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THE CONCEPT OF LAMINAR KINETIC ENERGY & ITS APPLICATIONS TO FORMULA 1

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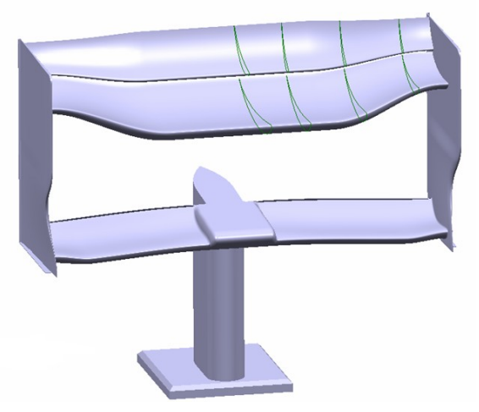
INTRODUCTION

CFD is a powerful tool to validate automotive rear wing designs and configurations. However, even sophisticated Reynolds stress models yield errors in lift coefficient beyond those allowed for in the design. This is the basis for an investigation into improving the lift prediction without resorting to LES.

OBSERVATIONS

Flow over the rear-wing configuration below was simulated with RSM using a fine mesh [1]. It was then compared with experimental values. The resulting pressure coefficients at the centre and outermost cross-sections are shown in Figures 1 and 2.

	RSM Simulation	Experimental
C_L	-0.5700	-0.5395
C_D	0.1450	0.1445



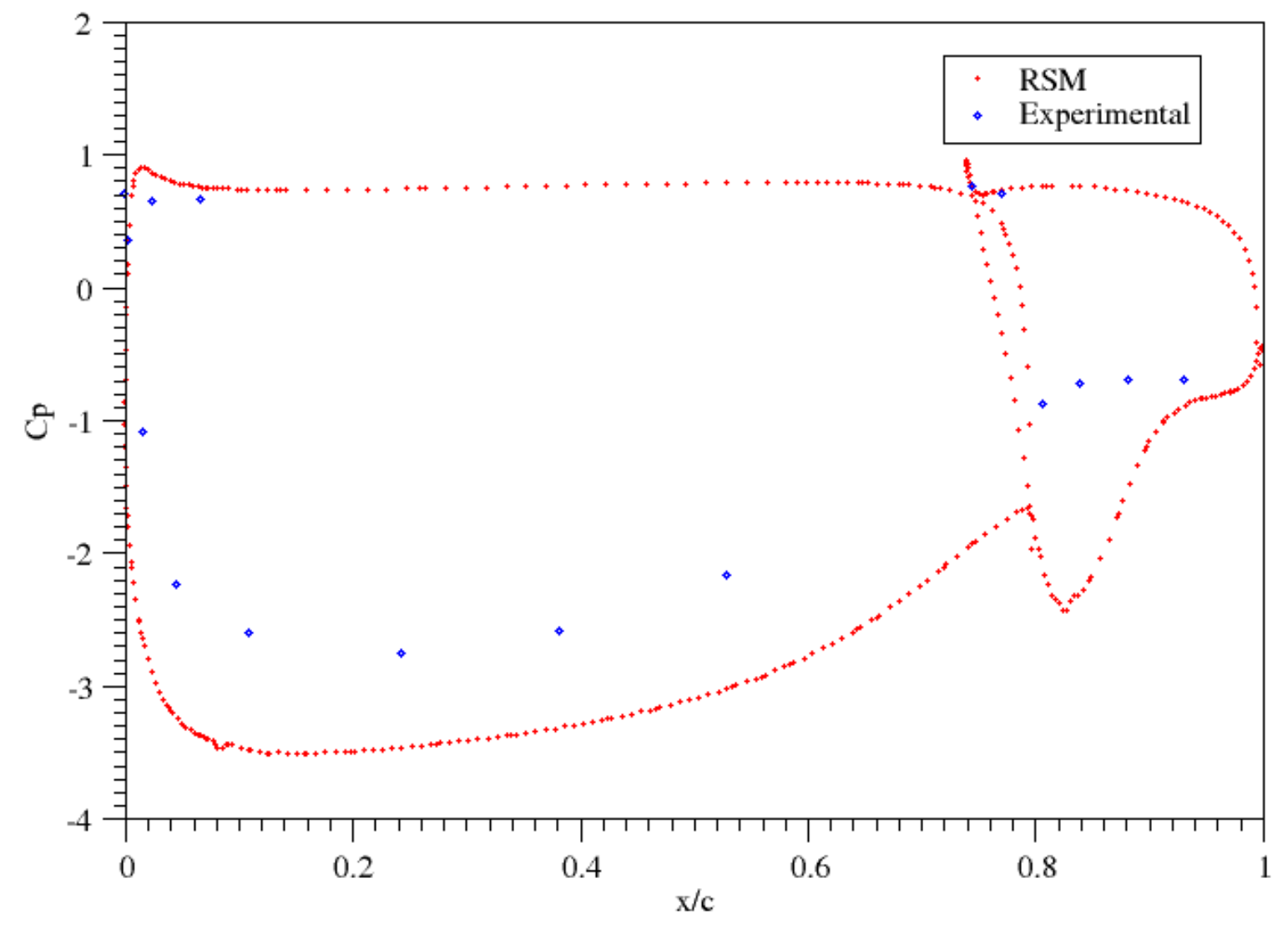


Figure 1: Pressure Coefficient at y = 0 mm

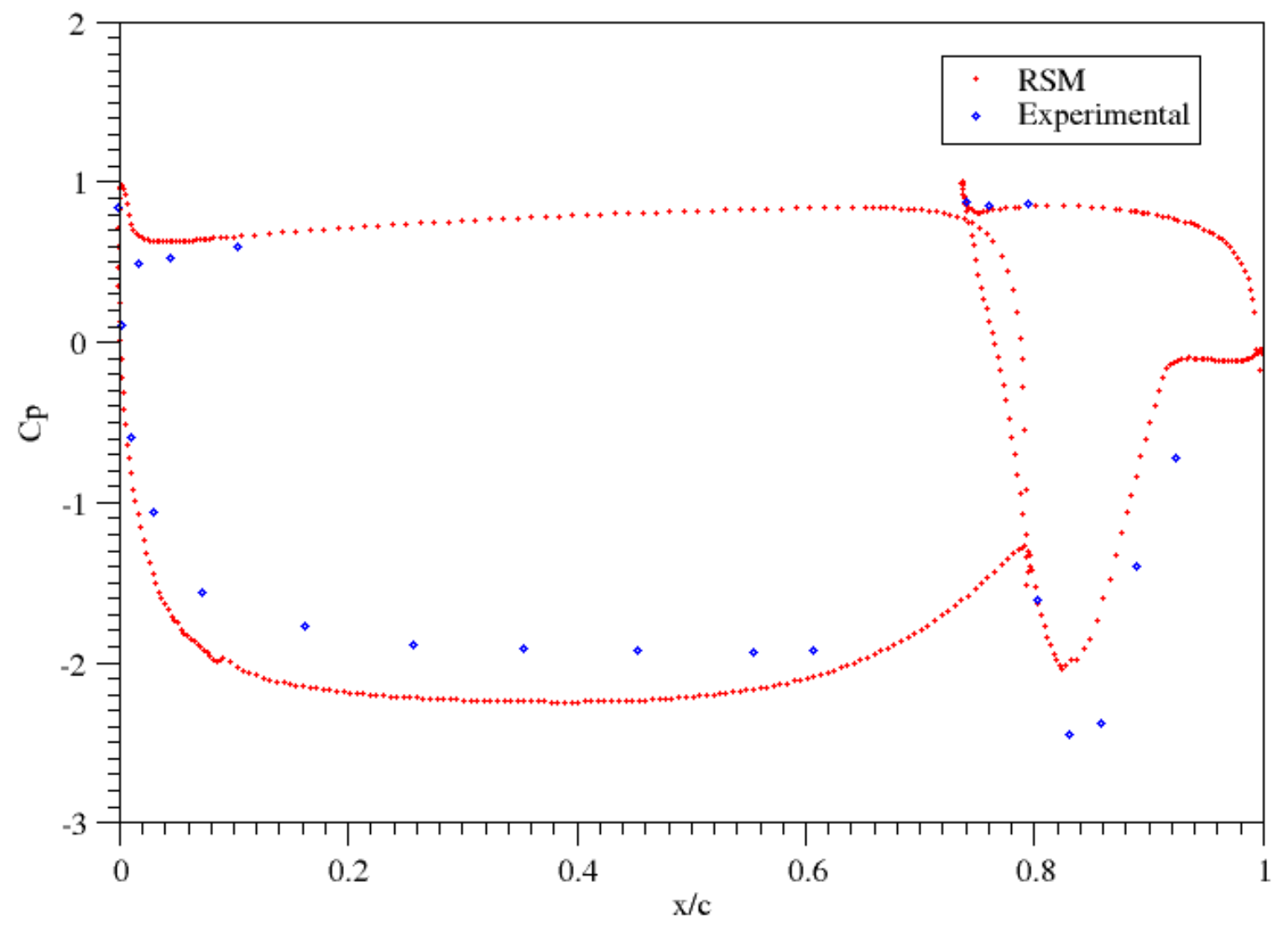


Figure 2: Pressure Coefficient at y = 420 mm

- A known weakness of RANS models is transition prediction
- Characteristics of laminar and turbulent boundary layers differ considerably

TRANSITION

Types of laminar-turbulent transition:

- Bypass transition
- Natural transition
- Transient growth

RANS models can only predict bypass transition. Contributions to bypass transition include:

- Adverse pressure gradients
- Curvature of the streamlines
- Roughness
- Heat transfer

A sufficiently large adverse pressure gradient in a laminar boundary layer causes laminar separation and turbulent re-attachment. This situation can be seen in Figure 3.

Figure 3: Flow Visualisation for Rear Wing at 20°

METHODS

Methods of predicting transition on a RANS basis include low Reynolds number models and intermittency models.

A common method of validation is with the T3 plate tests shown in Figure 4. The work of Savill [2] shows a comprehensive investigation into low Reynolds number modelling of transition.

Intermittency models are based on a two—equation turbulence model but also include an equation for intermittency.

Test Case	Upstream Velocity (ms^{-1})	Upstream Turbulence Intensity (%)	Pressure Gradient
T3A	5.4	3.0	zero
T3B	9.4	6.0	zero
T3A-	19.8	0.9	zero
T3C1	5.9	6.6	variable
T3C2	5.0	3.0	variable

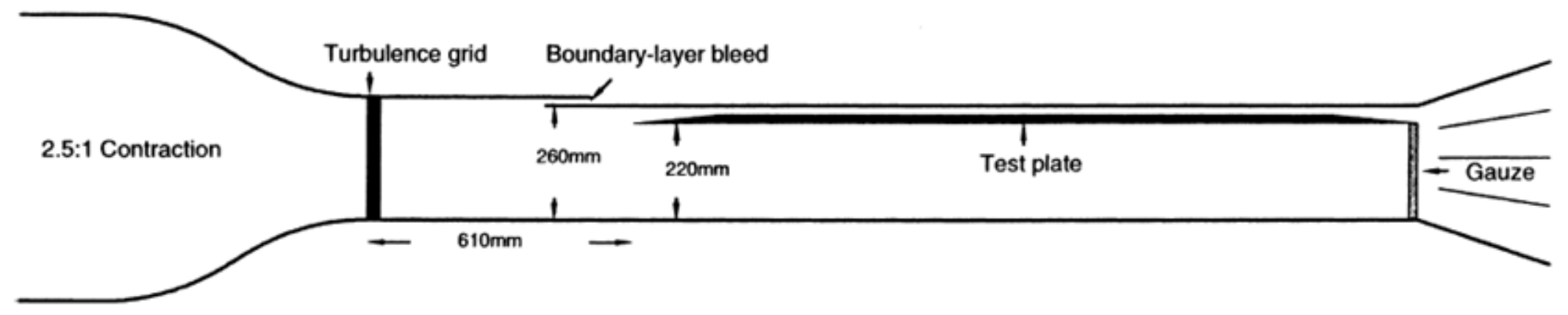


Figure 4: T3 Flat Plate Configuration and Test Cases

Many intermittency models have non-local variables which makes application to modern CFD codes difficult. Menter et al. [3] recently developed an intermittency model using local variables, which performed well on many of the T3 flat plate tests. However the physical basis is difficult to determine.

LAMINAR KINETIC ENERGY

In 2004 Walters and Leylek presented another solution. They combined the concept of laminar kinetic energy, introduced by Mayle and Schulz in 1997 [4], with a low Reynolds number k-ε model

Modelling with laminar kinetic energy is physically sound. Laminar kinetic energy refers to the stream-wise fluctuations caused by the “splat mechanism” described by Bradshaw [5]. The energy of the large lengthscales are re-directed tangentially when they are brought to rest by the wall. The fluctuations then break down into turbulence. λ_{eff} separates the small and the large scales:

$$\lambda_{eff} = MIN\left(C_\lambda d, \lambda_T\right), \qquad \lambda_T = \frac{k^{3/2}}{\epsilon}$$

DEVELOPMENT

The 2005 version of the Walters-Leylek model [6] is currently being implemented into Code_Saturne. It uses ω as the scale determining variable.

The model is being implemented step-by-step to understand the effects of the individual terms, as shown in Figure 5

1. Near wall dissipation and a viscous damping function are added to the k-ω model.
2. Inclusion of large scale turbulent viscosity
3. Includes the effects of laminar kinetic energy.

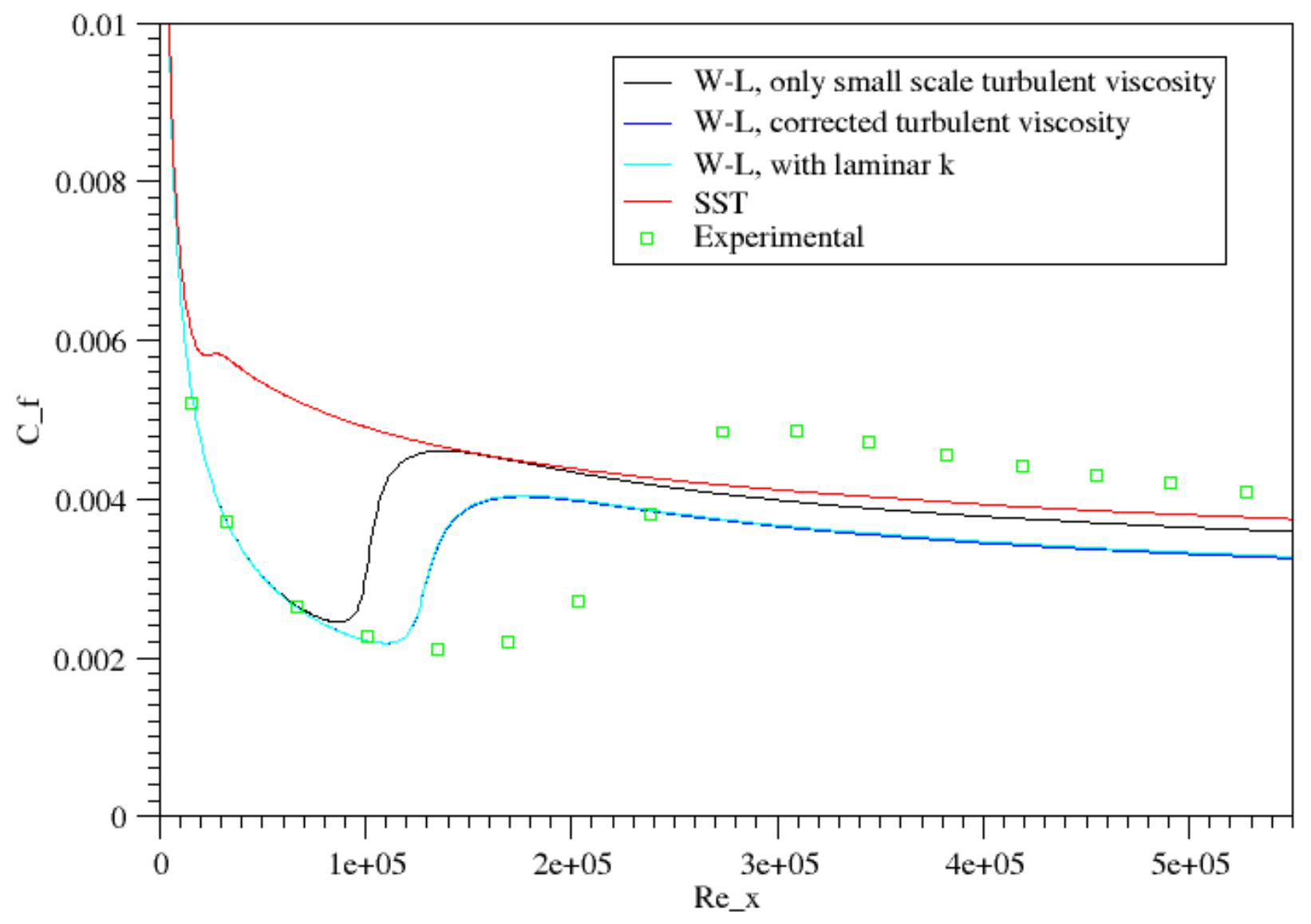


Figure 5: Skin Friction Coefficient for T3A Test Case

GOALS

1. Include term to account for reduced intermittency effect
2. Repeat process for larger scale test case, then a case with pressure gradient
3. Develop a more appropriate definition of effective lengthscale
4. Apply to the rear wing.

REFERENCES

[1] C_P, C_D & C_L results provided by *CD-adapco* and the car manufacturer

[2] A.M. Savill. “*Evaluating Turbulence Model Predictions of Transition*” Applied Scientific Research 51:555562, 1993

[3] F.R. Menter et al. “*A Correlation Based Transition Model Using Local Variables Part 1—Model Formulation*”. Journal of Turbomachinery, 128:413422, 2006

[4] R.E. Mayle and A. Schulz. “*The Path to Predicting Bypass Transition*”. Journal of Turbomachinery, 119:405411, 1997

[5] P. Bradshaw. “*Turbulence: The Chief Outstanding Difficulty of Our Subject*”. Experiments in Fluids, 16:203216, 1994

[6] D.K. Walters and J.H. Leylek. “*Computational Fluid Dynamics Study of Wake-Induced Transition on a Compressor-Like Flat Plate*”. Journal of Turbomachinery 127:5263, 2005

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