Available online at www.sciencedirect.com
ScienceDirect
Journal of Cultural Heritage 8 (2007) 370–376
Journal of Cultural Heritage
http://france.elsevier.com/direct/CULHER/

Original article

Daily natural heat convection in a historical hall

Carla Balocco*

Dipartimento di Energetica ''Sergio Stecco'', Università di Firenze, Via S. Marta 3, 50139 Firenze, Italy

Received 24 January 2007; accepted 20 April 2007

Abstract

The use of numerical simulation methods for the Cultural Heritage is of increasing importance for the analysis, conservation, restoration and appreciation of works of art. This is particularly important when their preservation and planned maintenance is the primary aim. Today museums, and particularly historical buildings converted to museums, should be considered as places where precious artefacts should have first-rate protection and conservation. It is a question of solving the compromise between protection, conservation and comfort for works of art and/or visitors, with the consequence that preservation and planned maintenance criteria must prevail over use requirements. Refurbishment and conservation of a building, and requirements for visitor presence and works of art need different thermo-physical indoor parameter values. The present paper concerns the thermal and air velocity analysis of the *Salone dei Duecento* (the Hall of the Two Hundred of the Palazzo Vecchio (Old Palace)) in Florence. In this paper an appropriate transient 3D model by Computational Fluid Dynamics (CFD) software based on the finite element method (FEM) was used. Variations and interaction between indoor and outdoor microclimatic conditions, and thermo-physical behaviour of the building connected to lighting, visitor presence and cooling–heating fan coils system were considered. The 3D modelling method provided by the present paper can be applied to several situations where there is interaction between outdoor and indoor climate variations and the building structure. It can be very useful for defining measures to preserve tapestries, understanding deterioration processes, and developing new conservation techniques and strategies for care and exhibition.

Keywords: Historical building; Thermal comfort; Tapestry conservation; Thermodynamics; CFD simulation

1. Research aim

The application of Computational Fluid Dynamics (CFD) based on the finite element method (FEM), in the Cultural Heritage field specifically oriented to conservation and preservation of works of art, is the main aim of this project. This approach is particularly useful for all old buildings and especially for those not usually provided with mechanical systems for the control of indoor air conditions. For these buildings the problems are related to the proper design and installation of heating, ventilation and air conditioning systems, and to real difficulties, times and costs for carrying out a direct monitoring campaign. The analysis of the temperature and vapour concentration distribution due to natural convection, fan coils systems and people presence was performed by a transient conditions simulation, using a CFD [1], to *Salone dei Duecento* (the Hall of the Two Hundred) of the *Palazzo Vecchio* (the Old Palace) in Florence. The present paper provides a 3D modelling that can be applied to all those situations where the interaction between the external climate variations, the building's structure and a fluid flow domain connected to indoor microclimatic conditions is strongly in evidence. It can be very useful for defining measures to preserve the works of art, understanding the deterioration processes and developing new conservation techniques and strategies for maintenance and exhibition. As a matter of fact, the CFD–FEM simulation provides fundamental air flow patterns prediction. Cultural heritage experts, in particular the experts at the *Opificio delle Pietre Dure*, the leading restoration laboratory in Florence, and the architects and

* Tel.: +39 055 479 6236; fax: +39 055 479 6342.
E-mail address: carla.balocco@unifi.it

1296-2074/$ - see front matter © 2007 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.culher.2007.04.004

technicians of the Restoration Centre of the Florence Municipality (*Fabbriche di Palazzo Vecchio*), are interested in this research work. The simulation method used in the present paper is useful for understanding the natural heat convection system inside historical buildings, and also for analysing and comparing different techniques for conserving, preserving and exhibiting works of art.

2. Introduction

Many studies have been carried out in order to assess the optimal features of the indoor climate of museums [2–7], with particular attention to the deterioration and conservation conditions of materials. Microclimate and in time and space variations of its parameters play a fundamental role in the degradation process of materials: e.g. sudden intense variations of air temperature and connected relative humidity are supposed to induce indoor thermo-physical and structural stress in several materials. The use of technological innovation, experimental studies and simulation is of increasing importance for the analysis, conservation and restoration of the Cultural Heritage. This is particularly important when the preservation of works of art and their planned maintenance is the primary aim. Today historical buildings are usually converted to museums so they should be considered places where precious artefacts should find first-rate protection and conservation. This is a question of solving the compromise between protection, conservation of works of art and comfort for visitors, with the consequence that preservation and planned maintenance criteria must prevail over use requirements. European and Italian laws and standard rules provide some basic indications [6,8–11]. Methodologies for precise experimental measurements, comparative analysis and collecting data and information about thermo-hygrometric and natural/artificial lighting parameters address works of art conservation [5,12]. They also provide reference values for plant design, suggestions for coupling works of art and visitor thermo-hygrometric requirements and the maximum admissible vapour quantity together with the minimum acceptable temperature level. The stability requirements of microclimatic conditions are the most binding. Variations in thermo-physical parameters need to be reduced because they are as damaging as their absolute values, also ensuring a sufficient comfort level for users.

3. The architectural and environmental conditions of the Hall

The *Salone* is located on the first floor to the left side of the *Palazzo Vecchio* in Florence (the present town hall). It is one of the most important official venues in Florence and the seat of the Town Council and of several political, economic and functional activities. In addition to these very different uses, its museum character is fundamental. The architectural features of the *Salone* can be considered a single volume with a base area of about 369 m^2, 9.81 m high and a volume of 3619 m^3. The south-west wall is 153 m long and the north-west one 233 m. On the north-west and south-west walls, there are respectively five and three wide arch windows. The internal surfaces of the walls are frescoed and their lower parts are faced with typical local stone and marble. The floor is supported by the cross vaults of the *Sala D'Armi* (Arms Room) of the building. The flooring is terracotta with local stone strip rectangular divisions. The ceiling covering system holds up the moulding of the coffered ceiling and the ceiling itself, with an order of nine wood girders. The ceiling is decorated with oil paintings and small wood panels. In Table 1 the thermo-physical properties of the structures of the building are shown.

The present intention of the Municipality to replace ten precious ancient tapestries depicting the Old Testament episodes in the life of Joseph highlights all the potentialities for museum utilisation that is subject to a constant visitor number increase. Serious damage to the ten tapestries was caused when they were used to decorate Italian embassies abroad and other prestigious venues, because of problems of moving and handling. From the end of the 19th century to the beginning of the 20th, they were displayed for years in disastrous conditions, sometimes in full daylight and thermo-hygrometrically damaging conditions. The lack of interest in their conservation was due to the fact that these artefacts were considered decor rather than works of art, and they were not given the care and attention which was originally devoted to them. Consequently they were often left permanently on display, without the alternation of prolonged periods in store necessary to prevent their rapid deterioration. In the second half of the 1970s, a great deal of work began on the recovery of this heritage, enhanced through the by now historic *Medici exhibitions* of 1980, the year in which the tapestry restoration section of the *Opificio delle Pietre Dure* was set up. They were detached, photographed and subjected to an exhaustive examination of their state of conservation, after which they were rolled up and placed on racks [13]. Although they had been subjected to important conservation operations, these ought to have been followed by periodical reviews and restoration. At present there is a widespread lively *querelle* on their possible replacement inside the Hall. Consequently any intervention must be justified by a rigorous restoration and conservation of the museum container, i.e. the building, the Hall itself and mainly of these

Table 1
Thermo-physical properties of the main structural and building materials

Description	Thickness (m)	Thermal conductivity (W/m K)
Wall – local stone	1.23	2.31
Wood frame	0.08	0.15
Double glass (mm 5-4-5) with Argon	0.015	0.265
Triple glass (mm 5-4-5) with lead glass in the cavity	0.015	0.63
Wood coffered ceiling	0.15	0.138
Wood girder	0.50	0.993
Terracotta and flake of plasters; floor	0.46	0.71