**Blade efficiency**

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## 1 Introduction

The instantaneous blade efficiency i.e. the blade efficiency in every instant of the drive, can be assessed using the complete model of rower, oars and boat or by analysing a simpler model. The latter option has been chosen in this article because of its convenience and speed of calculation. The results have to be interpreted with care.

The graphs produced are not representative for the whole stroke. But when the boat speed and the oar angle (and the other parameters) have the same value as assumed for the graph, at that point the efficiency is "exactly" the same as for the boat.

In the reporting of the results of the simulation model also the instantaneous blade efficiency has been included for some cases. The result is of relative interest. The mean efficiency measured over the whole stroke is more important.

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## 2 Definition of the model

See Fig 2.1. A is the oarlock moving with the constant boat speed $v_B$. The oar position is described by the oar angle φ, (ranging from φ to φ2) with respect to the line through the pin perpendicular to shell centre line. $F_B$ is the force on the blade in the centre C. L = AC is the outboard length of the oar.

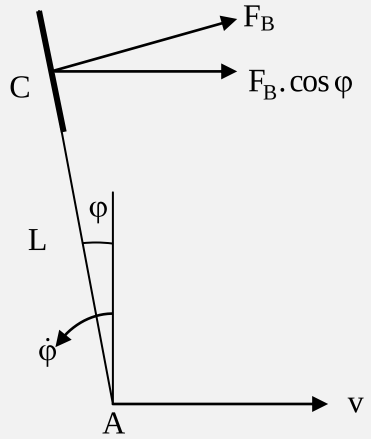


Fig 2.1
Basic configuration

The input power to the oar is $P_i = F_B.\dot{\varphi}.L$
The power lost at the blade is $P_L = F_B\,(\dot{\varphi}.L - v_B.\cos\varphi)$
The blade efficiency is:

$$\eta = \frac{P_i - P_L}{P_i} = \frac{v_B.\cos\varphi}{\dot{\varphi}.L}$$

We express the force on the blade in terms of oar angular velocity and boat speed.
See Fig 2.2. The blade velocity with respect to the water is u, the component of u perpendicular to the blade is $u_l$ and the component parallel to the blade is $u_p$.

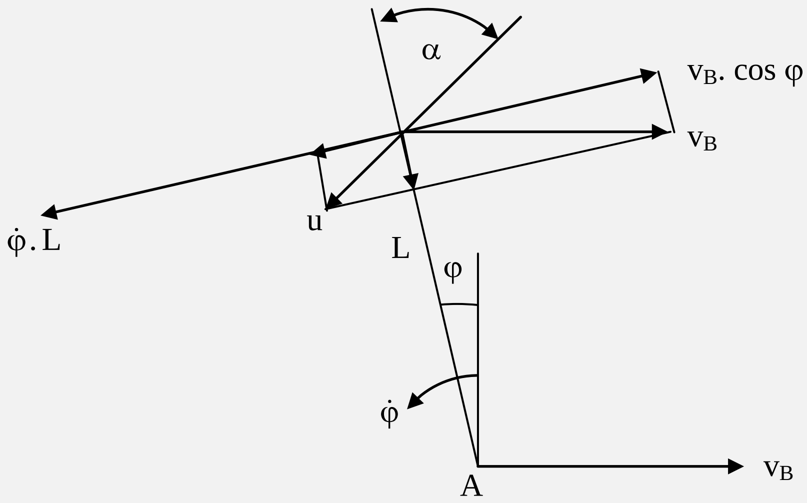


Fig 2.2
Decomposition of velocities

$$u_l = \dot{\varphi}.L - v_B.\cos\varphi \quad \text{and} \quad u_p = v_B.\sin\varphi$$

$$u = \sqrt{u_l^2 + u_p^2}$$

The angle of attack follows from $\alpha = \arctan\dfrac{u_l}{u_p}$

The drag- and lift force follow from:

$$F_D = 0.5.\rho.u^2.A.C_D$$

$$F_L = 0.5.\rho.u^2.A.C_L$$

where ρ = water density, A = blade area and $C_D$ and $C_L$ are the lift and drag coefficients.

The resulting force F is the blade force $F_B$ as has been demonstrated in Lift and drag.

Thus: $F_B = 0.5.\rho.u^2.A.\sqrt{C_D^2 + C_L^2}$

The efficiency has been calculated for a constant (not depending on the oar angle) blade force. The corresponding angular velocity has been determined by iteration.

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**3 Coefficients**

The graph of the hydrodynamic coefficients $C_D$ and $C_L$ as function of the angle of attack and as presented in Lift and drag is repeated below in Fig 3.1.
They have been taken from:

*Journal of Sports Sciences, April 2007; 25(6): 643-650*
*Nicholas Caplan & Trevor N. Gardner,*
*"A fluid dynamic investigation of the Big Blade and Macon oar blade designs in rowing propulsion"*

The following expression for $C_D$ and $C_L$ are derived from the results in this paper but are the interpretation of this author:

$$C_D = 2C_{L\max}(\sin\alpha)^2$$
$$C_L = C_{L\max}\sin(2\alpha)$$

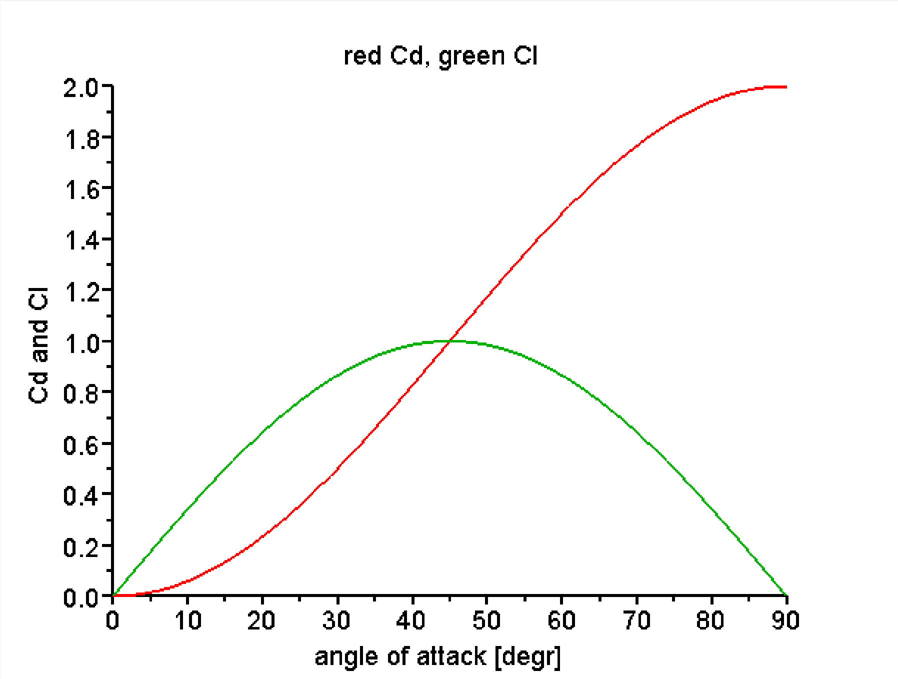


Fig 3.1
Hydrodynamic coefficients

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**4 Results**
Results are presented for the following input data. See Table 4.1. In order to avoid singularities the swept angle is slightly smaller than 180°. The values belong (more or less) to a top level a heavy man's eight.

| Quantity | Symbol | Value |
|---|---|---|
| Blade area [$m^2$] | A | 0.08,0.10,0.12 |
| Force on blade [N] | $F_B$ | 300 |
| Boat speed [m/s] | $v_B$ | 6 |
| Outboard length [m] | L | 2.4 |
| Oar start angle [degr] | $\varphi_1$ | -88.2 |
| Oar finish angle [degr] | $\varphi_2$ | 88.2 |
| Water density [$kg/m^3$] | $\rho$ | 1000 |

Table 4.1
Input data

Fig 4.1 shows the required oar angular velocity for every oar position to obtain the required blade force.

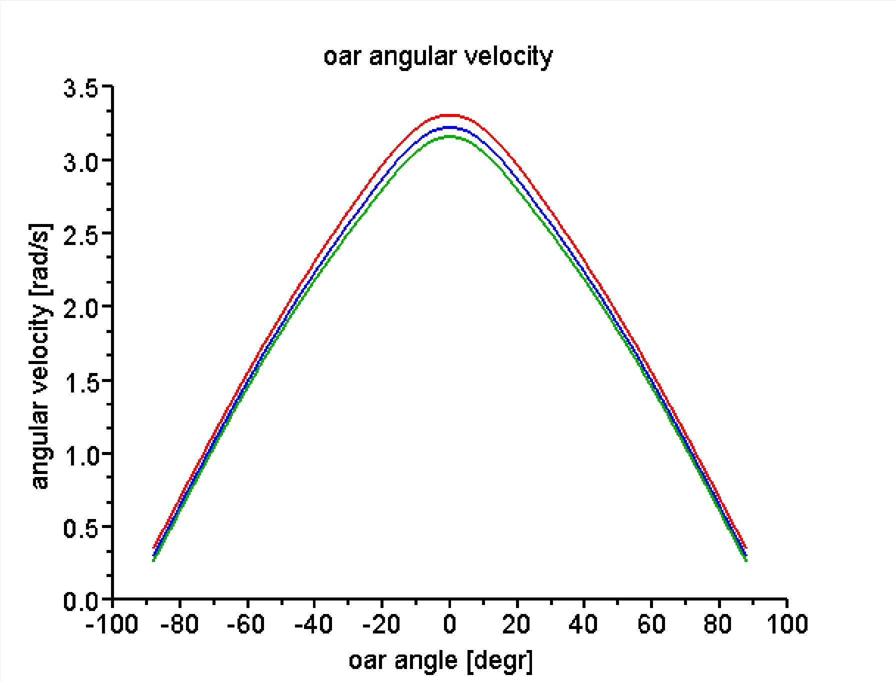


Fig 4.1

Oar angular velocity to obtain the reqired blade force

Blade area: **0.08**, **0.10**, **0,12** $m^2$

Fig 4.2 shows the angle of attack of the flow with respect to the blade.
Fig 4.3 shows how to interpret the angle of attack α.

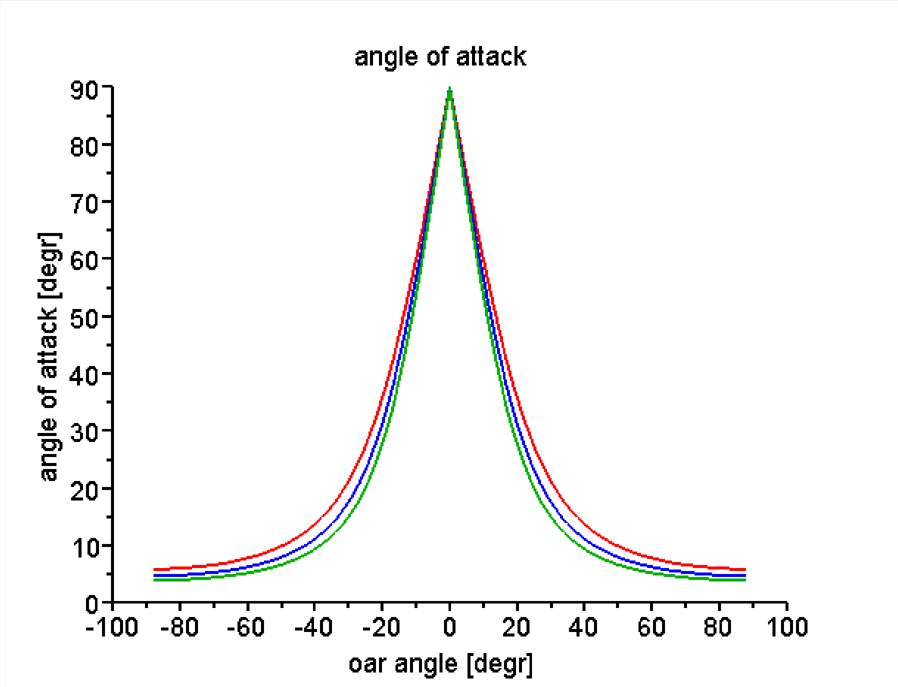


Fig 4.2
Angle of attack α
Blade area: **0.08**, **0.10**, **0,12** $m^2$

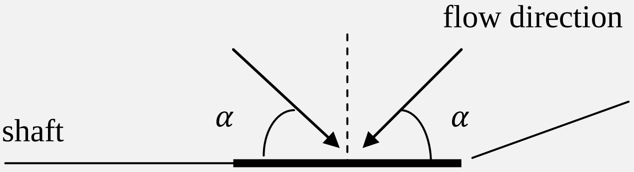


Fig 4.3
Angle of attack α

Finally, Fig 4.4 shows the blade efficiency.

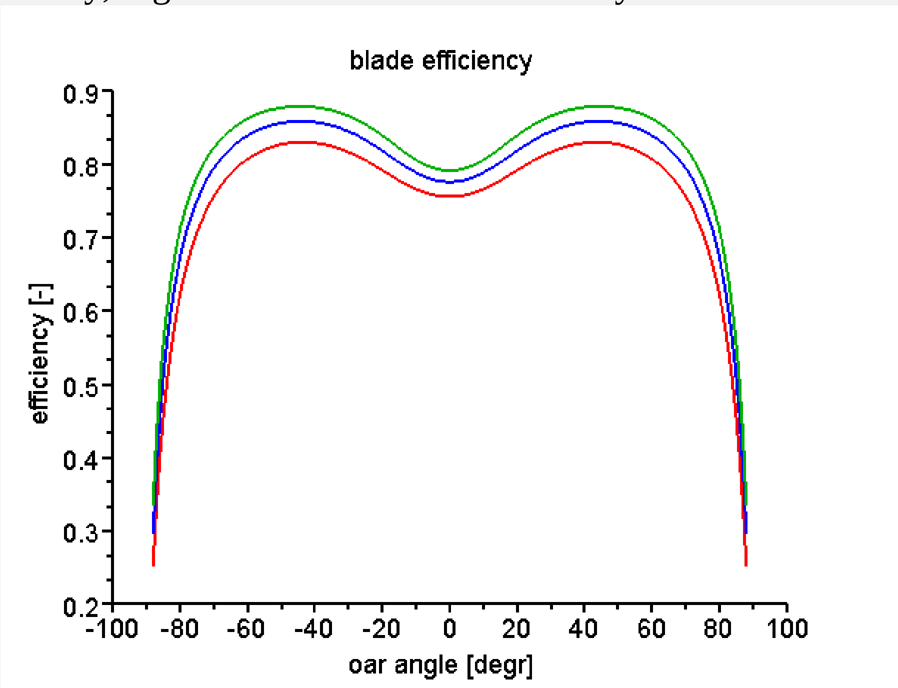


Fig 4.4
Blade efficiency
Blade area: **0.08**, **0.10**, **0,12** $m^2$

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**Concluding remark**
Clearly the blade efficiency drops sharply at oar angles greater than some 60$^o$ at both sides of the oarlock perpendicular. For the second part of the drive this is not a problem. Crews seldom extend the stroke beyond 50$^o$. For the first part of the stroke the graph is a warning. The tendency of reaching farther and farther at the catch means entering an interval with considerable loss of efficiency.

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