Design and manufacturing of injection-molded small blades

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Sandia National Laboratories blade workshop
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Air X

400 W, Ø 1.16 m, 3-bladed

Air X blades

carbon-fiber reinforced thermoplastic

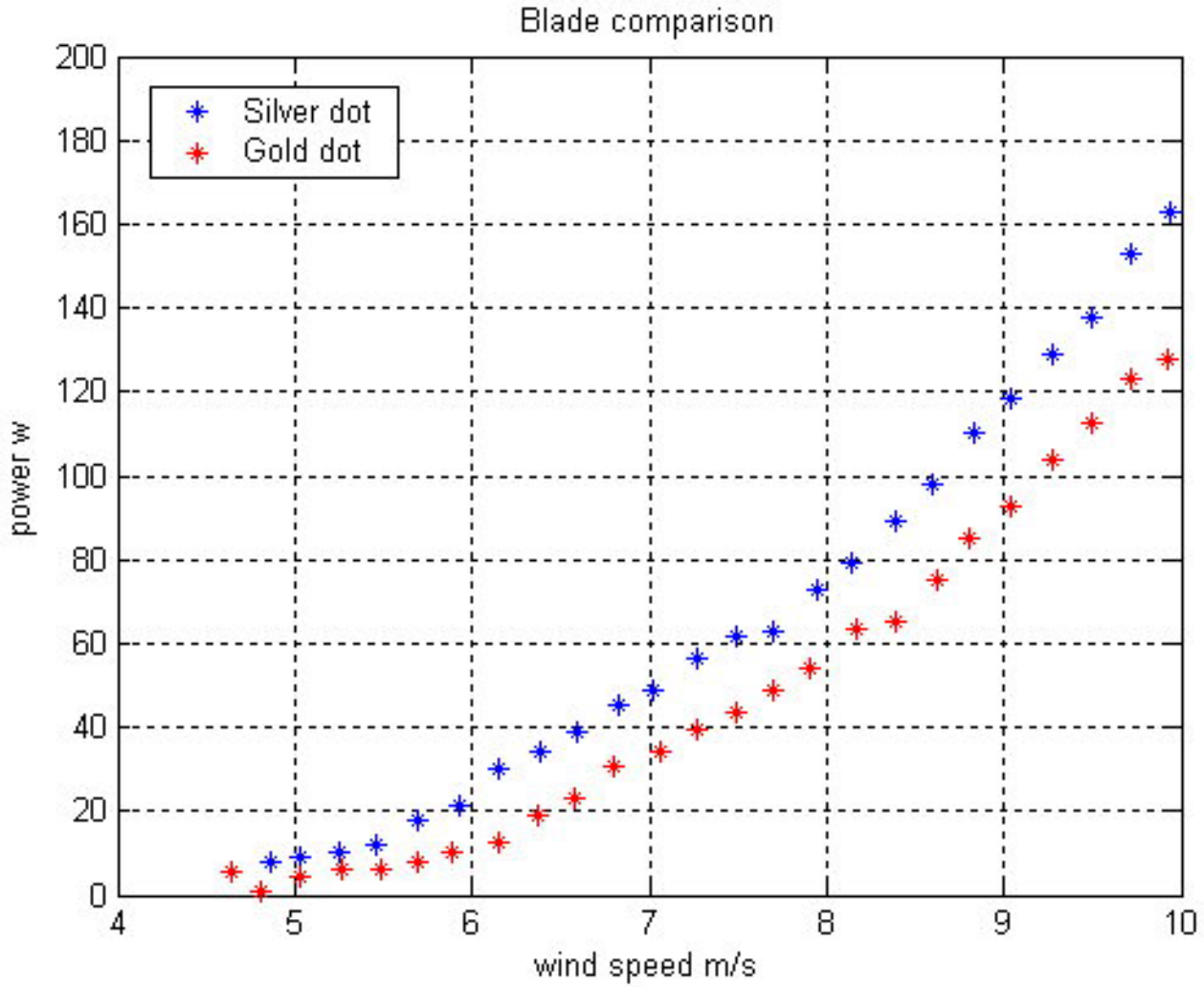
chord : 115 mm at the root ; 17 mm at the tip

weight : 180 g

geometric tolerances

Pitch affects efficiency and flutter characteristics

Accuracy of airfoil shape reproduction affects efficiency, particularly at the leading edge


Blade comparison
Silver dot
Gold dot
power w
wind speed m/s
0
20
40
60
80
100
120
140
160
180
200
4
5
6
7
8
9
10

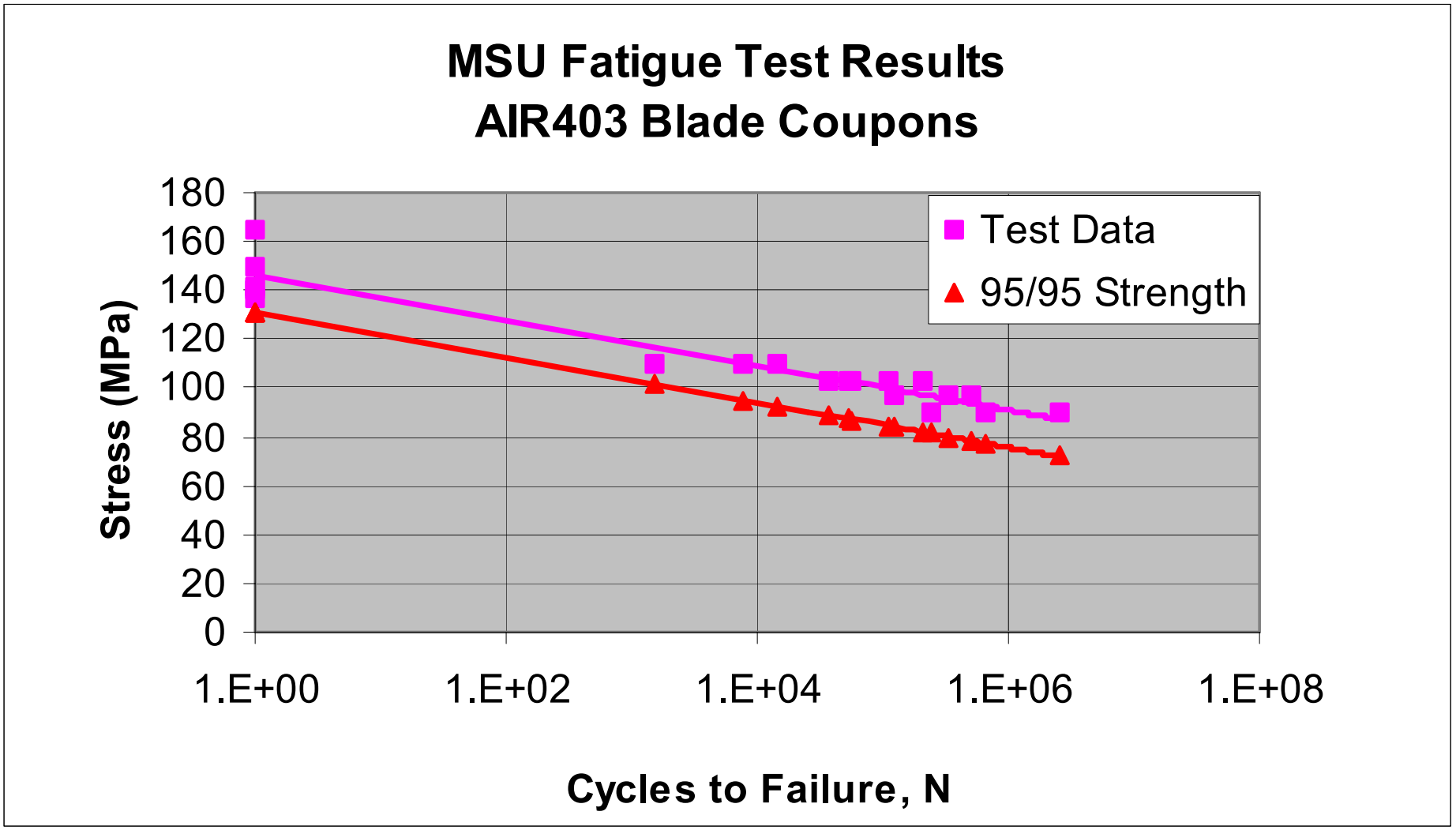
quality improvements in molding

- 90 s cooling in water
- blades hung on rack while still exothermal
- pitch measured ; blades sorted by pitch
- stacked and shipped in 1-layer boxes

U.L. certification : blade characterisation

Ultimate tensile strength from textbook case

No existing fatigue curve : data experimentally obtained by Montana State University (J. Mandell) with 50 samples on extensometer ; confirmed by experimental static tests.


MSU Fatigue Test Results
AIR403 Blade Coupons
Stress (MPa)
180
160
140
120
100
80
60
40
20
0
1.E+00
1.E+02
1.E+04
1.E+06
1.E+08
Cycles to Failure, N
Test Data
95/95 Strength

new blade design for the Air X

Problems identified :

- material thickness at root causes fatigue failures
- flutter
- mold wearing out (flashing)
- Low Re operation

Material thickness at root reduced by using ribs.

flutter

Overspeed control on Air 403 was blade tip flutter

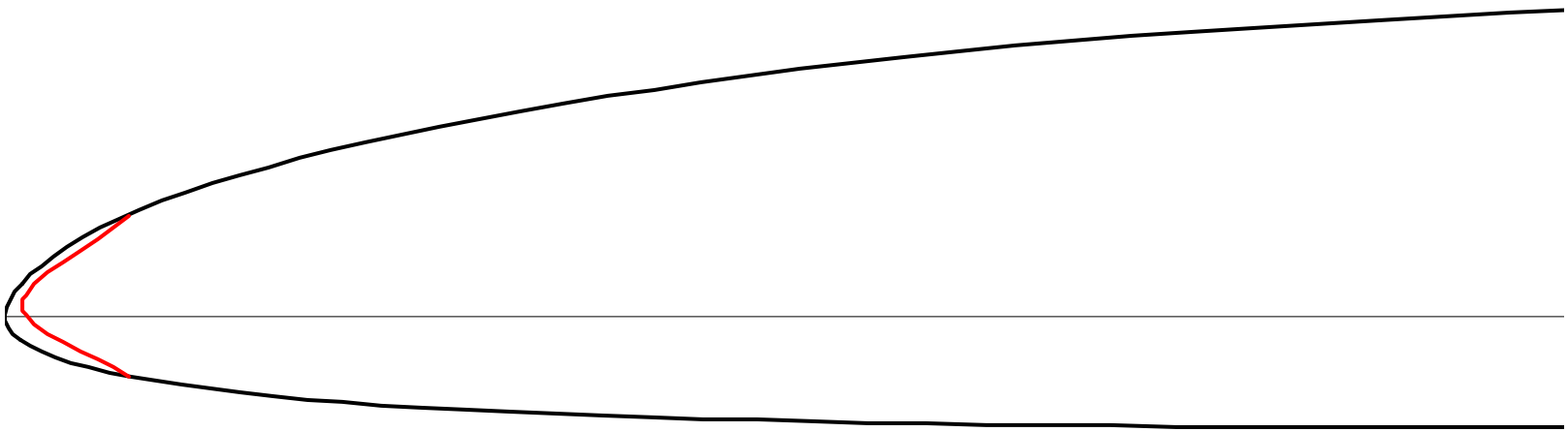
Air X electromagnetically controlled

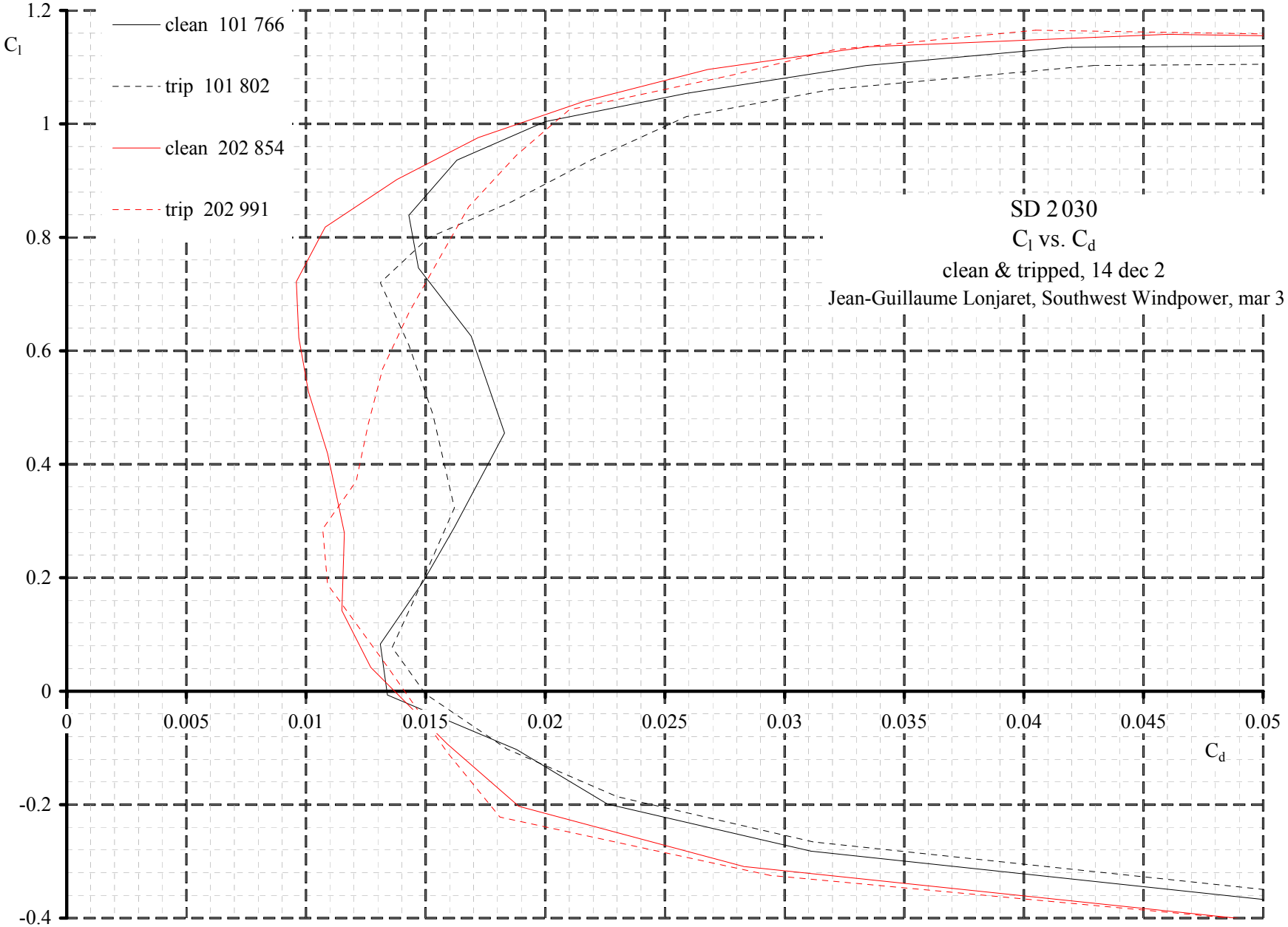
Flutter still needed for protection in case of failure

flashing

Material escapes between halves of the worn-out mold.

Edges need to be manually sanded down : labor intensive and aerodynamically detrimental




clean 101 766
trip 101 802
clean 202 854
trip 202 991
SD 2030
C_l vs. C_d
clean & tripped, 14 dec 2
Jean-Guillaume Lonjaret, Southwest Windpower, mar 3
C_l
C_d
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05


BOTTLES