PERFORMANCE ANALYSIS OF ELLIPTICAL CROSS SECTIONED BENDS OF HVAC DUCT FOR LESS PRESSURE DROP

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Abstract: In this paper, a performance analysis of the elliptical cross sectioned bend of HVAC duct has been carried out. Static pressure loss in HVAC ducts system is most concern, and in this a theoretical analysis is done using CFD. As a first step, modeling based on specifications is done. Then, CFD TOOL "ANSYS' Fluent 14.5 is used for performance analysis of the elliptical duct. During analysis cross section is varied as circular, rectangle and elliptical, and its effect on static pressure and total pressure of the duct is investigated. This is helpful for selecting the appropriate duct cross section. The purpose of this paper is to give a better understanding of the performance behavior under different aspects to improve the design of the Duct.
Keywords: Duct Cross section; HVAC; Simulation Model; CFD tool; Pressure loss

I. INTRODUCTION

Duct is device which is used to carry the cold air from one place to another place for air conditioning purpose it deliver air from the fan to the diffusers which distribute air to the room. This air that is distributed is ultimately delivered in response to a pressure difference created by one or several fans. Generally the circular cross sectioned duct are best for air conditioning system but it requires more space as compared to another cross section, for solving this disadvantage rectangular duct is used but this duct also have some measureable static pressure drop compared to circular, so in order to achieve maximum energy efficiency the best duct design methods and cross section size have to be chosen carefully. There are three methods described by the ISHRAE Handbook of Fundamental which is Equal Friction method, Velocity Reduction Method and Static Regain. In duct design method the equal friction method is used widely. This method is based on making the pressure loss per foot of duct length the same for the entire system. This method will produce a well-balanced duct system is all runs of duct are the same. The optimized duct design concept is based on minimizing the static pressure losses of the duct system. The duct system optimal design is a form of large scale optimization problem. In this study a CFD model was built and simulations were done under different cross section area. The static pressure drop for those conditions were analyzed and displayed. The final CFD model is tuned until the closest results to the experimental data were achieved. In this study layout of duct network is final according to space availability in the building and made all calculation regarding the cooling load in tones, air volume flow rate in CFM (cubic feet per minute), air velocity in m/sec and length of duct in meter.

II. STUDY OF BUILDING STRUCTURE

Building has seven rooms; these rooms are for educational building and having different cooling load and different occupancies.

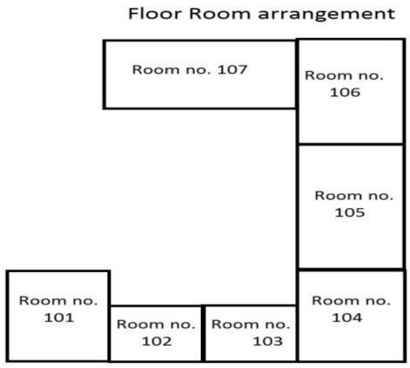


Fig.1: Floor room layout

On this floor 7 rooms in which air conditioning have to be done. Full measurements of these rooms are mention in table as follows:

Table 1: Cooling load observation sheet

S. No.	Room	Size (ft X ft)	No. of Windows & oriantaion	No. of Doors	No. of Occupants	Light Watts	Electrical Equipment Details	Watts Consume
1	101	29.53X42.65	E4, N4	W 1 (4X7)	65	480	1 Com.+ 8 fan+ 1projector	28152
2	102	22.97X14.68	N4	S 1 (3X7)	5	60	1 Com.+ 8 fan+ 1printer	7038
3	103	19.69X14.68	N4	S 1 (3X7)	5	60	1 Com.+ 8 fan+ 1printer	7038
4	104	29.53X26.25	W4, N4	E 1 (3X7)	35	240	4 fan + aggregate mixture	17595
5	105	29.52X42.65	W4	E 2 (3X7)	35	480	8 Fan+ Crushing test m/c+UTM	24633
6	106	29.52X26.25	W4, S4	E 1 (3X7)	10	240	4 Fan	10557
7	107	42.65X22.97	S4	N 2 (3X7)	35	360	6 Fan	24633

Table1 gives the details about room size, number of windows and doors and their orientation, number of occupants, lighting watts and other electrical equipment detail and their watts consuming.

III. COOLING LOAD AND VOLUME FLOW RATE OF AIR

Cooling load estimation is first part of duct designing, with the help of cooling load along with air changes volume flow rate is estimated. Table 2 shows the cooling load and volume flow rate on each room. Volume flow rate kept in CFM (cubic feet per minute) and cooling load in TR (tones of refrigeration).

Table 2: Cooling load & CFM

Sr. no	Room Number	Area in ft^2	BTU	TR	CFM Required for 5 Air Change
1	101	1259.45	96000	8	4000
2	102	337.2	24000	2	1000
3	103	337.2	24000	2	1000
4	104	775.16	60000	5	2500
5	105	1259.45	84000	7	3500
6	106	775.16	36000	3	1500
7	107	979.67	84000	7	3500
Total				**34**	**17000**

In table 2 total cooling load is 34 TR and for 5 air changes requires 500 CFM per ton of refrigeration, so the total CFM required for the flow is 17000.

IV. THEORETICAL CALCULATION FOR DUCT EQUIVALENT DIAMETER

In this study layout of duct network is decided by according to space available on the building which is shown in fig .2.

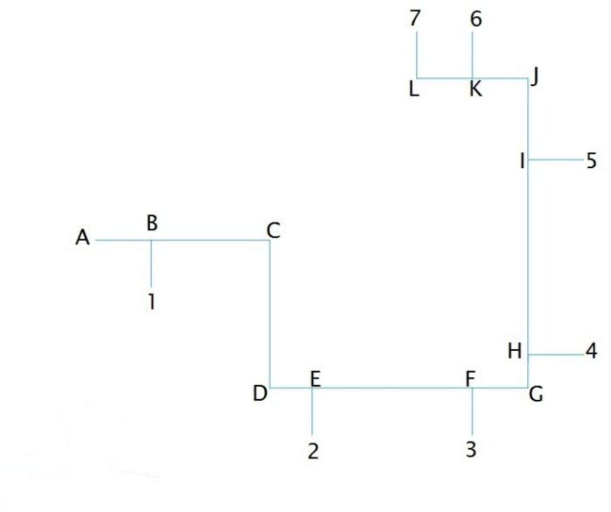


Fig.2: Duct Network layout

In fig.2 duct layout is divided in to some parts to understand the behavior of cross section of duct at each section. Then duct is design theoretically with equal friction method, with help of prior calculation shown in table2 which is total volume flow rate for 5 air changes is 17000 CFM and initial velocity of 1600 FPM (feet per minute). This velocity is select according to ISHRAE handbook for less noise.

Table 3: Cross section of duct by Equal friction method

Sr. no	Section	Length in Meter	Circular		Rectangular		Elliptical	
			D (m)	Area In m^2	a (m)	b (m)	a (m)	b (m)
1	A-B	2	1.09	0.93	1.33	0.70	1.32	0.90
2	B-C	7						
3	C-D	8						
4	D-E	1.5						
5	B-C-D-E	16.5	0.99	0.77	1.28	0.60	1.23	0.80
6	E-F	7.5	0.97	0.74	1.25	0.59	1.21	0.78
7	F-G	2						
8	G-H	1.5						
9	F-G-H	3.5	0.93	0.68	1.23	0.55	1.15	0.75
10	H-I	10.5	0.86	0.58	1.12	0.52	1.06	0.70
11	I-J	3						
12	J-K	1.5						
13	I-J-K	4.5	0.71	0.40	0.99	0.40	0.92	0.55
14	K-L-7	2	0.61	0.29	0.86	0.34	0.74	0.50
15	B-1	2	0.65	0.33	0.66	0.50	0.75	0.56
16	E-2	2	0.39	0.12	0.40	0.30	0.51	0.30
17	F-3	2	0.39	0.12	0.40	0.30	0.51	0.30
18	H-4	2	0.55	0.24	0.59	0.40	0.67	0.45
19	I-5	2	0.61	0.29	0.61	0.48	0.74	0.50
20	K-6	2	0.45	0.16	0.35	0.46	0.68	0.30
21	L-7	2	0.61	0.29	0.61	0.48	0.74	0.50

Table 3 shows the circular cross section area which is calculated through equal friction method for duct deigning, and then it convert in to rectangular cross section and elliptical cross section by keeping the discharge constant.

V. MODEL CONSTRUCTION

Model of duct network was created in Ansys 14.5 software for this study as shown in Fig 3. A number of such models were created by changing the cross section area and keeping the rest of the specifications as same and exported the model in ANSYS 14.5 Fluent CFD software. ANSYS Fluent software is a CFD tool which gives the solution for fluid analysis.

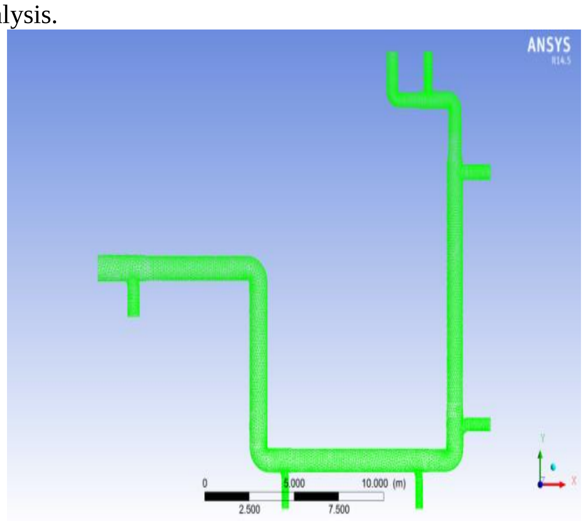


Fig. 3: Model of duct network

Procedure: In this study ANSYS 14.5 Fluent is used to simulate Bends of duct network under different types of equations like Conservation of Mass and Naviour stoke equation related to fluid mechanics involved have been solved with appropriate boundary conditions. The finite volume method and grid generation in the CFD environment provided by the software was used. Following is the brief outline of the method adopted

- Create working fluid of air and select Cross section of duct.
- Assign inlet condition of the duct. The main inputs are inlet velocity, static pressure and density of air.
- Now create the Boundary Conditions at the inlet and outlet. At the inlet pressure – 0 Pascal gauge pressure and inlet velocity is 1600 fpm.
- Set the k-epsilon flow for 10% turbulence flow.
- Define the mesh distribution using Automatic-Sizing was gives in this study.
- Solving the application to obtain the result.
- Getting the pressure and velocity at each bend inlet and outlet shows in fig. 4.

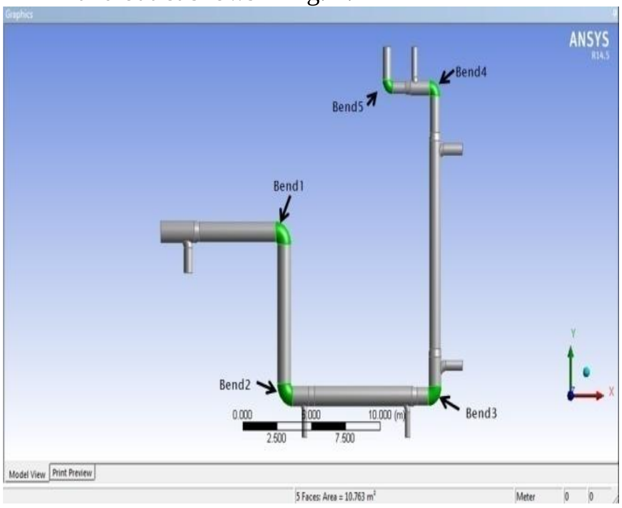


Fig. 4: Bends on duct network

VI. RESULT AND DISCUSSION

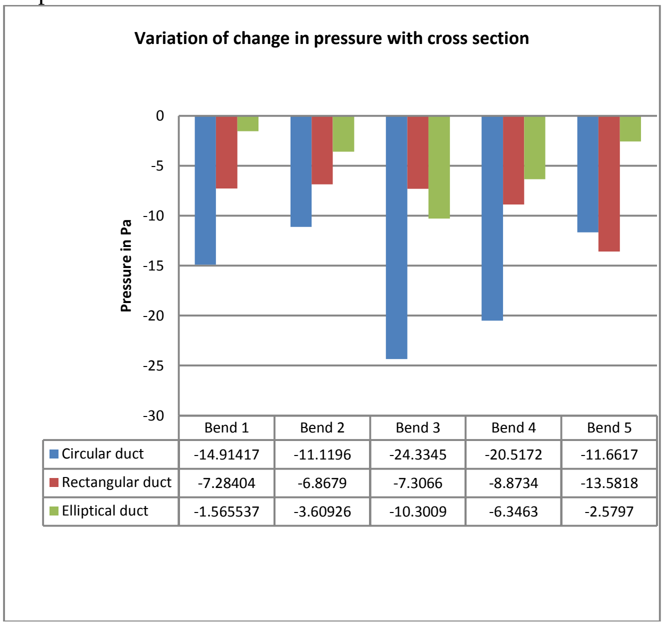
The results of the analysis are shown in table.4, Graph 1 and Graph 2 shows the pressure and velocity variation respectively, this Graphs compared three types of cross section area.

Table 4: effect of cross section area on Pressure and velocity

Location	Properties	Circular			Rectangular			Elliptical		
		Before	After	Difference	Before	After	Difference	Before	After	Difference
Bend 1	Pressure	2.45457	-12.4596	-14.91417	3.51677	-3.76727	-7.28404	1.1281	-0.437437	-1.565537
	Velocity	7.85114	9.23113	1.37999	7.77911	8.48568	0.70657	7.9225	8.06248	0.13998
Bend 2	Pressure	-16.6105	-27.7301	-11.1196	-20.5668	-27.4347	-6.8679	-5.5929	-9.20216	-3.60926
	Velocity	6.2311	7.69243	1.46133	6.71761	7.6663	0.94869	7.02888	7.48754	0.45866
Bend 3	Pressure	-33.7354	-58.0699	-24.3345	-35.6839	-42.9905	-7.3066	-14.3579	-24.6588	-10.3009
	Velocity	8.25821	10.4107	2.15249	7.83122	8.20173	0.37051	8.0071	8.92086	0.91376
Bend 4	Pressure	-57.5087	-78.0259	-20.5172	-57.4764	-66.3498	-8.8734	-22.9202	-29.2665	-6.3463
	Velocity	6.28994	8.07632	1.78638	6.18312	6.85395	0.67083	6.03614	6.85742	0.82128
Bend 5	Pressure	-71.165	-82.8267	-11.6617	-75.4015	-88.9833	-13.5818	-26.9234	-29.5031	-2.5797
	Velocity	4.22921	6.25561	2.0264	5.65715	8.53466	2.87751	4.60982	5.46705	0.85723

A. Effect of cross section on change in pressure

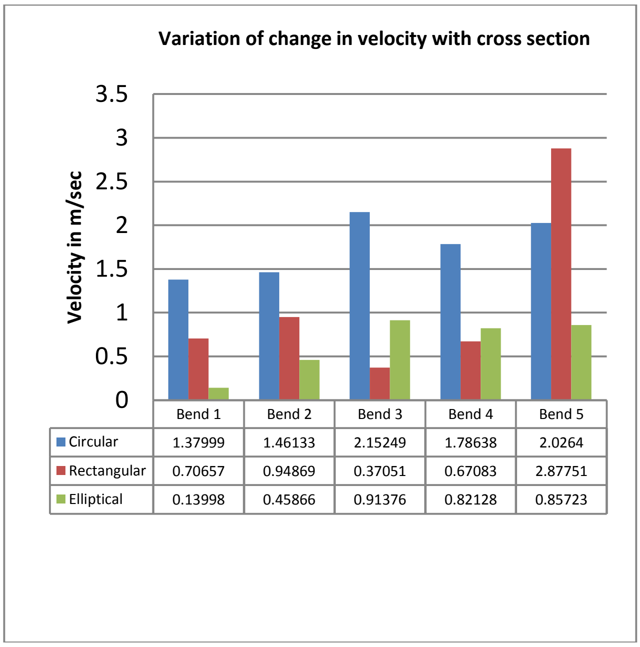
The results obtained by the fluent after giving the boundary conditions as mentioned earlier in the procedure adopted. From the Graph 1 show values of the maximum change in static pressure are obtained in case of circular duct cross sectioned and minimum static pressure change is obtained in elliptical cross sectioned duct.



Graph.1. Variation of change in pressure with cross section

B. Effect of cross section on change in Velocity

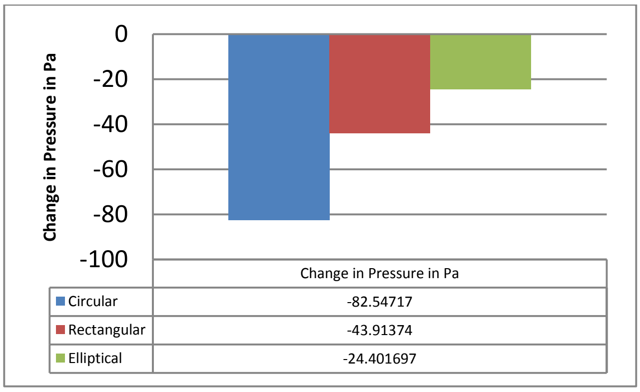
The effect of changing the cross section area of duct on the velocity is obtained in Table 4 and Graph 2. It can be concluded that the minimum pressure change gives higher velocity it mean increase in velocity gives static pressure decreases.



Graph.2. Variation of change in Velocity with cross section

VII. CONCLUSIONS

In this paper, investigations on the effect of change in cross section on static pressure at bend have been presented through theoretical design and CFD simulation. It is shown that for elliptical cross sectioned duct the static pressure change is less as compared to circular and rectangular cross sectioned duct.



Graph.3. Total Change in static Pressure in all bends

Duct cause negative static pressure and fan gives positive static pressure, in order to overcome negative pressure fan has to give more positive static pressure that means more energy is required to overcome negative pressure. So here need to optimize duct for minimum static pressure drop, in study this can be achieved by changing the cross section of duct. In Graph 3 it is clear that the total change in static pressure is less for elliptical bends which need less energy as compared to rectangular and circular cross sectioned duct. This analysis helps in saving of fan energy in HVAC system.

VIII. FUTURE SCOPE

This Work optimizes the problem of static pressure drop. Negative static pressure drop leads energy consumption by fan, so this work is useful for optimize the energy consumption.

REFERENCES

[1] Dr. Neihad Al-Khalidy "Design Optimization of Industrial Ducts using computational fluid Dynamics" Third International Conference on CFD in the Minerals and Process Industries CSIRO, Melbourne, Austria, 10-12 December 2003
[2] Abushakra, B., I. S. Walker, M. H. Sherman. 2004. Compression Effects on Pressure Loss in Flexible HVAC Ducts. International Journal of Heating, Ventilating, Air-Conditioning and Refrigeration Research, 10(3): 275 – 289
[3] J.J. Miau, T.S. Leu, J.H. Chou, S.A. Lin, C.K. Lin, "Flow distortion in a circular-to-rectangular transition duct" AIAA J. 28 (8) (1990)1447–1456.
[4] Air Conditioning part-1 "HVAC Handbook" ISHRAE Handbook 2007.
[5] Technical Insulation "HVAC Handbook" ISOVER December 2010.

