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SOLAR THERMAL ENERGY RESEARCH GROUP

Analysis, Design and Manufacture of a Solarised Gas Turbine Compressor

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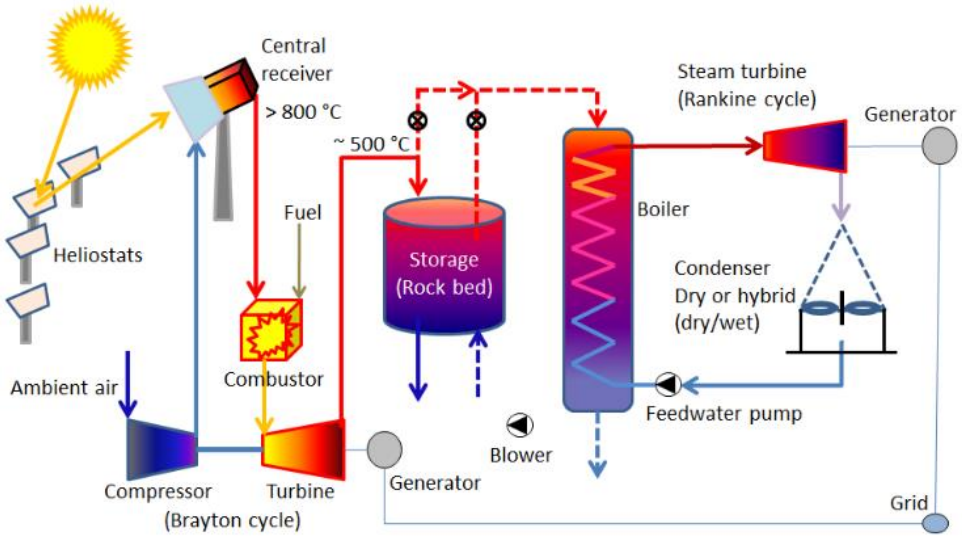
OVERVIEW

- Introduction
- 1-D Flow Model and Analysis
- 3-D Flow Model and Analysis
- Structural Analysis
- Design for Manufacture
- Conclusion

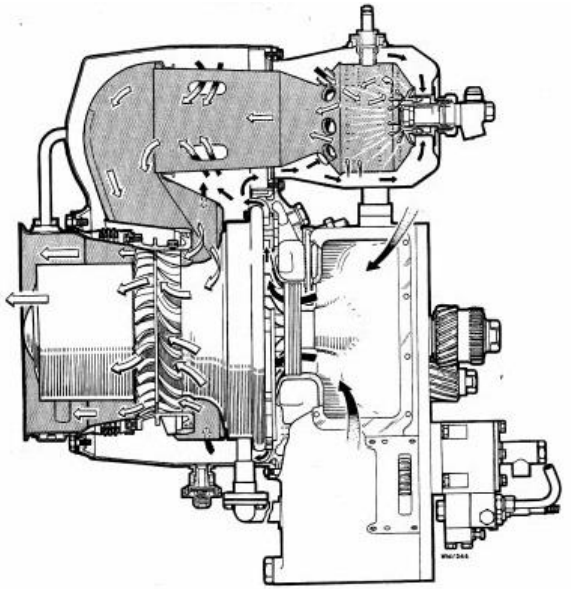
INTRODUCTION

Gas Turbines for Solar Thermal Applications



INTRODUCTION

What is known?



Luiten (2015):

- $p_{t,4}/p_1$ from 2.6 to 3.3
- eff. from 63.8% to 85.6%

Homann (2015):

- Net power output: 23.6% to 54.6%

INTRODUCTION

What is next?

Practical implementation:

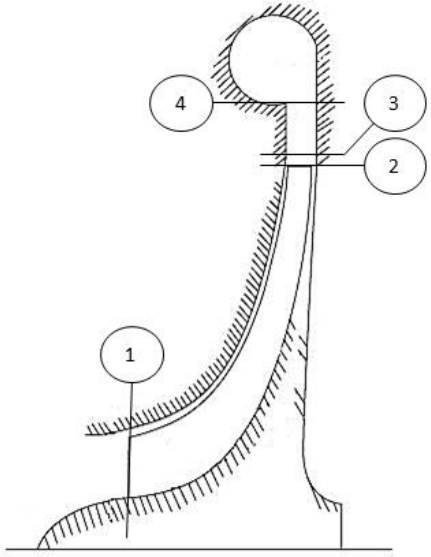
- Is the design sufficient?
- Are predicted results achievable?
- Is it structurally sound?
- Can it be manufactured?

1-D MODEL & ANALYSIS

Mean-line Design Code

CenCom by Aungier (2000)

Supported by Dixon (2010)



Match Luiten's performance results

1-D MODEL & ANALYSIS

Results

Property	Dixon	Aungier	Luiten
p_1 [kPa]	111.5	95.3	-
p_2 [kPa]	195.5	203.7	195.3
p_4 [kPa]	304.5	312.9	326.0
T_4 [K]	429.3	434.3	443.9

3-D MODEL & ANALYSIS

Theoretical Review

Geometry	☑
Boundary conditions	☑
Mesh	☑
Fluid Models	☑*

3-D MODEL & ANALYSIS

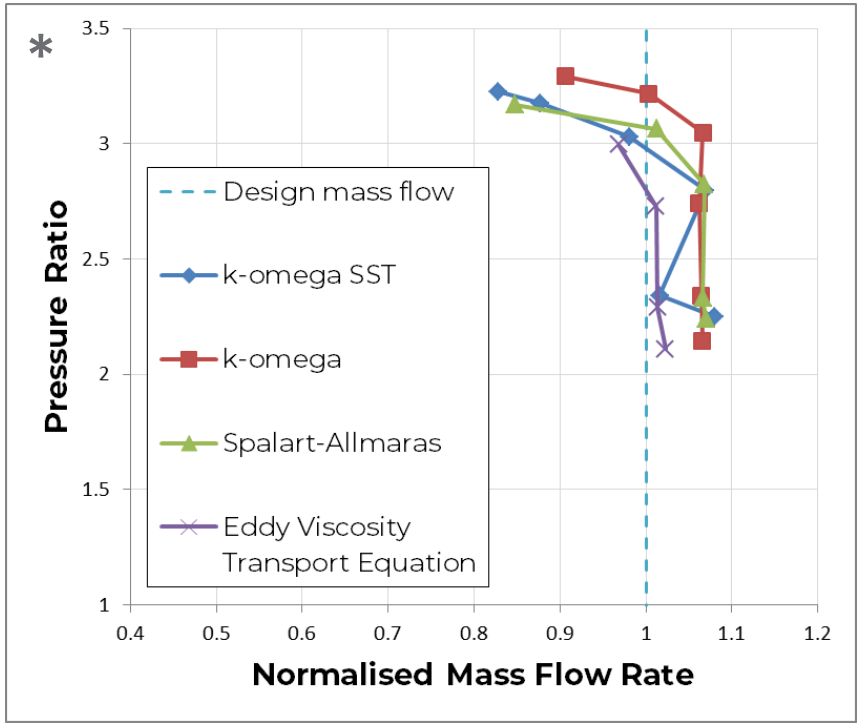
Theoretical Review

Geometry

Boundary conditions

Mesh

Fluid Models



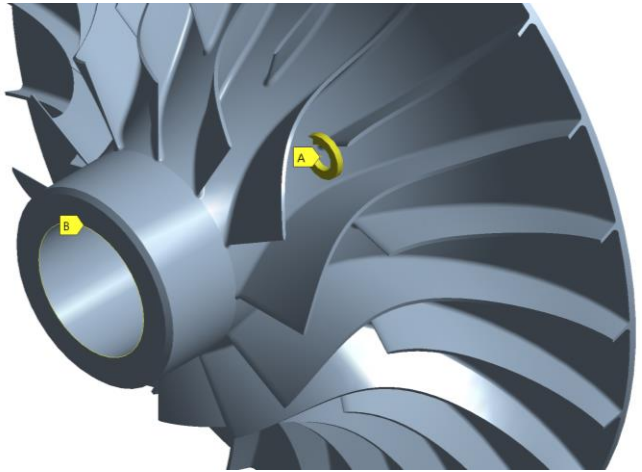
3-D MODEL & ANALYSIS

Practical Review

Property	*Present*	Luiten	Aungier
p_1 [kPa]	97.8	96.7	95.3
p_2 [kPa]	215.7	214.8	203.7
p_4 [kPa]	328.7	328.6	312.9
T_4 [K]	432.9	423.9	434.3
c_4 [m/s]	60.3	62.6	97.1

STRUCTURAL ANALYSIS

Setup



Geometry

Boundary conditions

Mesh

Material: that's an interesting one...

STRUCTURAL ANALYSIS

Material @ over-speed

	Al 6082		Al 7075	
	48300 rpm	50600 rpm	48300 rpm	50600 rpm
max. def. Z [m]	3.08×10^{-4}	3.38×10^{-4}	3.10×10^{-4}	3.40×10^{-4}
max. stress [MPa]	260	286	270	296

STRUCTURAL ANALYSIS

Deflection & Stress Results

Property	Coarse	Medium	Fine
max. def. R [m]	1.02×10^{-4}	1.02×10^{-4}	1.02×10^{-4}
max. def. Z [m]	2.81×10^{-4}	2.81×10^{-4}	2.81×10^{-4}
max. total def. [m]	2.93×10^{-4}	2.93×10^{-4}	2.93×10^{-4}
max. stress [MPa]	243	242	245
Nodes	1 167 708	2 235 908	7 578 461
Elements	751257	1 473 141	5 176 278

STRUCTURAL ANALYSIS

Modal Results

Mode Nr.	Damped Frequency [Hz]
1	831.2
2	1156.8
3	1734.5
4	2828.9
5	2830.8
6	2838.5

STRUCTURAL ANALYSIS

Forces, X-Rays & Ultrasound

Extend 1-D analysis to turbine

- Axial force from 480 N to 1 400 N

X-Rays ☒

Ultrasound ☑

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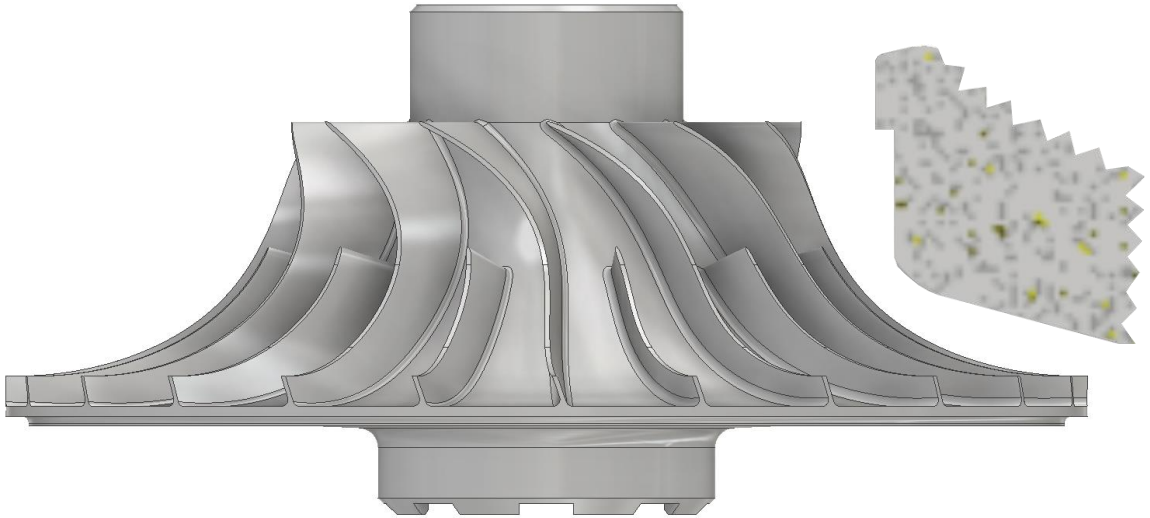
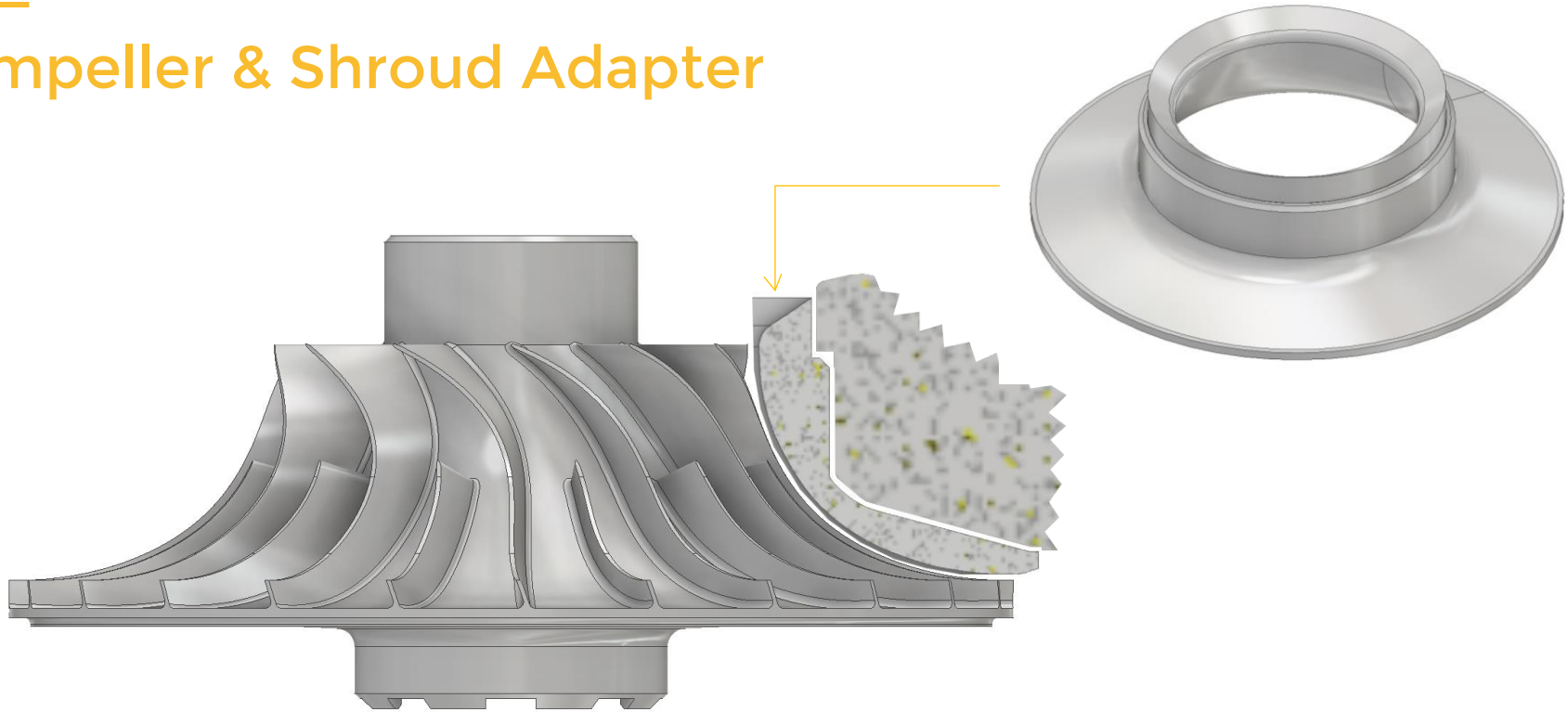
DESIGN FOR MANUFACTURE

Impeller & Shroud Adapter



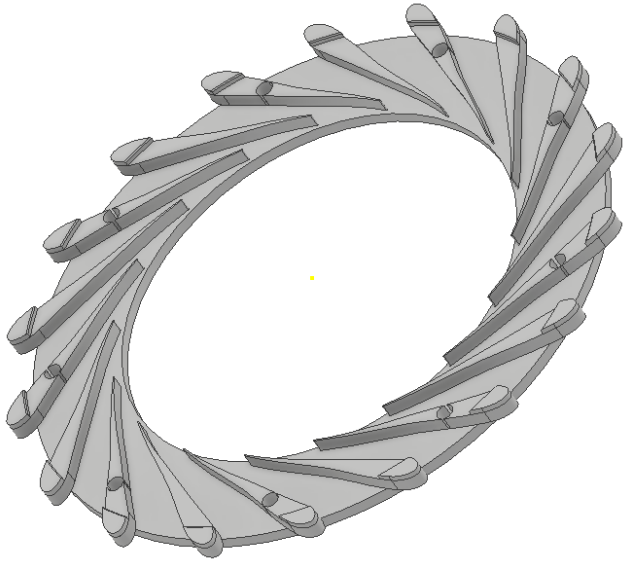
DESIGN FOR MANUFACTURE

Impeller & Shroud Adapter



DESIGN FOR MANUFACTURE

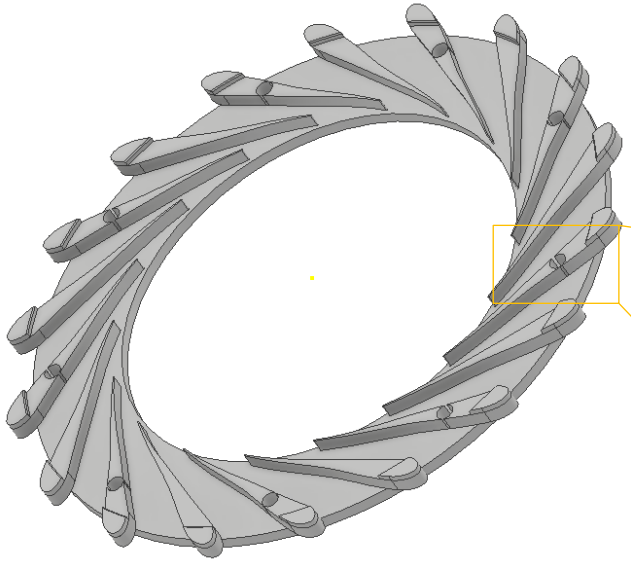
Diffuser



- Hub plane
- Bolt holes

DESIGN FOR MANUFACTURE

Diffuser



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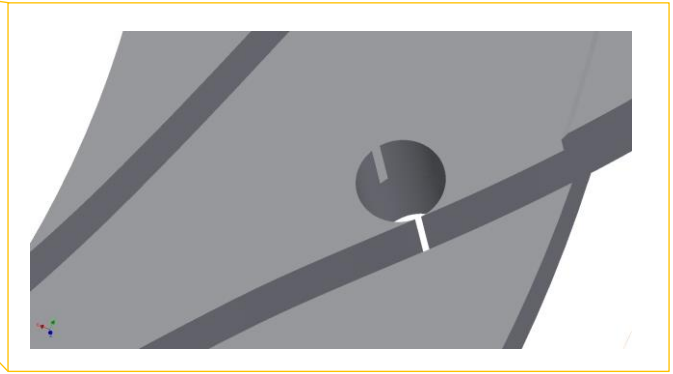

CONCLUSION

Future Work

- Model downstream conditions
- Adapt combustor
- Experiments!

THANK YOU

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