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AIR CURTAINS AS A PROTECTION FOR CULTURAL HERITAGE

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ABSTRACT

The employment of air curtain to segregate pollutants diffusion near the sources for fire prevention is actually more and more diffused in industry buildings. Their success is due to the peculiarity to compart spaces without fixed barriers which should interfere with people and equipments. The application of air flows in museum deals with the problem to separate visitors and objects in order to protect the latter from pollutants.
When the device is installed near the object to protect, this represents a "direct protection method", and a proposal of this kind of system is on to go in the HVAC and air distribution system retrofitting of the Galleria dell'Accademia in Firenze where Michelangelo's David and other masterpieces are placed in. CFD characterisation of the case-study is reported.

KEYWORDS: CFD, Cultural Heritage, Ventilation Efficiency, Air Curtains

INTRODUCTION

The principal aim of the paper deals with the study of the fluid-dynamic field in the indoor space of the museum of the Galleria dell'Accademia of Firenze, to evaluate the diffusion of the air pollutants which could represent a risk for the statue of the Michelangelo's David.
The use of air curtains may often represent a protection for the cultural heritage without operating on the material of the objects, and without limiting the perception of the work of art.
The employment of air curtain to segregate pollutants diffusion near the sources for fire prevention is presently widely diffused in industry buildings [1], because of their peculiarity to separate zones without fixed barriers which should interfere with people and equipments.
The application of air flows in museum deals with the problem to separate visitors and objects in order to protect the latter from pollutants.
A proposal for a new air distribution system to protect the statue from pollutants deposition, resulting from a series of numerical simulation implemented on 3D models in order to characterize the existing situation, has been carried out. .

DESCRIPTION OF THE CURRENT STATE AND FIRST IDENTIFICATION OF THE FACTORS OF RISK

The pollution control in Museum buildings is related to the composition of Museum atmospheres, the latter being directly connected with the urban pollution existing where the building is located [2], [3].
The simulations have been performed by the calculation software Fluent® which uses the technique of the computational fluid dynamics (CFD). Numerical simulation is needed to perform forecasts on this case study, non-being possible the realization of a prototype.
The principal space of the Galleria dell'Accademia which has a latin cross plant, is realized with the principal nave, which hosts the Michelangelo's statues of Prigioni and Pietà, an with

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the Tribuna where David is placed; there are also two lateral branches where painters of the XVI Century are displayed. The space of the Tribuna is covered by a steel and glass dome. The current air distribution system is composed by under floor ducts and air terminal units located at floor level along the perimeter of the rooms, near the walls.
The rear area of the Tribuna is provided of air diffusers on the floor under the bench and an extraction units on the top of the wall.
Pollutants could rise from visitors and objects hosted in the Museum: the gallery of plaster casts could be dangerous pollutant source, because gypsum may represent a risk factor because of the property to absorb and to relase substances in presence of condensate. These risk factor might be subject of further investigation, to evaluate the presence of dangerous substance in the museum halls.

CREATING THE MODEL

The modelling step of these research, starts with the preprocessing of the cloud of points of the David surface that is obtained with reverse engineering technique on the basis of deep previous studies carried out on the statue [4].The model related problems have been diffusively analysed in [5].
The complete model results of about 1.200.000 cells, 2.400.000 faces and 222.000 nodes. The mesh is built with a progressive increase of density of the nodes in proximity of the statue which represents the surface of greater interest, to obtain better definition of the simulation results.
The presence of visitors usually surrounding the statue (4000 pers/day) is provided modelling a rectangular surface measuring 60 x 180 cm for each person. An inert gas is emitted from these surfaces to evaluate the path of the pollutants emitted by visitors (Figure 1). Each surface emits $2.32x10^{-6}$Kg/s of inert gas, which corresponds to the emission of the CO_2 of a person in standard activity.

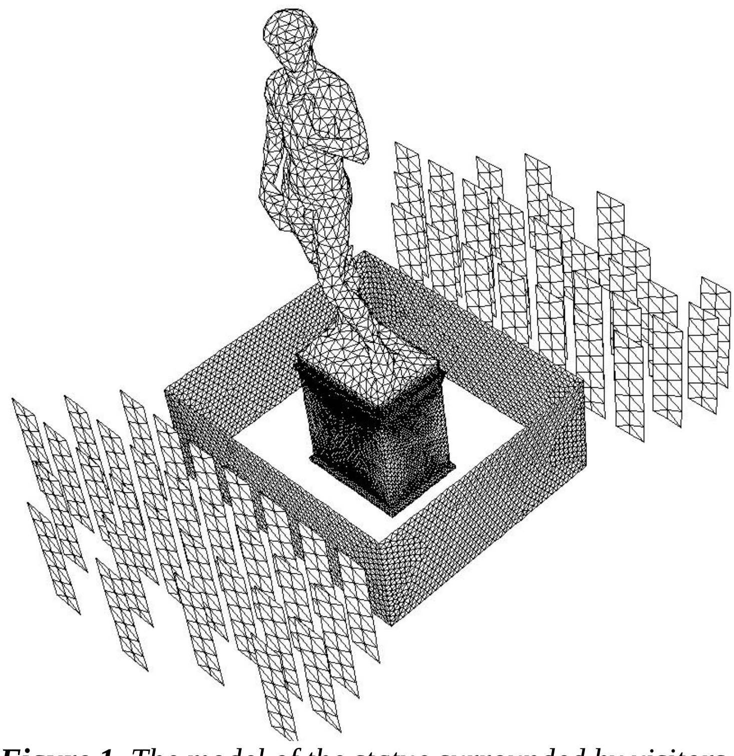

Figure 1. *The model of the statue surrounded by visitors*

CFD CHARACTERIZATION OF THE EXISTING SITUATION

Results of the CFD simulations on the model of the museum in the existing conditions can be summarized as follows.
The mapping of the air velocity in the environment allows to investigate the presence of the stagnation areas, which need to be removed.
The air distribution system shows a flow balanced zone represented by the nave and the lateral branches, and the pressurized zone of the Tribuna. This because in the nave and in the transept the inlet flow rate is about equal to the outlet one, while the Tribuna is served only by emission air units. A compact vertical flow realized from the floor of the apsis area, without interacting sensitively with the statue recalls pollutants from people standing in the back side of the statue. The path of the tracking gas (Figure 2) shows how these pollutants follow a vertical line before loosing rapidly velocity in proximity of the top of the statue (Figure 3). This phenomenon represents a danger for the statue, which, standing in the zone where the air is inclined to stagnate, is submitted to the deposit of the pollutants (Figure 3, where velocity vectors are coloured by velocity magnitude in m/s).
The zones of the gallery and of the branches are characterized by recirculated flow rate which brushes the walls and the vault, from the inlet terminals till the outlet ones. The central zone, assigned to visitors, remains isolated from the principal flow, that confines the pollutants in proximity of the sources. The frontal part of the statues could be however liable to deposit phenomena because of the low values of the air velocity.

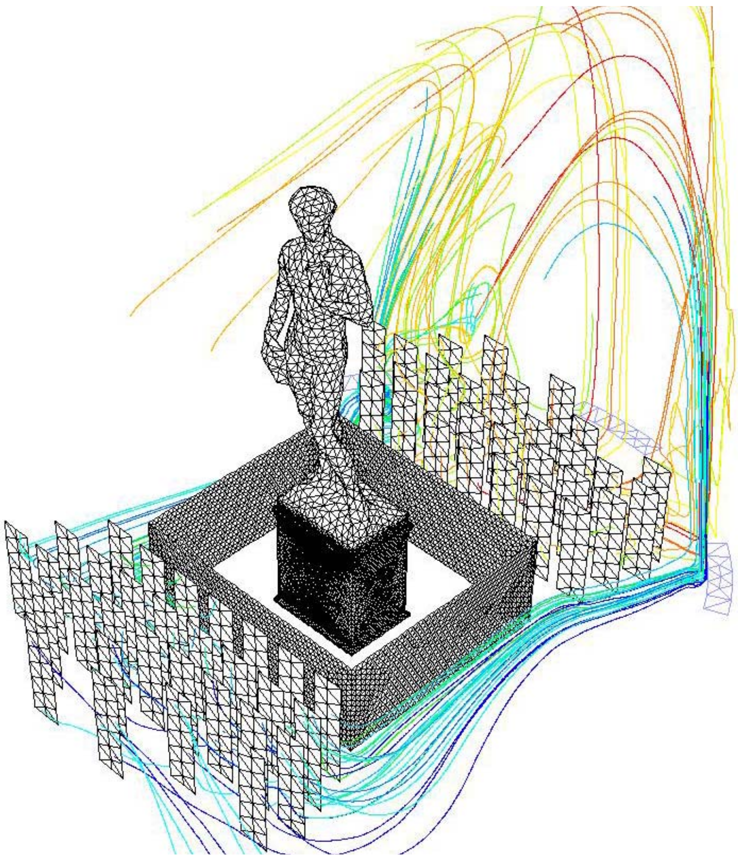

Figure 2. *The path of the pollutants emitted by people*

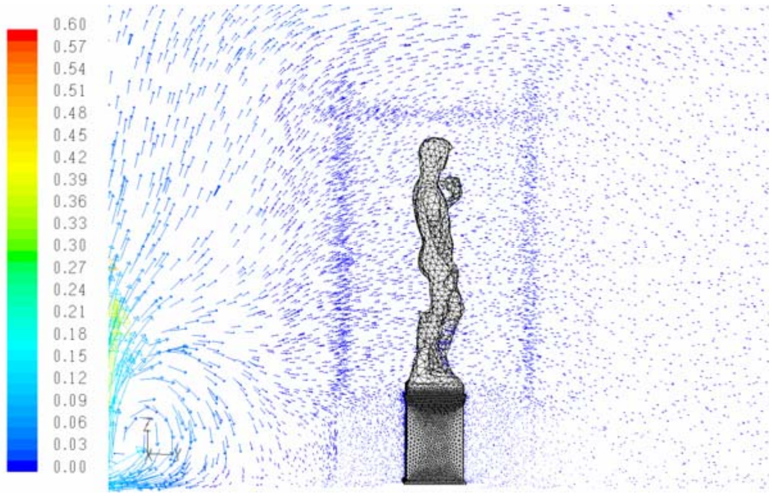

Figure 3. *Velocity field around the statue: longitudinal view*

PROPOSALS OF INTERVENTION

A number of proposals have been stated on the basis of CFD numerical simulations. These descend from a set of numerical simulation finalized to remove the stagnation zone in the area surrounding the statue, to segregate the microenvironment of the statue from the surrounding environment where visitors stand and to improve the ventilation efficiency of the air distribution system. This aim is realized adopting different way to introduce the air flow, creating a pressurized area where the statue is placed.

A preliminary case provides to lift 1.8 m up the inlet units of the floor of the apsis to limitate the interaction of the inlet flow with people standing in proximity of the statue. The pollutants from the inlet units step over the statue without interact with it (Figure 4), but emitted substances recalled from visitors in front of the statue have an higher path, comparing it with the existing situation, which could generate a dangerous deposit zone between the statue and the protection screen.

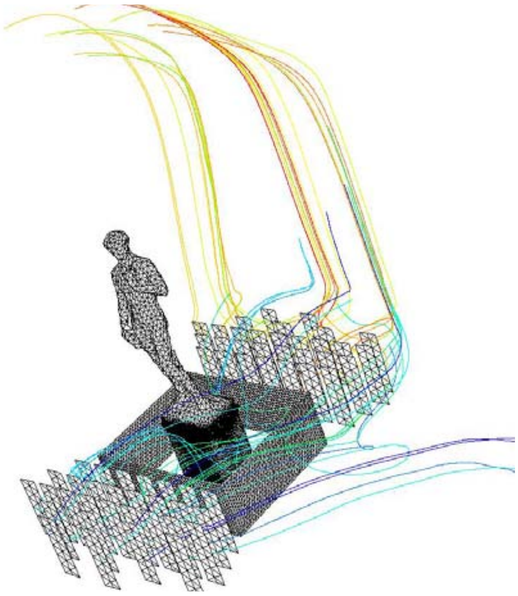

Figure 4. *Pollutans path in a preliminary study case with the lift upward of the inlet terminal air units of the apsis*

Established the impossibility to improve the system arranging inflow and outflow in a different way, a proposal which only eliminates the air flow rate from the inlet units of the

apsis is carried out. This circumstance defines a pressure condition which produces a fluid dynamic separation of the three branch of the museum from the area where the statue stands. The air flow rate of the apsis inlet units is diverted by means a proper duct toward an air curtain placed at the bottom of the statue, the latter increasing the fluid-dynamic separation in order to better isolate the statue from the surroundings.
A solution provides an air curtain rising from a 5 cm wide slot on the perimeter of the base. The air velocity (corresponding the 4000 m^3/h of the inlet flow suppressed of the apsis) is fixed sufficiently high to reach the highest zones of the statue without a remarkable gap of flow. The results of the simulation show the beneficial effect of the air flow from the bottom and of the suppression of the apsis units. The absence of the inlet flow rate from the apsis allow not to lift the pollutants as in the existing situation while the air curtain separate the statue from the surrounding where visitors stands. The air velocity is high enough to separate pollutants from the statue, but not sufficient to reach properly the level of the shoulders of the sculpture, see Figure 5.

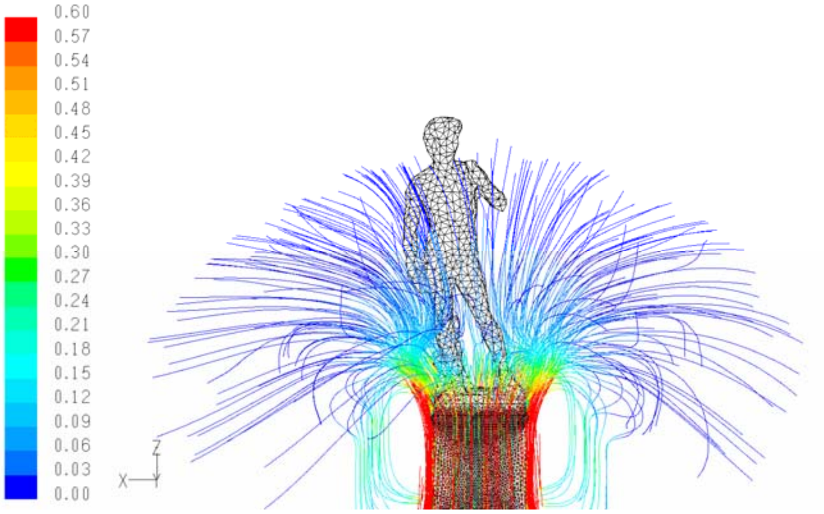

Figure 5. *Flow path lines coming from the base*

The introduction of an extraction unit on the top of the statue produce an improvement of the path of the flow rate air velocity that rises in the head zone of the statue. This hypotesis is finalized to evaluate the effectiveness of the air curtain, in analogy to the *push and pull system* already adopted in the industrial field, and described in detail in technical literature, [6],[7]. The proposed solution with air extraction on the top of the statue shows a tangible ventilation efficiency improvement due to the major uniformity of the air velocity near the surface of the statue.

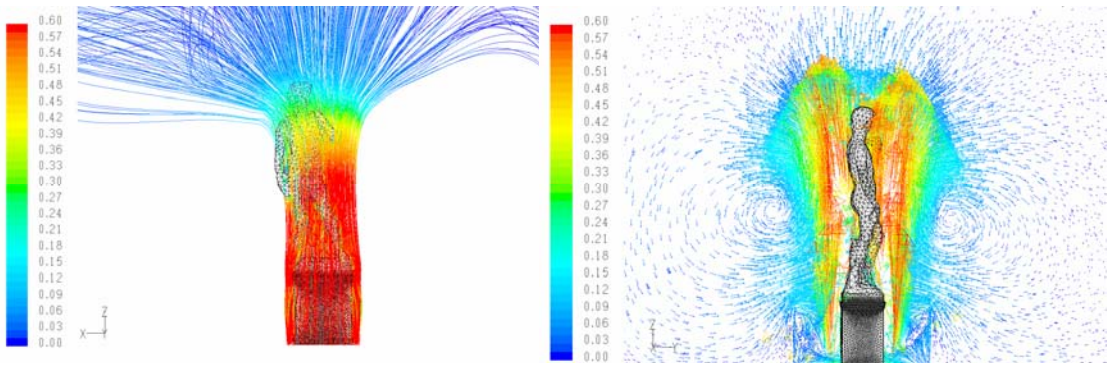

Figure 6. *Final solution with low inlet velocity and zenital extraction***:** *air path lines rising from the base of the statue and field of velocity vectors*

This last configuration is characterised by a low inlet velocity (1.3 m/s), a flow rate of 4000 m^3/h and 2500 m^3/h of zenithal extraction, which determine a marked overpressure zone around the statue.
The numerical studies define the geometrical and cinematic characteristics of the air coming from the bottom in strictly controlled temperature and umidity values [8], [9], [10]; it is possible to observe low velocity at the bottom of the statue (1m/s) and a sufficient high velocity value on the top of it (0.3m/s) (see Figure 6). This last velocity field allows the constitution of a barrier against the likely presence of pollutants from outside the area.
The path of track gases (Figure 7) shows that pollutans are recalled from the air curtain, and transported with sufficiently high velocity value which doesn't allow stagnation zone near the statue.

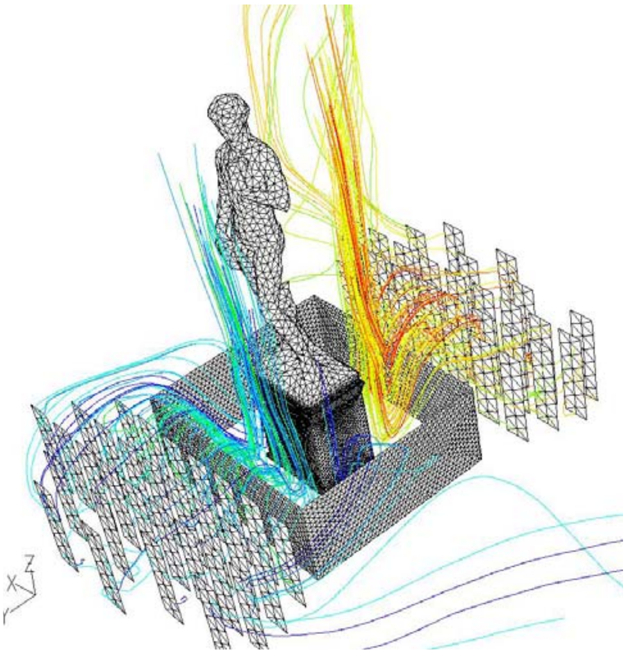

Figure 7. *Path lines of the pollutants*

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