EFFECT OF GROOVE AT CAR PARK EXTRACTION SYSTEM

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To my beloved wife

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ABSTRACT

Efficient smoke removal system from a car park is very important to maintain visibility and other safety factors for drivers. In this study, the effect of grooves and transverse grooves on car park extraction system was investigated through numerical simulations. Simulations of car park extraction system performance were carried out for five cases of different groove geometries along with a fire source simulating a car fire. Results indicate that the transverse grooves arrangement is observed to contribute minimum back layering of flow of throughout the whole domain. This indicates higher visibility for the domain. However, higher temperature distribution is also observed for the same type of groove arrangements.

ABSTRAK

Cekap asap penyingkiran sistem dari tempat letak kereta adalah sangat penting untuk mengekalkan penglihatan dan faktor-faktor keselamatan yang lain untuk pemandu. Dalam kajian ini, kesan alur dan alur melintang pada sistem pengekstrakan tempat letak kereta telah disiasat melalui simulasi berangka. Simulasi tempat letak kereta prestasi sistem pengekstrakan telah dijalankan bagi lima kes geometri alur yang berbeza bersama-sama dengan sumber api simulasi kebakaran kereta. Keputusan menunjukkan bahawa susunan alur melintang diperhatikan menyumbang lapisan belakang sekurang-kurangnya aliran di seluruh seluruh domain. Ini menunjukkan penglihatan yang lebih tinggi untuk domain. Walau bagaimanapun, taburan suhu yang lebih tinggi juga diperhatikan untuk jenis yang sama pengaturan alur.

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Nomenclature

C_f	-	Skin-friction coefficient $C_f = \frac{\tau_w}{\rho U_\infty^2}$ [dimensionless]
C_{fs}	-	Skin-friction coefficient for continuous smooth-wall [dimensionless]
Re_θ	-	Reynolds number based on momentum thickness ($U_\infty\,{}^{\theta}/_{v}$)
Re_{Xv}	-	Reynolds number based on streamwise distance from the virtual origin [dimensionless]
s	-	Streamwise distance between two grooves [m]
u	-	Mean velocity in x-direction [m/s]
U_{rms}	-	Turbulence intensity ($\sqrt{\bar{u}'^2}/U_\infty$ [dimensionless]
U_∞	-	Free stream velocity [m/s]
u^*	-	Local friction velocity [m/s]
u^+	-	${}^{u}/_{u^*}$ [dimensionless]
u'	-	Fluctuation velocity [m/s]
w	-	Width of groove [m]
x	-	Coordinate in the streamwise direction [m]
Xv	-	Coordinate in the streamwise direction measured from the virtual origin [m]
y	-	Coordinate normal to the wall [m]
y^+	-	${}^{yu^*}/_{v}$ [dimensionless]
δ	-	Boundary layer thickness [m]
δ_0	-	Boundary layer thickness near the upstream edge of the first groove [m]
v	-	Kinematic viscosity of air at average room temperature [m^2/s]
μ	-	Viscosity of air at average room temperature [kg/m.s]
θ	-	Momentum thickness [m]
τ_w	-	Shear stress at the wall $\mu \left.\frac{du}{dy}\right\|_{y=0}$ [N/m^2]

CHAPTER 1

INTRODUCTION

1.1 Research Background

Smoke obscures visibility and also contributes fatalities in a fire incident. It is therefore increasingly realised that occupant safety in a fire can be greatly improved by providing an efficient smoke extraction system. Moreover, such systems can limit property damage, both directly by reducing the spread of smoke, and indirectly by providing better visibility and thus easier access to the seat of the fire for fire fighters.

Smoke extraction is one of the tools, which the fire safety engineer may use to ensure adequate fire safety within a building. As such it should not be considered as isolation, but as an integral part of the total package of fire safety measures designed for the building. Thus the need of for smoke extraction in any building should be designed in conjunction with the means of escape, compartmentation and active suppression systems.

As underground car park is characterized by restricted height, in case of a fire, smoke layer will drop fast leading to difficulty in evacuation, conducting search and rescue operation. If the area or volume of car park is greater than a value, such as 2000m2 in China [1], smoke extraction system is required. Smoke extraction system is often combined with ductwork ventilation system, providing prevention of the build-up contaminated air fumes during the normal use and smoke extraction in the event of a fire.

In residential buildings it is likely that a fire would occur within an occupant's apartment. During the occupants escape, it is probable that smoke would enter the common corridor or lobby. The smoke control system is designed to ventilate this smoke and to protect the common stair, to ensure safe occupant escape and clear access for the fire service. In multi-storey apartment buildings, the main escape route is always via common corridors and/or lobbies to protected stairs.

Smoke can easily spread from the accommodation, and if a door is simply left open for a short period of time quickly fill a corridor or lobby, making escape difficult for occupants. Smoke entering the stairs can also make escape difficult for occupants of higher storeys. In taller buildings the fire and rescue services need clear access to stairs and lobbies to form a bridgehead for operations, using a fire fighting shaft which is protected from smoke.

W. Chakroun (2005) highlight Skin-friction coefficient of turbulent boundary layer flow over a smooth-wall with transverse square grooves was investigated. The skin-friction coefficient determined from the velocity profile increases sharply just downstream of the groove. This behavior is observed in most grooved-wall cases. Integrating the skin-friction coefficient in the stream wise direction indicates that there is an increase in the overall drag in all the grooved-wall cases.

A study had been made of the process of laminar to turbulent transition induced by the von Karman vortex street, in the boundary layer on a flat plate by Kyriakides et al. [4]**.** It was established that, the onset of the strong von Karman wake induced transition process was a function of the free stream velocity, the position of the cylinder with respect to the plate, the cylinder diameter, the drag coefficient and the minimum velocity in the developing wake at the stream wise position of the onset of the boundary layer transition. It was also established that, in the case of weak wake-boundary layer interaction, the boundary layer transition process was accelerated by the overall free stream turbulence increase due to the wake of the cylinder.

1.2 Problem Statement

Smoke exhaust ventilation systems are important for creating a smoke free layer above a floor by removing smoke which for the purposed of improved conditions to allow the safe escape and/or rescue of people and animals, to protect property by mean of permit a fire to be fought while still in its early stages.

Fire smoke layer is a crucial because it directly affects performance, reliability of smoke ventilation system and fire safety requirements. Ducted systems are commonly used for smoke ventilation system with limitation which reduces the useable floor to floor clear ceiling height. Rapid developments of Jet fan system in smoke ventilation system industry especially for underground car park by conventional jet fan system and centrifugal jet fan system for the replacement of ducting system. Conventional jet fan still constrain floor to floor ceiling height. Hence, centrifugal jet fan introduce but however, turbulent occur through centrifugal jet fan over the slab soffit.

The minimum clear height above escape route as required by BS-7346-4-2003 is as shown in Table 1 and in the minimum MS 1780-2005, the minimum height required to be 2m clear of smoke layer from floor level.

Table 1.1 BS-7346-4-2003, components for smoke and heat control systems

Type of building	Minimum height (y)
Public buildings, eg. Single-storey malls, exhibition halls	3.0 m
Non-public building, e.g. offices, apartments, opening hall type prisons	2.5 m
Car parks	2.5m or 0.8H, whichever is the smaller

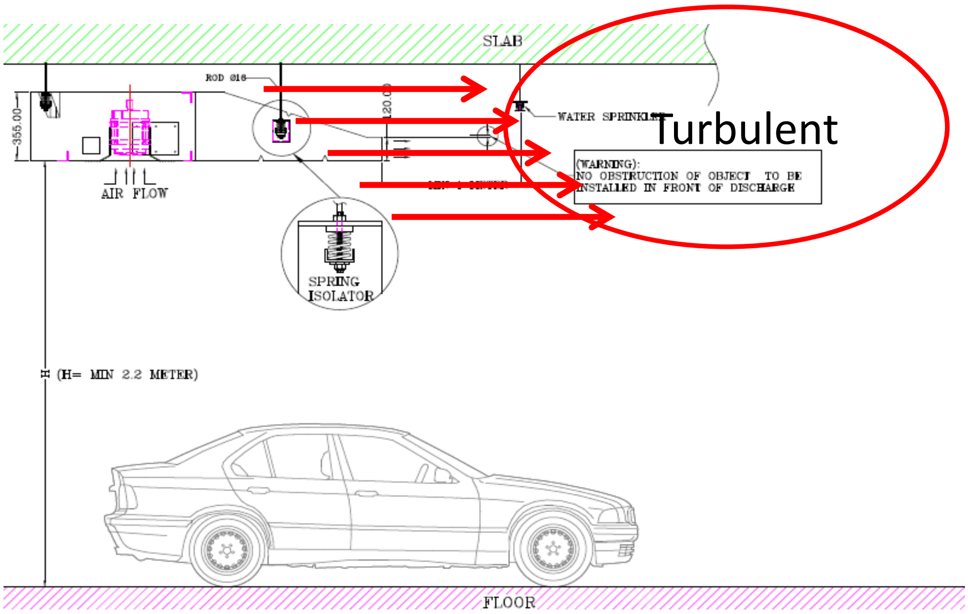

Figure 1.1 Schematic of jet fan ventilation system (Source From Kruger Ventilation Industries PTE LTD (Jet Fan Model : IJC II 100))

Turbulent layer of the flow within the underground car park and soffit will be investigated. Besides that, several changes had been made in the geometry of the such as the velocity of jet fan, surface roughness of the flat plate, floor to floor heirght and the magnitude of velocity inlet in order to investigate the effects on the overall flow. The aforementioned parameters and properties will be further discussed in later chapter.

1.3 Research Objectives

The objective of this literature research is:

i) To determine the effect of surface roughness and skin friction coefficient of flow along flat plate.

ii) To determine the maximum skin friction coefficient on the flat plate.

iii) To determine the maximum discharge velocity at jet fan's outlet.

iv) To determine the suitable surface riblet profile for flat plate.

1.4 Scope of Research

This thesis is to conduct a research on the behavior of fluid flow along underground car park. The flat plate theory is implemented by integrating the information of fluids into simulation. Velocity profile, surface roughness and skin friction coefficient are identified, verify and validate. The scopes of this thesis are as follows:

i) Identification of smoke properties, concept of smoke extraction system.
ii) Identification of underground car park's smoke extraction system design parameter.
iii) Development of a 2D flat plate model as a simple single level underground car park model.
iv) Development of a 3D model for car park simulation
v) Numerical solution on the velocity distribution, surface roughness and skin friction coefficient of the groove.

1.5 Significant of Study

i) To improve the efficiency and effectiveness of centrifugal jet fan smoke extraction system.
ii) To optimize the design of centrifugal jet fan smoke extraction system.

1.6 Organization of Thesis

The following steps are required to be implemented for the purposed of completing this research, they are:

i) Data collection from the published journals.
ii) Design flat plate model by using Ansys Fluent.
iii) Selection of 2D and 3D model by using the aid of Fluent.
iv) Setting of boundary conditions.

v) Numerical analysis of velocity distribution of the model, surface roughness and skin friction co-efficient.

vi) Analysis of velocity profiles surface roughness and skin friction co-efficient.

vii) Discuss the velocity distribution, surface roughness and skin friction coefficient of the smoke extraction system and the effect of no of jet fan used to the system.

viii) Conclusion

A weekly activity of this thesis has been presented in Gantt chart and appended in Appendix 1 and 2 for thesis 1 and 2 respectively.

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