International Journal of Medical, Medicine and Health Sciences
World Academy of Science, Engineering and Technology
ISSN: 2517-9969
Vol:5 2011-02-20
Vol:5, No:2, 2011

Experimental Technique for Vibration Reduction of a Motor Pump in Medical Device

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***Abstract*—**Many medical devices are driven by motor pumps. Some researchers reported that the vibration mainly affected medical devices using a motor pump. The purpose of this study was to examine the effect of stiffness and damping coefficient in a 3-dimensional (3D) model of a motor pump and spring. In the present paper, experimental and mathematical tests for the moments of inertia of the 3D model and the material properties were investigated by an INSTRON machine. The response surfaces could be generated by using 3D multi-body analysis and the design of experiment method. It showed that differences in contours of the response surface were clearly found for the particular area. Displacement of the center of the motor pump was decreased at K≈2000 N/M, C≈12.5 N-sec/M. However, the frequency was increased at K≈2000 N/M, C≈15 N-sec/M. In this study, this study suggested experimental technique for vibration reduction for a motor pump in medical device. The combined method suggested in this study will greatly contribute to design of medical devices concerning vibration and noise intervention.

***Keywords*—**Motor pump, Spring, Vibration reduction, Medical devices, Moment of Inertia

I. Introduction

VIBRATION is one of the side effects characterized in a motor pump with spring. Many medical devices are driven by motor pumps. The motor pump was constrained with springs in the medical device. It could directly influence mechanical responses such as vibration and noise. Thus, the effects of vibration could be related directly to the characteristic of the parts. The vibration generally occurred in 300 to 3600 rpm. The optimization is one of the most important techniques used in recent medical industry. To avoid the costs of research and development, we used design of experiments (DoE). In this paper, the effects of stiffness and damping coefficient were analyzed in order to reduce the vibration.

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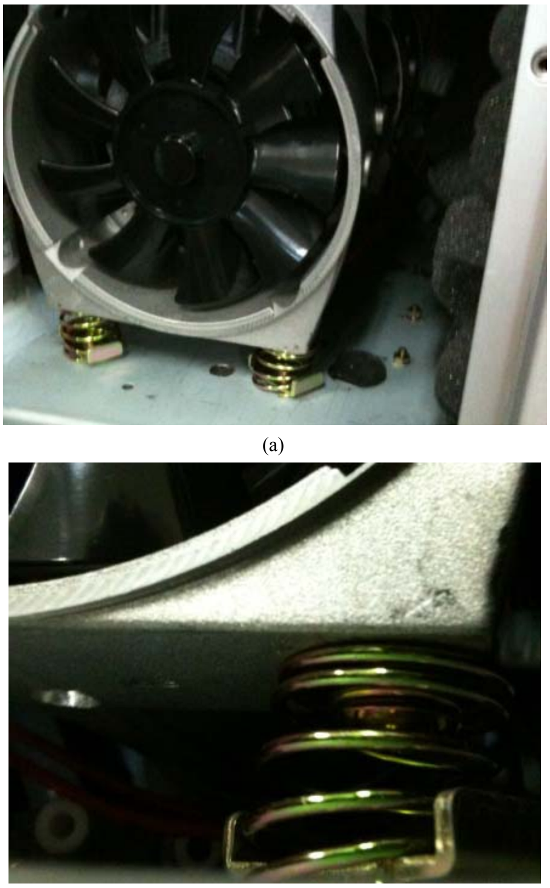
II. Method

A. 3- dimensional (3D) Modeling of Motor Pump and Spring

We consider a motor pump (Spatech Co., Korea) for vibration analysis (Fig. 1). The 3D model of motor pump and the spring was simplified and simulated by using a multi-body dynamic analysis software, MSC.ADAMS (MSC.Software Co., USA). Then a theoretical model is developed which accounts for stiffness (K) and damping (C) coefficient of the spring



(a)

(b)

Fig. 1 A typical (a) a motor pump (b) spring attached to the motor pump

World Academy of Science, Engineering and Technology
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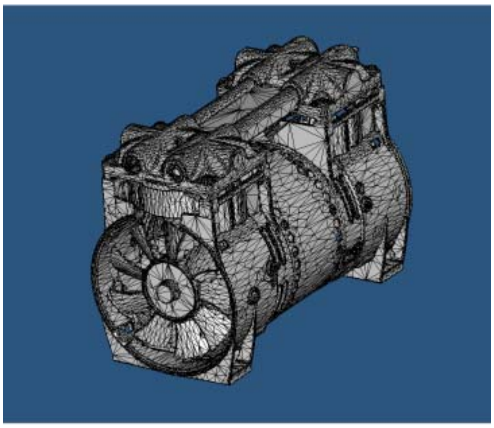


Fig. 2 A 3D model of motor pump

(Fig. 1(b)). The appearance of motor pump had been scanned by a 3D laser digitizing scanner (DS-2016, Laser Design, USA; Fig. 2).

B. Experiments and Calculation of Moments of Inertia (MoI) for the Motor Pump

To measure the MoI (I), we measured first of torque (τ) and angular acceleration (α) (Fig. 3).

$$I = \tau / \alpha$$
$$\alpha = a / r$$

Where, 'τ' is the torque induced by a small weight, 'a' is the acceleration, 'r' is the radius of a driving plate. Then, the weight-force (WF) was same as tension (T) of the string which was fastened between the driving plate under the motor pump and weight.

$$\tau = r \cdot T$$
$$\sum F = mg - T = ma$$

$$WF = T = m(g - a)$$

Where, 'm' is the mass, 'g' is the gravity acceleration. Therefore, the weight-force could be substituted with the following equation.

$$I = \tau / \alpha = r \cdot m(g - a) \div a / r = m \cdot r^2 \cdot (g / a - 1)$$

C. Experiments and Calculation for the Stiffness and Damping Coefficient of spring

Stiffness and damping coefficient of the spring was measured by experimental test with mathematical calculation (Fig. 4). The experimental test for the spring was performed by INSTRON (8874 series, Instron, UK). The material properties of the spring were obtained from tensile and compression tests

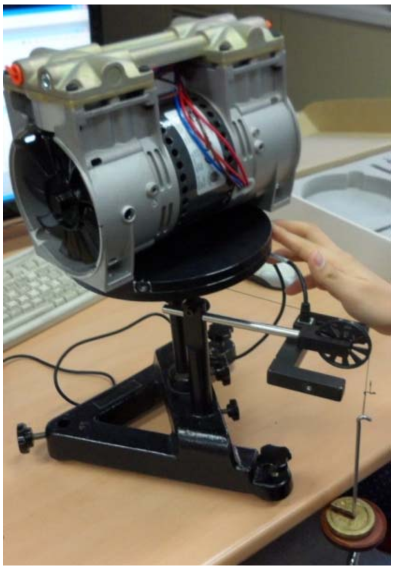


Fig. 3 An experiment of MoI for the motor pump

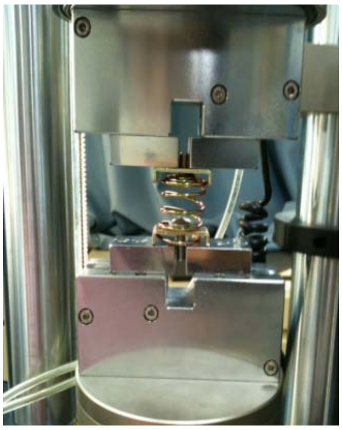
to calculate the stiffness and damping coefficients.

TABLE I
DESIGN OF EXPERIMENT BY USING CENTRAL COMPOSITE DESIGN

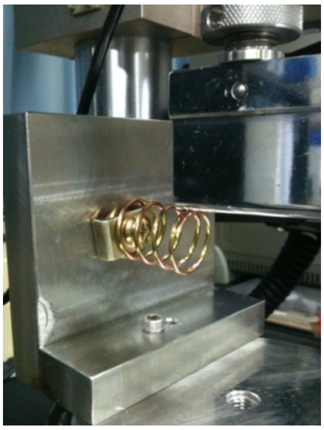
Test Number	Stiffness coefficient (N/M)	Damping coefficient (N-sec/M)
1	1190.35	4.68
2	1190.35	14.04
3	3571.05	4.68
4	3571.05	14.04
5	697.29	9.36
6	2380.70	2.74
7	2380.70	15.97
8	4064.11	9.36
9	2380.70	9.36
10	2380.70	9.36
11	2380.70	9.36
12	2380.70	9.36
13	2380.70	9.36

D. Response Surface Method

A total of 13 tests were designed and carried out in the central composite design (CCD) method (Table 1). The CCD, first described by Box and Wilson [1], is an experimental approach for seeking the optimal conditions for a multivariable system. Each experimental condition was applied to MSC.ADAMS.



(a)



(b)

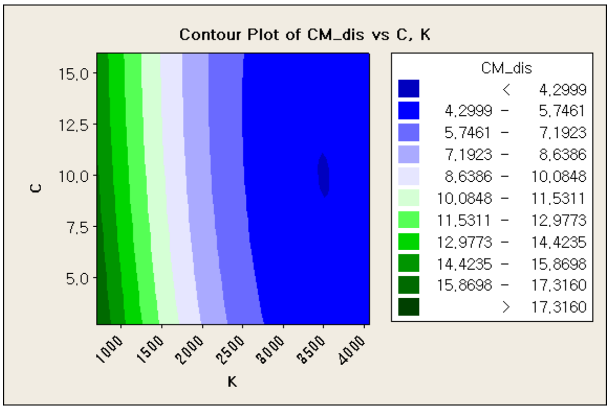
Fig. 4 An experiment to measure stiffness coefficient and damping coefficients of (a) vertical coefficients (b) horizontal coefficients

III. RESULT

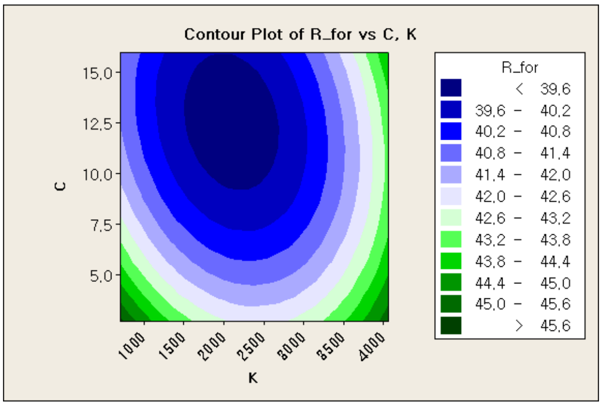
The result indicated that changes in stiffness coefficient affected displacement of the center of the motor pump more than damping coefficient (Fig. 5). It showed that reaction forces of spring were decreased due to stiffness and damping coefficients about K≈2000 N/M, C≈12.5 N-sec/M. However, as the result, the change of vibration frequency was increased at K≈2000 N/M, C≈15 N-sec/M.

IV. DISCUSSION

This study is a pilot study for analyzing vibration reduction of medical devices. We analyzed a multi-body model of a motor pump and springs for preventing side effects, such as vibration and noise, through an analysis of stiffness and damping coefficients. The purpose of the present study is to reduce vibration. The DoE and RSM method take simultaneously into account many variables and their interactions. The methods are also the most useful approach to obtain the optimized parameters when testing a minimum number of experiments. Therefore, it can be used in vibration reduction of a Motor Pump in Medical Device.



(a)



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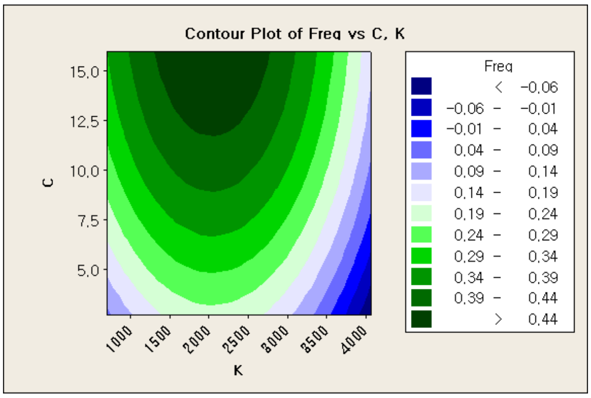

(c)

Fig. 5. (a) Displacement of the center of the motor pump (b) reaction force of spring (c) vibration frequency due to stiffness and damping coefficients

ACKNOWLEDGEMENTS

This research was supported by the Yonsei Medical Instrumentation Education Center in cooperation with Program in Gangwondo Leading Strategy Industry of the Nurturing and Training Talent.

REFERENCES

[1] Box, G. E. P. and Wilson, K. B., On the Experimental Attainment of Optimum Conditions, Journal of the Royal Statistical Society, 13(1): 1-45, 1951.