Blade spring measurements and results

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G050101-00-K

Blade types

- Top (D040298)
  - Working Length 480, thickness 4.3, root width 95
- Middle (D040297)
  - Working Length 415, thickness 4.6, root width 59
- Bottom (D040296)
  - Working Length 635, thickness 4.2, root width 49

Blades and their behaviour

- For the controls prototype a total of 49 blades have been made.
  - 12 (4 of each type) at reduced spec (MF2), 37 (12 of each type + 1 extra) at full spec (MF1).
- All have been inspected and appropriately loaded, data has been collected and tabulated on all blades.
- There is significant variation in the final blades, this can be:-
  - Initial shape (tip height above the blade root)
  - Total deflection when loaded
- Cosmetically there is also considerable variation.

What was measured

- Thickness of blades along their length for a sample of blades, also root width, tip width and length.
  - 4 of each type from MF1; 2 of each type from MF2
- Undeflected shape on table, undeflected shape on BTF, deflection under load (and deflected tip location)
  - All blades
- Bounce mode and internal frequency
  - Which blades?

Data taken

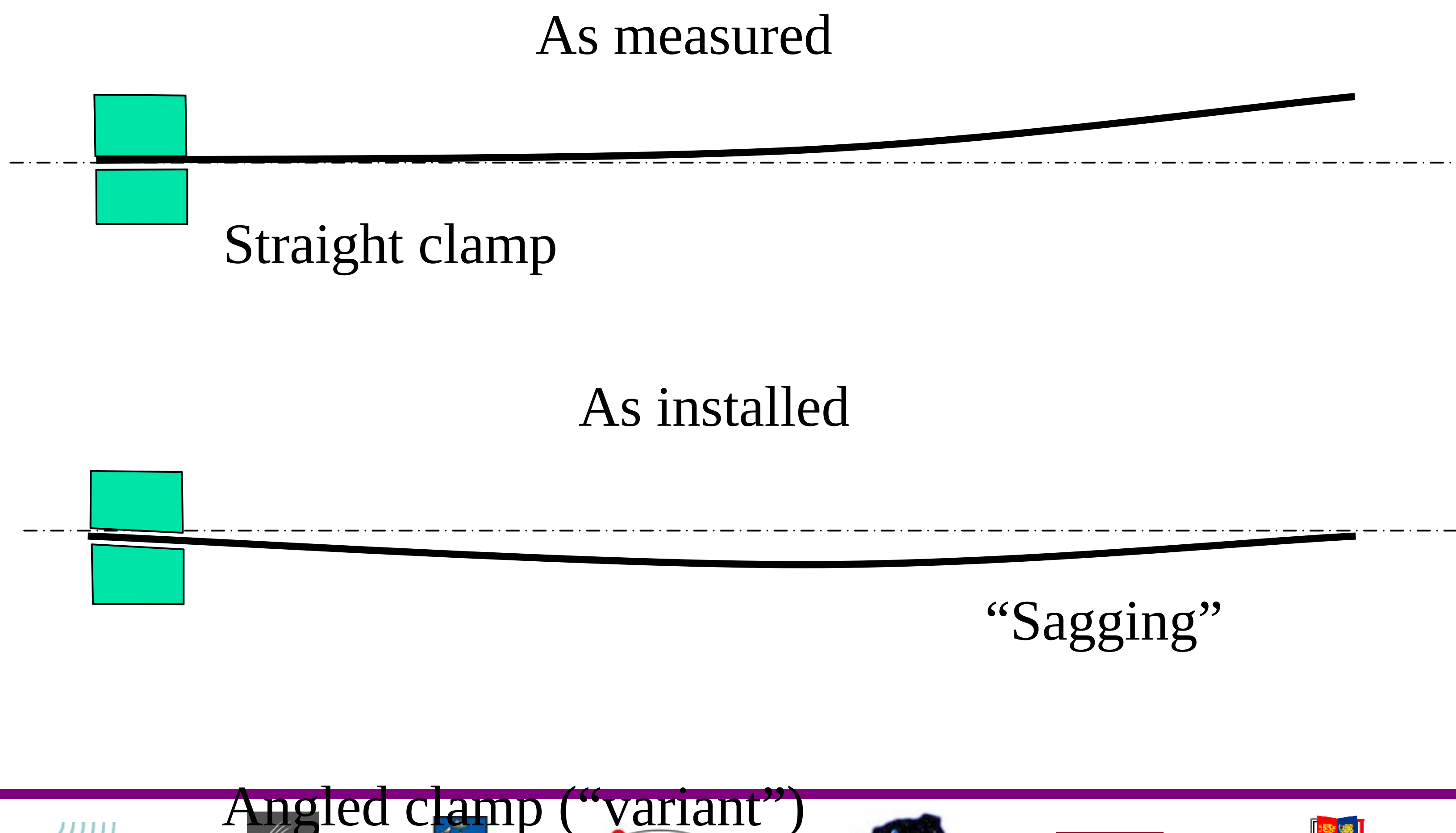
- The following data were collected for each blade:
  - Unloaded tip height WRT horizontal
  - Loaded tip height WRT horizontal
  - Bounce frequency, and internal mode
  - On bench metrology
  - (additional measurements were taken to assess deflection in the measurement facility to remove it from the results)
- This allowed us to derive
  - Blade deflection under load
    - Hence blade stiffness
  - Final blade tip height for the design load
    - Hence angle to clamp blade WRT horizontal to get blade tip in the correct place.

Blade thickness,etc results

- Checked 12 (out of 37) MF1 blades and 6 (out of 12) MF2 blades.
- Root width, tip width, length.
  - Two minor infringements.
- Thickness along the length (8 points along the length)
  - Some minor infringements.
  - Little to choose between the suppliers.
  - MF2 marginally better in terms of SD on thickness.
  - Remember this. Tolerance on thickness was +/- 0.0004" which is about 0.25%. Since the error on stiffness goes with the cube of thickness we might expect to see a stiffness error of order 0.75%.

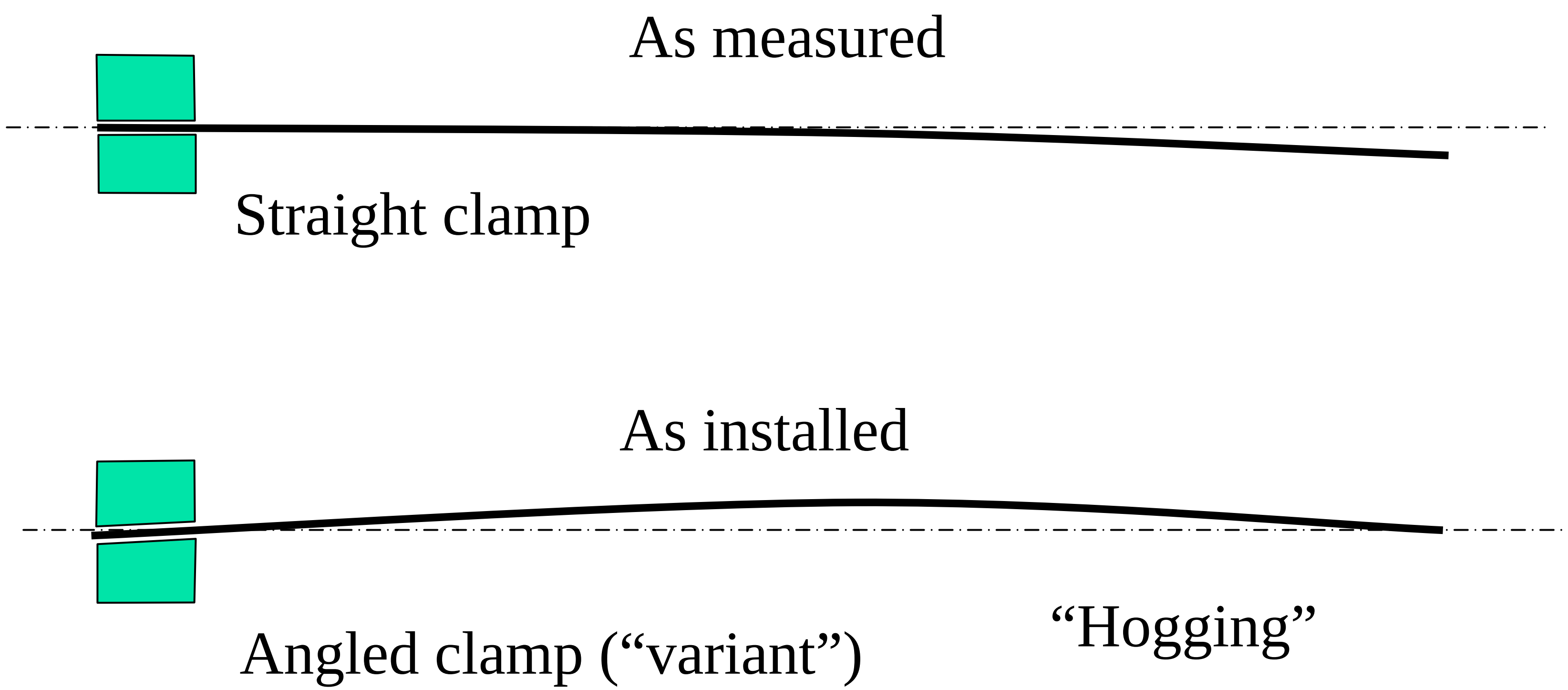
Shape of blade in use - 1

- Tip too high (wrong initial shape or wrong stiffness)



Shape of blade in use - 2

- Tip too low (wrong initial shape or wrong stiffness)



Blade processing:

- Make blades
- Reject if
  - wrong stiffness or “not a spring”
  - too far out of shape (or possibly modify shape)
  - Other manufacturing errors
- Pair blades for use

Criteria for discarding blades

- Some blades may be geometrically in spec but be unsuitable for use in a suspension.
  - They would be unsuitable if they don't behave as a spring i.e.When a blade is loaded does it take a set?
- They may be unsuitable if:
  - The blades do not deflect the correct amount when loaded (wrong stiffness)
  - The flat blade falls more than *x* mm above or below the horizontal, i.e. the clamp variant is very large, forcing the blade to hog a lot. (bad combination of stiffness and initial shape).
- They may fall out side geometric spec but be worth using if:
  - The flat section of the blade is curved
- The bounce frequency is anomolous (any evidence for this?)

Criteria for accepting blades

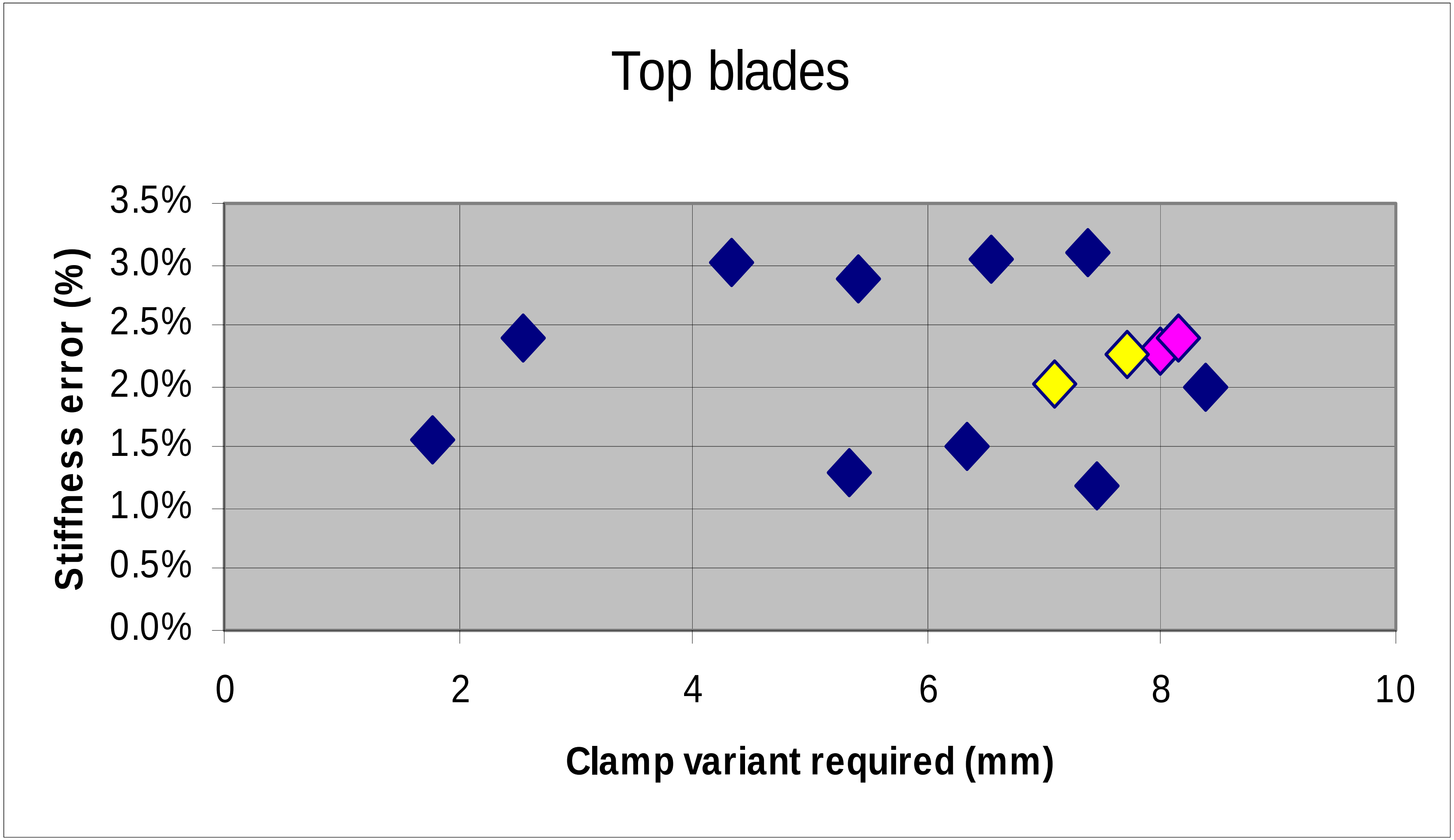
- "Obvious, but wrong"
  - Stiffness, initial curvature
- "What's wanted"
  - Stiffness, tip height under load
  - Tip height under load is a function of initial curvature and stiffness
  - Subject to concerns about "hogging" and "sagging" as noted below.

With blades, what makes an ideal pair?

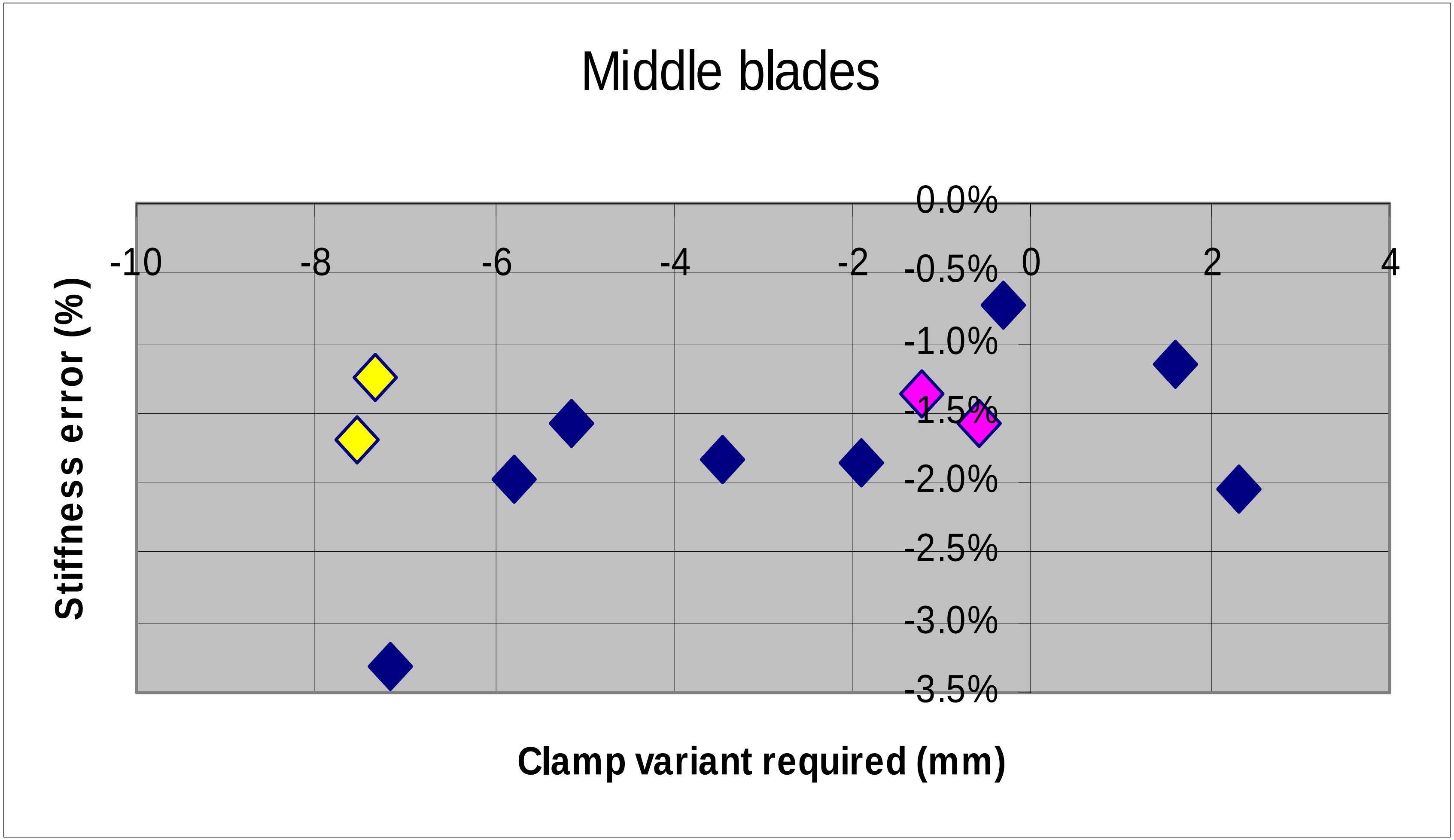
Some ideas about how we should pair blades

1. Same deflected height (clamp variant).
2. Same deflection (same stiffness)
3. Same deflected height and same undeflected height (same stiffness & variant)
4. As 1, 2 or 3. + same bounce frequency
5. As 1, 2 or 3. + same internal mode

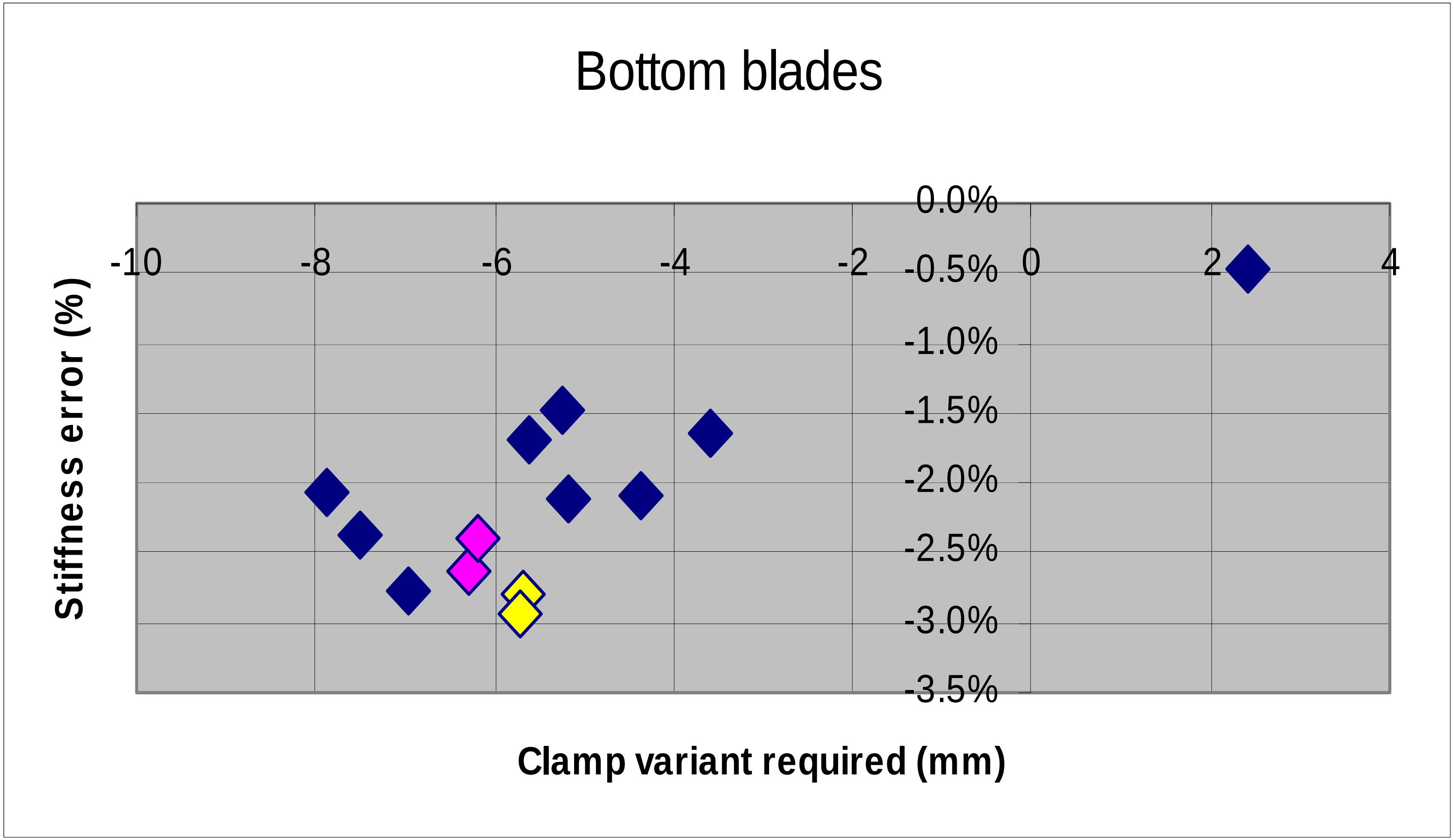
Results for stiffness and deflected height



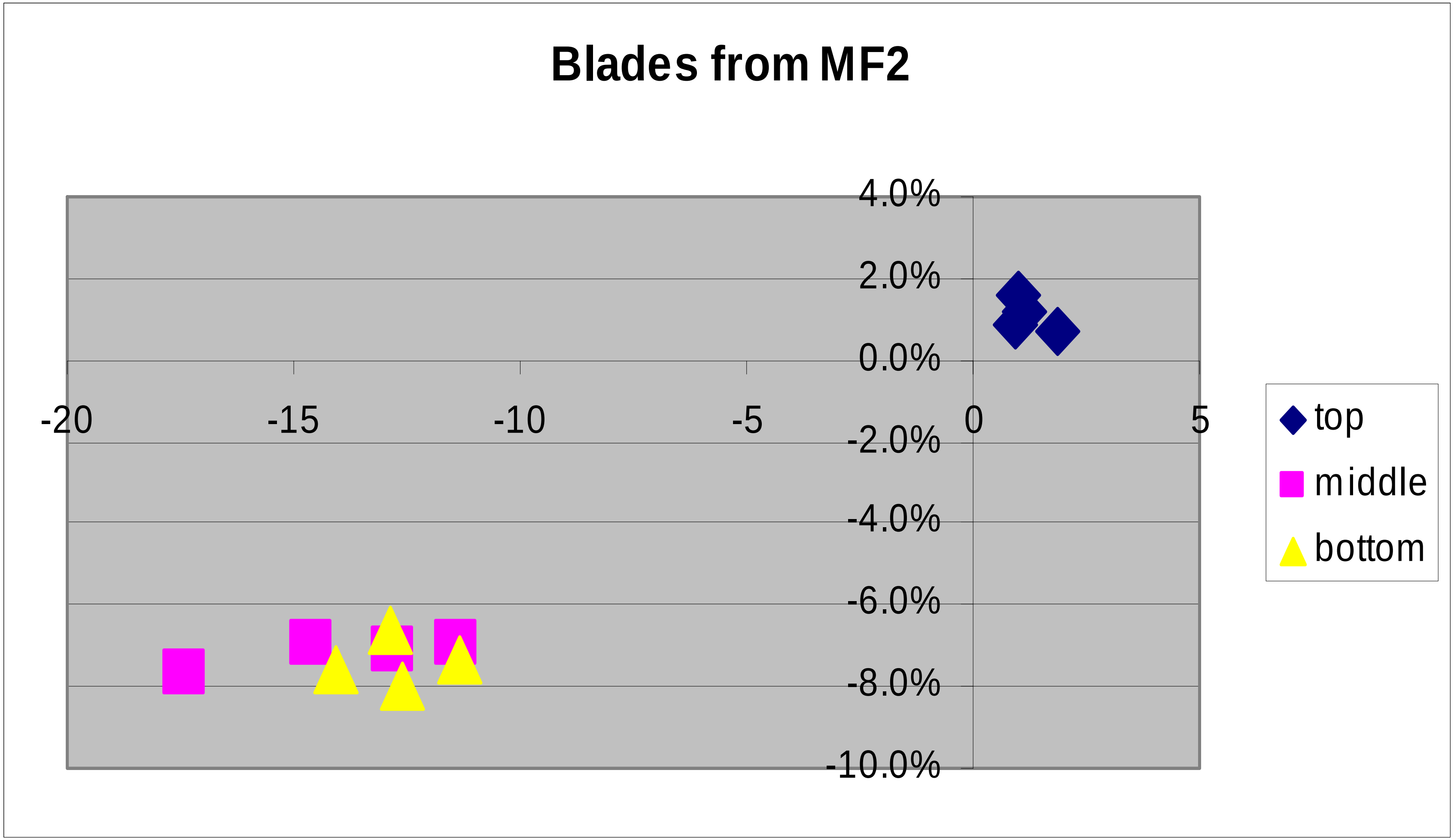
Results for stiffness and deflected height



Results for stiffness and deflected height

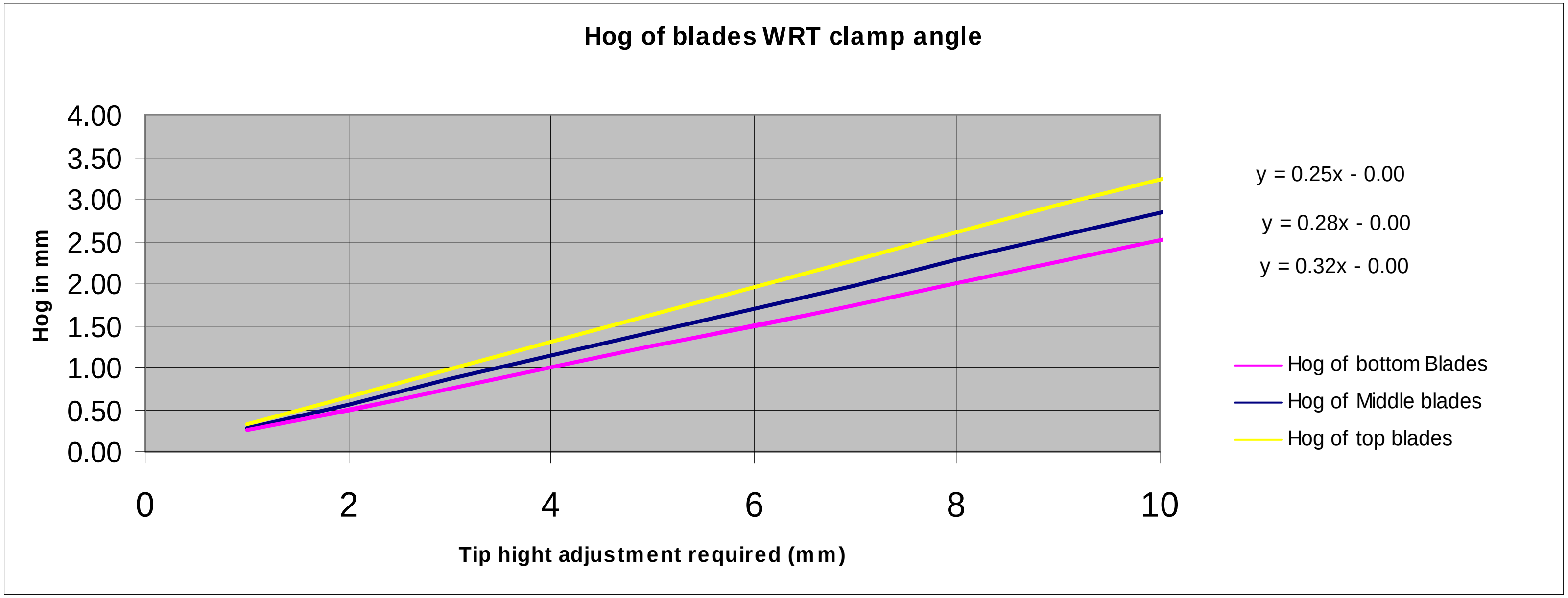


Results for stiffness and deflected height



Blade Hogging

- Using "imperfect" blades will require the blade clamps to be angled. This will mean that the blades will hog, either up or down.
- The amount of hogging of a blade is directly related to the clamp variant, and can be calculated directly from the blade geometry.



Conclusions – Controls PType

- Total of 49 blades made
- Some rejected for manufacturing oddities
  - Interesting lessons learned here
  - flatness of root section
- Six pairs selected
- More pairs could have been found
- Why were the stiffnesses from MF2 so far out on some blades?

Conclusions – Noise Ptype 1

- Proposed approach - homework
  - Establish limits on acceptable sagging/hogging; hence "variant"
    - (maybe try some "badly matched" blades on CP?)
  - Establish limits on acceptable error in stiffness (absolute) (matlab)
  - Establish limits on errors in pairing stiffness (M Barton/NAR and the 1.5%)
  - ? Establish limits on acceptable internal frequencies (how?)
  - Use existing results to adjust "alpha" value in design
  - Any smart ideas as to why some of the blades from MF2 were soft?

Conclusions – Noise Ptype 2

- Proposed approach – manufacture & test
  - Make blades; measure; reject if outside limits above then pair.
  - Each SUS needs 2 pairs of each type (+spares)
    - N Ptype thus needs 4 pairs of each type + spares
  - Suggest 12 blades of each type (TBC) should be ordered to allow 4 pairs to be found
    - By this we mean 12 blades that conform to drawing
    - Allow material for at least 14 blades of each type