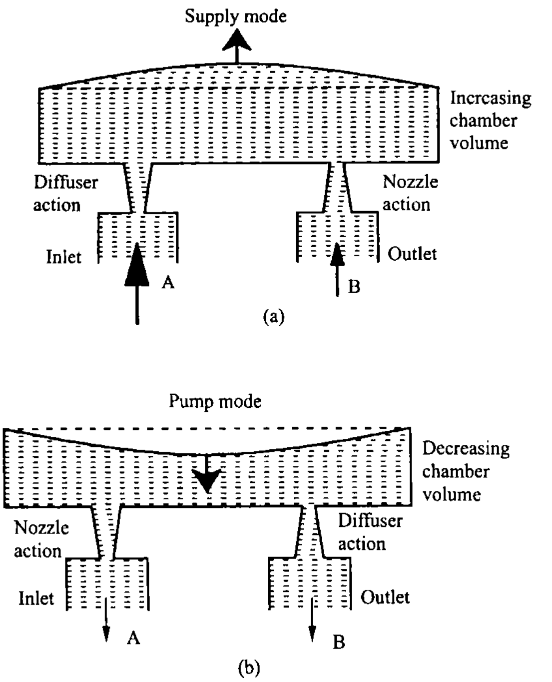
Fig. 2 Typical no_valve piezoelectric pump and no_valve mechanism.

2.2 Principle of operation

Fig. 3 (I) shows the principle of operation of a valve piezoelectric pump. In the suction process, the movement of a vibrator from the limit position on the left to that on the right increases the pump room capacity and lowers the internal pressure. In the suction process, when the internal pressure becomes lower than the external pressure on the suction side, the inlet valve is pushed down to let the fluid in through the suction opening. In the exhaust process, the movement of the vibrator from the limit position on the right to that on the left decreases the pump room capacity and raises the internal pressure. When the internal pressure becomes higher than the external pressure, the outlet valve is pushed down to let the fluid out through the suction opening.



(I) Operating principle of the valve piezoelectric pump.



(II) Operating principle of the no_valve piezoelectric pump

Fig. 3 Operating principle of the piezoelectric pump.

Fig. 3 (II) shows the principle of operation of Stemme's no_valve piezoelectric pump. Since the fluid resistance at opening B is higher than that at opening A in the supply mode of this pump, more fluid flows into opening A than into opening B. Since the fluid resistance at opening A is higher than that at opening B in the pump mode, more fluid flows out of opening B than out of opening A. The difference between inflow and outflow is a pump flow.

2.3 Cause of cavitation

For the piezoelectric pump shown in Fig. 3, the pump room capacity increases and the internal pressure lowers in the supply mode. At this moment, cavitation may be caused between the piezoelectric vibrator and the liquid. Since the centerline of the piezoelectric vibrator shows the most remarkable internal pressure drop, it is the most likely to cause the cavitation. Generally speaking, since the piezoelectric pump vibrator moves faster than that of the piston pump, cavitation is more likely to occur in the vibrator than in the piston pump. In the pump mode, the pump room capacity decreases and the internal pressure rises. At this moment, there is no possibility that new cavitation occurs in the pump room. The above analysis reveals that a signal for which the occurrence process of the cavitation in the piezoelectric pump is studied is periodic and non_continuous in the supply mode only.

3 Sampling theorem and application conditions

In order to reproduce an original continuous signal faithfully from a sample value signal, a certain restriction on the sampling period Ts or the sampling interval Δt is required in sampling. The sampling theorem[12-14] was discovered by Someya in 1960. Assuming that the continuous time signal x(t) does not contain a frequency exceeding fm [Hz].

At this moment, if the sampling interval Δt is selected the following equation is satisfied, that

$$\Delta t = T_s = \frac{1}{f_s} \leqslant \frac{1}{2f_m}, \qquad (1)$$

is, if the sampling frequency f_s is selected the following equation is satisfied,

$$f_s = \frac{1}{\Delta t} = \frac{1}{T_s} \geqslant 2f_m, \qquad (2)$$

$x(t)$ at an arbitrary time is determined as a discrete_time signal. Conditions under which the sampling theorem is applicable must be provided with periodicity and continuity for an original signal to be discrete.

4 Signal system of piezoelectric pump

The piezoelectric pump is a reciprocating pump driven in vibration form. The go and return processes of a piezoelectric vibrator correspond to the suction and exhaust processes of fluid movement, respectively. A combination of a suction process and an exhaust process composes an entire process in pump operation. Cavitation occurs in a suction process, but new cavitation does not occur in an exhaust process. From the viewpoint of whether cavitation occurs or not, a piezoelectric pump has three signal systems: a signal system in a suction process where cavitation occurs, a signal system in an exhaust process where it does not occur, and a signal system in the entire process where it occurs at intervals. Some methods to study the statistical characteristics of conventional cavitation consider the system of the entire process (11).

According to the sampling theorem, even if cavitation does not occur at half period in an exhaust process, an image related to it must be extracted. If such a data system is used, since an image signal has no cavitation at half period in an exhaust process, wrong information will be given to the cavitation image signal. In addition, it is not advantageous to make an analysis from the viewpoint of time and economy because there is a large number of data samples. If only a cavitation image signal in the suction process is used, this image signal will be an image signal periodic and non_continuous. Therefore, the sampling theorem is not applicable to a non_continuous signal.

5 How to apply sampling theorem to cavitation in piezoelectric pump

5.1 How to apply sampling theorem

In order to apply the sampling theorem, eliminate the exhaust process by moving forward the suction process sequentially in terms of time so that there is no interval between the final value of the suction process and the initial value of the next suction process on the time axis, and synthesize a system in which the suction process is artificially continued. This new system has half period of the entire process.

In sampling, if the initial value is in the suction process, move the 2m+ 1st half period before the mth half period so that it will be the m+ 1st period of the new system. If the initial value is in the exhaust process, move the 2m+ 2nd half period before the m+ 1st half period, so that it will be the m + 1st period of the new system. The sampling theorem can be applied to this new system because it has periodicity and continuity.

5.2 Cavitation outflow time difference

Cavitation in a piezoelectric pump occurs in the suction process on the surface of the vibrator. In the present study, the directly observing and recording equipment uses this pump outflow indelibility to observe and detect cavitation through the window of outlet. The valve piezoelectric pump is closed by an outlet valve in the suction process. For the no_valve piezoelectric pump, the fluid passing through the no_valve mechanism is directed toward the pump. For this reason, cavitation caused at a half period in the suction process does not flow out to the discharge opening. Cavitation that flows out up to the window of outlet is at a half period in the exhaust process. The time difference δ between the time cavitation occurs on the surface of the vibrator and the time it flows out to the discharge opening window, the piezoelectric pump vibration period (entire_process period) T, and the time δ_1 required from the time the suction process is completed to the time the cavitation flows out to the discharge opening window are given according to equation (3).

$$\delta = 1/(2T) + \delta_1,\ 0 \leqslant \delta_t < 1/(2T), \quad (3)$$

Note that the time the cavitation, observed and detected at the window of outlet, occurrs is not known because it is difficult at the present moment to calculate and measure the outflow time δ1 from both theory and experiment.

5.3 Development of sampling system

Fig. 4 shows the system to which the sampling theorem of the cavitation in the piezoelectric pump is applied. At the discharge opening window in the present study, a transparent elastic pipe is used, and the pump suction and exhaust processes correspond to the cyclic displacement processes of contraction and expansion, respectively. The contraction cycle corresponds to a suction process and there is no possibility that cavitation occurs in the exhaust process immediately before this cycle. The expansion cycle corresponds to an exhaust process and cavitation that occurs in the suction process immediately before this cycle flows out. This system monitors the expansion period at the transparent elastic window of outlet with a laser sensor and records only the images of the cavitation corresponding to this period, with a microscope, a computer, a printer, and other devices.

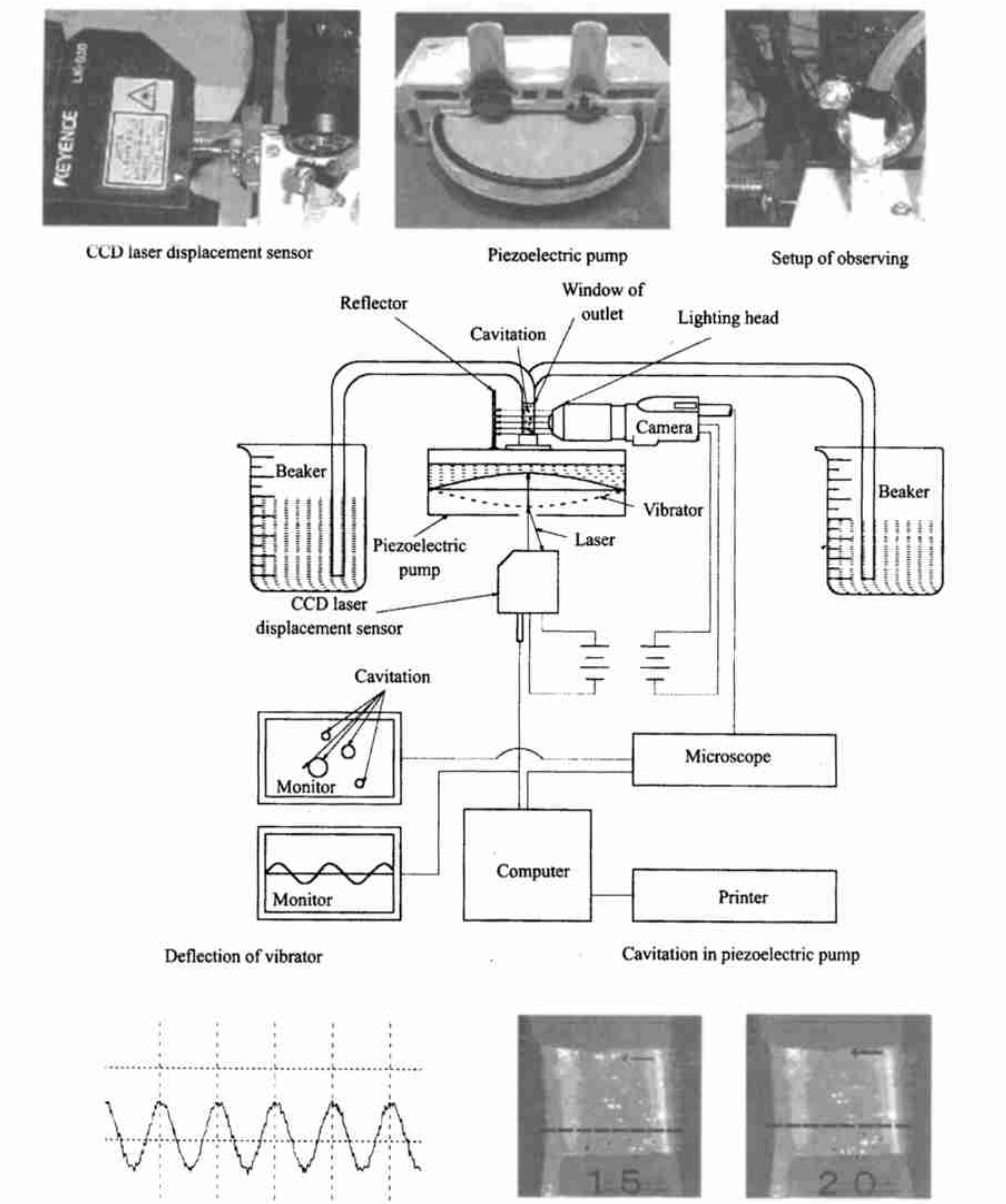


Fig. 4 Sampling system of cavitation in the piezoeletric pump.

6 Conclusion

(1). We have developed the method of applying cavitation in a pump, driven in the piezoelectric vibration form as a periodic non_continuous signal, to the sampling theorem. (2). We have manufactured a sampling system using the method of applying the sampling theorem to periodic non_continuous signals of cavitation in a piezoelectric pump. (3). Sampling experiments have been conducted with and without the sampling system and its effectiveness verified.

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抽样定理在周期性非连续信号的压电泵气穴现象中的应用方法

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摘要: 抽样时间间隔由抽样定理来决定。压电泵气穴现象所摄取的连续画像也应遵从该定理来抽取得到不连续的静止画像。可是, 作为由振动形式驱动的压电泵, 气穴现象只发生在吸入工程, 了解其气穴现象统计特性时, 如果按着抽样定理, 在吐出工程的半周期, 即使是不发生气穴现象也必须依次抽样。若利用这样的数据系统, 数据的样本将过大, 对其解析的时间性与经济性均不利。而且, 在吐出工程的

半周期,是与气穴无关系的信号。因此对于气穴现象数据系统,可以说是输入了错误情报信号。为此,开发了适用于压电泵气穴现象周期性非连续信号的抽样定理的方法;同时,利用这个方法,以有阀压电泵为例,调查了该泵的气穴现象特性之一的中心多发性,发现里利用新方法测得的中心多发几率高于原方法。

关 键 词:压电泵;数据处理;采样系统
中国分类号:TH38 文献标识码:A

作者简介:张建辉(1963-),男,吉林省长春人,博士。主要从事机械方面的研究。

中国仪器仪表学会第五届青年学术会议 征文通知

中国仪器仪表学会第五届青年学术会议将于2003年8月在天津大学召开。本次会议由中国仪器仪表学会青年工作委员会承办,天津大学协办。

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(1)论文应具有较高学术或应用价值,未公开发表;(2)第一作者年龄不超过45周岁(到2003年9月);(3)来稿请用Word97/2000编排,A4纸打印,一式三份并附软盘,排版要求请参考《仪器仪表学报》或《天津大学学报》,提供中英文摘要,全文控制在四个版面内;(4)来稿需注明文章所属类别(见征文范围),以及各类资助、获奖的项目名称和编号;(5)来稿另用A4纸打印论文题目、作者姓名、第一作者简历、通讯地址、邮编、电话、手机和电子信箱等;(6)版权纠纷,作者自负。

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本次会议录用的论文将刊登在《仪器仪表学报》或《天津大学学报》2003年的增刊上。

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四. 重要日期

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