Buletinul Ştiinţific al Universităţii "POLITEHNICA" din Timişoara

Seria HIDROTEHNICA

TRANSACTIONS on HYDROTECHNICS

Tom 58(72), Fascicola 2, 2013

Considerations Regarding the Geometrical Construction of Distributors/Collectors Equipment Used in Ventilation/Air Conditioning.

Carmen MÂRZA[1] Eugenia DUCA[2] Georgiana CORSIUC[1]

Abstract: Ventilation / air conditioning ducts are characterized by large sections of hundreds of millimeters. On the path of the fresh or conditioned air duct insertion, respectively of the exhaust air discharge one uses distributors / collectors. These are designed to equalize the fluid flow and pressure in the system devices.

In this paper we propose a graphical and analytical case study of two geometrical types of distributor / collector for circular duct:

- **Solution I: annular torus shape;**
- **Solution II: succession of horizontal cylinders, which follows, respectively chamfer the exterior and interior nappes of the torus.**

Keywords: distrubutors, collectors, torus, cylinder, intersection, ellipse.

1. FUNDAMENTALS OF HIGH-TECH ARCHITECTURE

With the development and industrialization of society, naturally, appeared a new trend in architecture that belongs to the post modern style, namely the so-called high-tech architecture. In fact, this style corresponds to the cubism, respectively to the expressionism movements from the arts. A part of the society looked critically and with skepticism in this direction, but in the end it was acceptated because it responds very well to the needs and expectations of contemporary people, who became pragmatic and efficient.

Thus, the high tech style or structural expressionism is characterized by straight lines and right angles, through linear cuts, or by circular shapes and simple curves. It creates an impression of austerity, simplicity and functionality. The feature of "cold" is due to the materials and colors used. Thus, one uses abundant metal, steel, plastic, glass, meaning shiny and chromate surfaces. One uses metallic colors, that are not found in nature, like gray, silver, blue, red, etc.We can therefore conclude that the high tech architecture is urban, sophisticated and artificial.

Among the first buildings of this style which prevails in the world of architecture was the Pompidou Centre in Paris, conducted by the architects Renzo Piano, Richard Rogers and Gianfranco Franchini. This style is well suited to buildings for offices, exhibition spaces, airports, show-rooms, but also extended to residential buildings.

At this time there are a number of buildings, mainly characterized by big openings and large spaces such as the Pompidou Centre in Metz (architect Shigeru Ban), Oriente Station (architect Santiago Calatrava), Hearst Tower (architect Sir Norman Foster) - Fig.1, The Lloyd's building or the Inside-Out Building (architect Richard Rogers) - Fig .2, Lisbon Portela airport. The last one represents the inspiration of this paper. Moreover, in a previous work, the authors have studied other piping components [5] and further, in this paper they perform a graphical and analytical analysis of the distributors / collectors used in air conditioning installations.

Fig. 1. Hearst Tower (New York) [6]

[1,3] Technical University of Cluj-Napoca, Faculty of Building Services Engineering, B-dul 21 decembrie 1989, 128-130, 400604, Cluj-Napoca , Romania , e-mail: Carmen.Marza@insta.utcluj.ro, Georgiana.Iacob@insta.utcluj.ro.

[2] Technical University of Cluj-Napoca, The Faculty of Automation and Computer Sciences, Str. G. Baritiu 25, 400027, Cluj-Napoca, Romania, Eugenia.Duca@math.utcluj.ro

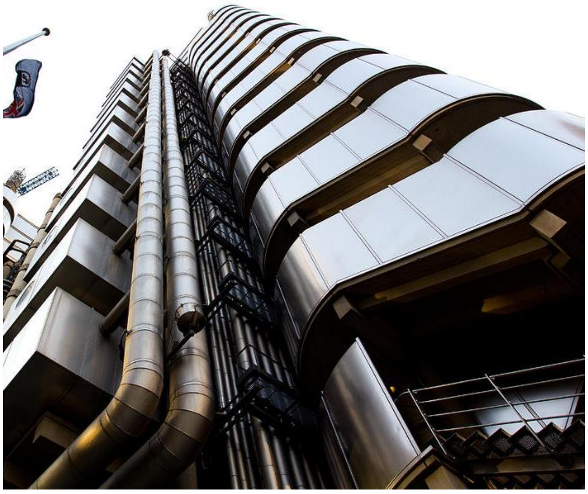


Fig. 2. The Lloyd's building (London) [7]

2. CASE STUDY ON GEOMETRIC REALIZATION OF DISTRIBUTORS / COLLECTORS IN AIR CONDITIONING INSTALLATIONS.

In the architectural styles previous to high tech architecture, the facilities of any kind were made buried or concealed. This way was very well suited in classic styles, in which, we have to admit, utilities had a limited role. With the increasing demands of the occupants regarding the habitat conditions - in general, namely the microclimate - in particular, installations in a building acquired a fundamental role and their scale increased. Implicitly, the space allocated to them is larger. Thus, the masking, the execution of false ceilings or the realization of specific technical areas has become an expensive choice because much of the effectively area of the building was occupied, reducing the useful space. From this point of view, high tech architecture provided a perfect solution by performing the installations visible, designed from the projecting phase, as part of the architecture. Obviously, their design has become precious, to provide harmony to the eye and, why not, to the occupants spirit.

In this context, we present two technical solutions to achieve distributors that can be used to the route of a ventilation / air conditioning duct, to suply fresh air in the room, or collectors to remove polluted air out of the rooms.

From geometrical point of view their construction is the same, the name being different due to the functional role. Usually, distributors / collectors are used commonly in plants that carry liquids and less to those that transport air. Here, being a unique building, which belongs to the high tech architecture, one offers special solutions according to the style features. These parts of installations are used for adjusting and balancing flow.

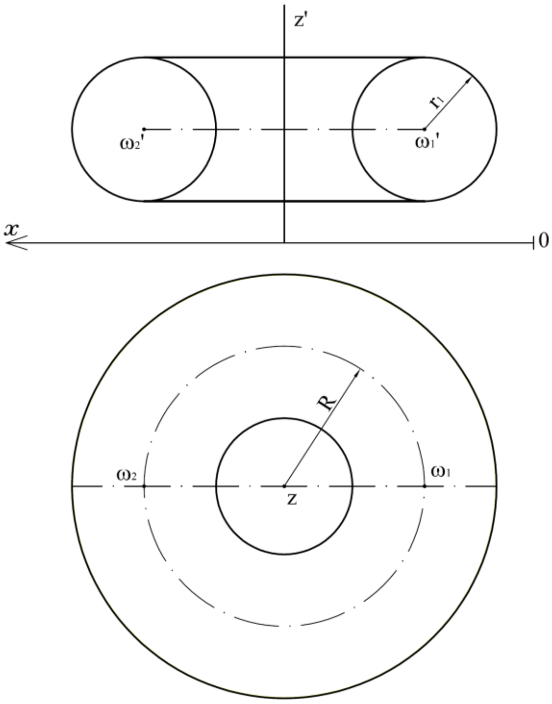
2.1. FIRST SOLUTION

In the first solution proposed, the authors thought to make the tubing where the collector/distributor was a torus, connected to the circular tubing fresh air inlets or vicia air outlets.

In Figure 3 is represented the torus having the vertical axis (z,z’) as follows: in Figure 3.a is the double projection of the torus and Figure 3.b shows the axonometric projection [2].

The analytical equation of the torus with the vertical axis Z(z,z’), whose generatrix circle is of radius „r_1” and the centre is $\Omega_1(\omega_1, \omega_1')$, respectively the middle circle of radius „R” is given by [1]:

$$(x^2 + y^2 + z^2 + R^2 - r_1^2)^2 - 4R^2(x^2 + y^2) = 0 \qquad (1)$$



a. Orthographic representation

b. Axonometric representation

Fig. 3. Distributor/collector as a torus

Even though, from mathematical point of view, this solution is simpler, the effective construction of the thorus from metal sheet is more difficult. In addition, the intersection of the torus and circular tubes that carry air is also difficult to achive, resulting warped curves in space. For this reason it is proposed the following solution.

2.2. SECOND SOLUTION

The second solution represents a geometrical transformation of the previous solution, where the torus is replaced by a succession of horizontal cylinders that follow, respectively chamfer the external and internal nappe of the torus [5]. Considerations regarding the selection of the horizontal cylinders and of the angles of the cutting vertical planes are analyzed as it follows. One can notice that in horizontal projection, the cylinders follow the line of the equator, respectively of the torus collier circle. In Figure 4 we noted with I, II and III the cylinders of radius r, which composed a modulus of the studied surfaces.

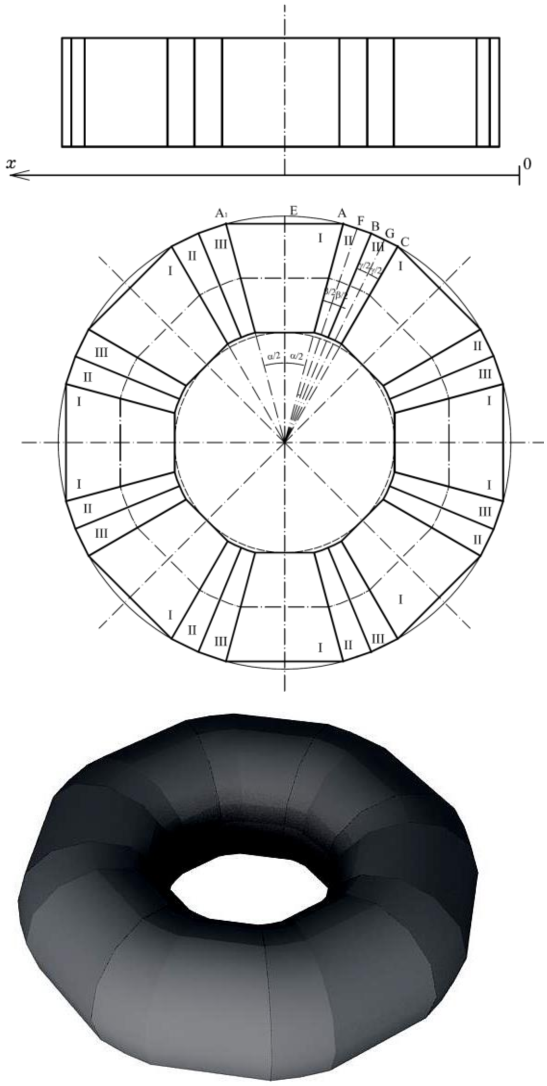


Fig.4. Views of the set of cylinders and 3D representation

We noted with A_1, A, B, C, E, F, G points on the concerned cylinders axes. Points A_1, A, B, C are the extremities of these cylinders, namely A_1 and A are the extremities of the axis of cylinder I, A and B are the ends of the axis of cylinder II respectively B and C extremities of cylinder III. Points E, F, G represent the middle of the axis A_1A, AB and BC. The considered points have the following Cartesian coordinates:

$$E(0, R\cos\frac{\alpha}{2}, 0)\;; \tag{2}$$

$$A(R\sin\frac{\alpha}{2}, R\cos\frac{\alpha}{2}, 0)\;; \tag{3}$$

$$F(R\cos\frac{\beta}{2}\sin\frac{\alpha+\beta}{2}, R\cos\frac{\beta}{2}\cos\frac{\alpha+\beta}{2}, 0)\;; \tag{4}$$

$$B(R\sin\frac{\alpha+2\beta}{2}, R\cos\frac{\alpha+2\beta}{2}, 0)\;; \tag{5}$$

$$G(R\cos\frac{\gamma}{2}\sin\frac{\alpha+2\beta+\gamma}{2}, R\cos\frac{\gamma}{2}\cos\frac{\alpha+2\beta+\gamma}{2}, 0)\;; \tag{6}$$

$$C(R\sin\frac{\alpha+2\beta+2\gamma}{2}, R\cos\frac{\alpha+2\beta+2\gamma}{2}, 0), \tag{7}$$

knowing that:

$$OF = R\cos\frac{\beta}{2}\;; \tag{8}$$

$$OG = R\cos\frac{\gamma}{2}. \tag{9}$$

Generally, a cylinder whose generatrices are parallel to the line of equation [1]:

$$D:\ \begin{cases} y = mx \\ z = 0 \end{cases}; \tag{10}$$

and which is tangent to the sphere of center (a, b, 0) and radius r, has the equation [1]:

$$(y - mx + am - b)^2 + (1+m^2)z^2 = (1+m^2)r^2. \tag{11}$$

Customizing for the positions shown in Fig. 4 further are explained the equations of the three cylinders.

Therefore, cylinder I has the generatrices parallel to Ox and it is tangent to the sphere of radius „r" and the centre in E. The equation of cylinder I is:

$$\left(y - R\cos\frac{\alpha}{2}\right)^2 + z^2 = r^2. \tag{12}$$

Cylinder II has the generatrices parallel to the line of equation:

$$\begin{cases} y = -(tg\frac{\alpha+\beta}{2})x + R(\sin\frac{\alpha+\beta}{2}\sin\frac{\alpha}{2} + \cos\frac{\alpha}{2}) \\ z = 0 \end{cases}. \tag{13}$$

It is tangent to the sphere of radius „r" and having the centre in E. Its equation is:

$$\left[y + x tg\frac{\alpha+\beta}{2} - R\cos\frac{\beta}{2}\left(\cos\frac{\alpha+\beta}{2} + \sin\frac{\alpha+\beta}{2} tg\frac{\alpha+\beta}{2}\right)\right]^2 + \left(1 + tg^2\frac{\alpha+\beta}{2}\right)z^2 = \left(1 + tg^2\frac{\alpha+\beta}{2}\right)r^2 \Leftrightarrow \tag{14}$$

$$\left(y\cos\frac{\alpha+\beta}{2} + x\sin\frac{\alpha+\beta}{2} - R\cos\frac{\beta}{2}\right)^2 + z^2 = r^2 \tag{15}$$

The cylinder III it is obtained as a cylinder tangent to the sphere of centre G and radius r, whose generatrices have the direction:

$$m = -tg\frac{\alpha+2\beta+\gamma}{2}. \tag{16}$$

Its equation is:

$$\left[y+xtg\frac{\alpha+2\beta+\gamma}{2}-R\cos\frac{\gamma}{2}\left(\cos\frac{\alpha+2\beta+\gamma}{2}+\sin\frac{\alpha+2\beta+\gamma}{2}tg\frac{\alpha+2\beta+\gamma}{2}\right)\right]^2+$$
$$+\left(1+tg^2\frac{\alpha+2\beta+\gamma}{2}\right)z^2=\left(1+tg^2\frac{\alpha+2\beta+\gamma}{2}\right)r^2 \quad \Leftrightarrow \quad (17)$$

$$\left(x\sin\frac{\alpha+2\beta+\gamma}{2}+y\cos\frac{\alpha+2\beta+\gamma}{2}-R\cos\frac{\gamma}{2}\right)^2+z^2=r^2 \quad (18)$$

The cylinder I (AA_1) intersects the cylinder (AB) about the curve:

$$\begin{cases}\left(y-R\cos\frac{\alpha}{2}\right)^2+z^2=r^2\\ \left(x\sin\frac{\alpha+\beta}{2}+y\cos\frac{\alpha+\beta}{2}-R\cos\frac{\beta}{2}\right)^2+z^2=r^2\end{cases} \quad (19)$$

The cilinder II (AB) intersects the cylinder (BC) about thr curve:

$$\begin{cases}\left(x\sin\frac{\alpha+\beta}{2}+y\cos\frac{\alpha+\beta}{2}-R\cos\frac{\beta}{2}\right)^2+z^2=r^2\\ \left(x\sin\frac{\alpha+2\beta+\gamma}{2}+y\cos\frac{\alpha+2\beta+\gamma}{2}-R\cos\frac{\gamma}{2}\right)^2+z^2=r^2\end{cases} \quad (20)$$

In general, the curve of intersection of two cylinders is not a plane curve.

Indeed, the intersection of the cylinder I with the plane which passes through the line OA is the ellipse:

$$\cos^2\frac{\alpha}{2}\left(x-R\sin\frac{\alpha}{2}\right)^2+z^2\sin^2\frac{\alpha}{2}=r^2\sin^2\frac{\alpha}{2} \quad (21)$$

The intersection between the cylinder II with the plane which passes through OA ia the ellipse given by the relation:

$$\cos^2\frac{\beta}{2}\left(x-R\sin\frac{\alpha}{2}\right)^2+z^2\sin^2\frac{\alpha}{2}=r^2\sin^2\frac{\alpha}{2} \quad (22)$$

The curves 21 and 22 are contained in the vertical plane which passes through OA, respectively are identical if $\alpha = \beta$. Therefore, the cylinders I and II intersects about the ellipse:

$$\begin{cases}\cos^2\frac{\alpha}{2}\left(x-R\sin\frac{\alpha}{2}\right)^2+z^2\sin^2\frac{\alpha}{2}=r^2\sin^2\frac{\alpha}{2}\\ y=xctg\frac{\alpha}{2}\end{cases} \quad (23)$$

The intersection of the cylinder II with the vertical plane which passes through OB is the ellipse having the equation:

$$\cos^2\frac{\beta}{2}\left(x-R\sin\frac{\alpha+2\beta}{2}\right)^2+\left(\sin^2\frac{\alpha+2\beta}{2}\right)z^2=$$
$$=r^2\sin^2\frac{\alpha+2\beta}{2} \quad (24)$$

The intersection of the cylinder III with the vertical plane which passes through OB is the ellipse:

$$\cos^2\frac{\gamma}{2}\left(x-R\sin\frac{\alpha+2\beta}{2}\right)^2+\left(\sin^2\frac{\alpha+2\beta}{2}\right)z^2=r^2\sin^2\frac{\alpha+2\beta}{2} \quad . (25)$$

The two plane ellipses concide if $\beta=\gamma$. Therefore the intersection curve of cylinders II and III is the plane ellipse:

$$\begin{cases}\cos^2\frac{\beta}{2}\left(x-R\sin\frac{\alpha+2\beta}{2}\right)^2+\left(\sin^2\frac{\alpha+2\beta}{2}\right)z^2=r^2\sin^2\frac{\alpha+2\beta}{2}\\ y=xctg\frac{\alpha+2\beta}{2}\end{cases} \quad .(26)$$

3. CONCLUSIONS

From mathematical point of view first solution seems simpler because the thorus equation is known, but the practical construction of this element raises technology problems. The second solution proves engineering ingenuity and creativity. This allows the realization in safer conditions of the connections between the horizontal cylinders that form the assembly. This solution requires a laborious mathematical study as the choice of the cylinders must be made so that the intersection curves will be plane (ellipses), easy to construct, to ensure a perfect seal between the various portions and a high degree of silence. Also, it must achieve a continuous surface which provides a laminar air flow with minimum pressure loss and allows the main objective of the distributors / collectors, meaning equalizing the pressure in the system [4].

In Figure 5 are presented similar achievements of the second solution, encountered in Lisbon airport. We noted that the intersections between the ducts that transport air - made of vertical and oblique cylinder - with the distributor is achieved through connecting pieces that have been studied by the authors in a previous paper [5]. Both the achievement of the distributor and of the connecting elements of the tubing are technologically safer and easier to make.

Fig. 5. Part of air conditionig installation.

REFERENCES

[1] *D., Andrica, L., Topan,* Analytic Geometry, Cluj University Press, Cluj-Napoca, 2004

[2] *D., Dragan, C., Marza,* Geometrie Descriptiva. Probleme, U.T. PRES, Cluj-Napoca, 2006.

[3] *D., Dragan, C., Marza, M., Granescu,* Descriptive Geometry, U.T. PRES, Cluj-Napoca, 2007

[4] *F., Domnita, T., Popovici, A., Hotupan,* Instalatii de ventilare si conditionare, U.T. PRES, Cluj-Napoca, 2011

[5] *C., Marza, E., Duca, G., Corsiuc,* Graphical, analytical, and aesthetic study between air conditioning solutions in large spans, Mongeometrija 2012, Novi Sad, Serbia.

[6] http://en.wikipedia.org/wiki/Hearst_Tower

[7] http://en.wikipedia.org/wiki/Lloyd's_building