Dynamics of Cavity Resonator Speaker System(4)
Generalized Multiple Degree of Freedom Cavity Resonator

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1. Preface

It was found that Multiple Degree of Freedom Cavity Resonator(MDOF-CR) may be generalized. Here is the summary of generalized MDOF-CRs. New MDOF-CR is presented in this report.

2. Multiple-Degree of Freedom Cavity Resonator (MDOF-CR) Speaker System

Multiple Chamber Aligned in Series(MCAS) or Multiple Chamber Aligned in Parallel(MCAP) is equipped with two or more ducts, hence each one of these should be called as a type of MDOF-CR. These systems have different equations of motion; however, solution of these equations are essentially the same. MCAS-CRs and MCAP-CRs are typical MDOF-CRs.

3. Combined MCAS and MCAP-CR and CBS-CR

Fig.1a, b shows two types of generalized MDOF-CRs.。

| Fig. 1a Combined MCAS/MCAP | Fig. 1b CBS-CR Carbon Bond Structured |
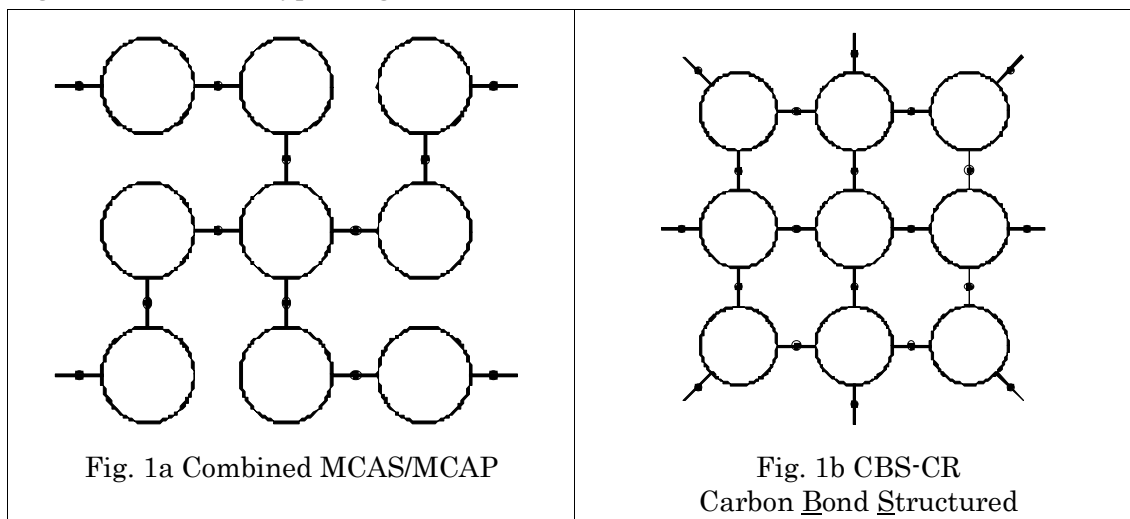
Combined MCASS/MCAP-CR has well organized equations of motion. This may be practical; however, if number of connected series is large (say 3 or greater), quality of sound that goes through many ducts may become worse. Fig.1a may be the practical limit of this type. This cavity resonator has 12 characteristic frequencies. We may not

need more characteristic frequencies.

CBS-CR shown in Fig.1b is another practical MDOF-CR. If rectangular chambers are arranged in a plane, this connection is very practical. This type has 20 characteristic frequencies, so we may not need more chambers than Fig.1b, while theoretically there is no limit of connected chambers. The name of CBS (Carbon Bond Structured) does not have any chemical meanings: just this seemed like carbon bonds to me.

3.1 Carbon Bond Structured Cavity Resonator (CBS-CR)

We may not need to discuss equations of motions of combined MCAS/MCAP, because they are easily extended from MCAP equations.

CBS-CR has more characteristic frequencies than MCAS or MCAP, if number of chambers is same. Equations of CBS-CR are so complicated, I reduced the number of chambers like Fig.2. This resonator has 12 characteristic frequencies.

$$m_0\ddot{x}_0 + \left(k_u + k_0 r_0^2\right)x_0 + k_0 r_0\left(r_1 x_1 + r_2 x_2 + r_3 x_3\right) = f(t)$$
$$m_1\ddot{x}_1 + k_0 r_1\left(r_0 x_0 + r_1 x_1 + r_2 x_2 + r_3 x_3\right) + k_1 r_1\left(r_1 x_1 - r_4 x_4 - r_8 x_8\right) = 0$$
$$m_2\ddot{x}_2 + k_0 r_2\left(r_0 x_0 + r_1 x_1 + r_2 x_2 + r_3 x_3\right) + k_2 r_2\left(r_2 x_2 - r_5 x_5 - r_9 x_9\right) = 0$$
$$m_3\ddot{x}_3 + k_0 r_3\left(r_0 x_0 + r_1 x_1 + r_2 x_2 + r_3 x_3\right) + k_3 r_3\left(r_3 x_3 - r_6 x_6 - r_7 x_7 - r_{10} x_{10}\right) = 0$$
$$m_4\ddot{x}_4 + k_1 r_4\left(-r_1 x_1 + r_4 x_4 + r_8 x_8\right) + k_4 r_4\left(r_4 x_4 + r_6 x_6 - r_{11} x_{11}\right) = 0$$
$$m_5\ddot{x}_5 + k_2 r_5\left(-r_2 x_2 + r_5 x_5 + r_9 x_9\right) + k_5 r_5\left(r_5 x_5 + r_7 x_7 - r_{12} x_{12}\right) = 0$$
$$m_6\ddot{x}_6 + k_3 r_6\left(-r_3 x_3 + r_7 x_7 + r_{10} x_{10}\right) + k_4 r_6\left(r_4 x_4 + r_6 x_6 - r_{11} x_{11}\right) = 0$$
$$m_7\ddot{x}_7 + k_3 r_7\left(-r_3 x_3 + r_6 x_6 + r_{10} x_{10}\right) + k_5 r_7\left(r_5 x_5 + r_7 x_7 - r_{12} x_{12}\right) = 0$$
$$m_8\ddot{x}_8 + k_1 r_8\left(-r_1 x_1 + r_4 x_4 + r_8 x_8\right) = 0$$
$$m_9\ddot{x}_9 + k_2 r_9\left(-r_2 x_2 + r_5 x_5 + r_9 x_9\right) = 0$$
$$m_{10}\ddot{x}_{10} + k_3 r_{10}\left(-r_3 x_3 + r_6 x_6 + r_7 x_7 + r_{10} x_{10}\right) = 0$$
$$m_{11}\ddot{x}_{11} + k_4 r_{11}\left(-r_4 x_4 - r_6 x_6 + r_{11} x_{11}\right) = 0$$
$$m_{12}\ddot{x}_{12} + k_5 r_{12}\left(-r_5 x_5 - r_7 x_7 + r_{12} x_{12}\right) = 0$$

$$\cdots\cdots(1)$$

Refer to MCAP001E for definition of symbols.

Fig.2 12 DOF CBS-CR

(1) is equations of motion of forced vibration of 12DOF CBS-CR. CBS-CR may be better than MCAP-CR with same number of chambers.

We may reduce the number of CBS-CR to 4. This case, it has 7 characteristic frequencies.

Solution of CBS-CR is pretty much the same as MCAP solution that is described in MCAP001E. We eliminate the first equation from equations (1) in order to make forced

vibration to free vibration, then calculate stiffness matrix and mass matrices, then solve

$$\left| \mathbf{K} - \lambda \mathbf{M} \right| = 0 \,.$$

Then we get eigenstate values of CBS-CR, and eigenstate values are converted to characteristic frequencies as expressed in MCAP001E.

4. Summary

MCAS-CR, MCAP-CR, Combined MCAS/MCAP-CR, and CBS-CR are typical MDOF-CRs. MDOF-CRs are thus flexible and extendable. Calculation methods and solutions have been introduced, so anyone can design and develop one's own MDOF-CR speaker systems.