Design of Stator-less Turbine

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Intoduction

1. **State of art conventional design—**
   - **A stator and a rotor**
   - **Adiabatic total/total efficiency between 85-91%**
   - **Δ h/u^2=1.5-2.**

2. **S.L Turbine design**
   - **A rotor only—swirl is present in turbine intake**
   - **Adiabatic total/total efficiency between 90-94%**
   - **Δh/u^2=2-3.**
   - **Examples**

     Rolls Royce Mtu-390—1100 kw gas turbine

     G.E T.S -50---------------25000 kw gas turbine

Both use a stator-less second counter rotating stage turbine behind the High Pressure turbine stage.

OCN S.L Turbine design

1. **the inlet swirl [tangential velocity*radius] is carried without diffusion from the compressor rotor through the combustor to the turbine rotor inlet**

2. **The inlet swirl has a small tangential angle not attainable with conventional stator design.**

3. **The swirl amount may be changed by varying the turbine design mean blade radius.**

The OCN S.L Turbine t-s diagram

1. **First expansion stage pure isentropic—100% efficient.**

2. **Second expansion stage—through rotor blades—more efficient [see slope] than conventional due to-**
   - **Smaller camber angle**
   - **Supersonic convergent blade shape.**
   - **Higher blade length / chord ratio**
   - **No incidence losses.**

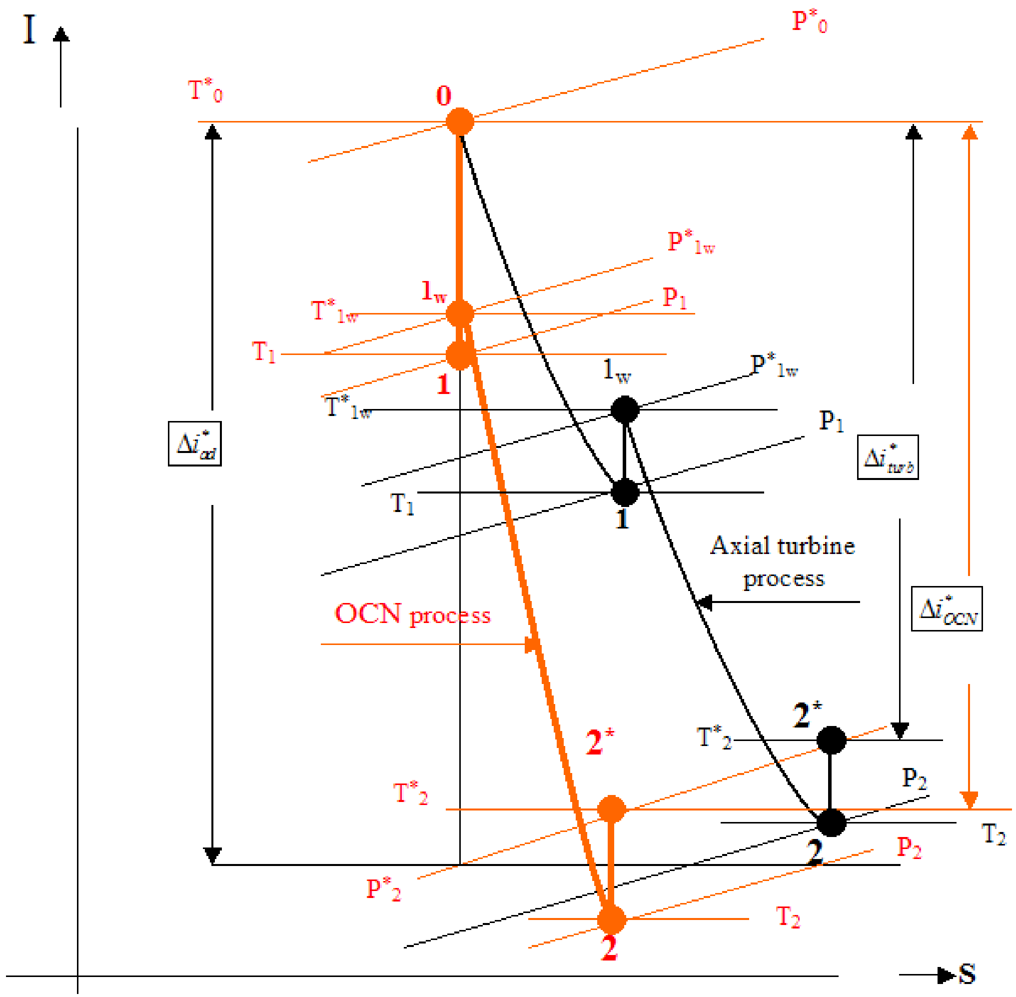


Fig. 1:
OCN S.L
and
Conventional Turbine T-S Diagram

Turbine efficiency

$$\eta^*_{tot} = \frac{\Delta i^*}{\Delta i^*_{ad}}$$

T^*_0 -Turbine inlet total temperature in absolute motion

P^*_{1w} - Turbine wheel inlet total pressure in relative motion

P^*_0 - Turbine inlet total pressure in absolute motion

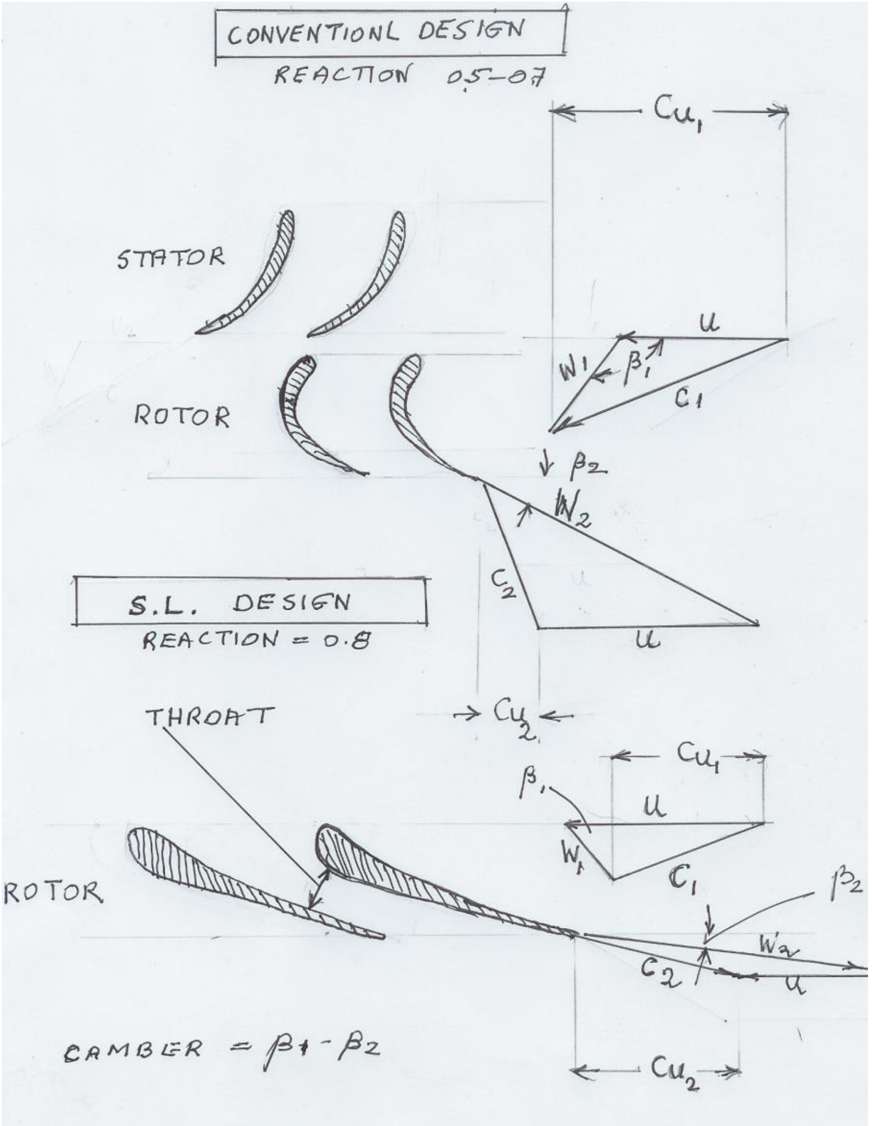


FIG. 2 — VELOCITY TRIANGLES

Fig. 2:

OCN Velocity Triangles on Middle Radius

Typical OCN S.L Turbine blade cascade

	OCN	CONVENTOONAL
α1	12	30
β1	56	120
β2	15	30
Camber	44	90
α2	30	60

<u>Turbine power</u>

P= G*U*[Cu2- Cu1] = G*U* [W2cosβ2-U-Cu1]

where

G= Mass flow

U= Meridional turning velocity

Cu1=Turbine inlet swirl (negative)

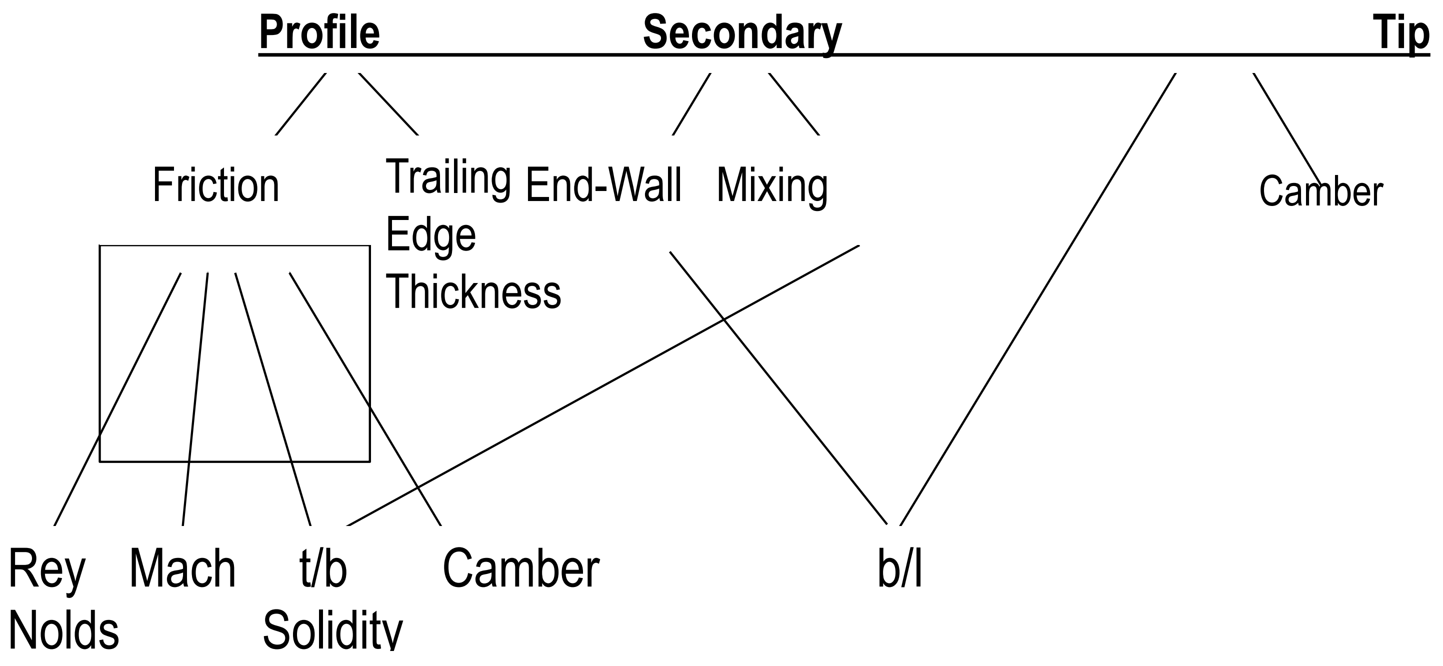
β2=outlet tangential blade angle

Are <u>input values</u>

For constant values of pressure ratio and inlet temperature

<u>THE POWER IS DETERMINED BY W2 WHICH IS A FUNCTION OF ITS LOSSES THROUGH THE CASCADE</u>

Turbine velocity losses



Turbine velocity losses - Continued

All above losses are expressed as the square of velocity loss/no-loss- velocity in percentage.

The following value of

Ψ= [1- profile-secondary-tip]^0.5

Determines the value of W2=W2 theoretical*ψ

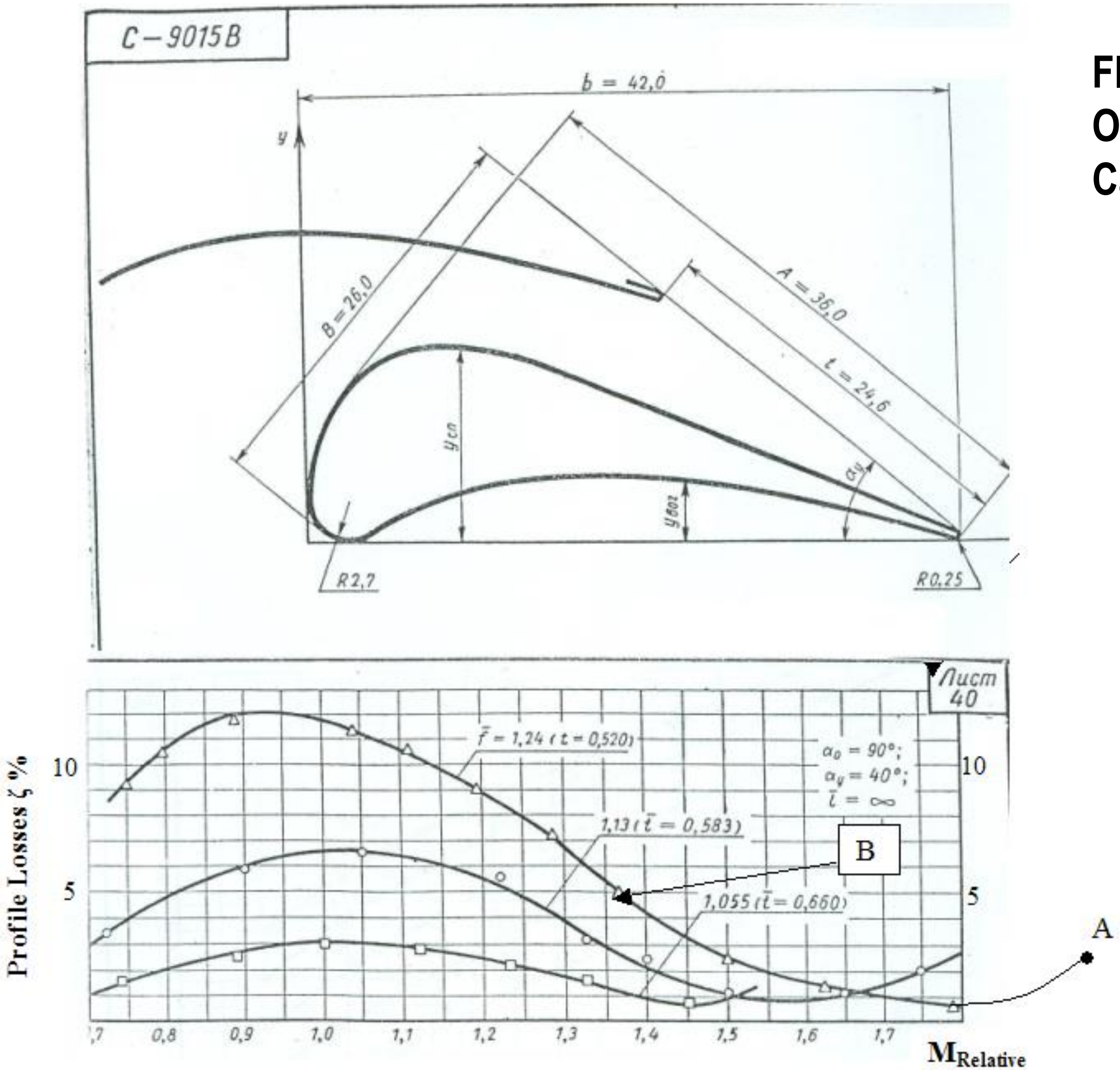
Now---efficiencies may be calculated.

Typical turbine efficiency results

Input conditions—T=1500k P.R=3.4 U=500m/sec
Cu=450 m/sec for S.L ,550 m/ sec for conventional [max.result]

	OCN-S.L	CONVENTONAL
1. Stator velocity losses%	0	4
2. blade velocity losses%		
Profile	5	6.4
Secondary	2.2	3.6
Total blade----	7.25	10.0
Efficiency without tip loss—	92.9	87.5
Efficiency with a tip gap of 1% of blade length	91.6	86.0

FIG.3
OCN S.L Turbine
Cascade Data



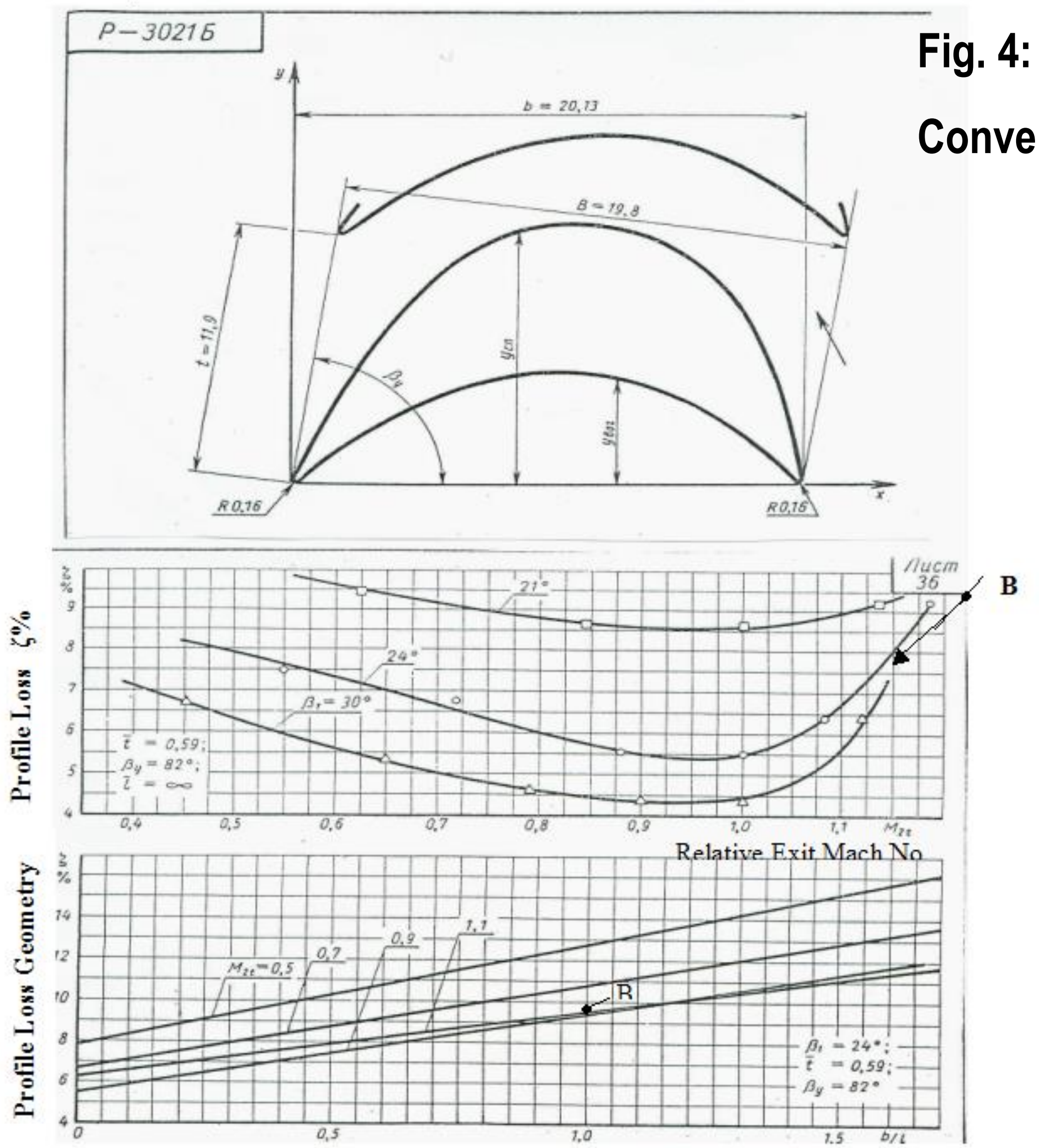


Fig. 4:

Conventional Turbine Cascade Data

Fig. 4a: Conventional Turbine Cascade Data

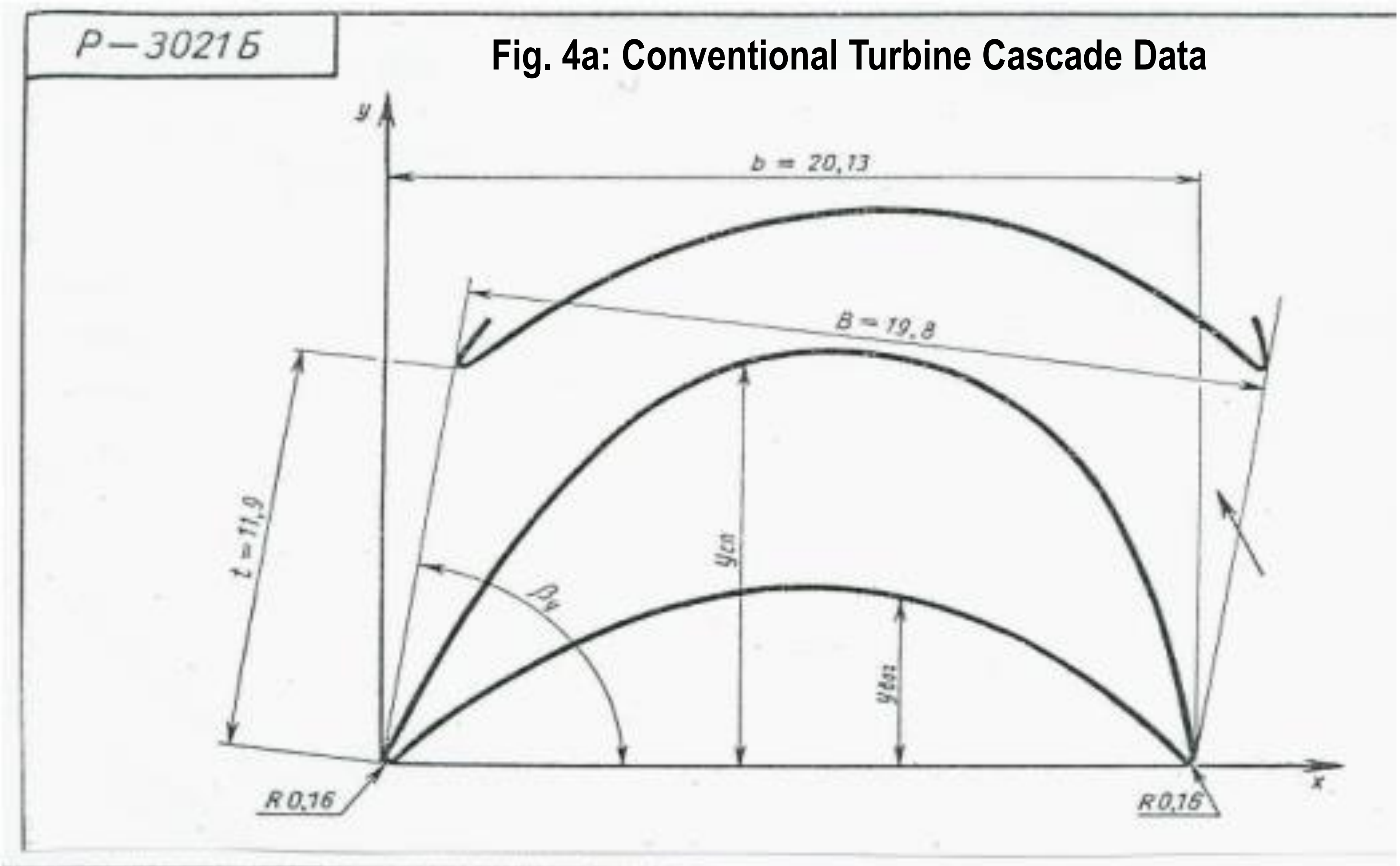


Fig. 4b: Conventional Turbine Cascade Data

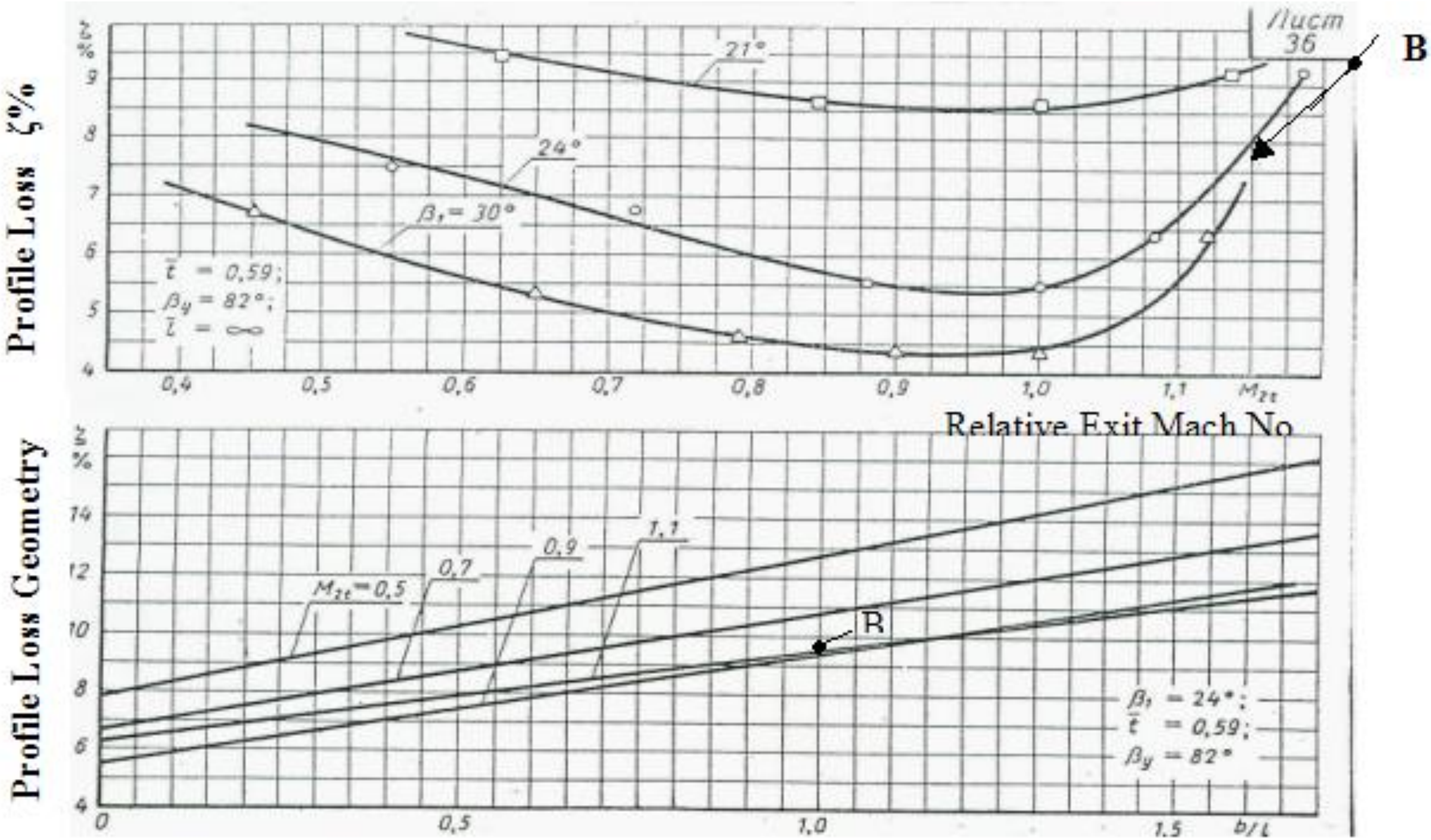


Fig. 5a: Aspect Ratio and Blade Deflection Angle Effect on Secondary Losses.

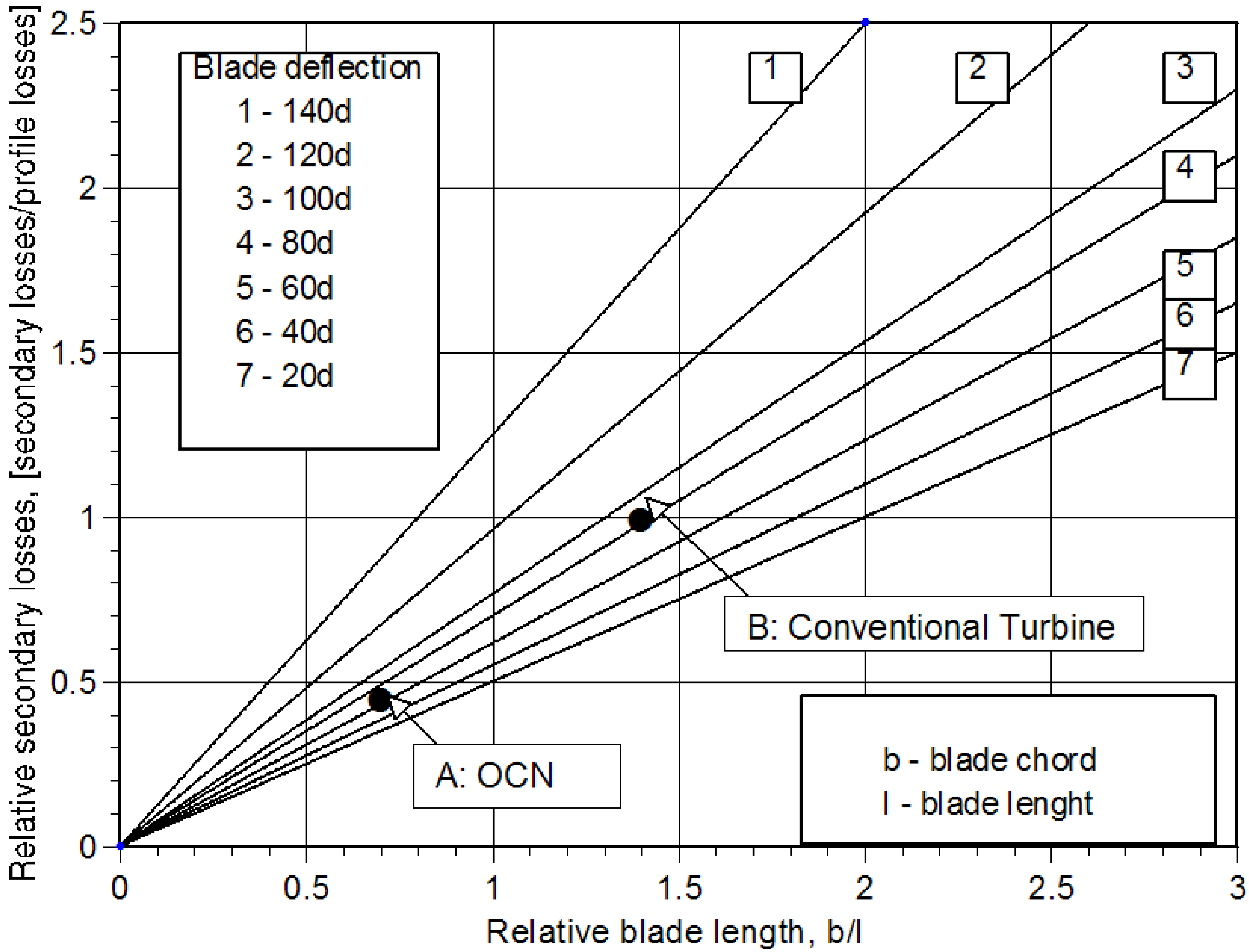


Fig. 5b: OCN S.L Turbine losses compared to conventional losses

Name of parameter	OCN	Conventional turbine
Blade chord, (B) [mm]	23	25
Blade length, (L) [mm]	33.8	18.8
Blade deflection, (Δβ) [d]	44	92
Blade outlet angle, (β2) [d]	16	32
Relative blade chord, (B/L)	0.682	1.33
Relative secondary losses	0.45	1.0
Profile losses, [%]	5	7.7
Secondary losses, [%]	2.25	7.7
Blade total losses, [%]	7.25	15.4

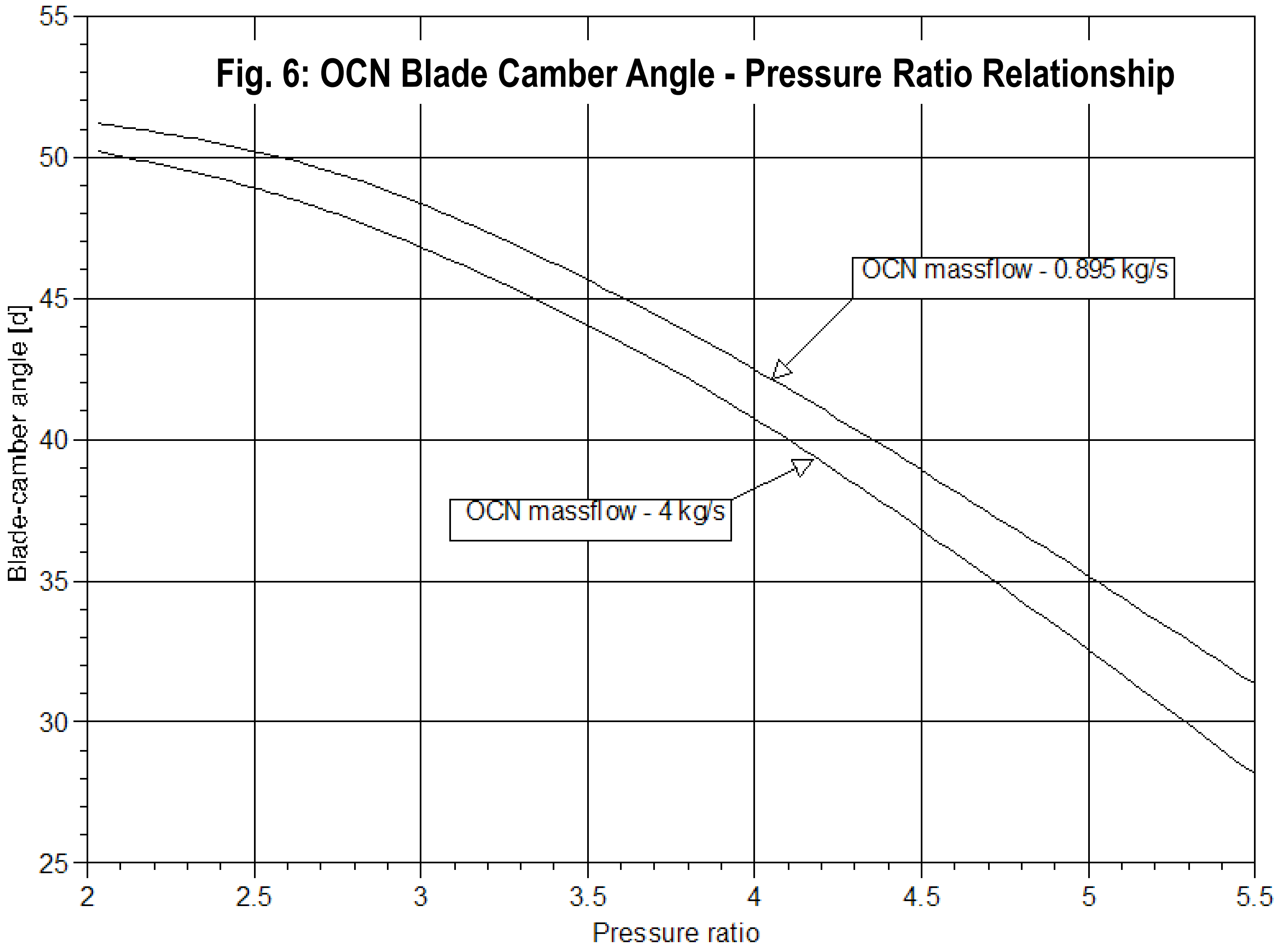


Fig. 6: OCN Blade Camber Angle - Pressure Ratio Relationship
OCN massflow - 0.895 kg/s
OCN massflow - 4 kg/s
Blade-camber angle [d]
55
50
45
40
35
30
25
2
2.5
3
3.5
4
4.5
5
5.5
Pressure ratio

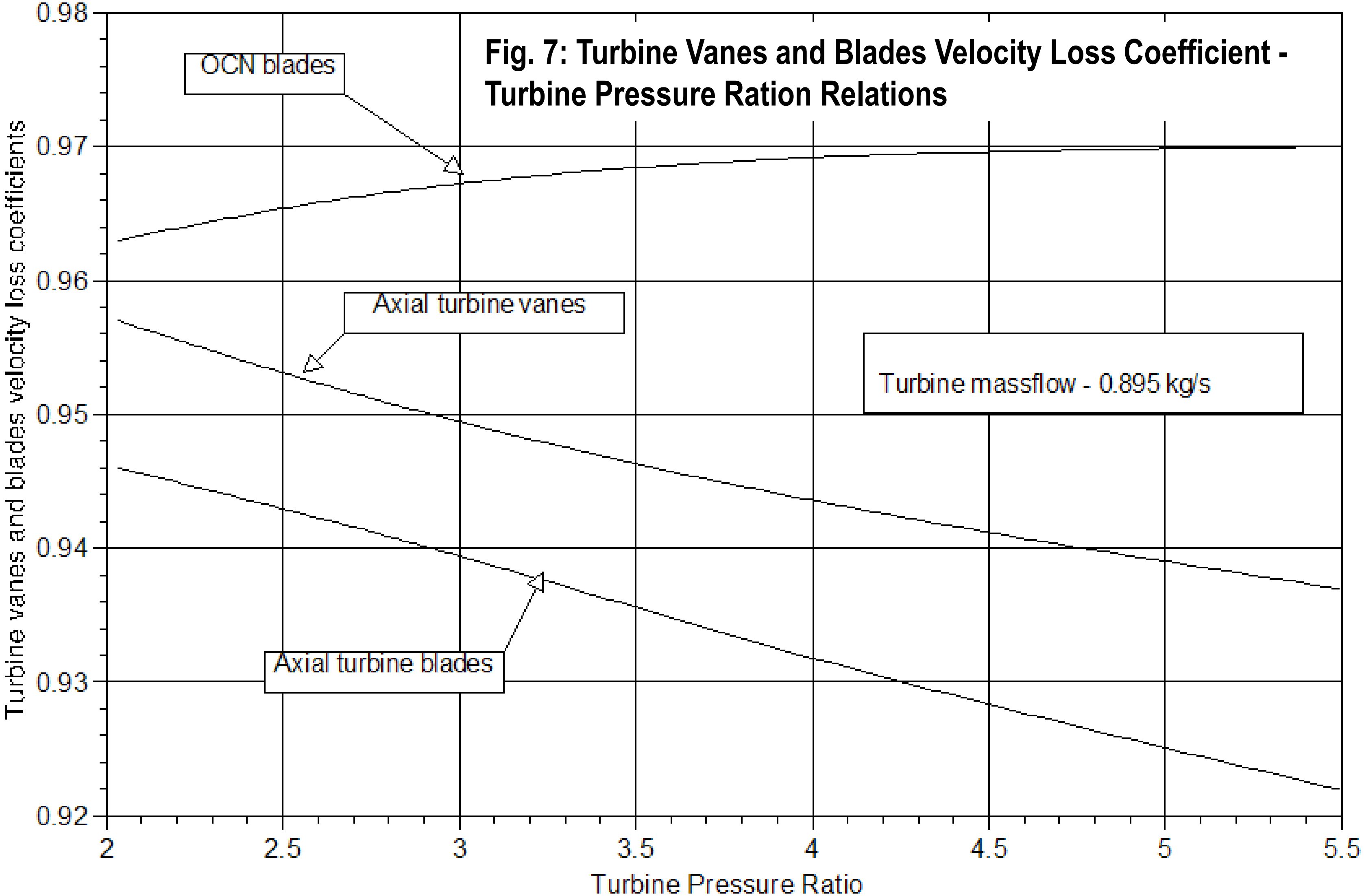
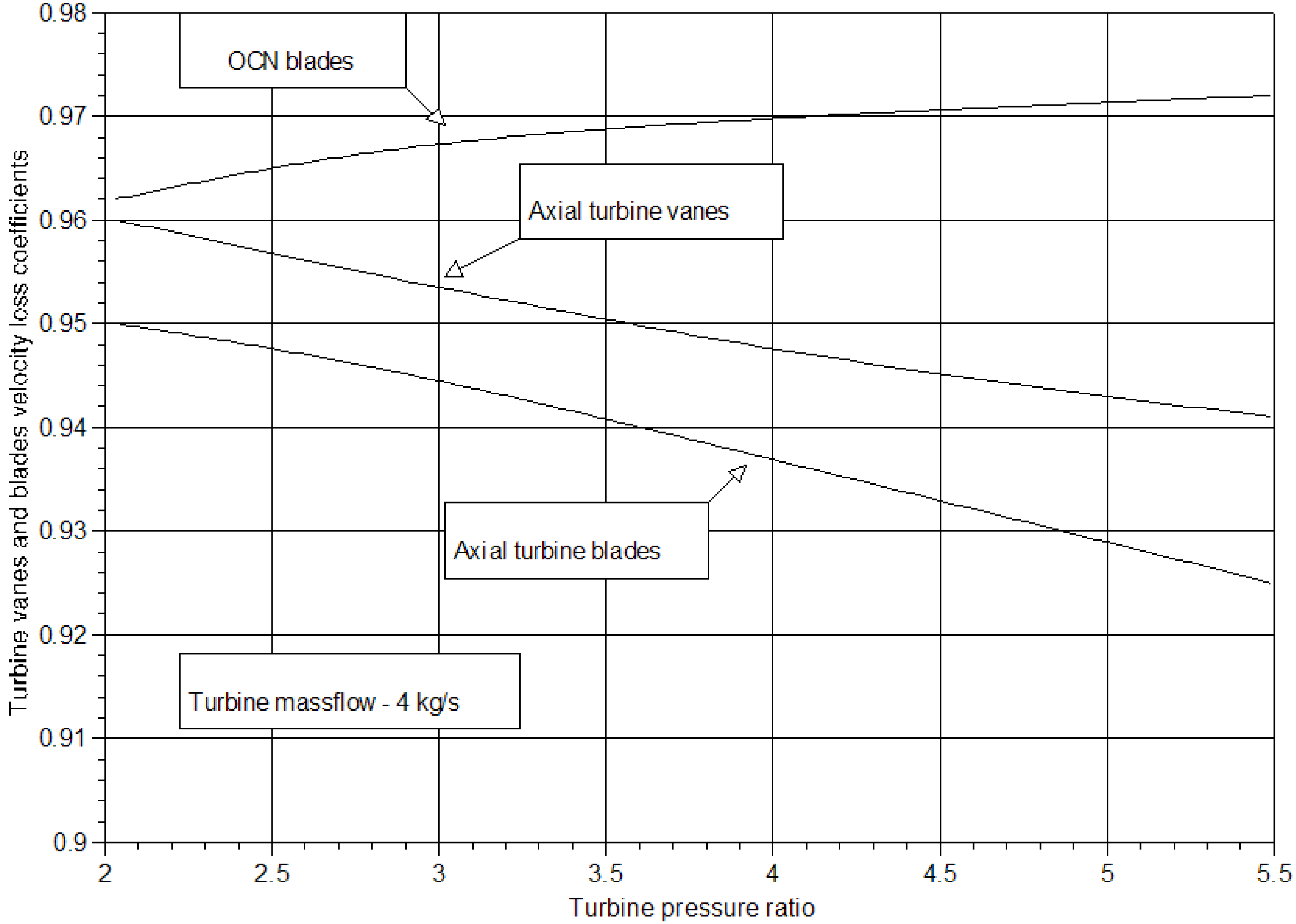


Fig. 7: Turbine Vanes and Blades Velocity Loss Coefficient - Turbine Pressure Ration Relations
OCN blades
Axial turbine vanes
Axial turbine blades
Turbine massflow - 0.895 kg/s
Turbine vanes and blades velocity loss coefficients
0.98
0.97
0.96
0.95
0.94
0.93
0.92
2
2.5
3
3.5
4
4.5
5
5.5
Turbine Pressure Ratio

Fig.8: Turbine Vanes and Blades Velocity Loss Coefficients - Turbine Pressure Ratio Relationship



Efficiency analysis

1. Losses calculated and verified by 3 different sources and substantiated by test results.
2. figs. 7,8 present the results—
3. Figs 9,10 present consequent turbine efficiencies
4. The S.L Turbine advantage is from 3-5%--increasing with increase of pressure ratio.
5. Potential efficiency improvement of 1-2% more by increasing swirl inlet velocity—for OCN S.L Turbine only.

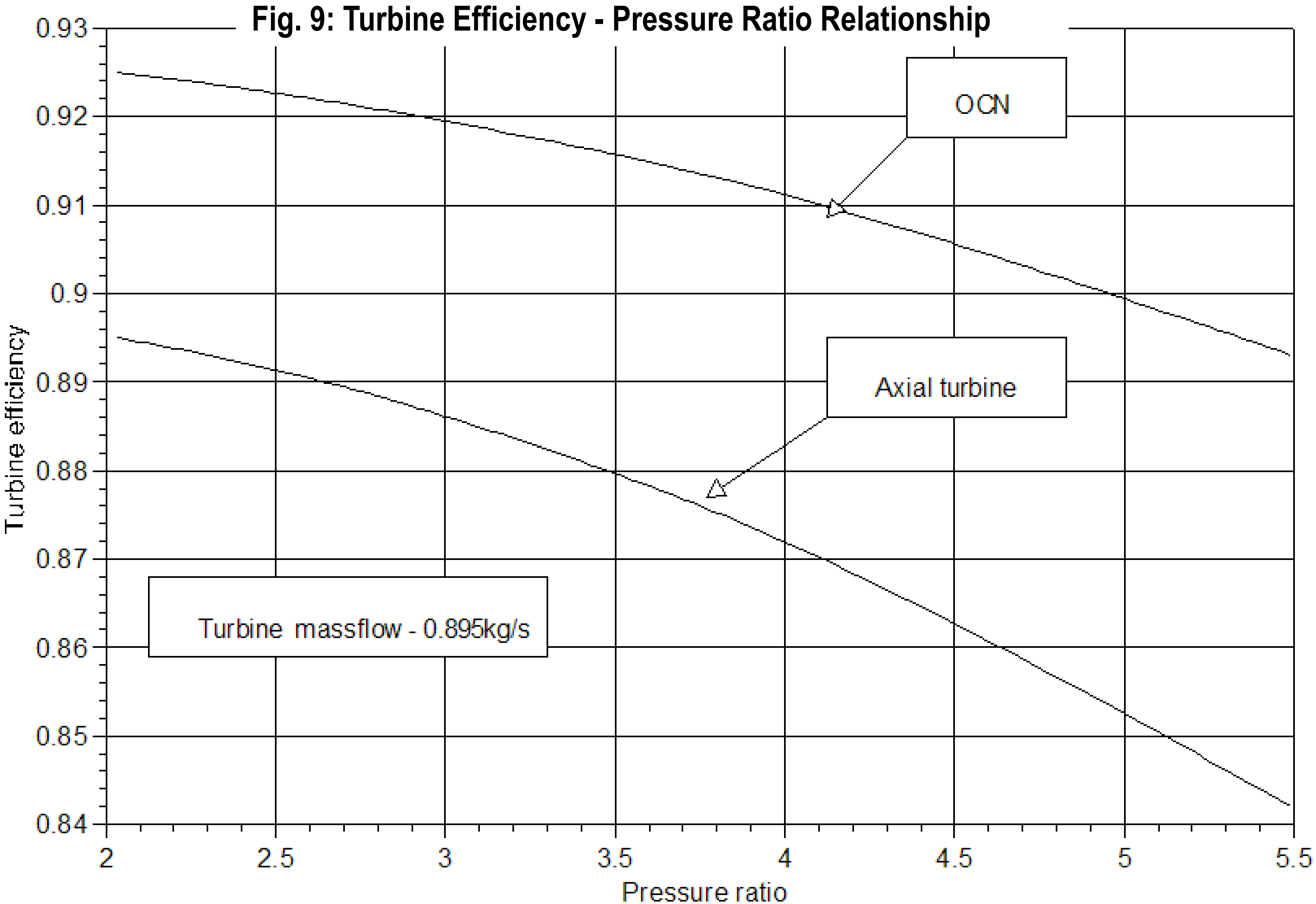


Fig. 9: Turbine Efficiency - Pressure Ratio Relationship
0.93
0.92
0.91
0.9
0.89
0.88
0.87
0.86
0.85
0.84
Turbine efficiency
2
2.5
3
3.5
4
4.5
5
5.5
Pressure ratio
OCN
Axial turbine
Turbine massflow - 0.895kg/s

Fig. 10: Turbine Efficiency - Pressure Ratio Relationship

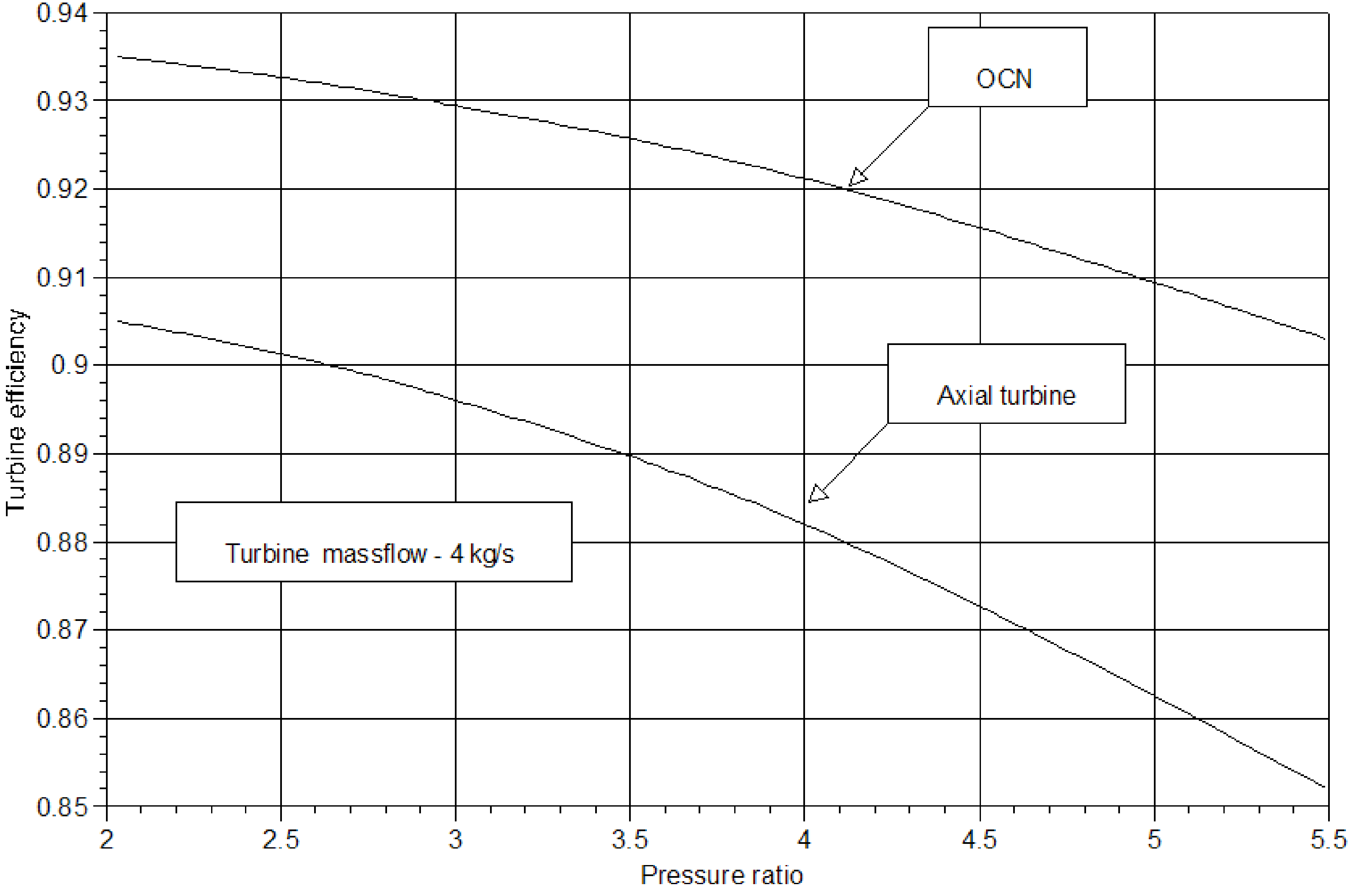


Fig. 11: OCN Degree of Reaction - Inlet Absolute Gas Velocity Relation

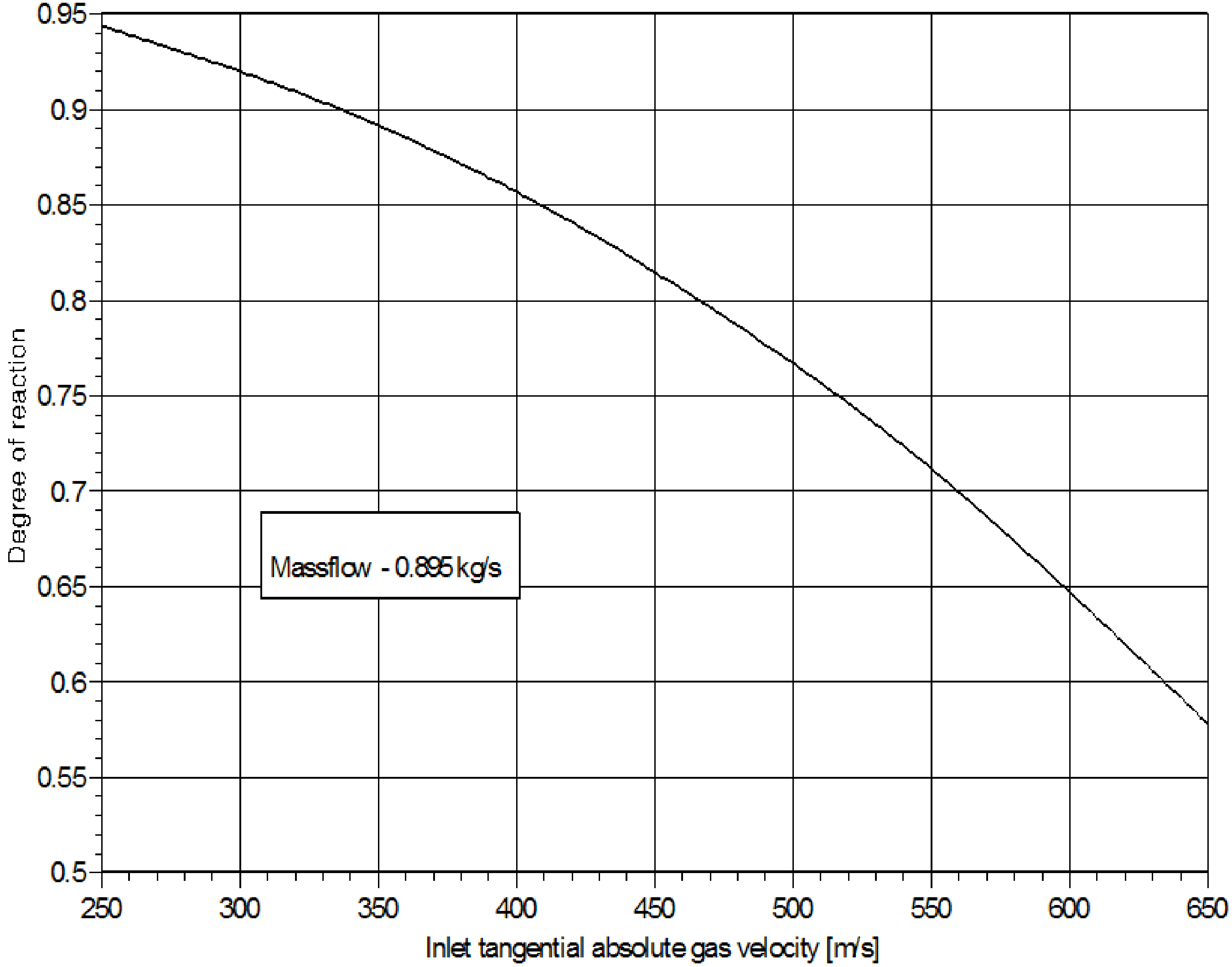
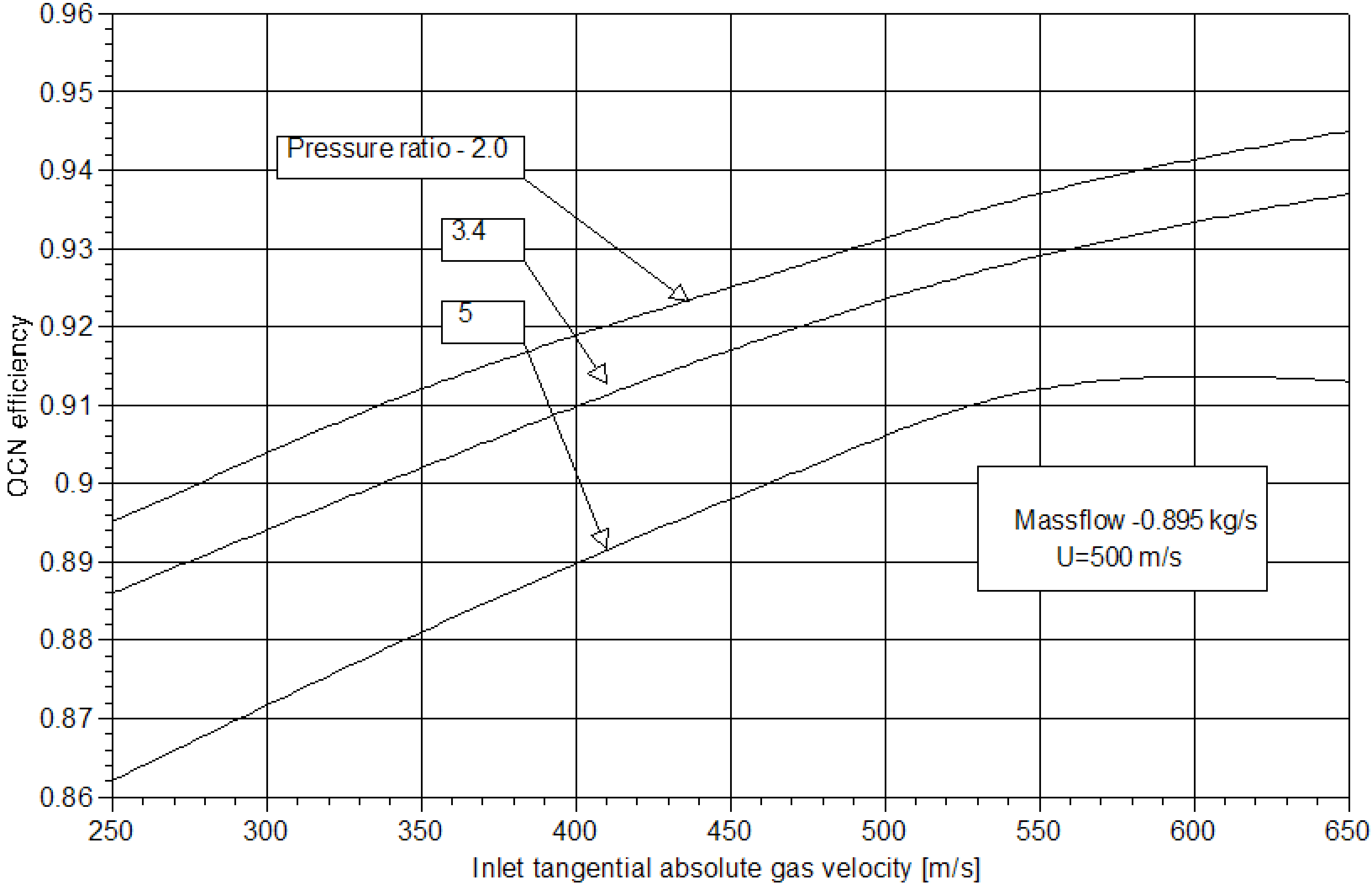


Fig. 12: OCN Efficiency - Inlet Tangential Absolute Gas Velocity Relations



Conclusions

1. **OCN S.L Turbine design presents a potential adiabatic efficiencies gain over conventional by 3-5%**
2. **The S.L design can be applied to the H.P turbine using the OCN rotating combustor vortex.**
3. **The cycle thermal efficiency gain by using 2 counter-rotating S.L Turbines is between 15-25% [relative] as function of cycle pressure ratio and turbine inlet temperature.**
4. **The OCN S.L Turbine can expand by using only 2 stages a cycle pressure ratio of 30:1—replacing typically 7 rotating rotors and 7 stators, and keeping the adiabatic efficiencies at 90% level.**

THE WEIGHT AND COST BENEFEITS ARE SIGNIFICANT

Thank You For Your Patience