Analysis of Domestic Split Unit Air Conditioning System of Outdoor Unit

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Abstract — This paper presents the results of FEA analysis carried for domestic split unit air conditioner system outdoor unit. In the current investigation dynamic analysis is carried out to know the natural frequency of the outdoor unit to check the resonance. So what is resonance?-The resonance is phenomena which is occur due to matching of natural frequency with the external excitation frequency, Due to this we can observe high amplitude of vibration and it leads to failure. In the current work the external excitation is due to AC fan motor and air compressor.

The current work is carried out using software tools CATIA, HYPRMESH, NASTRAN and HYPERVIEW. The Finite Element Method (FEM) is the most commonly used numerical technique, which provides accurate estimates of vibration parameters for these classes of problem. In this work it is found that the natural frequency does not match with excitation frequency. This results in the normal operation of split unit air conditioner system outdoor unit.
Keywords: Air conditioner, CATIA, Model analysis, HyperMesh, Nastran.

INTRODUCTION

Air conditioners are typically categorized into split-type and multi-type air conditioners. Split-type air conditioners have an indoor unit and an outdoor unit connected by communication pipes. Multi-type air conditioners have plural indoor units connected to an outdoor unit. Air conditioners may also be categorized into ones that air conditioners operate a refrigerant cycle in one direction to only supply a room with cool air, and ones that selectively operate a refrigerant cycle in two directions to supply a room with hot or cool air. Now days, mostly every home has their own air conditioner system is to provide comfort during hot days and nights. A frequent problem for the air conditioner manufacture is the noise comes from the air conditioner. Noise is considered undesirable and the cause of the noise may in some cases even limit the heating or cooling efficiency of the air conditioner [1].

Many mathematical models have been proposed in the past for modeling refrigeration systems. These models can be classified as steady state and transient simulations. Steady state simulations are commonly used for performance prediction and product design.[2]. For particular applications, efficiencies of both living and non-living creatures depend, as it were, on the physical environment. The nature keeps conditions in the physical environment in the dynamic state extending from one great to the next. Temperature, mugginess, weight and air movement are a percentage of the critical environment variables that at any area continue changing as the year progressed. Adjustment to these numerous a times an eccentric variety is unrealistic and hence meeting expectations productively is not attainable either for the living creatures or the non-living ones. In this manner for any particular reason, control of nature is crucial. Refrigeration and cooling is the subject which manages the methods to control the situations of the living and non-living subjects and consequently give them solaces to empower them to perform better and have longer lives [3].

Increasing concern about noise from electrical devices has led to increasing demand for quieter cooling fans. With the increasing of small axial fans released on the market, it is difficult to judge which ones have better acoustical performance [4]. The development and implementation of an online disturbance state-filter for the suppression of multiple unknown and time-varying vibrations of air conditioning systems. The proposed design has a form of the state-filter based on a Luenburger-style closed-loop speed observer [5].The clamor delivered by a ventilating and warming unit may be brought about by a few mechanical and aeromechanic sources, including: vibration of the compressor shell, electric engine vibration, and fan commotion. The compressor shell vibration and subsequent acoustic radiation may be investigated expecting the methods of vibration to be equal to a conveyed monopole source field [6]. A couple of test and numerical studies have been found of barbecues and supporting development's real effect on the exact determination of fan's working trademark. However those studies have not explored the reason for working point change particularly on the air acoustic field [7]. When the rotary compressor *is* operated at a relatively high frequency range (such as 30 Hz - 90 Hz) and the reciprocating compressor is operated at a relatively low frequency range (25Hz-75Hz), the capacities of these compressors *in* proportion to a change in operating frequency can be obtained with low input and at high efficiency [8].

METHODOLOGY

In this work, three dimensional modeling was carried out using Catia V5, HyperMesh is used as a preprocessor tool and the discretized component is solved using Nastran tool.

Dynamic analysis (free natural frequency) carried out to determine the natural frequency of split air conditioner system outdoor unit. This is done mainly to determine weather is system under the influence of resonance or not. The excitation frequency of split unit air conditioner system outdoor unit should not match with natural frequency of any of member of split air conditioner system outdoor unit. The iges file is imported to the HyperMesh. The element type and element size were to be determine by the geometry and size of structure. These are the following different type of element used based on the component geometry.

Table 1.Different type of element and component

Element	Type of element	Component
1D	C bar	Back side grill
2D	SHELL (quad)	Top cover, front cover, right side cover, left side cover, supporting stand, fans, air compressor
3D	SOLID (Hexa)	Finn & condenser

The RBE2(rigid body element) entity stimulate an infinitely rigid element which couple a set of nodes/dofs by enforcing the same amount of motion for each of them, which simply yield in no relative displacement between the nodes upon it is attached. In this analysis the RBE2 is used to stimulate a rigid connection and pin joints. Similarly RBE3 is an interpolation element which defines a linear relationship between nodes/dofs and is usually used to distribute loads and mass upon the corresponding nodes and to constrain the displacement of one node by the weighted average of the displacement of the other nodes. The AC motor fan was idealized or simulated using a CONM2 and RBE3 element. CONM2 element was to represent the mass of AC motor fan and RBE3 being deformable element transfers the load to the supporting structure.

CAD AND FEM DESCRIPTION

GENERAL ASSEMBLY

A concept of split air conditioner outdoor unit was developed using CATIA V5 and is shown in Figure 1.

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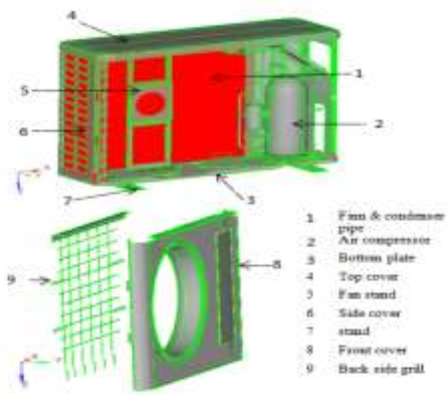

Figure 1: Three Dimensional Model and different parts

MESHED 3D MODEL OF SPILT UNIT AIR CONDITIONER SYSTEM OUTDOOR UNIT

The 3D model was imported and meshed using the HyperMesh (v11.0) tool as shown in Figure2. The FE modelling of a back side grill is carried using the CBAR element (1D) because one of the dimension is very large compared other two. The components like covers, compressor, and stand are modelled using 2D shell elements. In Finn and condenser pipe all the dimensions are dominant so the FE modelling of these components is carried by 3D Hexa elements.

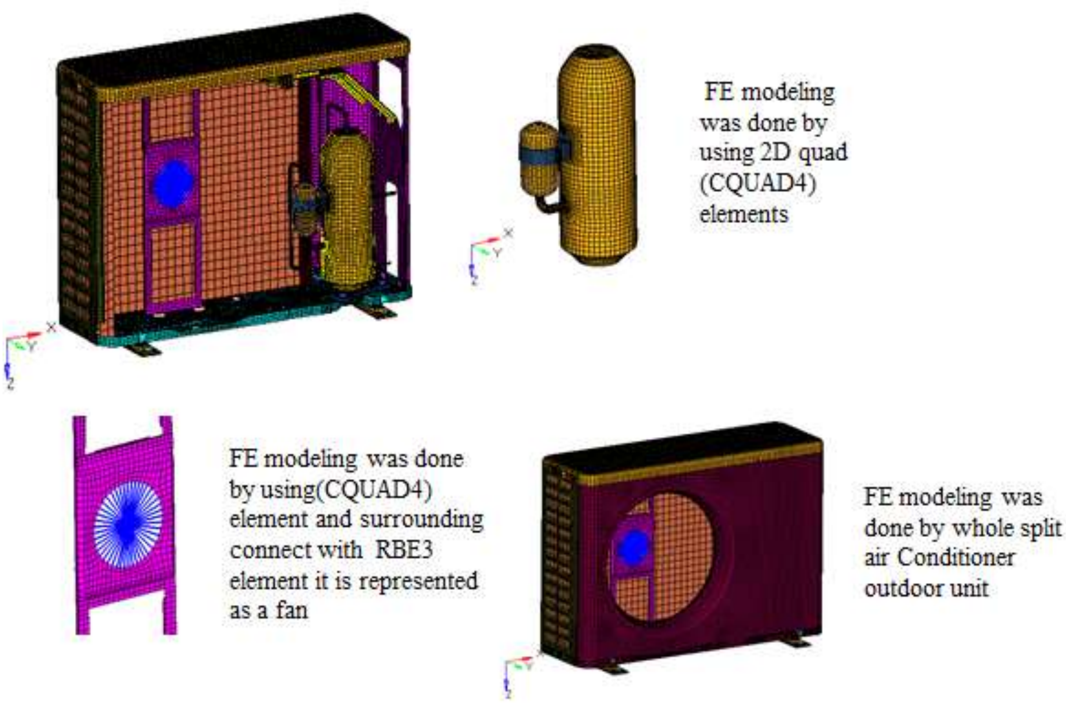

Figure 2: Finite element model of split unit air conditioner system outdoor unit

Table 2.FE model summary

Model summary		
Number of grid	Points	52041
Number of CBAR	Elements	1167
Number of CONM2	Elements	*3*
Number of CQUAD4	Elements	44163
Number of RBE2	Elements	480
Number of RBE3	Elements	3
Number of HEXA	Elemnts	1924

MATERIAL PROPERTIES

Spilt unit air conditioner system outdoor unit is manufactured with the help of material such as, galvanized sheet metal, copper alloy and mild steel. All the cover is of galvanized sheet metal due to good anti corrosive of property. All condenser pipes should transfer heat and temperature respectively. In order to transfer the heat and temperature properly we are using copper alloy. Instead of copper aluminum alloy can be used, as it being a light in weight.

The following are the metal properties for that are used in the component:

Table 3. Material properties

Sl.no	Material	Mechanical properties		
		E	μ	ρ
1	Galvanized sheet metal	$2E10^5$ N/mm^2	0.3	$7.85e10^{-9}$ $tonnes/mm^3$
2	Copper alloy	$1.25E10^5 N/mm^2$	0.33	$9.75e10^{-9}$ $tonnes/mm^3$
3	Mild steel	$2.10E10^5 N/mm^2$	0.3	$7.89e10^{-9}$ $tonnes/mm^3$

BOUNDARY CONDITIONS

The split unit air conditioner system is standing on the supporting stand and these stands are rigidly fixed to any structure. This is accomplished by constraining all degrees of freedom of the stand as shown in below Fig.3.

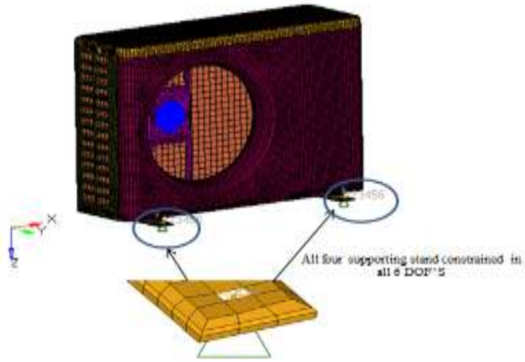

Figure.3. Boundary conditions

RESULTS AND DISCUSSION

As already mentioned earlier, the modal analysis was carried out. The natural frequencies and their corresponding mode shapes are extracted from the analysis. The mode numbers and the corresponding natural frequencies obtained are listed in Table4.

Table 4: Mode numbers and corresponding natural frequencies

Mode number	Frequency in (Hz)	Mode number	Frequency in (Hz)	Mode number	Frequency in (Hz)	Mode number	Frequency in (Hz)
1	6.027	12	27.782	23	66.548	34	78.263
2	7.831	13	27.868	24	66.641	35	78.968
3	8.834	14	30.808	25	66.781	36	80.121
4	13.925	15	32.205	26	68.530	37	82.113
5	13.549	16	36.53	27	68.998	38	84.754
6	14.682	17	44.215	28	70.513	39	86.719
7	16.095	18	44.911	29	70.700	40	87.673
8	21.285	19	49.8031	30	72.527	41	88.978
9	23.550	20	50.24	31	73.305	42	90.320
10	25.083	21	55.679	32	75.99	43	92.250
11	26.45	22	57.338	33	77.538	44	94.418

Figures 4 and 5 shows typical mode shapes Corresponding to 6^{th} and 10^{th} matching with fan and air compressor respectively.

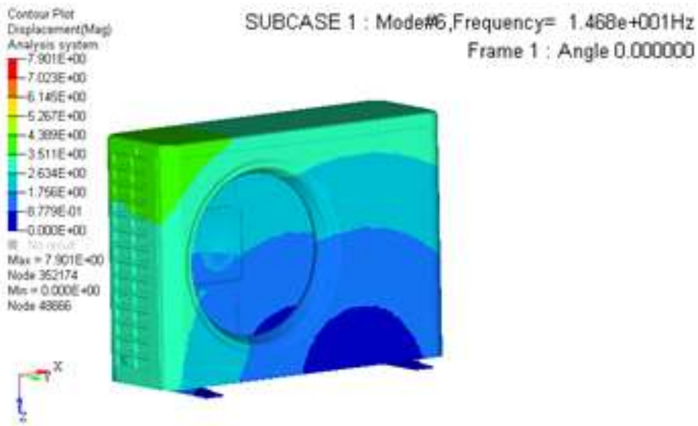

Figure 4: Mode shape for 6th mode of vibration (*f2*=14.682Hz)

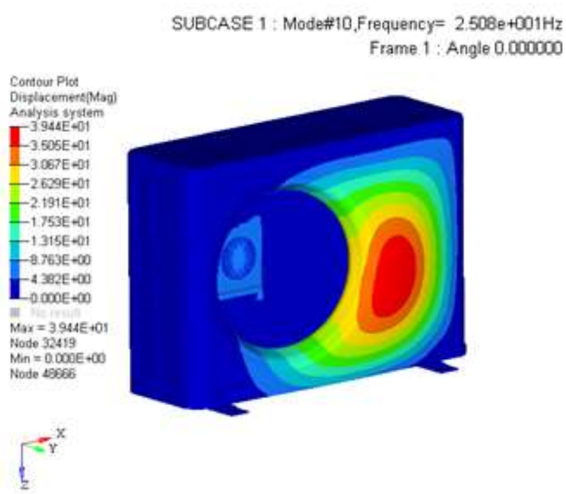

Figure 5: Mode shape for 10th mode of vibration (*f10*=25.083 Hz)

Table 5: operating frequency of fan and rotary air compressor

Operating condition	
Fan	Rotary air compressor
1075-1100 rpm (18Hz)	1800-5400rpm (30-90Hz)

In order to avoid resonance the operating frequency should lie outside 15% range of natural frequency.

CONCLUSION

During the analysis the natural frequency of the component is found to be matching with the operating frequency of air conditioner fan and compressor as shown in table 5. The compressor operating frequency is 30 to 90 Hz. The frequency obtained from the analysis is found to be matched from 10 modes to 43 modes as shown in table 4. The 7^{th} mode is matching with the operating frequency of fan i.e. 18 Hz. Further study is carried to reduce the frequency coincident from operating frequency of fan and compressor by using forced vibration analysis.

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