# Carbon Fiber Composites for Duct design based on VAV network in HVACs system

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**ABSTRACT**

In this paper the materials of duct design like galvanized steel, aluminum, copper, fiber glass and carbon fiber are compared with their various properties, heat losses. This is based on ASHRAE standard selection of duct material. The purpose of this research is to optimization of HVACs system. DUCT Designing is very necessary for transmission of large amount of air with suitable pressure in HVAC system with optimum losses. Now a day the most common duct design method is based on Equal friction method, Static regain method, velocity reduction method. This project based on VAV network system. In duct designing the main purpose of duct in HVAC's system is to flow of cool air from air handling unit to air conditioning space likes residential building, industrial and commercial building. HVAC duct are generally rectangular in shape and aspect ratio kept less than 3, and round duct also used in HVACs system. In large (lengthy) rectangular duct the bending problem occurs. Heat loss occurs in aluminum duct due to high thermal conductivity. We expect that the carbon fiber material can be used in duct network in HVAC's system. This material is light weighted, high performance products with graphite composites, high stiffness, and high strength and reduces the heat losses in duct branch due to low thermal conductivity. No insulation requirement in carbon fiber material. Fiber glass fabric has been also used in HVACs duct system. There is low strength in fiber glass composite. The results are analyzed to compare duct design methods, materials and the effects of several factors that influence optimal design are investigated.

## LITERATURE REVIEW

### 1. INTRODUCTION

This paper based on duct design analysis in HVACs system. There have been many works done on this field. Duct design systems are categories in two parts as duct network and air handling unit in HVACs system. Mainly VAV network of duct system are mostly used because its 30% effective other then. There are mainly three metals and one non metal used in duct network and air handling unit such as galvanized steel, aluminum, copper and glass fiber (fabric non metal) their properties which are related to material selection of duct network and air handling unit. In this literature material selection procedure has to be taken from ASHRAE journals of metal duct selection and ASTM standard, SMACNA.s Round Industrial duct. In this paper basically 4 metals and 1 non metal are used. Such as given below

1. Galvanized steel (Zn coated ) it should be carbon content not more than 0.15% and G60 or G90 are usually used in duct network
2. Stainless steel Types 304 and 316, with 2B finish. Types 304L and316L have lower carbon content for better welding. Type 316 is used for kitchen hoods.
3. Aluminum ductwork is normally 3003 alloy 14 temper per ASTM B 209 with dimensional tolerances of ANSI Standard H 35.2. normally 6061 alloy T6 temper per SMACNA's HVAC-DCS (for rectangular ducts for 3 in. w.g. or less)
4. Cold-rolled copper ducts are rarely used. Beryllium copper grade C17000 with TH04 temper are used.
5. Fiber glass is used as an insulating material and fabric of these are used directly as in duct design.
6. Carbon fiber can also be used in duct design where high strength is needed and light weight required.

## 2. SOME PROPERTIES OF BASIC MATERIALS

| **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 |

## 3. MODELING AND OPTIMIZATION OF HVAC SYSTEMS

This part includes Modeling and optimization of HVAC systems using a VAV air-conditioning system by ASHRAE standards. The variable volume system compensates for varying load by regulating the volume of air supplied through a duct. Special zoning is not required, because each space supplied by a controlled outlet is a separate zone. Significant advantages of the variable volume system are low initial cost and low operating costs. The first cost of the system is far lower than that of other systems that provide individual Space control because it requires a simple control at the air terminal. Compared to the traditional control strategy, the proposed model saved up to 30% of energy.

The past decades have seen significant growth in the energy consumed by heating, ventilating, and air conditioning (HVAC) systems. Design of energy-saving control strategies for HVAC systems has gained attention. An effective HVAC system control strategy adjusts controllable variables for effective energy use. A schematic diagram of a typical HVAC system is shown in Fig. 1. The system includes two parts, an air handling unit (AHU) and variable air volume (VAV) terminals. Numerous papers have reported contributions to the optimization of HVAC systems with the aim to improve energy efficiency. The analytical models of HVAC systems are usually computationally complex and involve assumptions that may not hold in practice. Unlike physics-based models, this is depend entirely on experimental data which make them application relevant and easy to compute Kusiak and Li and Kusiak et al. developed neural network models minimizing energy consumption of an air handling unit and variable-air-volume box. The energy consumption for VAV system is chiefly associated with the thermal loads (cooling or heating) and the power to deliver these loads. The material required for this system should be low thermal conductivity. VAV duct systems are commonly designed using maximum airflows to zones as if they are CAV systems.

## 4. METHODS OF DUCT DESIGNING

There are three duct design methods are presented in the *1997 ASHRAE Handbook—Fundamentals* (ASHRAE 1997): equal friction, static regain, and the T-method. Of the three, the T-method, introduced by Tsal et al. (1988a, 1998b), is the only optimization-based method. The T-method finds optimal duct sizes and fan size in order to minimize system life-cycle cost. The system life-cycle cost includes the initial ductwork cost based on optimum duct sizes and the year-round electrical energy cost of the fan. The initial cost of the fan is not included. The calculation procedure of the T-method consists of three main steps: system condensing, fan selection, and system expansion. In the first step, the entire duct system is condensed into a single duct section for finding the ratios of optimal pressure losses using sectional hydraulic characteristics. An optimal system pressure loss is found in the second step. In the third step, the system pressure is distributed throughout the system sections. The T-method's calculations are based on a fixed amount of airflow throughout the year to determine duct sizes, overall system pressure drop, and fan energy cost. However, in VAV systems, the airflow vary continuously throughout a year's operation; therefore, the fan power changes with varying airflow. Fan power is also influenced if static pressure at the end of the longest duct line is controlled. Spitler et al. (1986) investigated fan energy consumption for VAV systems and found, for some buildings, that a large number of hours may be spent at a minimum flow fraction. Obviously, spending a large number of hours at the minimum fraction makes a significant impact on the fan electricity consumption. System life-cycle cost defined in the T-method does not account for these varying airflows of VAV systems, and, thus, the T-method may give non-optimal values for VAV system optimization.

In this study, the system life-cycle cost accounts for the impact of varying airflow rates on fan energy consumption. The system life-cycle cost is minimized to find the optimal duct sizes and to select a fan. For comparison purposes, several example VAV systems are optimized using the T-method by selecting maximum airflows as design air volumes, and then they are optimized again using an optimization procedure that accounts for varying airflow rates. The VAV optimization method differs from the T-method in that duct sizes are selected as explicit design variables that have discrete values; part-load fan characteristics are considered to find fan efficiencies for different airflows; and duct static pressure control is incorporated into the operating cost calculation. As a preliminary step to finding a VAV duct design procedure, this paper examines the problem domain analysis of VAV duct systems in terms of duct sizes. Tsal and Behls (1986) analyzed a two-dimensional hypothetical CAV duct system using a scalar field technique, which is the graphical representation of the objective function in terms of pressure losses of duct sections. The analysis will reveal which type of optimization is required, local or global optimization, and, consequently, suggest a VAV optimization technique. A companion paper (Kim et al. 2002) covers the economic analysis of VAV systems in order to compare a VAV optimization technique with the T-method by simulating designed systems under VAV operation.

## 5. Non metal duct:

Fabric Ductwork is made by Duct Sox Products Company. it’s made with glass fiber fabric Uniform air dispersion which results in more effective air distribution Less packaging, minimal jobsite waste Reduced material use, less energy to ship, less labor and resources required to install Lower equipment costs, reduced installation costs, structural savings (lightweight) Increased efficiency of air delivery, reduced maintenance costs, no painting Better airflow increases comfort, more aesthetically pleasing Quiet air delivery and uniform air dispersion, better ventilation effectiveness. Fig shows metal vs non metal ductwork

## 6. Different type of investigate by researchers are discussed as:-

1. Metal Duct Selection and Application by ASHRAE Journal (online June 2000 by John H. Stratton) in this journal various types of duct material are investigated and their uses, requirement and in this journal non metals are not considered.
2. Modeling and optimization of HVAC systems using a dynamic neural network (online 27 April 2012 by Andrew Kusiak, Guanglin Xu) ELSEVIER Publication on Energy. In this paper the air handling unit and VAV duct design are considered and optimization process is achieved.
3. Strength of plates of rectangular industrial ducts. (Online 2011. By THARANI THANGAa, BASSAM HALABIAHb, and K.S.SIVAKUMARAN). Published by Elsevier Ltd. In this paper the bending problem are investigated in large rectangular industrial duct.
4. Optimum Duct Design for Variable Air Volume Systems, Part 1: Problem Domain Analysis of VAV Duct Systems. **(**Online 2002 by Taecheol Kim, Jeffrey D. Spitler, Ph.D., P.E. Ronald D. Delahoussaye, Ph.D**.**) Published in ASHRAE Transactions: Research. This paper is based on ASHRAE standard and designing method are improved and uses VAV system.
5. Evaluation of four control strategies for building VAV air conditioning systems. (Online 3 October 2010 by Xue-Bin Yang, Xin-Qiao Jin, Zhi-Min Du, Bo Fan, Xiao-Feng Chai.) Published by Elsevier Ltd. On Energy and buildings this is also based on VAV system of air conditioning.
6. Experimental investigation of heat recovery system for building air conditioning in hot and humid areas. (Online 2 January 2012 by Shahram Delfani, Hadi Pasdarshahri, Maryam Karami, ) Published by Elsevier Ltd. On Energy and buildings. In this paper thermal analysis are done.
7. Performance assessment of residential mechanical exhaust ventilation systems dimensioned in accordance with Belgian, British, Dutch, and French and ASHRAE standards (Online 11 august 2012 by J. Laverge, X. Pattyn, and A. Janssens.) Published by Elsevier Ltd. On Energy and buildings.
8. Optimization of HVAC systems for distributed generation as a function of different types of heat sources and climatic conditions. (Online 10 October 2012 by Dashamir Marini.) Published by Elsevier Ltd. On applied Energy
9. Energy performance of a lightweight opaque ventilated facade integrated with the HVAC system using saturated exhaust indoor air. (online 7 March 2012 by Claudio Cianfrini, Massimo Corcione, Emanuele Habib, Alessandro Quintino) Published by Elsevier Ltd. On Energy and buildings.
10. Removal of submicron particles using a carbon fiber ionizer-assisted medium air filter in a heating, ventilation, and air-conditioning (HVAC) system(Online 15 February 2011 by Jae Hong Park, Ki Young Yoon, Jungho Hwang.) Published by Elsevier Ltd. On buildings and environment. In this paper the carbon fiber ionized filter are investigated.

11. Processing and properties of copper coated carbon fiber reinforced aluminum alloy composites. (Online 1 May 2008 by B. Bhav Singh, M. Balasubramanian) Published by Elsevier Ltd. I have take from this paper carbon fiber properties and some idea about the project
12. Constructing HVAC energy efficiency indicators (Online 27 December 2011 by Luis Pérez-Lombard, José Ortiz, Ismael R. Maestre, Juan F. Coronel) Published by Elsevier Ltd. On Energy and buildings..

## 7. CONCLUSION

The main aim of this project is to compare and add new material like carbon fiber, aluminum, 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. I want the carbon fiber composite can be used in duct network due to their high excellent properties. This material is used for some specific task like air conditioning in buses, train, airbus where light weight are needed. Glass fabric duct has been used but this duct is not used where moving parts are present because they are flexible duct and performance is affected in this duct so we expect that carbon fiber can be used and I am doing study on carbon fiber

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15. Material science and engineering by William F Smith, Javad Hashemi Ravi Prakash published by the McGraw hill Companies.