



RECYCLED PAPER COMPOSITE MATERIALS DEVELOPMENT AND APPLICATION IN DUCTS FOR AIR CONDITIONING SYSTEM, VENTILATION AND EXHAUST

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Abstract. This work develops composite tubes from recycled paper and resin for applications in air conditioning equipment, ventilation and exhaust systems. The main objective is the reduction of cost with its use with practical application, safe handling and insulating characteristics thermo acoustics. This action is accompanied by recycling, cleaning up the environment, economy, social inclusion and its reuse. During the work is addressed the collection of paper, sorting, selection, cleaning, preparation and resin addition aiming to provide structural reinforcement to the product. Parts are made manually and laboratory experiments are performed where a preliminary finite element analysis and bench tests were carried out in order to validate the proposed composite as part of extensive air conditioning machines. As subject the best way to design this sort of application is studied as well as the processing, impregnation, tension and practical verification of the degree of thermo acoustic insulation. Also its effective efficiency in conducting the air conditioning system air is studied. The results indicate that for this application, considering the composite consisting of 70% to 90% recycled material and 10% to 30% resin achieves a reduction in cost of 20% to 40% of fibrous materials found in commercial market.

Keywords: *Composites, Air Conditioning, Exhaust systems, Structural Reinforcement.*

1. INTRODUCTION

This work presents the development duct composite recycled paper, validated with applications for air-conditioning and exhausting systems. This composite material is developed from recycled paper sheets, impregnated with resin (base PVA glue) . This type of paper is chosen since it is discarded after reading therefore it can be purchased inexpensively and found in abundance. The main function of the recycled paper is to provide structural reinforcement and rigidity, since the paper itself has no physical properties to withstand the air conduction without large deformations. The resin is responsible for keeping the reinforcement bonded, enabling them to transfer the loads as well as to supply chemical characteristics to the ducts. The duct system may have varied geometries, which can be molded as needed in order to meet the desired architecture used by the designer. The validation of the product will come through laboratory testing to prove their efficiency and thermo-acoustic anti-flame propagation, as well as the assembling process for use on the air conditioning system.

2. DESIGN AND MANUFACTURING

The relevance of this work lies in the possibility of obtaining products with lower specific weight, easy manufacturing process associated with lower , easier assembly (less weight demands less support), thermo-acoustic insulation economy and lower incidence of accidents in the manufacturing / molding and assembly, when compared to the most used product in the market made of galvanized steel sheet.

2.1. Requirements

The first needs to perform air convection emerged at the beginning of human civilization in the manipulation and interaction with fire cooking food led with the need to exhaust the smoke, thus creating system based on chimney, made of available materials at that time easy such as stones, bricks, wood and bamboo, which can be considered as the first application in the ventilation ducts. All of these materials presented a problem when used as an air duct. The stones chimney, in addition to being difficult construction, is heavy and has very great air leakage. Ducts made of sheet

steel became the best choice of material for the construction of pipelines at that time. Over the years it has become necessary to create air conditioning systems for thermal comfort and cooling equipment. Thus arises the premise of air conduction.

Many advances have been achieved along the years, always with the premise of reducing cost and assembly time which conduct to application of pipelines to small snippets and interconnections extension, made of aluminum semi-flexible and flexible (with and without thermal insulation). Nowadays, lighter materials and structures based on composite materials have been applied due to their simplicity and quick assembly, however with high cost, such as glass wool, aluminum sandwich - expanded polyurethane, polyethylene and cement board (polystyrene - aggregate cement). In recent years, market demand is determined by materials having the following characteristics:

- Lead to energy savings;
- Are ecologically sound; - enable social inclusion;
- Are recyclable;
- Are easy to use;
- Provide the lowest cost labor.

2.2. Materials and manufacturing

The main characteristics of the materials used are listed below:

- Materials: recycled paper and resin based PVA;
- Composition: Cellulose (93%) and water (7%);
- Weight: 48.8 g / m² ;
- Thickness: 0.49 mm;
- Distribution of fibers: Random;
- Appearance of tubes or strips 1.25 mm wide;

In this first stage of development, the validation was performed throughout a manual process in the manufacture of the ducts in order to validate the material use and processing characteristics. Further improvements can be implemented in the near future in order to use automated manufacturing process within existing or dedicated equipments. The newspaper sheets are initially cut into its fold later in 7cm wide strips and rolled into straws (with the aid of a wire). Following these are molded directly on top of the mold duct. In case we used a PVC pipe of 50 mm diameter. The paper pipes were extended on the template and joined together by glue PVA-based white (which constitutes the resin in this application) in a single layer, which ensured its support in relation to the length (so as not to incur deformation by twisting and / or bending mostly).

3. RESULTS

The paper has a density (eight times) than the most commonly used material in the manufacture of air ducts, the galvanized steel sheet. The paper has a good noise absorption (acoustic insulation) and low heat conduction (thermal insulator). Use a material that today is not fully recycled, and even its recycling process demands high cost of energy and water. One additional advantage of the use of recycled paper in such applications is that it reduces the amount of discharged paper waste, reducing environmental pollution of the environment or fires. In the following table some comparative results are presented. It was used an air conditioner (mobile), adapting its air outlet fitting of the ducts. The developed ducts were coated with aluminum foil and compared to galvanized sheet metal ducts, more traditional market.

Table 1 – Comparative results

	Recycled paper	galvanized metal	Paper + aluminum
Velocity [m/s]	8,3	8,3	8,3
Internal temperature [°C]	14,8	16,4	15,4
	21,1	16,6	21,0
Noise [dBA]	72	80	73

Dimensions	Diameter=75mm Lenght=250mm	Diameter =75mm Lenght =250mm	Diameter =75mm Lenght =250mm
Weight [g]	50	225	52
Thickness [mm]	3,3	1	3,4
Condensation	no	yes	no

From the data shown in the table, it can be seen the following differences between the ducts sheet steel and paper:

- The speed used was the same without causing any damage to the paper product. Since use in air conditioning spd. maximum of 8m / s;
- The difference in temperature from the inside to the outside is clearly noticeable compared between the ducts, which proves the efficient thermal insulation duct;
- Acoustically proven its ability to isolate, quite considerable, in comparing the ducts tested;
- Weight, kg very less, directly influencing the facility (transportation, fixing, handling, among others);
- In the thick items and condensation, we see much smaller thickness in pipeline steel plate, but water condensation occurring precisely in opposition to what happens in the duct of paper; note: the steel duct would be necessary to add thermal insulation, as usual (in air conditioning), to solve the problem of water condensation on it (due to water vapor, the environment), but it would be increasing the thickness of the duct, which is not required in duct paper, which by itself forms a vapor barrier.

Some pictures of the experimental work is shown in the next figures, for each experiment the product are adjusted to the air conditioning system, allowing the blowing of cold air and the measurements were taken one by one of the ducts, temperature, speed and noise. As mentioned it was used a recycled paper duct coated with aluminum foil and duct galvanized sheet metal.



Figure 1 – Recycled paper duct with inner aluminum coating.



Figure 2 – Digital thermometers installed in the inner and outer side of the ducts.

The manufacture of flat plates is a versatile alternative to conventional manufacturing products, allowing to laminate the recycled paper to generate a plate. For air conditioning applications, it would be cut in the required dimensions and assembled in the same manner as the aluminum plate polyurethane and / or polystyrene cement, as shown in figure 3.

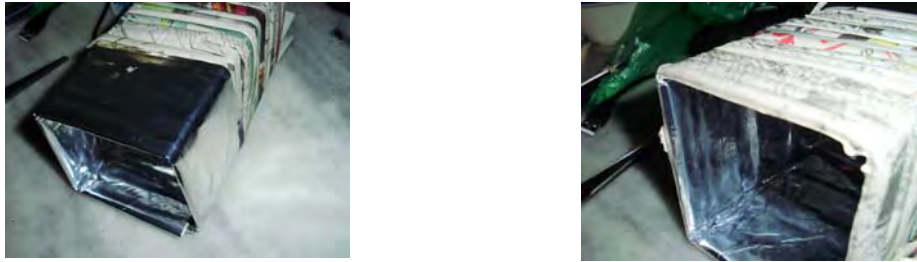


Figure 3 – Ducts manufactured by using recycled papers composite plates.

Flexible Ducts

This type of ducts have been widely used in direct applications of air supply and return air. It is very easy to use due to its high mobility inherent to its structure, being used mainly in extensions and interconnection pipeline networks. To test the applicability of the proposed ducts to this case, some flexible ducts were built and submitted to the same experiments as the others. Although the main focus of the work is the rigid pipes, due to wide applicability in the market today, the flexible ducts are increasingly being used in several applications, which justifies the validation of proposed ducts in this case.



Figure 4 – Flexible ducts with radial na helical windings.



Figure 5– Dutos Flexíveis com enrolamentos radiais e helicoidais, depositado sobre o papel jornal.

4. CONCLUSIONS

The results obtained show that the objective was achieved, as outlined in the following:

- Development of an air duct, composite, from reused paper newspaper and resin type PVA (white glue);
- Low cost of developing the product;
- Convenience, ease and security implementation and enforcement;
- For applications in air conditioning, ducts up to expectations developed thermo-acoustic insulation and lightness;
- The ducts presented have been already developed for about four years maintaining so far in perfect condition and functionality;



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- The duct that showed the best appearance and uniformity, was that built by the filament winding process. In this case, the expected behavior of the temperature on the outer face will also be more uniform due to the more homogeneous distribution of the thickness of the paper;
 - Ecological benefit achieved through the re-design, re-use and recyclability.
- However some limitations of recycled paper composite ducts can be established:
- In some applications they might not be adequately resistant to weather conditions. However, this is common also for other ducts materials and the solution generally adopted is the use specially developed protection systems;
 - They might have some limitations for certain types of exhaustion such as chemicals products and high temperature. These limitations can be solved in a relatively easy way by the using proper internal coating protection.

5. REFERENCES

- Albuquerque, Renata Jorge de, 2005, Desenvolvimento de Material Compósito para Reforço de Dutos de Aço. Dissertação de Mestrado. Rio de Janeiro: Universidade Federal do Rio de Janeiro COPPE.
- Almeida, J.F. de, 2001, Bíblia Sagrada pp.15, . 2ª Edição Revista e Atualizada. São Paulo. Sociedade Bíblica do Brasil.
- Araújo, Alex Maurício, 2009, Ventilação Aplicada à Engenharia de Segurança do Trabalho. Apostila. Recife: Universidade Federal de Pernambuco.
- Buss, Diva Elena. **1981**, Como fazer Papel Artesanal . Tese de Mestrado. São Paulo: Universidade de São Paulo.
- Carvalho, Jonas de, 2008, Projeto e Fabricação de Componentes em Material Polimérico Compósito. Notas de aula. São Carlos: Universidade de São Paulo.
- Kia, H. G., July 1993, “SMC - Sheet Moldind Compound - Science and Technology ”. Hanser Gardner Publications.
- MULTIVAC. MPU. 2010, São Paulo: CATÁLOGO MULTIVAC.
- Pinheiro, Ana Paula Basile, 2010, . Matéria Dutos. Revista Climatização e Refrigeração nº114. São Paulo, Fevereiro.
- Piggott, Michael, 2002, Load Bearing Fibre Composites. New York: Kluwer Academic Publishers.
- Rousseau, J.; Perreux, D.; Verdière, N. 1998, The Influence of Winding Patterns on the Damage Behaviour of Filament Wound Pipes. N° 59. pp. 1439-1449. In: Journal of Composites Science and Technology, Elsevier.
- SAINT-GOBAIN – VETROTEX, 2000, Vetrotex Glass Fibre. Chambéry: VETROTEX.
- THERMOSYSTEM. 2009, Thermofort. Ribeirão Preto: CATÁLOGO.
- Torreira, Raul Peragallo, 1997, . Elementos Básicos de Ar Condicionado, Hemus, São Paulo.