Pilot Study for Vibration Reduction of Medical Devices with using a Motor Pump

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SUMMARY
Many medical devices are operated by motor pumps. Some researchers reported that medical devices using a motor pump mostly affected the vibration. 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. 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.

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.

METHODS
A. 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 MSC.ADAMS (MSC. Software Co., USA). Then a theoretical model is developed which accounts for stiffness (K) and damping (C) coefficient of the spring (Fig. 1(b)). The appearance of motor pump had been scanned by a 3D laser digitizing scanner (DS-2016, Laser Design, USA; Fig. 2(a)).

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. 2(b)).

\[ I = \frac{\tau}{\alpha} \]  
\[ \alpha = \frac{a}{r} \]

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.

\[ T = r \cdot T \]  
\[ \sum F = m \cdot g - T = m \cdot a \]  
\[ WF = T = m \cdot (g - a) \]

Where, ‘m’ is the mass, ‘g’ is the gravity acceleration. Therefore, the weight-force could be substituted with Equation (6).

\[ I = \frac{\tau}{\alpha} = \frac{a}{r} \cdot m \cdot (g - a) \div a = \frac{m \cdot r^2 \cdot (g - a - 1)}{} \]

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; Fig. 3). The material properties of the spring were obtained from tensile and compression tests to calculate the stiffness and damping coefficients.
**Figure 3:** An experiment with the spring to measure and calculate stiffness coefficient and damping coefficients (a) for vertical coefficients (b) for horizontal coefficients

**D. Response Surface Method (RSM)**

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.

**Table 1: Design of experiment by using Central Composite Design**

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Stiffness coefficient (N/M)</th>
<th>damping coefficient (N-sec/M)</th>
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<tr>
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<td>4.68</td>
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<tr>
<td>2</td>
<td>1190.35</td>
<td>14.04</td>
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**RESULTS AND DISCUSSION**

It could confirm that changes in stiffness coefficient affected displacement of the center of the motor pump more than damping coefficient (Figure 4). And it showed that reaction forces of spring were decreased by stiffness and damping coefficients about $K \approx 2000$ N/M, $C \approx 12.5$ N-sec/M. However, in the result contours of vibration frequency were increased at $K \approx 2000$ N/M, $C \approx 15$ N-sec/M.

**CONCLUSIONS**

This study is a pilot study for analyzing vibration reduction of medical devices. We demonstrated a multi-body modeling 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 Response surface method take simultaneously into account many variables and their interactions. The methods are also the most convenient approach to obtain the optimized parameters when testing a minimum number of experiments. Therefore, it can be wonderfully used in a multi-body dynamic analysis.

**Figure 4:** (a) Displacement of the center of the motor pump (b) Change of reaction force of spring (c) Change of the result contours of vibration frequency by change stiffness and damping coefficients

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**REFERENCES**