Review Paper on Design and Optimization of Duct and Its Effect on System Performance

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Abstract— This paper focuses on the design parameter and procedure of duct. While designing the duct according to different cooling load condition requirement and according to availability of space how duct layout should be made optimum that should be decided. This paper focuses on study of design and optimization of air cooling duct. Generally while designing a duct it’s very important to select suitable shape, material, method of duct designing. At the same times the network structure of duct, topology or geometry of duct shape and size, location of air cooling fan, calculation procedure of duct design that’s are some parameter which is consider for effective duct design[1].

Key words: Duct

I. INTRODUCTION

Now a days in every manufacturing industry it is important to maintain certain temperature is required for proper functioning. So in different industry according to need different air conditioning system are to be used. Window air conditioning are proffered for office room while large centralized units are installed for conditioning the auditorium, hospitals & classrooms. After installation of air handling units or fan coil units it is very essential to distribute the conditioned air which is processed by Air handing unit which is supplied to the room which are to be condition by supplying chilled air.

Proper air distribution is achieved with proper duct design which leads minimum losses in the system, Suitable selection of fan with high efficiency [1].

II. SELECTION OF DUCT SHAPE

G. S. Sharma et. al. did research on "Duct design in air conditioning system and its impact on system performance". The paper focuses on the importance of duct design and how the different shape of duct can create an impact on system performance. Circular duct has low friction loss as well as it's easy to design but in actual practice rectangular duct is preferred because of space availability. Now a day’s various tools are also readily available for use of such work for energy efficient duct design.

In this paper it was approved that pressure drop for a typicalsystem comprising of straight ducts, bends and diffusers is lower for a circular duct system than for a rectangular duct as respectively.Fig.1 shows that when we use the circular duct system the static pressure in the duct in the range of $9.00e^{+01}$ Pascal to 0 Pascal over the length of 1.2 m, but in rectangular duct the static pressure in the duct in the range of $9.00e^{+01}$ Pascal to 0 Pascal over the 0.8 m length only.

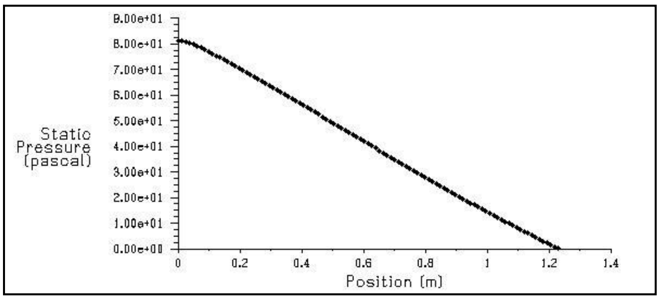

Fig. 1: Pressure Loss due to friction across Circular[2]

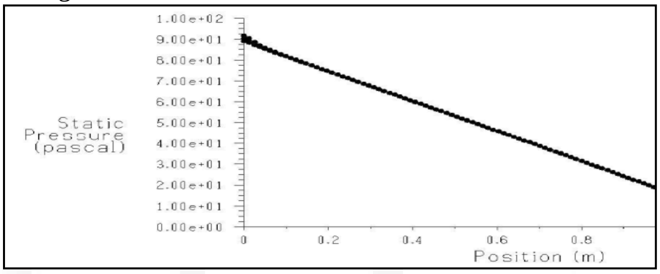

Fig. 2: Pressure Loss Due To Friction across Square Duct JF[2]

Therefore, one can very well conclude that by selecting a circular duct system is the best suitable for industrial application,but practical point of view Round ducts take up more height than do rectangular or square ducts. This means that in very less spaces, round HVAC ducts just not fit. It can also become unappealing to the eye when trying to connect the fan coil to the main duct, which means connecting round to square duct openings hence in actual practice in a industry rectangular ducts are to preferred [2].

III. METHODOLOGICAL APPROACH TO SELECT PERFECT DUCT DESIGN

Virendra V. Khakre et. al. did research on "Design of duct for a three-storey retail shop”. The importance of duct designing has been analysed in this paper which result of an impact on system performance. After duct designing in a system of three storey retail shop, focus was concentrated to make proper calculation of supply air quantity and calculation of size of duct by using Equal Friction method so person in the shop can feel desirable. For designing the duct, building cooling load and air flow rate is calculated and for measuring the rate of discharge of the air generally anemometer is to be used. The duct design for building was done by using equal friction method.

Equal friction method is most suitable conventional method which is to be used for design of duct. These methods is generally used where the ducts air distribution ducts length is small. However like a velocity reduction method it’s also include the damper. If in the system the duct length is too large then ducts near the fan get over pressurised.

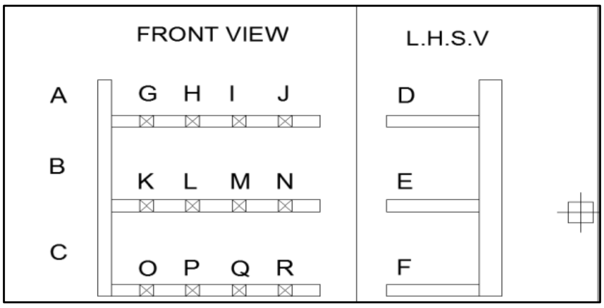

Fig. 3: Front view and Side view of duct layout [3]

The layout of three-storey retail shop as shown in fig.3. The dimension of building is shown in below table no.1. When the pressure loss occurs in a straight duct, then these losses is known as friction loss.

Item	Description	Ground Floor	1st Floor	2nd Floor
1	Total Interior Space (Volume)	187.52 m2	187.52 m2	187.52 m2
2	Total Exterior Wall Area	82.53 m2	82.53 m2	82.53 m2
3	Total Roof Area	56.13 m2	56.13 m2	64.8 m2
4	Total Glass/ Window Area	7.36 m2	18.48 m2	18.48 m2

Table 1: Dimension of three-storey shop [3].

This paper was concluded that while designing the duct, by using equal friction method building cooling load and air flow rate is calculated and by considering different frictional pressure drop for all three duct runs. The total pressure loss after16 mm of H_2o gauge was calculated, due to low value of pressure loss fan power for circulation in duct will be small. The loss through duct fittings is the major loss component (compared with the frictional loss) in our evaporative cooled air distribution system. The value of total pressure was critical hence it affects selection of fan in evaporative cooling system [3].

IV. SELECTION OF DUCT MATERIAL

Mohan Kashyap et. al. did research on "Carbon Fiber Composites for Duct design based on VAV network in HVAC system". In this paper the different materials of duct design i.e. galvanized steel, aluminium, copper, fiber glass and carbon fiber was compared with their various properties. This paper was based on ASHRAE standard selection of duct material. The aim of this research paper was the optimization duct of HVACs system. In general HVAC duct rectangular in shape and aspect ratio kept less than 3, and round duct also used in HVACs system. In this paper basically 4 metal and one non-metalwere used & the property of these material is shown below in table no.2. One can expect that the carbon fiber material can be used in duct network in HVAC's system. This material is lighter in weight; it also includes properties like high stiffness, and high strength. It also reduces the heat losses in duct branch due to low thermal conductivity. Fiber glass fabrichas been also used in HVACs duct system. There is low strength in fiber glass composite.

Materials	Graphite Composite (aerospace grade)	Graphite Composite (commercial grade)	Fiberglass Composite	Aluminum 6061 T-6	Steel, Mild 304 grade
Cost $/LB	$20-$250+	$5-$20	$1.5-$3.0	$3	$.3
Strength (psi)	90,000-200,000	50,000-90,000	20,000-35,000	35,000	60,000
Stiffness (psi)	$10x10^6$ - $50x10^6$	$8x10^6$ – $10x10^6$	$1x10^6$ – $1.5x10^6$	$10x10^6$	$30x10^6$
Density (lb/in^3)	.050	.050	.055	.10	.30
Specific Strength	$1.8x10^6$ – $4x10^6$	$1x10^6$ – $1.8x10^6$	363,640 - 636,360	350,000	200,000
Specific Stiffness	$200x10^6$- $1000x10^6$	160x 10^6 – $200x10^6$	$18x10^6$ – $27x10^6$	$100x10^6$	100x 10^6
CTE (in/in-F)	$-1x10^{-6}$ – $1x10^{-6}$	$1x10^{-6}$ – $2x10^{-6}$	$6x10^{-6}$ – $8x10^{-6}$	13x 10^{-6}	7 x 10^{-6}
Thermal conductivity w/mK	0.1 to 40 w/m K	0.178 to 40	.6 to 3	202 to 250	70 to 93

Table 2: Properties of material [4].

The main aim of this paper was to compare and add new material like carbon fiber, aluminium, galvanized steel, copper and fiber glass material. The various properties analysis has to be done. And the goal of optimal VAV system duct design is to determine duct sizes. This material is used for some specific task like air conditioning in buses, train, airbus where light weight was needed. Glass fabric duct has been used for some applications, but this duct was not used where moving parts are present because they were flexible duct and performance was affected in this duct so, carbon fiber can be used.

The results are analysed to compare duct design methods, materials and the effects of several factors that influence optimal design are investigated [4].

V. NETWORK STRUCTURE OF DUCT & LOCATION OF FAN

Sandy Joreans et. al. did research on "Design Optimization of Air Distribution Systems in Non-Residential Buildings". While designing a duct most heating, ventilation and air conditioning systems, i.e., the network structure of the ducts, as well as the number and location of the fans, is an important determinant of the installation's cost and performance. If in the system or in non residential building network layout with exensive air distribution system is essential. While designing the duct system of air distribution should be predefined and point of focus is only a sizing of each fan in the duct network.

This paper is focused on, presenting a novel problem formulation that integrates the layout decisions into the optimization problem. In network design and optimization problem, the optimal ductwork layout is decided by the duct and fan sizes, which results into minimization of costs. This novel combinatorial optimization problem is characterized by discrete decision variables, and non-linear constraints and can best be approached by met heuristic optimization techniques

The results obtained is shows that the layout has a great influence on the air distribution system's cost and energy consumption. Nevertheless, the layout has not been taken into account in previous design methods for air distribution systems. Instead, all existing design methods start from a layout determined using rules of thumbs, and focused solely on the sizing of each duct and fan in the air distribution network. [5].

VI. CALCULATION OF DUCT DESIGN

Lwin Myo et. al. Lwin Myo et. al. did research on "Duct Design of Assembly Hall at Mandalay Technological

University". This paper is focused on Design of duct for Assembly Hall at MTU. The layout of assembly of MTU is as shown in fig.4. After the testing of hall of MTU the result obtained is as follows:

Cooling load capacity:	65 tons,
Supply air:	564 CMM,
Entering temperature:	28.6˚C
leaving temperature:	14.52˚C
Duct design method:	Equal friction

For adequate supply air distribution the supply air for each duct section should be calculated, after that the duct section of reduction should be carefully designed. The return air duct is mandatory in this particular design because the fan was not located adjacent to the space to be cooled and doors are closed throughout.

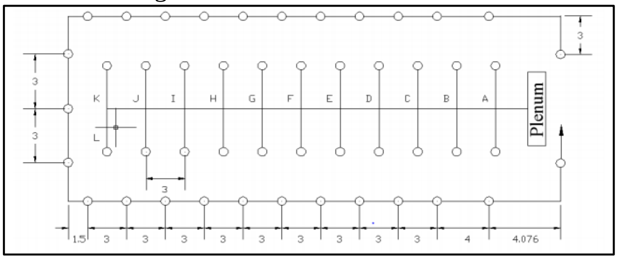

Fig. 4: Duct design plan for hall [6]

In conclusion, the design of duct can be applied in the implementation of air conditioning system in MTU's assembly hall [6].

VII. STRUCTURE & TOPOLOGY OF DUCT DESIGN

Po Ting Lin et. al. did research on "Optimal duct layout for HVAC using topology optimization". In this paper the point of focus was the applicability of topology optimization for optimal duct design layout. After a survey of fluid topology optimization process was presented on this paper with outlook of its applicability to initial duct design. There was also a presence of some initial investigation which was compared by an existing design. The computational cost of presenting large-scale topology/geometry optimization was currently one of the biggest limitations of its applicability, but due to gradually improvements in computing technology it was indeed a possibility.

In this paper by using structural mechanics origin & fluid dynamic migration topology optimization was to be introduced. Due to high computational cost, lack of professional tools it's not used currently in HVAC industry[7].

VIII. COST FACTOR IMPACT WHILE OPTIMIZATION OF DUCT

Taecheol Kim et. al. Did research on "Optimum Duct Design for Variable Air Volume Systems, Part 1: Problem Domain Analysis of VAV Duct Systems". These paper focuses on cost minimization while optimization of duct.

Generally, duct design method for variable air volume (VAV) system are based on the use of peak constant airflow. However, practically system operate much of the time at an off-peak load condition, and the impact of varying airflow rates to the sizing of duct systems has not been considered. In this paper an optimum duct design procedure for variable air volume system was to be investigated. By addition with that it's also focuses on the hourly airflow requirements, part-load fan characteristics, and duct static pressure control, discrete duct sizes and velocity limitations. In part 1, the domain of a Variable air volume optimization problem is analyzed to define the problem characteristics and to suggest an optimization procedure.

The main objective of this paper was optimal VAV system duct design i.e. to determine duct size and select a fan that minimizes system life cycle cost. The system life-cycle cost as introduced by Tsal et al. (1988a, 1998b) is made up of initial and operating costs. The initial cost includes the cost of the installed ducts and the fan. The duct cost is determined as a function of the cost per unit area of duct surface. While calculation of cost of HVAC equipment such as fittings, heating coil, and cooling coil are considered constant and are not included in the objective function, except the fan cost.So, to minimize the initial cost the smallest fan that satisfies the system design point was to be selected. While calculating total operating cost mainly the electric energy cost required by fan was considered & it was represented by present value of monthly costs.

The electric energy cost was to be assumes on basis of a unit energy cost and a demand charge based on the annual peak electricity consumption. Finally by considering different rate structure the energy consumption was calculated, and optimal cost in ideal condition was obtained. This paper is concluded that, the optimization of cost can be obtained by using proper selection of fan, duct material at initial working condition[8].

IX. VAV DUCT DESIGN PROCEDURE

Taecheol Kim et. al. did research on "Optimum Duct Design for Variable Air Volume Systems, Part 2: Optimization of VAV Duct Systems". This paper focuses on the duct design procedure in VAV duct system.

The VAV optimization procedure is mainly composed of the preparation of airflow data, the evaluation of the objective function, and the generation of a design solution that includes continuous and discrete solutions. Figure 5 shows the overall optimum duct design procedure. A time-varying airflow rate for Variable air volume duct systems can be provided by an hourly building simulation method. Second, the evaluation of the objective function requires fan selection, initial cost calculation, a search for fitting loss coefficients from the duct fitting database, system pressure loss calculation, and operating cost calculation. They are explained in cost factor impact while duct design. For constrained duct design problems, design constraints are defined and explained in this paper as to how they are incorporated in the optimization procedure. Third, For the estimation of system life-cycle cost different optimization methods were used. Mead down hill simplex method & Nelder method was applied for finding duct size and then for duct size the penalty approach for integer. When discrete value are assigned to variables optimum cost value is to be increased.

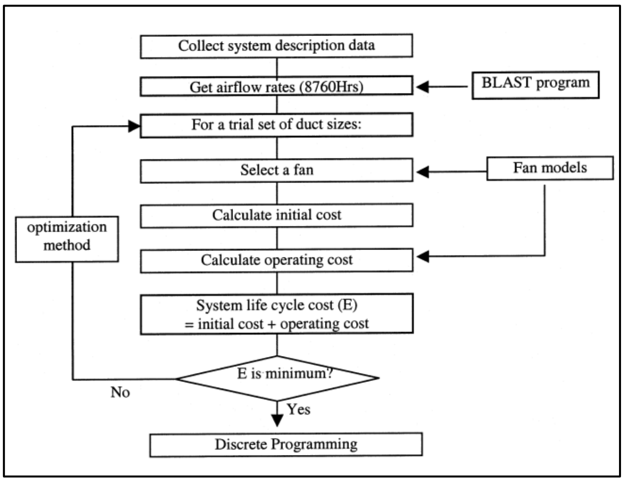

Fig. 5: Optimum duct design procedure [9]

In the conclusion of this paper we have found out that, the VAV optimization procedure allowed greater lifecycle cost savings (compared to the T-method) with lower electricity rates. The duct topology influences the degree to which the optimal solution is at the duct size constraints. Longer duct lengths tended to reduce the number of duct sections at the minimum size constraint. While different climatic conditions and operating schedules influenced the optimal design, they did not have a significant impact on the savings of the VAV optimization procedure. For the large office building, the life-cycle cost savings of the VAV optimization procedure [9].

X. CONCLUSION

The following various conclusions summarize the present paper:

1) Circular duct system is best suitable for industrial duct design purpose, but in practical point of view square duct is preferred in industry.
2) While designing the duct, the equal friction method is mostly preferred in industry.
3) Fiber glass fabric material is used in industry while designing of duct due to its unique properties i.e. lighter in weight, high strength, high stiffness.
4) The duct layout has great influence on the air distribution’s system cost and energy consumption.
5) The shape, size and other dimension influence on the optimization of duct.
6) The optimization of cost can be obtained by using proper selection of fan, duct material at initial working condition.
7) Longer duct lengths tended to reduce the number of duct sections at the minimum size constraint&while different climatic conditions and operating schedules influenced the optimal design, they did not have a significant impact on the savings of the VAV optimization procedure.

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