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Ergin Tasdelen
ARCELIK AS, Turkey, ergin_tasdelen@arcelik.com

Atilla Kaya
ARCELIK AS, Turkey, atilla.kaya@arcelik.com

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Investigation of the Effects of Coil Spring on Discharge Tube

*Ergin TASDELEN[1], Atilla KAYA[2]

[1]Arcelik AS, Compressor Plant, R&D Department
26110 Eskisehir, Turkey
Phone: +90 222 213 43 43, Fax: +90 222 213 43 44,
Email: ergin_tasdelen@arcelik.com

[2]Arcelik AS, Compressor Plant, R&D Department
26110 Eskisehir, Turkey
Phone: +90 222 213 43 43, Fax: +90 222 213 43 44,
E-mail: atilla.kaya@arcelik.com

*Corresponding Author

ABSTRACT

In this paper, effects of coil spring and coil spring parameters on vibration and acoustic characteristics of compressors are studied. Different tube and spring combinations are prepared and analyzed in order to compare the frequency response function of tube as well as no spring situation. Vibration responses of coil springs are investigated by experimental studies. Results are compared with numerical model. The numerical methods can be used to study the vibration characteristics of a compressor and decreases the need of preparing several prototypes.

1. INTRODUCTION

In hermetic compressors, one of the vibration transmission paths from main body to the shell is discharge tube. The main parts of discharge tube are tube part, coil spring on the tube and resonator cap. The end which is mounted to main body is excitation point. The point that tube is fixed to the shell is evaluation point to investigate the transmitted vibration energy towards compressor shell.

The coil spring on the tube has two main effects on tube. One of them is the mass effect. The usage of coil spring creates additional mass to the discharge tube and it causes change of natural frequency of discharge tube. The other one is the damping effect. Coil spring on discharge tube creates impact damping and reduces vibration kinetic energy of discharge tube.

The coil spring parameters effect vibration and acoustics characteristics of compressor therefore these parameters should be determined carefully.

2. EFFECTS OF COIL SPRING

Discharge tubes should provide two main functionalities in compressor. One of them is discharging of the pressurized refrigerant gases and the other one is reduction of vibration which is transmitted from main body through the shell. For vibration reduction function, coil spring on discharge tube has importance. Discharge tube is a vibration transmission path and because of its complexity of shape, design is performed most of times by trial and error method with some good engineering judgment.

Coil spring on discharge tube adds nonlinear characteristics to discharge tube. This causes modeling of this system analytically very challenging job. Some previous studies tried to model this complex system, and Wang and Park (2006) are modeled this system by using 2-degree of freedom impact damper system. Wang and Park (2006) stated that coil spring can have two different effects on vibration characteristics of discharge tube according to phase synchronization of coil spring and discharge tube. When out-of-phase, because of impact mechanism, momentum transfer occurs. However, in-phase case coil spring shows mass loaded effect.

Coil spring have some design parameters. These parameters are length of spring, spring constant, clearance between spring and discharge tube, position of spring, spring constant and etc. All these parameters should be selected carefully during design processes.

3. EXPERIMENTAL STUDY

To understand effects of coil spring and also coil spring parameters, an experimental study is done. Hammer test is used to obtain Frequency Response Functions of specimens. In real working conditions, discharge tube is excited from resonator cap by main body and it transmits the vibration energy to the shell from the other end of tube. Discharge tube is welded to shell by using an interconnecting tube. To simulate this configuration in experimental study, resonator cap is at free condition and other end of discharge tube is fixed to ground. Excitation forces are generated in compressors by piston mechanism and unbalanced inertia. In experiment, a hammer is used to excite specimen. Evaluation point is selected a near point to shell end, from this point by using accelerometer response of system is measured. Experiments are made multiple times for each specimen to check stability of experiment system.

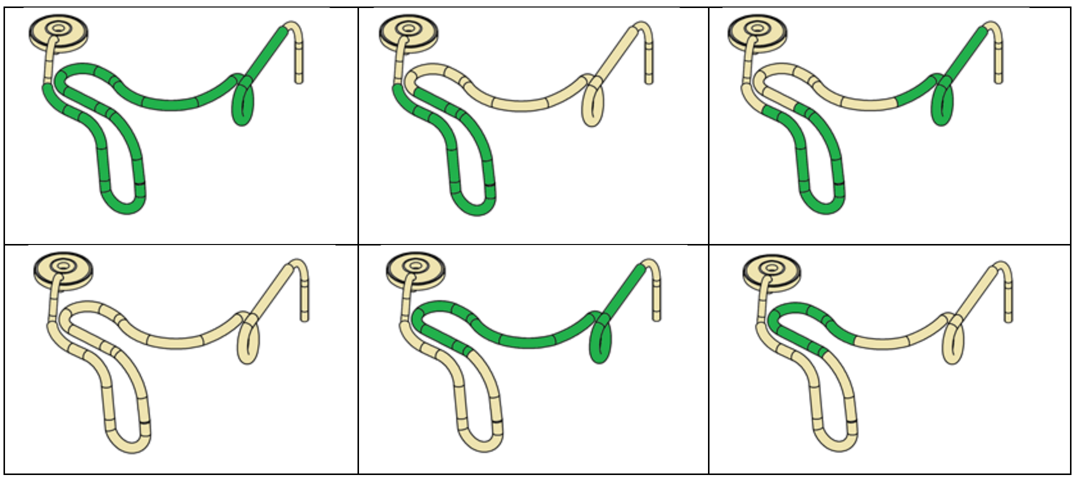


Figure 1 : Experimental Testing Specimens

In this experimental study, spring length and spring position parameters are variable parameters. By chancing them, six different type specimen sets are obtained. One of type does not have any coil spring on it. This type is needed to create a baseline to understand effects of coil spring in detail.

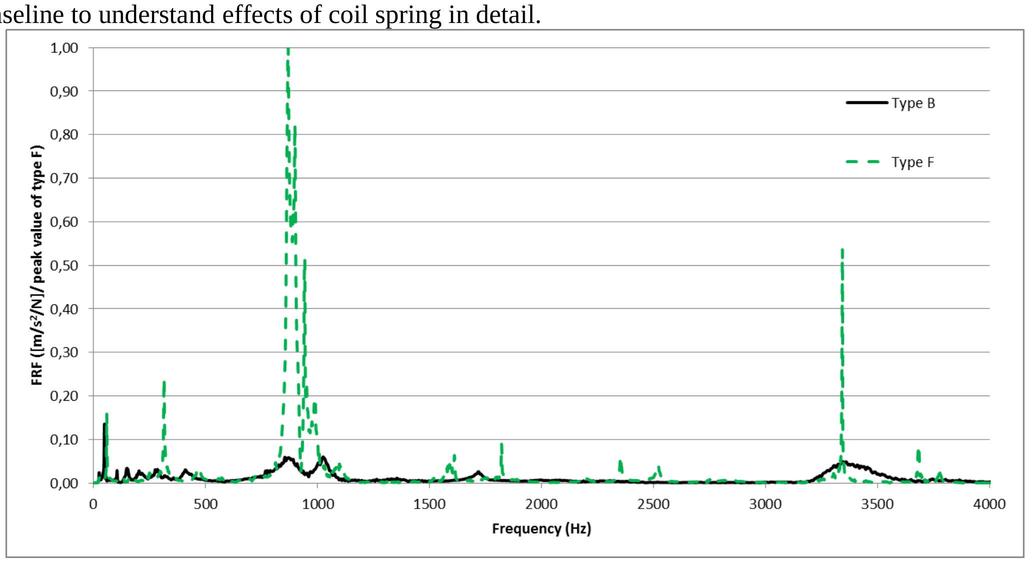


Figure 2 : Experimental FRF results of Type B and Type F

Figure 2 shows that experimental test results of type B and F. Type F does not have any spring on discharge tube. In higher frequencies, especially after 500 Hz, damping effect of spring comes up. Effects of coil spring on discharge tube observed similarly in previous studies. (Wang *et al*., 2004)

The Figure 3 shows that lower frequency responses of type B and F. In this figure, mass loading effect of coil spring causes a shifting to lower frequencies of peaks of type B with respect to peaks of type F.

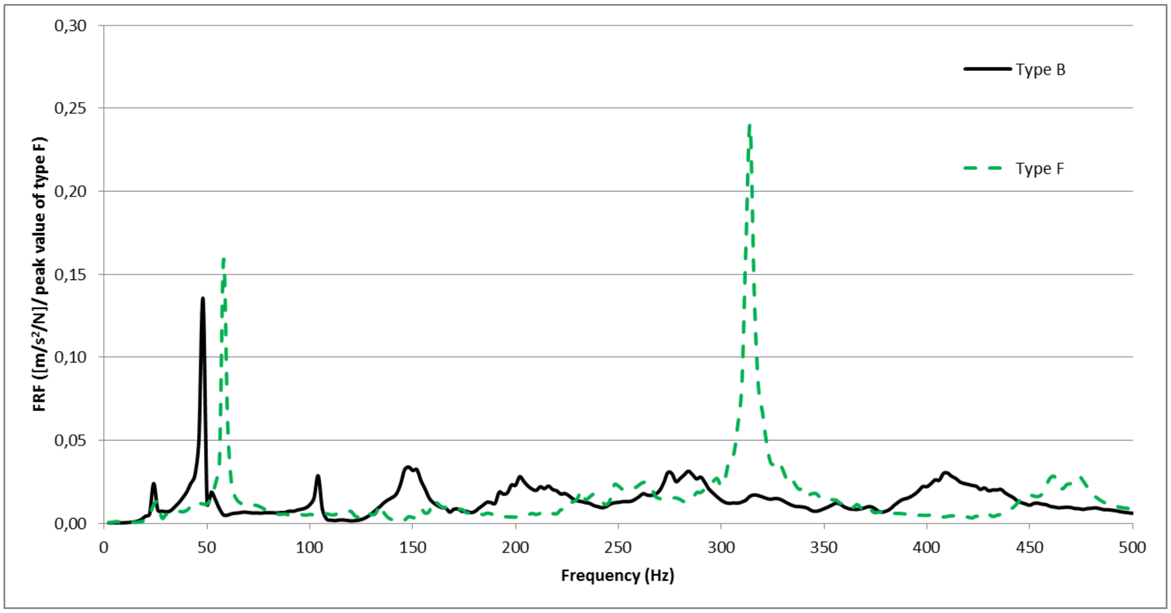


Figure 3: Experimental test results of type B and type F at lower frequencies

4. NUMERICAL ANALYSIS

Discharge tube has complex shape and also nonlinear characteristic because of coil spring on it. Therefore, analytical analysis and also a complete numerical analysis are very competitive duties. Samples or prototypes should be prepared for experiments. Tests should be done multiple times with multiple samples, so all of these take times. However, numerical analysis can be done easily and after verification of model is done, it needs less time than experiments.

A numerical model is created to investigate effects of coil spring on discharge tube. In this numeric analysis, main area of concern is mass effect of coil spring. Six different spring and tube combinations were created in experimental tests. Same six combinations are modeled numerically. Additional masses are created on discharge tube at specific locations to simulate experiment specimens.

To obtain same results with experiments, boundary conditions of numerical analysis are selected as same and also material properties are defined with respective to real material properties. Investigated frequency range is also defined same as experimental test results.

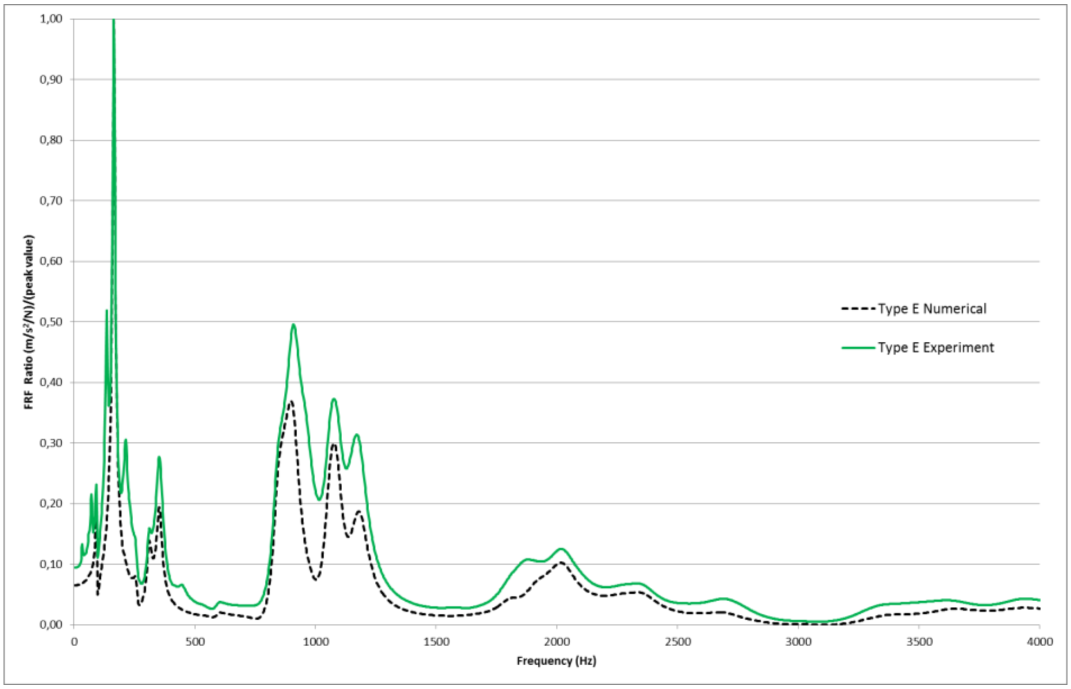


Figure 4 : Experimental tests and Numerical analysis results of Type E

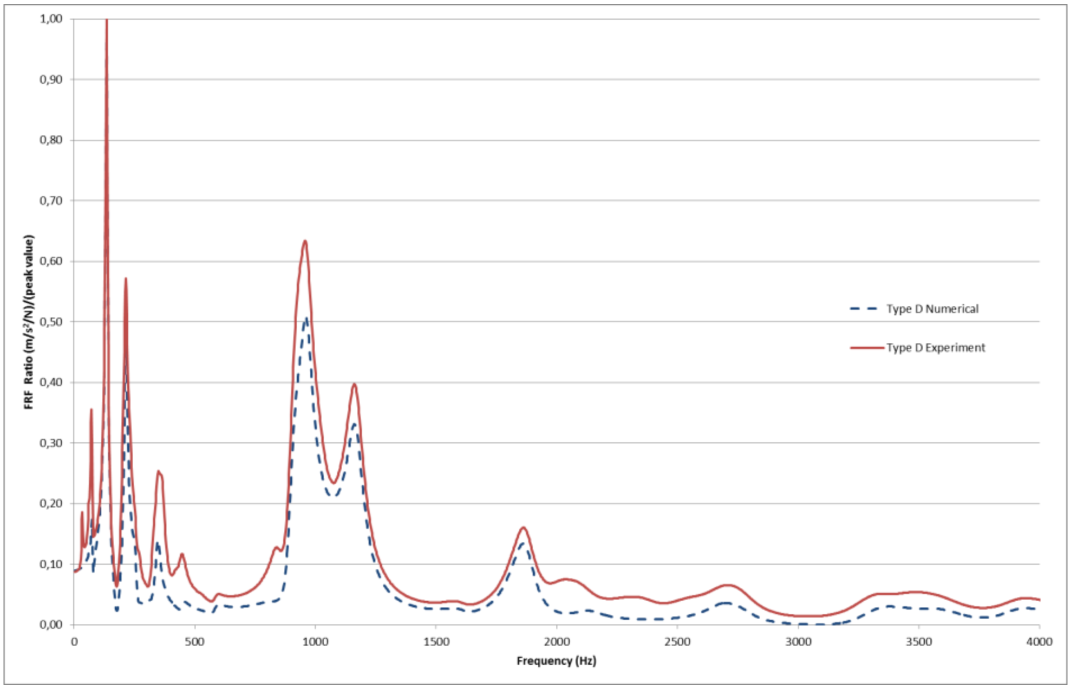


Figure 5 : Experimental tests and Numerical analysis results of Type D

Figure 4 and Figure 5 show that numerical analysis results are suitable with experimental results at both lower and higher frequencies. Peaks occur at same frequencies in results of numerical and experimental studies. According to these results, numerical analysis can be useful for design processes.

5. EVALUATION AND COMPARISION OF RESULTS OF TYPES

Numerical results are suitable with experimental results therefore types of samples can be evaluated by using numerical analysis.

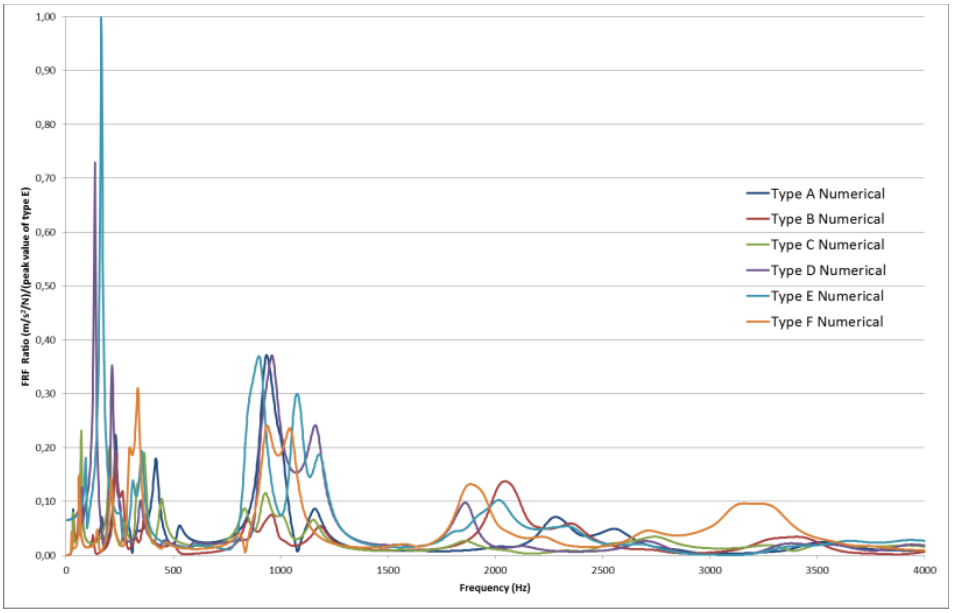


Figure 6 : Numerical analysis results of six types

Figure 6 shows that frequency response function graph of different coil spring and discharge tube combinations. Type F does not have any spring on tube; as a result of this it has high vibration amplitudes at frequencies between 3000 Hz and 3500 Hz. Figure 7 shows this trend obviously. The other types have spring on different locations with different length. These types do not have high vibrations at high frequencies. Spring provides positive effect at that frequency range.

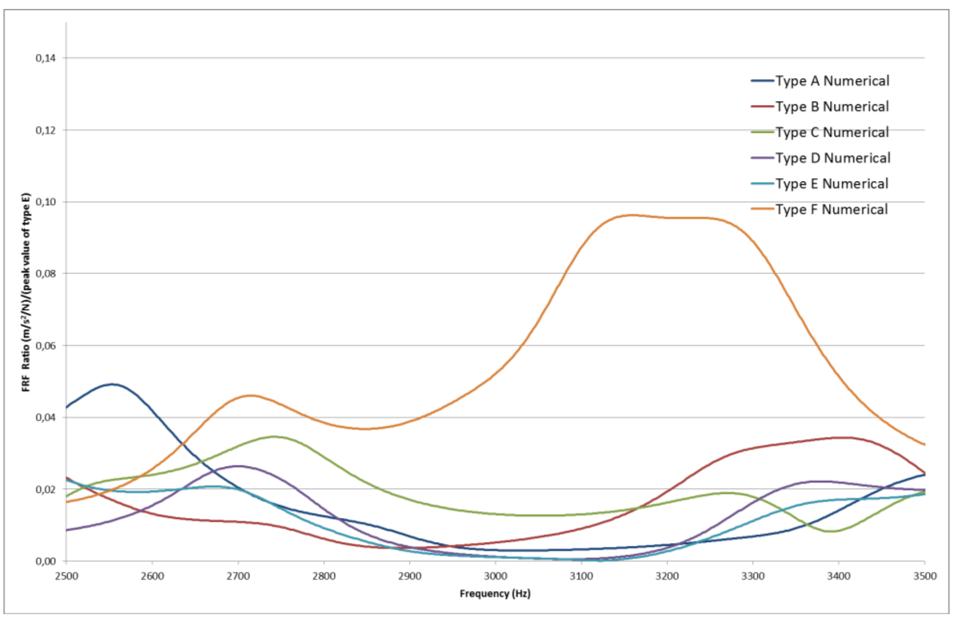


Figure 7 : Responses of different types at high frequencies

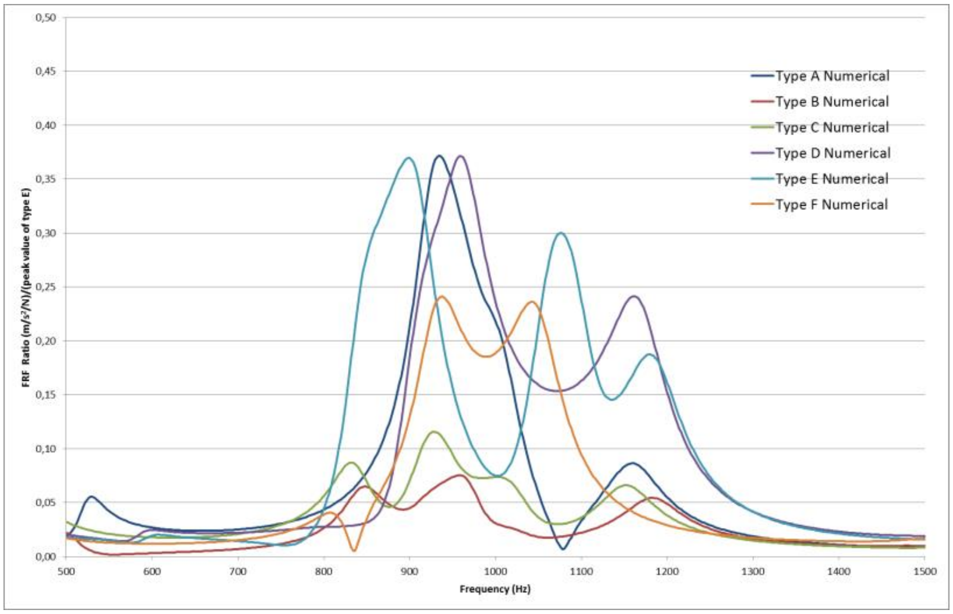


Figure 8 : Responses of different types at mid frequencies

Figure 8 shows that type B and type C have lower amplitudes than others at frequency range between 500 Hz and 1500 Hz. At lower frequencies between 100 Hz and 200 Hz, type D and type E vibrate high amplitudes. In contrast, vibration of type F has very low vibrations at same range which is shown in Figure 9. As a result of this, coil spring causes negative effect for these low frequencies.

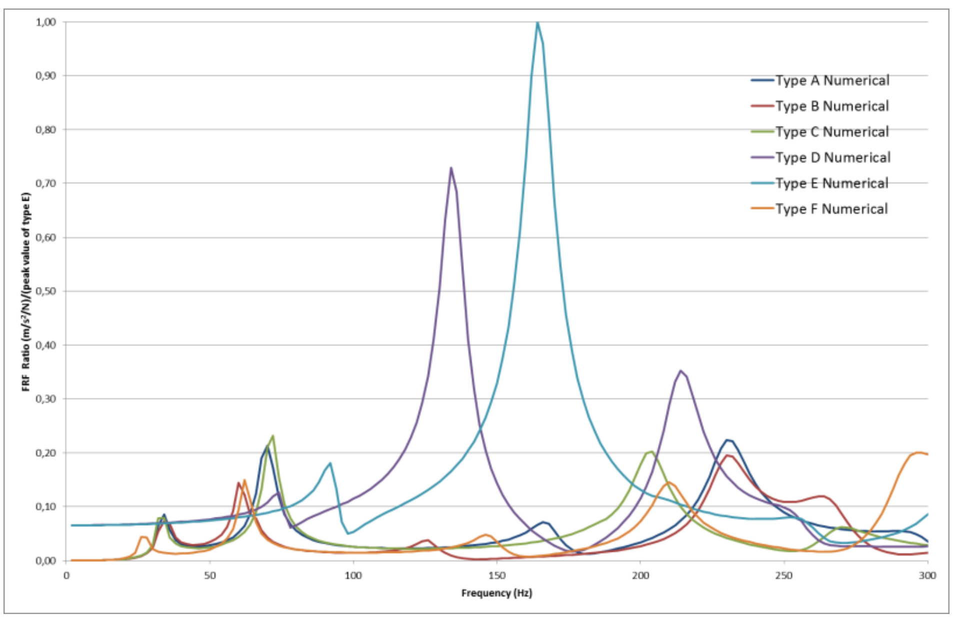
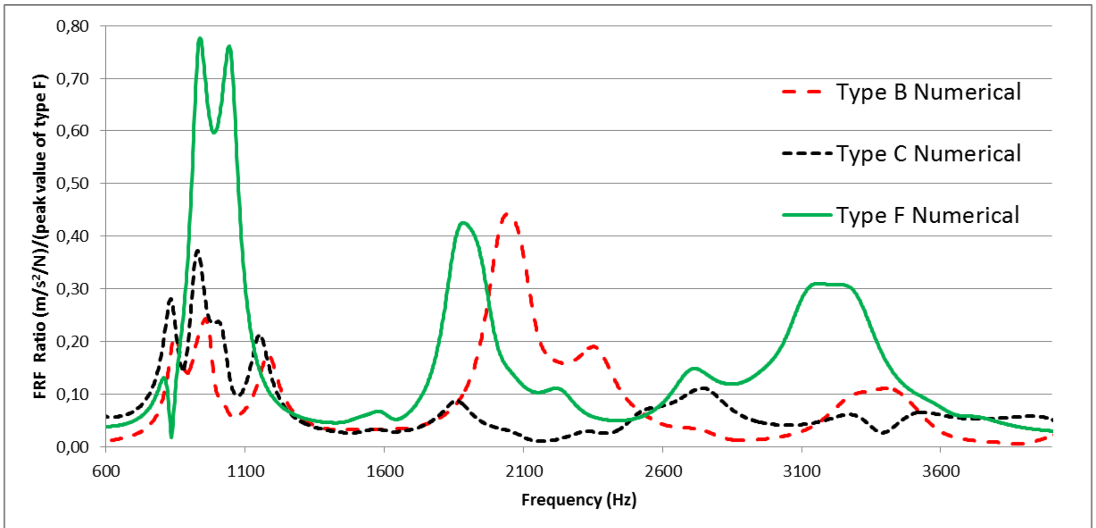
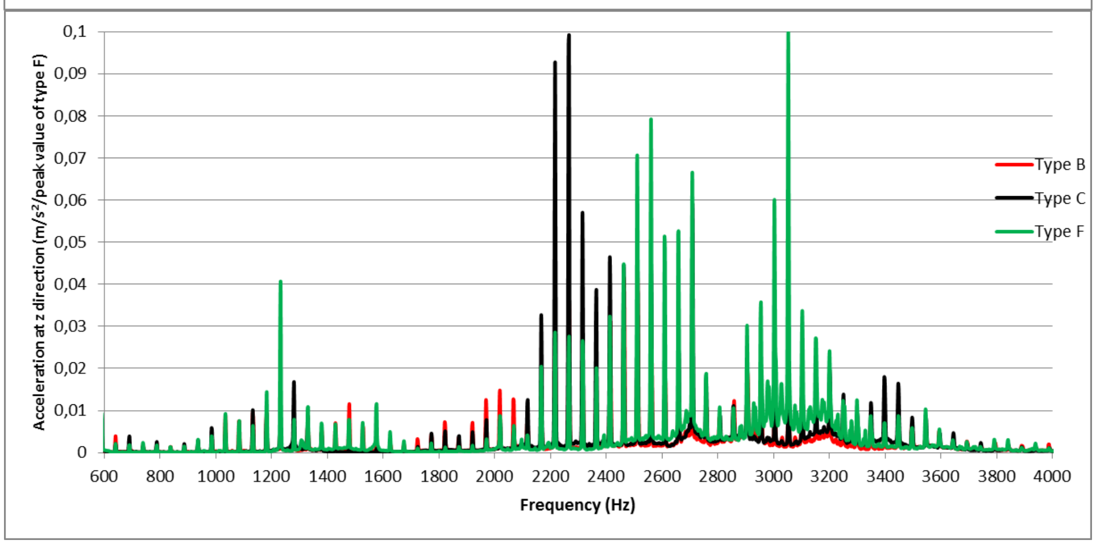


Figure 9 : Responses of different types at low frequencies

Prototype compressors are prepared to see effects of these different vibration characteristics on compressors. Vibration and sound measurements of all of prototypes are performed. In below Figure 10, first graph shows that numerical analysis results of type B, C and F discharge tubes. The second graph indicates that vibration measurement of compressor which is prototyped by using these three types and last graph shows sound measurement of compressors. Type F has higher vibration amplitudes than type B and C at frequencies about 3000 Hz. This reflects negatively on sound and vibration results of type F used in compressors. There is a resonance peak between 800 Hz and 1200 Hz in FRF graph of type F discharge tube. As a result of this, sound pressure level of this type compressor is higher than other types about 1250 Hz. All of these do not have any peak about 1600 Hz and sound level of all are low; therefore, spring has no effect on compressor vibration and sound characteristics about this frequency.





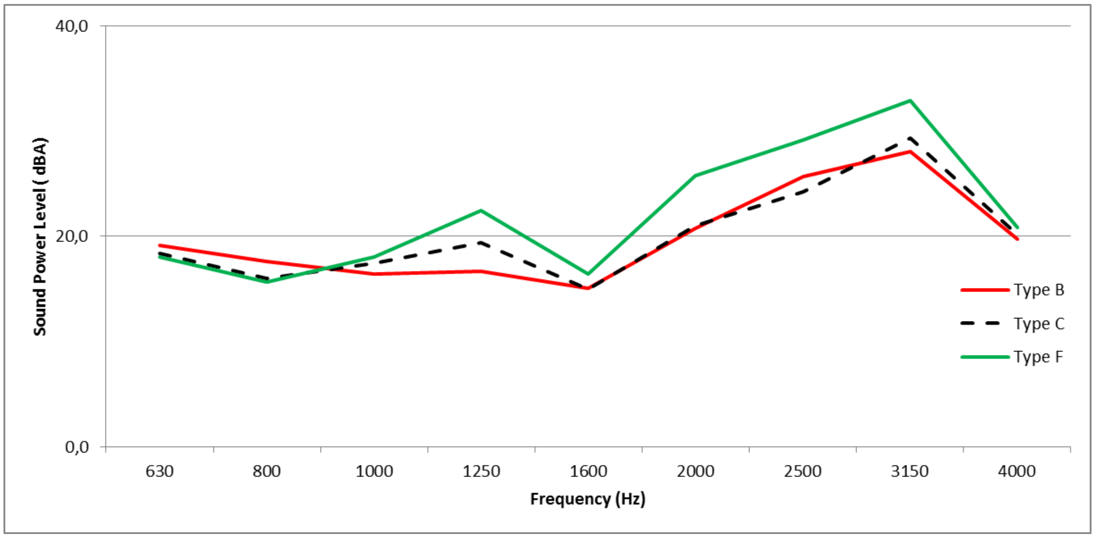


Figure 10 : Numerical analysis results of discharge tubes, sound and vibration measurement results of compressors with type B, C and F samples

6. CONCLUSIONS

Discharge tube on compressors has geometrical complexity and coil spring on it causes nonlinearity therefore analytical analysis of discharge tube with coil spring became very hard and it needs detailed study. Experiments can be used to overcome this problem and obtain desired designs by changing parameters. However, most of time experiments are needed so much time and repetitive tests. Numerical analysis is another design tool for engineers but numerical solutions should be verified initially.

In this paper, by changing length and position of coil spring on discharge tube different groups are created. By making hammer test, frequency response functions of specimens are obtained. After that, numerical model is prepared by using mass effect of coil spring. Numerical analysis is performed for six different types. Results of numerical and experimental studies are compared and numerical results show similarity with experiments. After numerical model is verified, by using numerical results effects of coil spring are investigated. These effects are observed on compressor by using sound pressure level and vibration measurements. The peaks which are observed on numerical and experimental analysis reflect negatively on sound measurements of compressor. As a result of this, numerical model is useful for pre-design processes of discharge tube with coil spring of compressors.

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ACKNOWLEDGEMENT

The authors gratefully acknowledge to Associate Professor Ender Cigeroglu, Middle East Technical University for valuable discussions about nonlinear vibrations.