

50HP Propeller Project Detailed Report

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2021-2022



- Project Proposal
 - Project Background, RE-DO Process, Design Analysis
 - Diagnosis, Proposed Next Steps, Timeline
- Design Optimization
 - Project Background, Methodology, Conclusions
- Design Update with Prototype testing data
 - Achieved balancing, Too efficient lowering Power draw.
- Final Product Testing & Project Close

Customer engaged GloTech to analyze their existing 50HP aerator propeller, and to provide an improved design solution

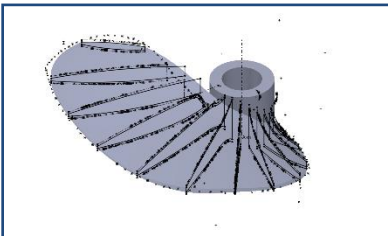
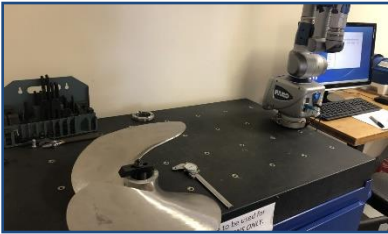
- Customer reported the following issue on their existing 50HP prop:
 - Hydraulic vibration: Excessive vibration during aerator operation under water. Top bearing “wears out unevenly”
- The project goal is for GloTech is to analyze the above mentioned issue and provide an improved design with the following features and benefits:
 - **Improved product quality:** reduced vibration, better casting quality and uniformity
 - **Product differentiation:** potential cost savings, pre-pitched and balanced prop, optional addition of customer LOGO / cast letters
- The preliminary design of the 50HP propeller has been completed using GloTech’s RE-DO™ (Reverse Engineering and Design Optimization) process. Preliminary timeline and fees to be provided based on the above

Our RE-DO™ (Reverse Engineering and Design Optimization) process is used to create the 50HP propeller solution

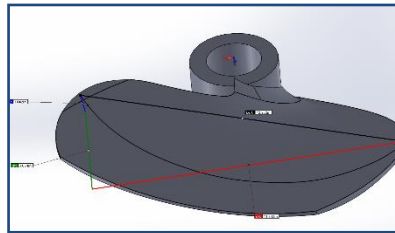
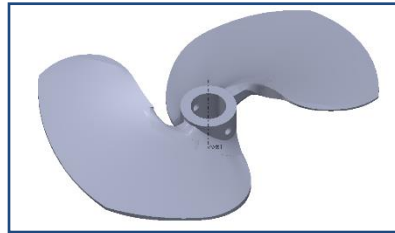
GloTech RE-DO™ Process for 50HP Propeller



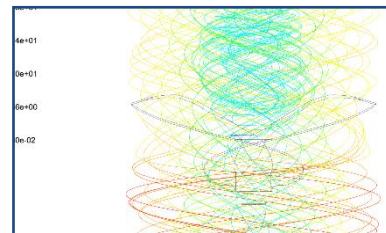
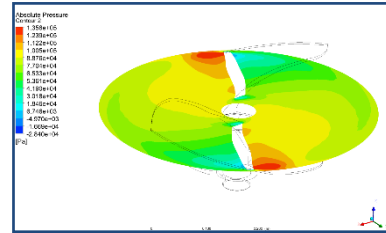
3D scan sample propeller using FARO technology



Create and analyze 3D models in SolidWorks



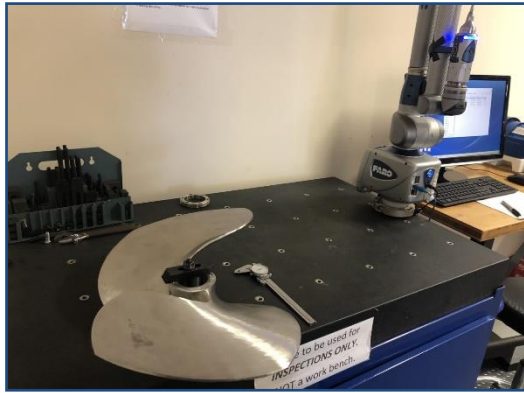
Improve design using GT's hydraulic expertise



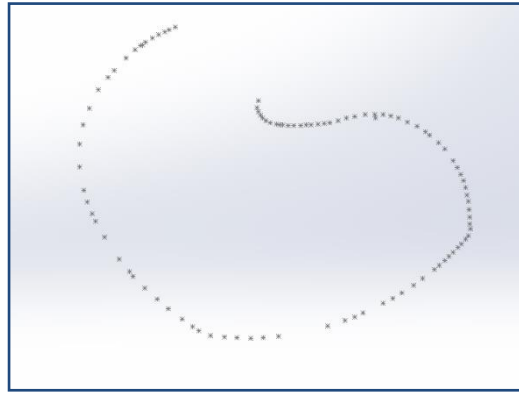
Next Step: provide turnkey product solution



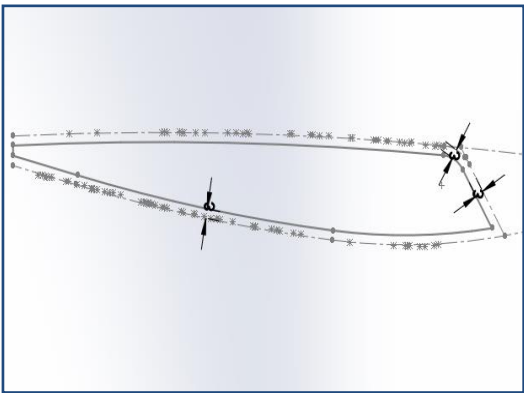
The sample 50HP propeller from customer was first scanned into SolidWorks using FARO Arm



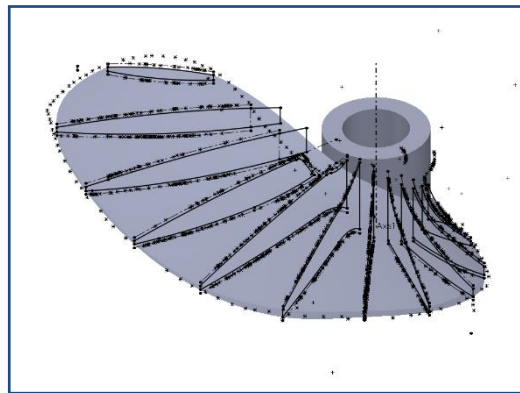
FARO scan setup



Blade Boundary Contour



Sample Scanned Plane

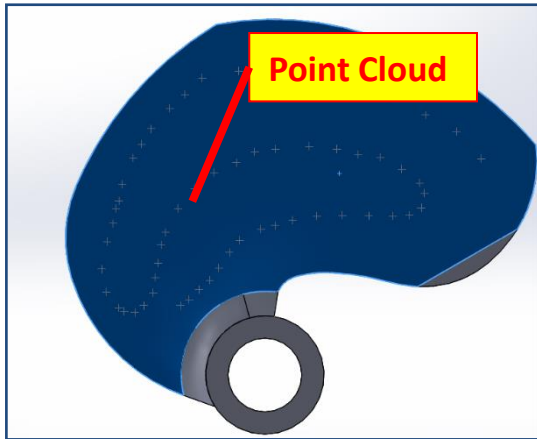


Blade Geometry Construction

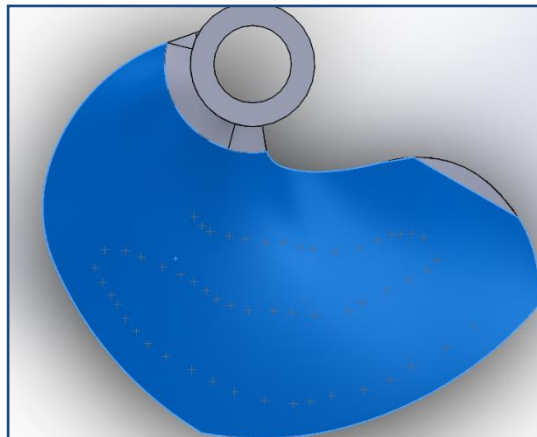
Scanning Techniques

1. Alignment was performed to set the correct position of the prop
2. Blade boundaries were scanned in to establish blade contour
3. 12 cutting planes were created to acquire the cross-sectional geometry of the blade
4. Blade profile was created using previously collected data points

Blade model was compared against sample part using FARO validation



Top Validation



Bottom Validation

Top Validation (unit: mm)

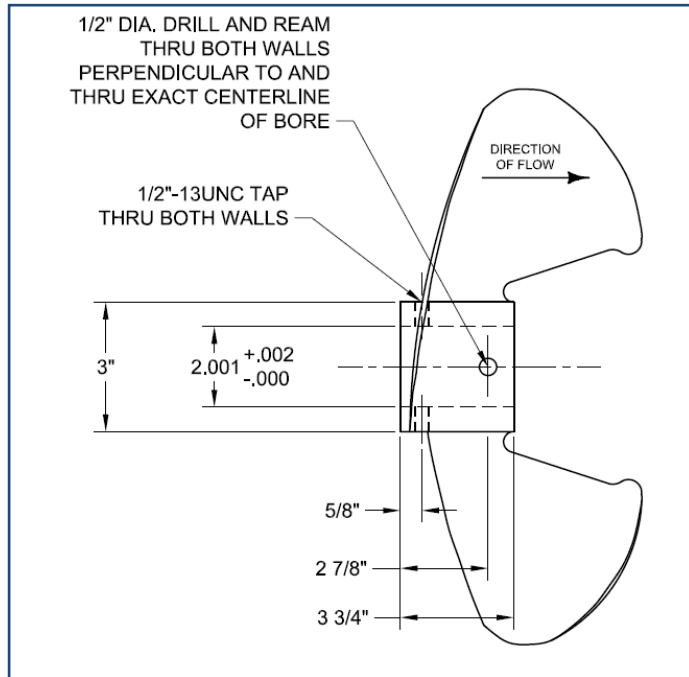
X	Y	Z	Deviation
150.3413	-38.9888	150.4208	0.0745
133.5606	-33.3474	169.349	0.1364
111.7944	-27.8062	181.015	0.0272
86.7772	-21.4215	194.7289	0.0274
65.8505	-16.2446	202.9589	-0.0633
51.2429	-12.7596	206.6299	-0.12
34.03	-8.6927	209.2321	-0.1878
10	-3.3076	209.9754	-0.0297
-18.0717	3.0193	211.6113	-0.0097
-43.5731	8.722	206.8293	-0.0758
-55.735	11.8213	195.2327	0.0035
-66.3004	14.8423	185.6657	0.0233
-79.1126	19.1817	171.4066	0.0158
-86.1415	22.2797	160.5803	-0.0796
-91.976	25.0642	150.9584	-0.0475
-99.6489	29.9499	132.518	0.15

Bottom Validation (unit: mm)

X	Y	Z	Deviation
146.0773	-19.4242	173.0193	-0.6069
127.7089	-14.4833	187.7654	-0.4704
105.1841	-8.2066	199.96	0.0469
90.9045	-4.8876	209.2368	0.1372
73.5702	-1.3309	215.4908	-0.4255
52.3297	3.1147	219.1453	-1.0911
38.1636	5.8429	223.3163	-1.0778
27.0685	8.5162	224.5939	-0.7798
7.824	13.6025	221.999	-0.5702
-11.9688	19.0114	216.5942	-0.5142
-25.986	23.2494	209.7597	-0.5164
-40.4024	27.4533	202.1779	-0.4588
-57.1958	31.3304	193.6295	-0.5956
-69.354	34.4466	184.7651	-0.3615
-76.9332	36.9995	176.6638	-0.0426
-84.1592	39.4568	168.0845	0.0812

• Validation results indicate the scan is accurate and the blade model is in line with the physical part

The first step of the analysis was to compare the scanned model to the drawing and specifications provided by Customer



Customer Drawing of 50HP Propeller

Sample Prop vs. Customer Drawing

Description	Drawing	Sample
Casting dia.	22"	~21"
Clipped Dia.	19.5"	~19.48"
Finish Pitch	12.0"	12.05" Avg.
Rotation	LH	LH
Hub Length	3.75"	3.20"
Hub Dia.	3.0"	3.25"
Weight	36 lbs	38.3 lbs

- **Both the prop diameter and pitch measurements are nearly identical to the customer drawing**
- **The hub profile is somewhat different. However, this should have limited impact on the prop performance**

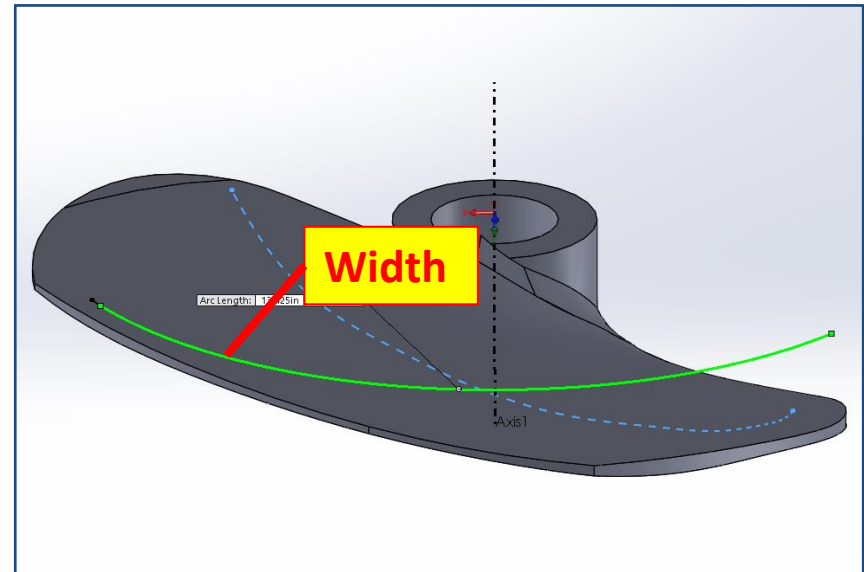
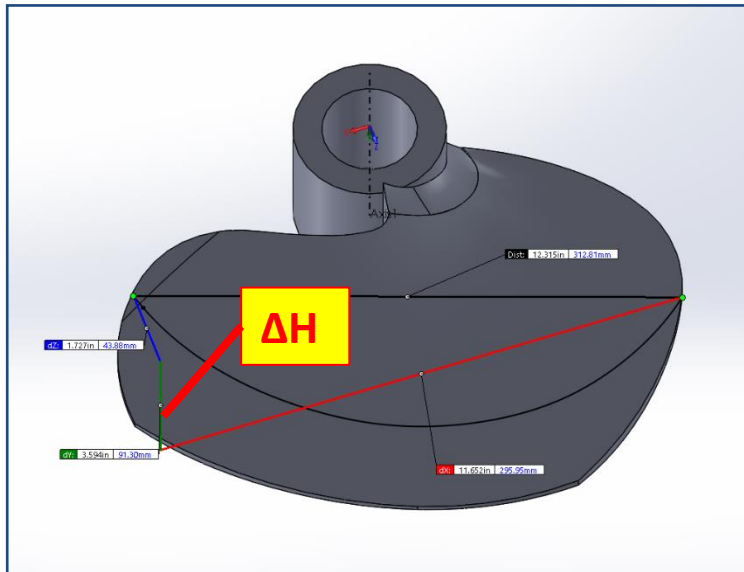
Sample propeller pitch was carefully measured at multiple locations

$$\text{Pitch} = \Delta H * [(\pi * D_i) / \text{width}]$$

Where ΔH = change in height

D_i = diameter at which pitch is measured

Width = projected arc length



- The pitch is how far the prop will move with one revolution and is calculated using the formula above.

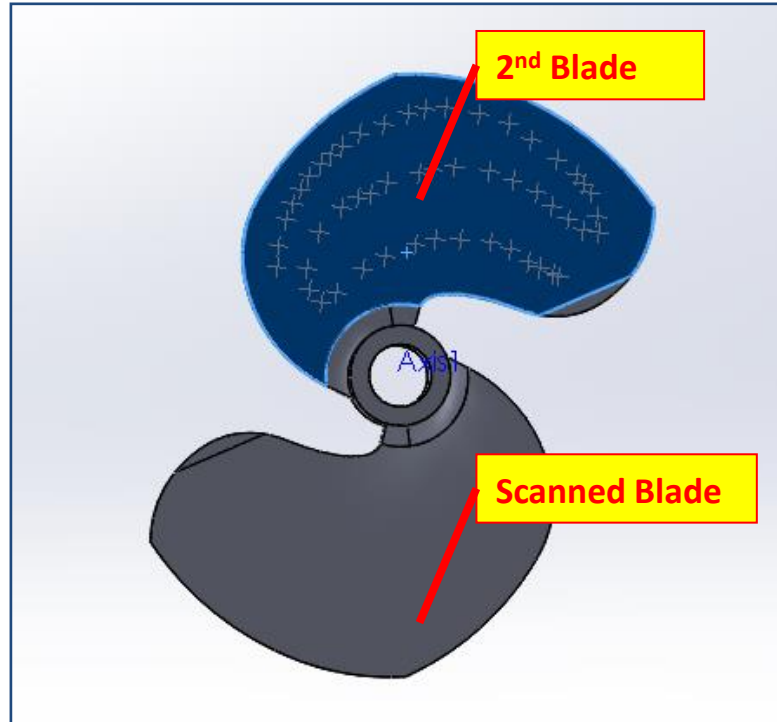
Calculated pitch value at multiple locations of the diameter

Sample Propeller Pitch Measurements

Location	Diameter	Height	Width	Pitch
40%	19.483	3.702	8.856	10.23445
45%	19.483	4.229	10.212	11.40631
50%	19.483	4.446	11.38	11.95647
55%	19.483	4.397	12.069	12.26461
60%	19.483	4.271	13.066	12.00449
70%	19.483	3.874	13.85	11.98433
75%	19.483	3.594	13.699	12.0436
80%	19.483	3.24	13.203	12.01623
85%	19.483	2.926	12.61	12.07213
90%	19.483	2.524	11.863	11.72042

- As shown from the calculations above, the pitch value is relatively consistent across multiple percentages of the diameter, except for areas near the hub

The next step is to compare the scanned blade against the other blade on the sample propeller



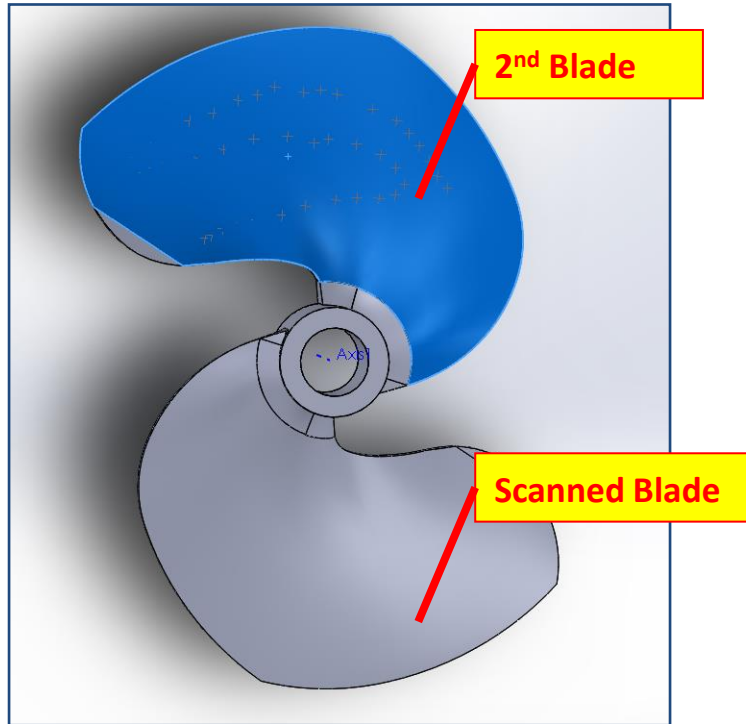
Top Surface Comparison

Top Comparison (unit: mm)

X	Y	Z	Deviation
106.2167	40.0115	-89.3186	1.2007
103.5906	33.8086	-112.318	1.3125
94.6052	27.5565	-133.353	1.0286
81.6194	20.8285	-153.576	1.1327
66.5769	14.8813	-171.898	1.1854
54.2846	10.6247	-182.884	1.5685
29.8359	4.1051	-197.883	1.7053
10.9684	-0.4559	-205.961	1.8457
-11.1355	-5.4726	-211.094	1.8535
-35.6781	-11.3377	-212.087	2.1827
-60.0248	-16.966	-206.518	2.1297
-80.9451	-21.8388	-201.534	2.2437
-96.1612	-29.6654	-156.613	1.8706
-67.2138	-21.4988	-163.744	1.5272
-29.5286	-11.2463	-165.239	1.6053
4.6716	-1.3722	-159.383	1.7883
33.4199	7.9723	-143.602	1.7832

- Positive deviation on the top surface indicates that the scanned blade is higher than the other blade. Max. amount of shift is 2.24mm (0.088")

Blade comparisons on bottom surfaces



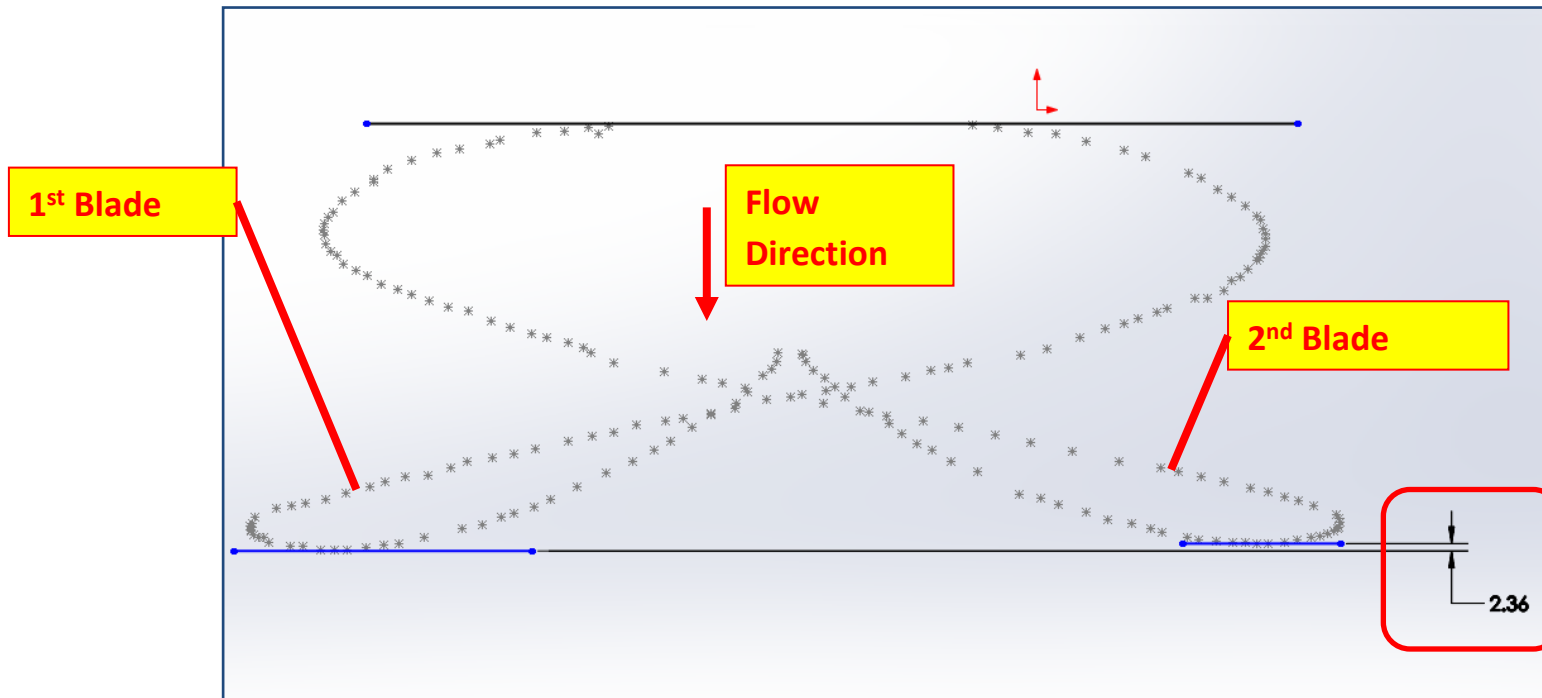
Bottom Surface Comparison

Bottom Comparison (unit: mm)

X	Y	Z	Deviation
80.4378	46.5691	-133.8201	-1.9757
72.5371	43.8721	-142.3542	-1.5279
66.0747	41.0141	-152.6549	-1.1541
58.2874	37.6904	-163.9992	-1.0268
50.2421	34.8143	-172.7991	-0.9910
40.4128	31.3690	-181.8064	-1.0159
22.4284	26.8100	-189.0406	-0.6802
-4.1670	19.1546	-198.2962	-0.6018
-16.4671	15.9120	-200.8849	-0.5106
-28.9416	13.2055	-198.0959	-0.6901
-50.1276	5.8610	-200.7748	-2.0984
-62.3819	3.0857	-193.9599	-2.3796
-76.3360	-0.6976	-188.9730	-2.4436
-93.6389	-5.7116	-178.1737	-2.6258
-110.8572	-11.4147	-171.0857	-2.9314
-134.2654	-20.1502	-152.3338	-1.5663
-147.7308	-25.2380	-140.7407	-1.5004

- **Negative deviation on the bottom surface indicates that the scanned blade is higher than the other blade. Max. amount of shift is 2.93mm (0.115")**

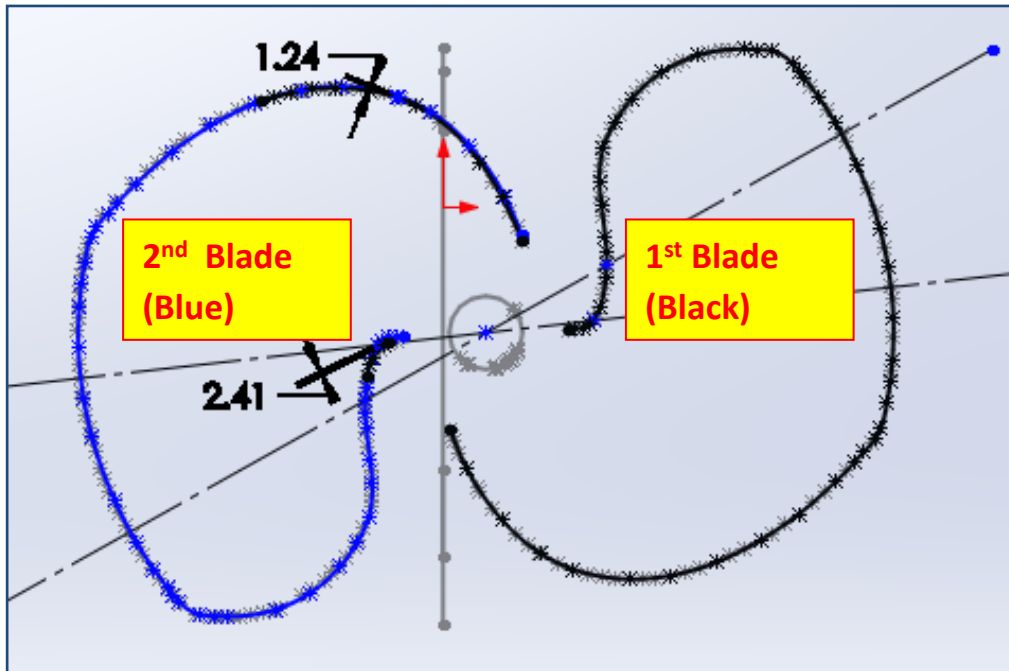
Blade height comparisons using boundary contours



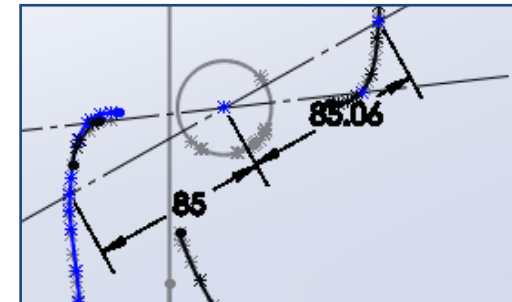
Blade Height Comparisons

- **Methodology:** Both blades were scanned for their boundary contour.
- **Observations:** The trailing edge (or highest point when the prop is installed) of the 1st blade is 2.36mm higher than the 2nd blade. This further confirms that the scanned blade was shifted upward along the axial direction

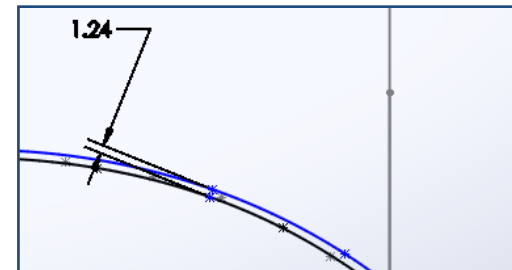
Further comparisons were made between these two blades



Boundary Contour Comparisons



Near-hub contour shows symmetry



Deviation near leading edge

- **Methodology:** Both blades were scanned for their boundary contour. The contour of the 1st blade was then rotated 180 degrees to be compared with the 2nd blade
- **Observations:** The 1st blade matches very well with the 2nd blade after the 180-degree rotation (see picture above). Only some small deviations were seen at the leading edge

At this point of the analysis, it seems like the vibration is likely to be caused by an uneven position of the two blades

- The scanned blade has a nearly identical diameter and pitch when compared to the customer drawing. This indicates that the scanned blade conforms to the design
- However, the scanned blade sits about 2 mm higher than the 2nd blade. The unbalanced hydraulic loads will create a force couple that causes potential vibration
- While a statically balanced propeller may work well during dry run, the unbalanced loads will be magnified under wet conditions, hence creating hydraulic vibration
- Excessive manual grinding that was seen on the blades may further cause unbalanced loading and disturbance to the flow pattern
- In conclusion, GloTech believes that the geometrical inaccuracy and non-uniform mass distribution seen on the sample prop could be the major cause of the reported hydraulic vibration

The following steps are proposed to resolve the reported issue

- GloTech to complete the 50HP prop design with the 2nd blade fully identical to the 1st blade in terms of axial position, orientation, thickness, etc.
 - Additional vane-smoothing techniques to be applied using GloTech's proprietary impeller design methodology, to ensure optimal hydraulic performance and efficiency
- GloTech to provide 2 (two) sample propellers using a combination of 3D printing / CNC machining techniques and precision casting, which will significantly reduce the prototyping lead time and cost
 - GloTech to cast, set the pitch, machine, and dynamically balance each prop prior to shipping. Customer will receive pre-pitched and fully dynamically balanced propellers, as opposed to "prop castings"
- Customer to test and approve the prototype propellers using its standard testing facilities and protocols

Preliminary project timeline Proposal

Week of

Project Phase	4/19	4/26	5/3	5/10	5/17	5/24	5/31	6/7	6/14	6/21	6/28	7/5	7/12	7/19	7/26	8/2
Finalize Design	▶															
Production Tooling			▶													
Prototype Production						▶										
Prototype Testing / Design Review												▶				

PRELIMINARY



50HP Propeller Design Optimizations

Joshua Rogers

07/28/2021



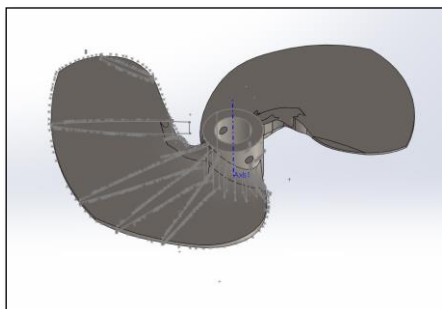
In 04.2021, a design proposal was presented to customer to address the hydraulic vibration issues

- It was previously identified that the unbalanced blade geometry is the main cause of hydraulic vibration
- In addition to correcting the blade geometry, GloTech has identified the following design optimization objectives:
 - Smooth out vane geometry, using a parametric, spanwise lofting technique
 - Reduce prop weight by thinning out on the back side of the propeller
 - Add keyway feature for additional mounting configuration

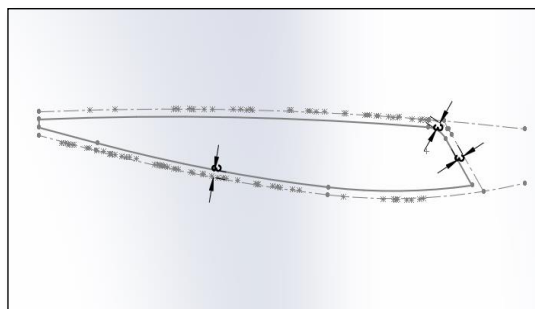
- **The goal is to optimize the propeller in order to eliminate vibration, while maintaining the same hydraulic / aeration performance.**

Using the scan from the 50HP, the propeller was modified as shown below.

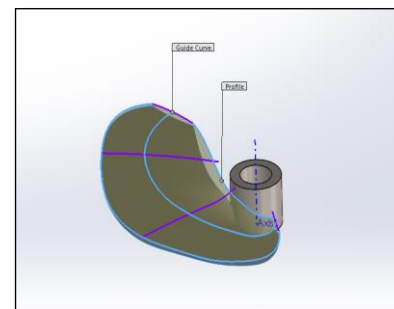
Original Scan of 50HP Prop



Original scan

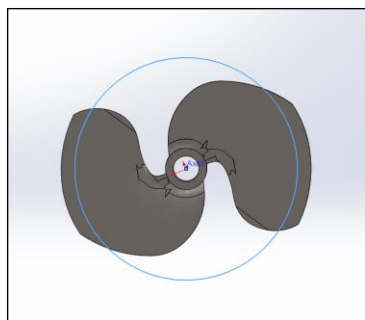


Profiles used for Guidelines

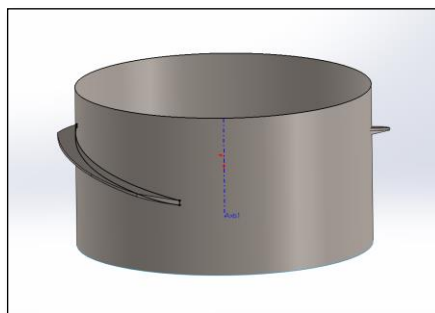


Loft (blue lines were created using a spline and connecting the guideline profiles)

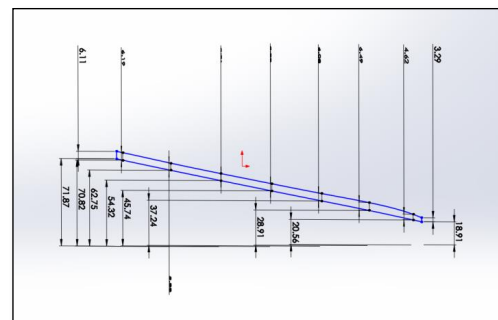
Reconstructing Hydraulic Sketches from Blade Model



Create a cylindrical surface



Create an intersection curve & the solid body modeled from the scan

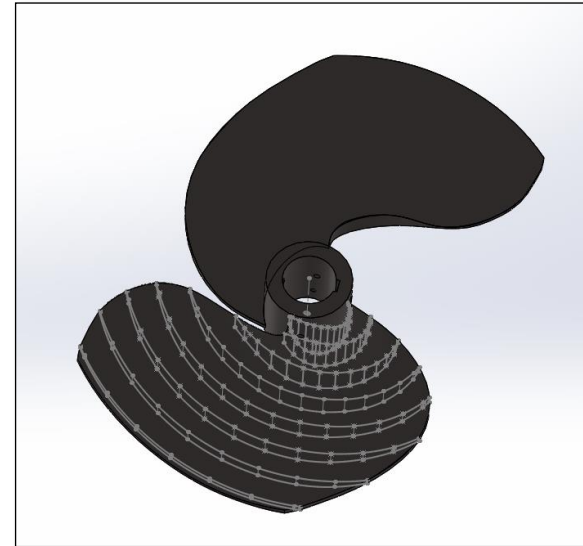
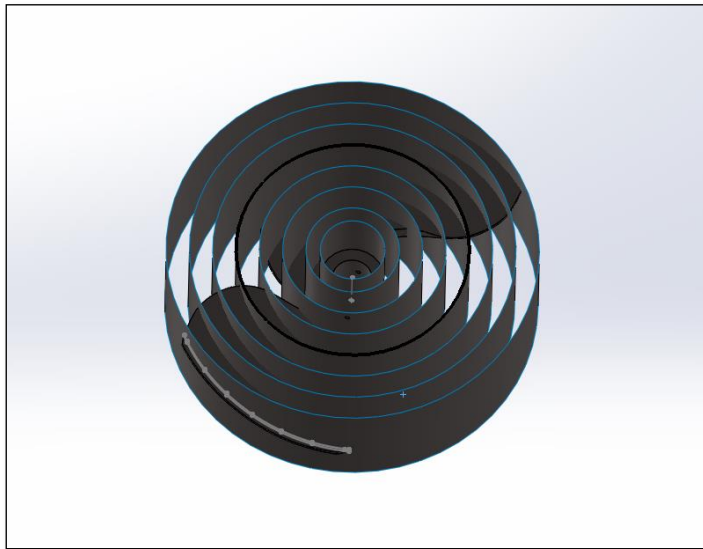


The side profile can then be furthered using 10deg intervalley placed planes

- The goal is to create a set of hydraulic sketches in order to obtain a modifiable prop blade.**

Using the scan from the 50HP, and the steps shown in the previous slide we can repeat this process for multiple cylindrical surfaces and sketches.

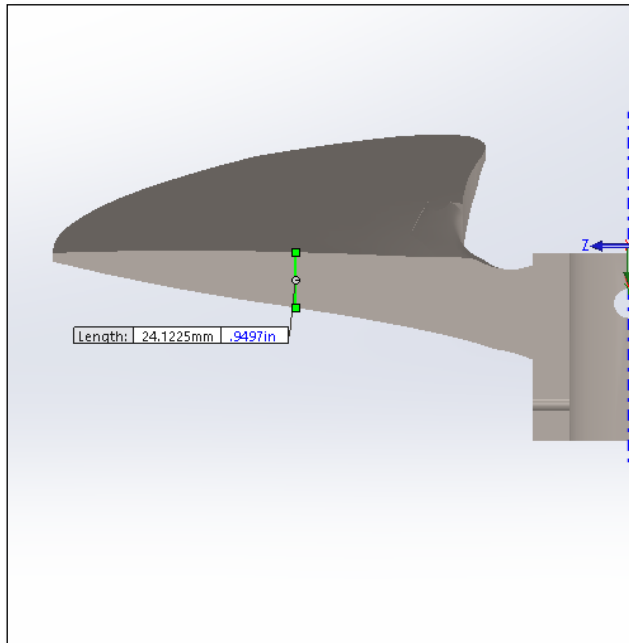
50HP Remolded Using 8 Hydraulic Sketches



- This is a standard practice when it comes to propeller hydraulic / tooling design

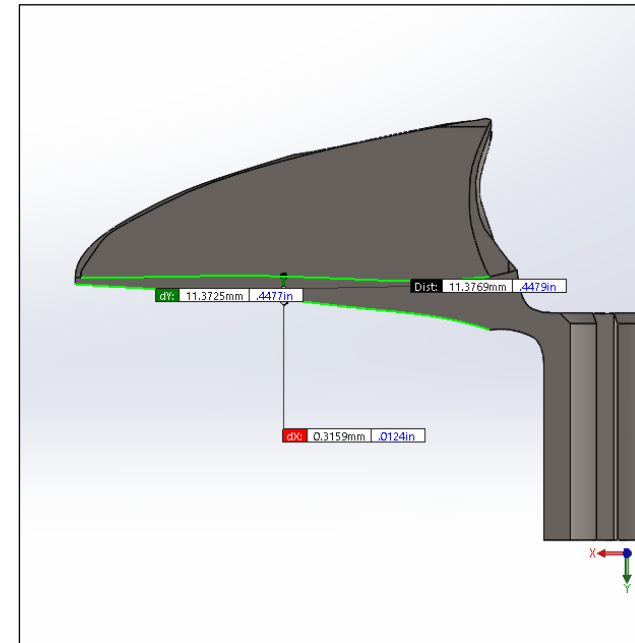
A previous scan was done on the 75HP propeller, which will be used as a design benchmark for the vane thickness reduction

50HP Prop



Thickness taken at 50% from the OD of 50HP prop is about 24 mm

75HP Prop

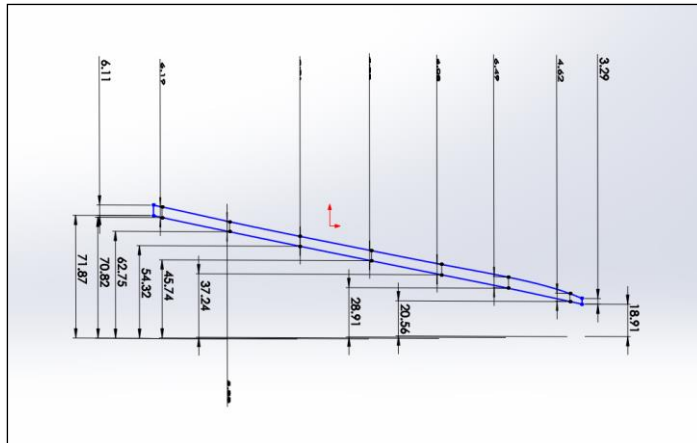
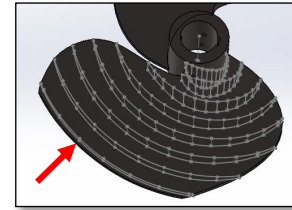


Thickness taken at 50% from the OD of 75HP prop is about 11 mm

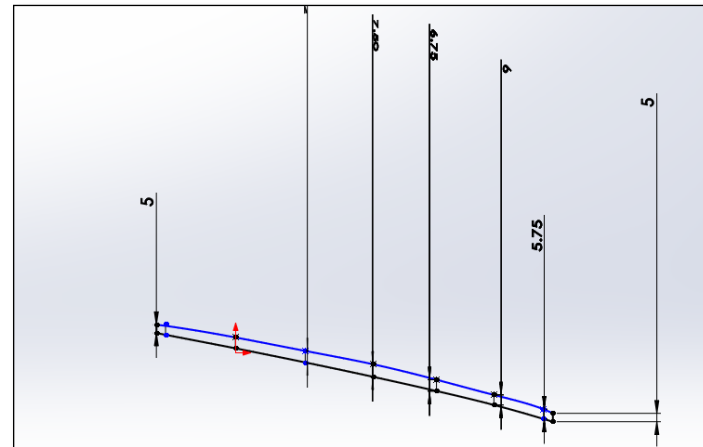
- **The goal is to thin out the geometry while maintaining the pitch desired. Hence the front (pressure) side of the prop geometry will remain unchanged**
- **While the 75HP prop is more lightweight, customer had reported occasional blade damage due to insufficient thickness / strength**
- **As such, excessive reduction in blade thickness should be avoided due to strength considerations**

Using the intersection curves we created, we now have the adjustability discussed. The first parameter changed was the edge thickness.

50HP @ OD



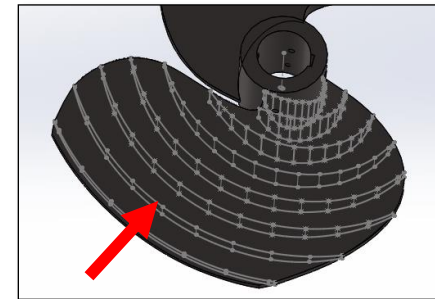
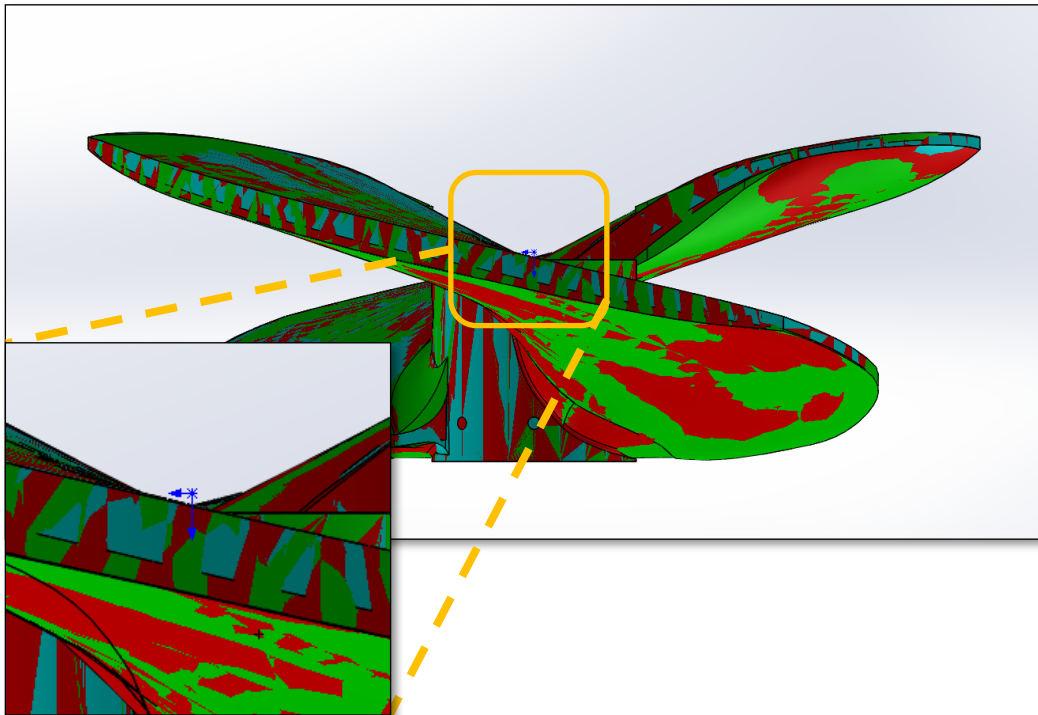
Before



After

- After comparing the vane thickness between the two props, it was noticed that the original 50HP prop has an edge thickness varying from 3mm to 7mm +, whereas the 75HP prop has a uniform 3mm thickness.
- Therefore, it was determined that a 5mm uniform thickness should be applied to the 50HP prop

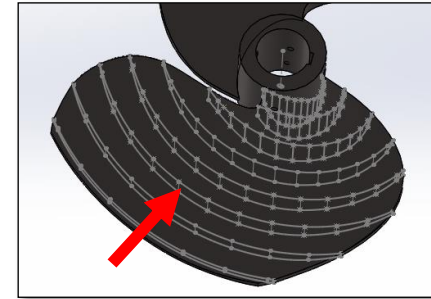
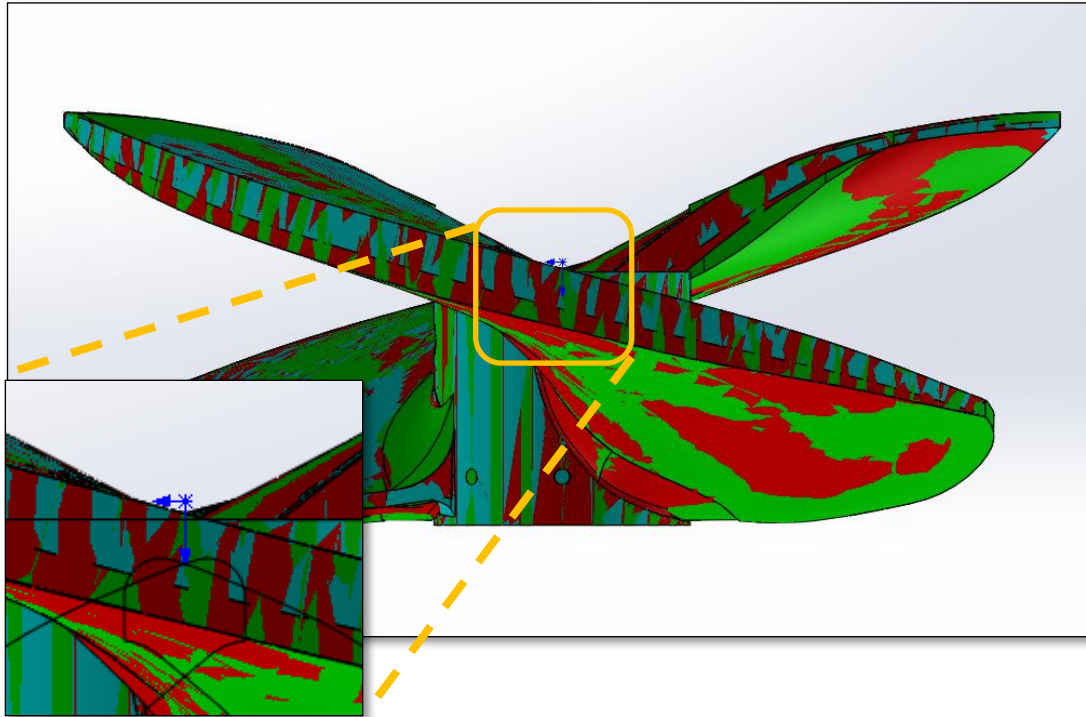
Using a cylindrical cut at 420mm, the vane thickness change can be easily compared.



Green: Original blade
Red: Smoothed blade
Cyan: Thinned blade

- The goal was to thin out the vane uniformly, while keeping the working surface the same. The thickness was reduced.

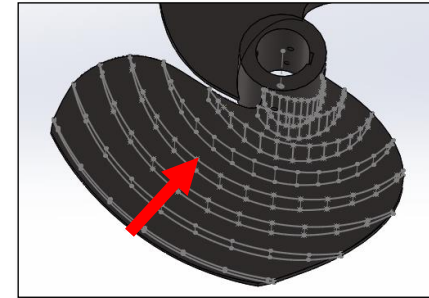
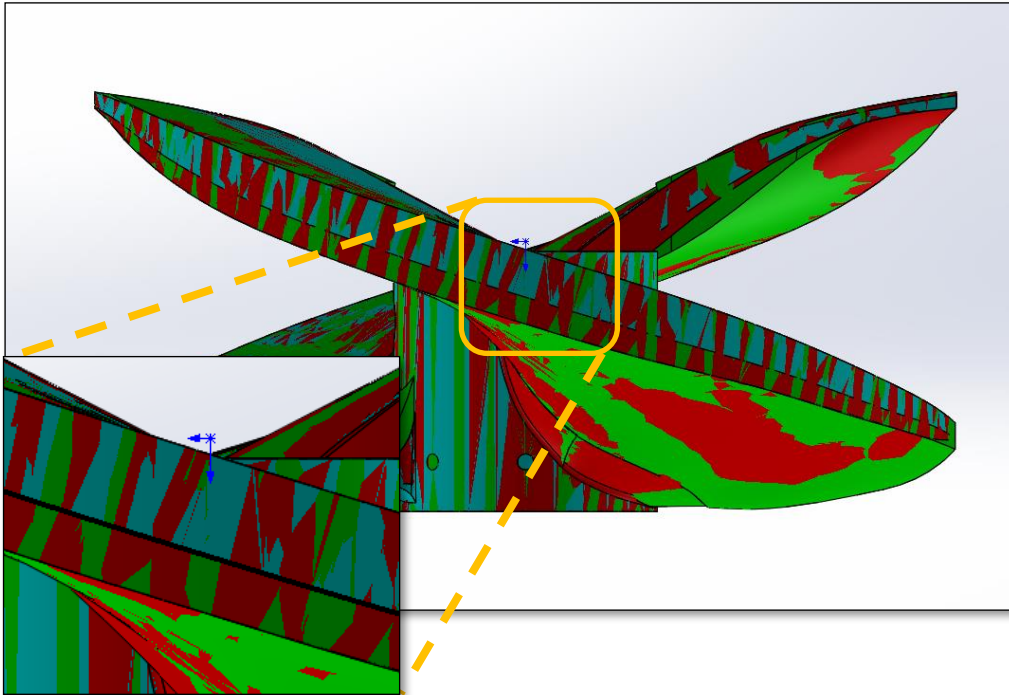
Using a cylindrical cut at 360mm, the Vane thickness change can be easily compared.



Green: Original blade
Red: Smoothed blade
Cyan: Thinned blade

- The goal was to thin out the vane uniformly, while keeping the working surface the same. The thickness was reduced.

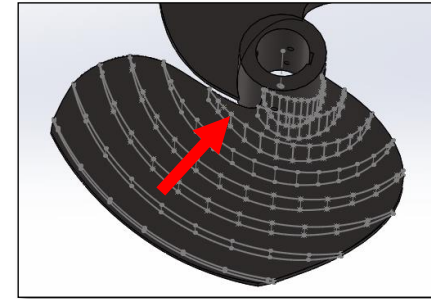
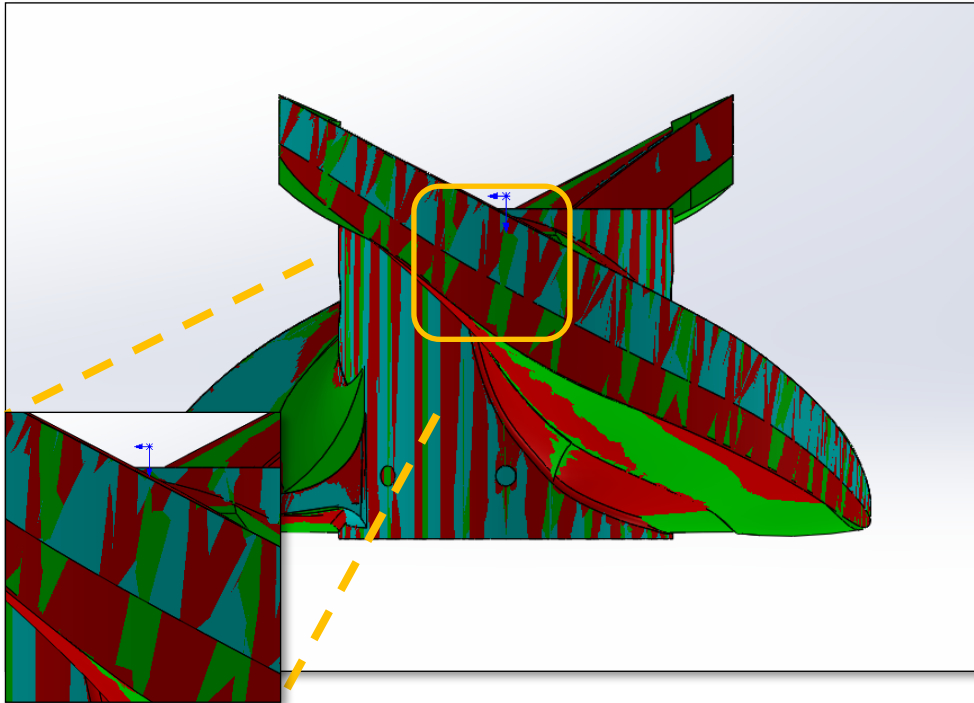
Using a cylindrical cut at 300mm, the Vane thickness change can be easily compared.



Green: Original blade
Red: Smoothed blade
Cyan: Thinned blade

- The goal was to thin out the vane uniformly, while keeping the working surface the same. The thickness was reduced.

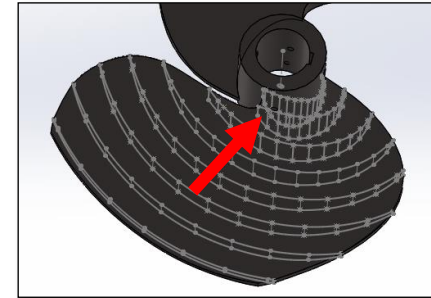
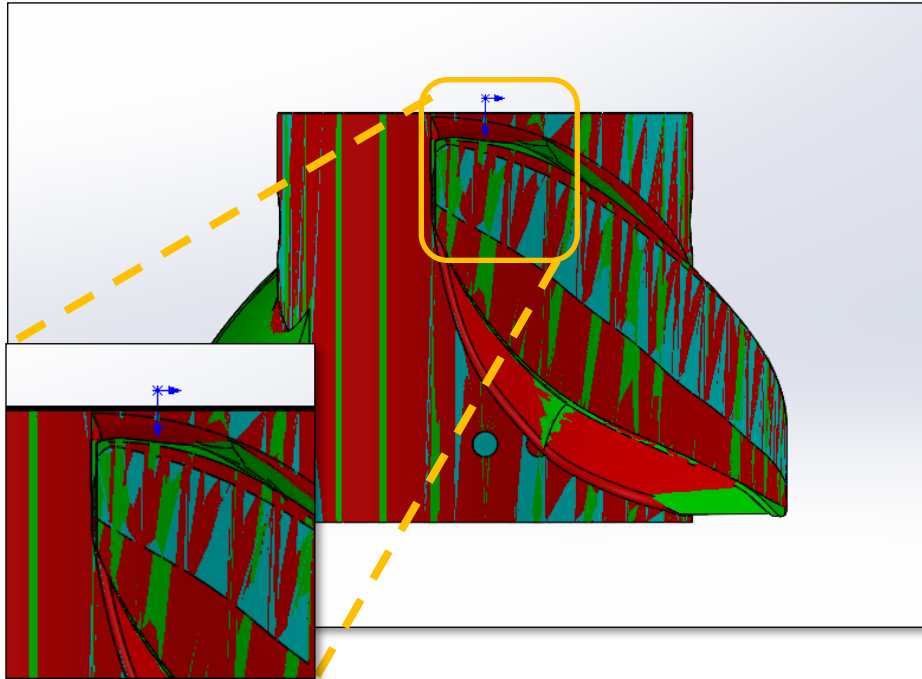
Using a cylindrical cut at 180mm, the Vane thickness change can be easily compared.



Green: Original blade
Red: Smoothed blade
Cyan: Thinned blade

- The goal was to thin out the vane uniformly, while keeping the working surface the same. The thickness was reduced.

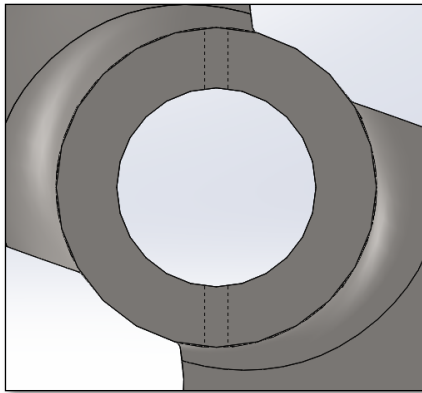
Using a cylindrical cut at 120mm, the Vane thickness change can be easily compared.



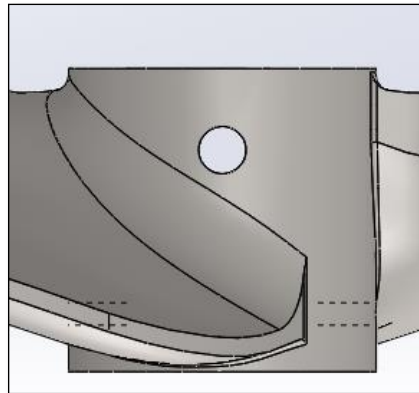
Green: Original blade
Red: Smoothed blade
Cyan: Thinned blade

- The goal was to thin out the vane uniformly, while keeping the working surface the same. The thickness was reduced.

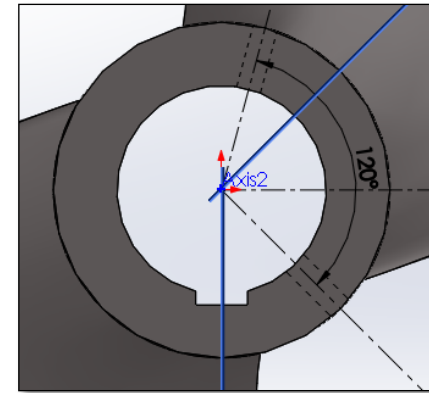
Using the original mounting configurations additional improvements were added.



Set screw location before

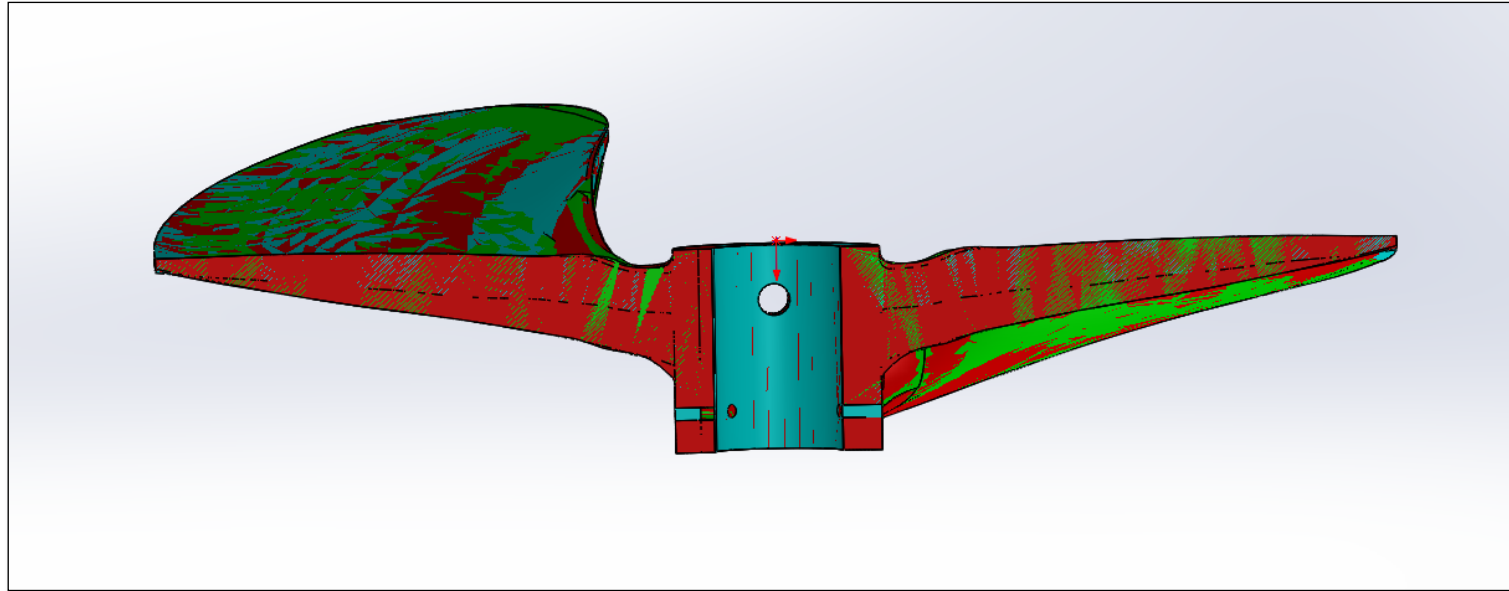


Pin location remains



Set screw location after

- **The goal is to optimize each aspect of the 50HP prop.**
 - The set screw set was changed from 180 deg apart to 120deg creating a more secure fit
 - A ½" key slot was added for additional mounting configurations



- Working side of the Vane Geometry smoothed while maintaining a consistent pitch
- Leading and trailing edges made more consistent while reducing overall thickness
- Overall weight reduction from the original scan is 5.37kg, or 30.4%



50HP Aerator Propeller Design Update

Presented to: Customer

Prepared by: Mark Gu & Josh Rogers

03/08/2022

(Updated on 03/17)



In 02/2022, customer conducted wet testing on the prototype 50HP props provided by GloTech



- On 02/16, GloTech joined customer in reviewing the sample QC and test results
- Test pass/fail criteria as identified by customer:
 - **Maximum vibration: 0.3 in/s**
 - **Power Drawn: 88-95% of nominal motor HP**



- Test results:

#	Description	Vibration (in/s)	Power Drawn
1	Polished (001) – as-is	0.250	81.7%
2	Unpolished (002) – as-is	0.275	76.2%
3	Polished (001) – pitched*	0.280	83.4%

** Polished sample was re-tested after pitch/rake adjustment*

50HP Sample Prop Wet Testing and QC Inspections at AAS

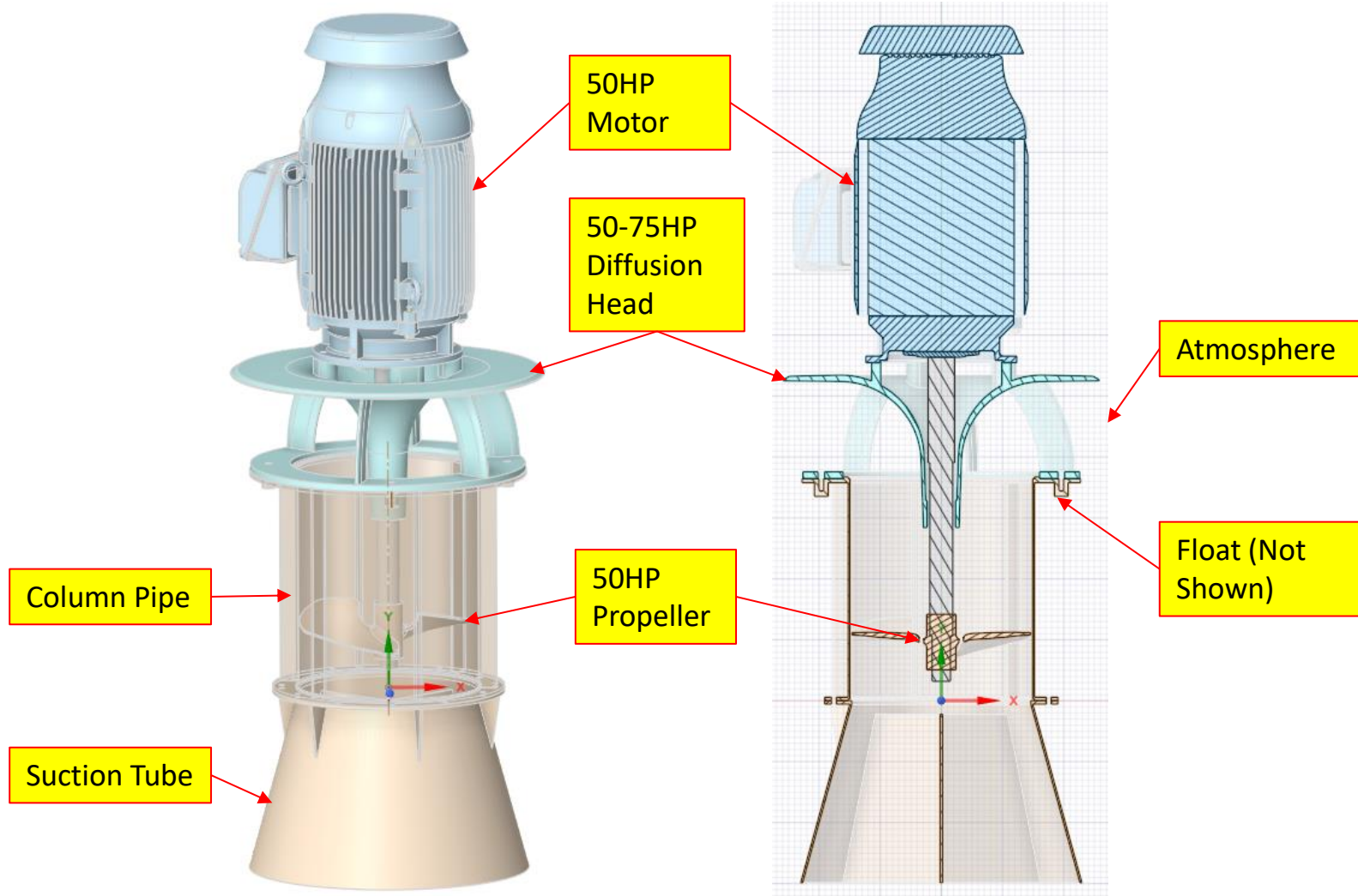
1. **Vibration measurements: 0.25 - 0.28 in/s -> Both samples passed the vibration test (<= 0.3 in/s)**
2. **Power (measured as % of amperage drawn): 76.2% - 83.4% -> Both are lower than the requirements (88-95%)**
3. **Potential causes: 1) uneven rake angle (test #3 suggests that rake adjustments contributed to a ~2% power increase); 2) blade thickness optimization may have inadvertently reduced the power consumption**

We conducted a CFD study to better understand the wet test results and to develop necessary design updates to meet Customer's targets

CFD Workflow

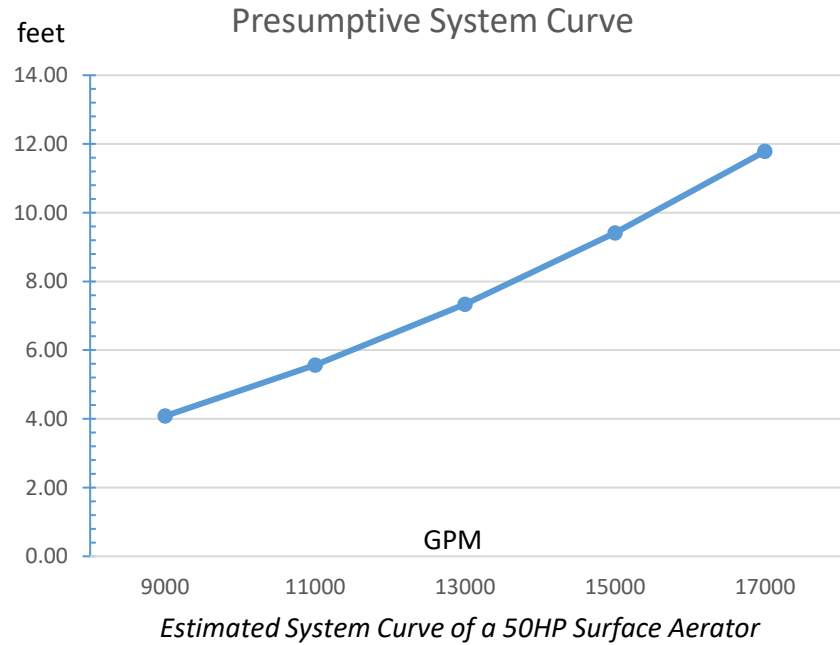
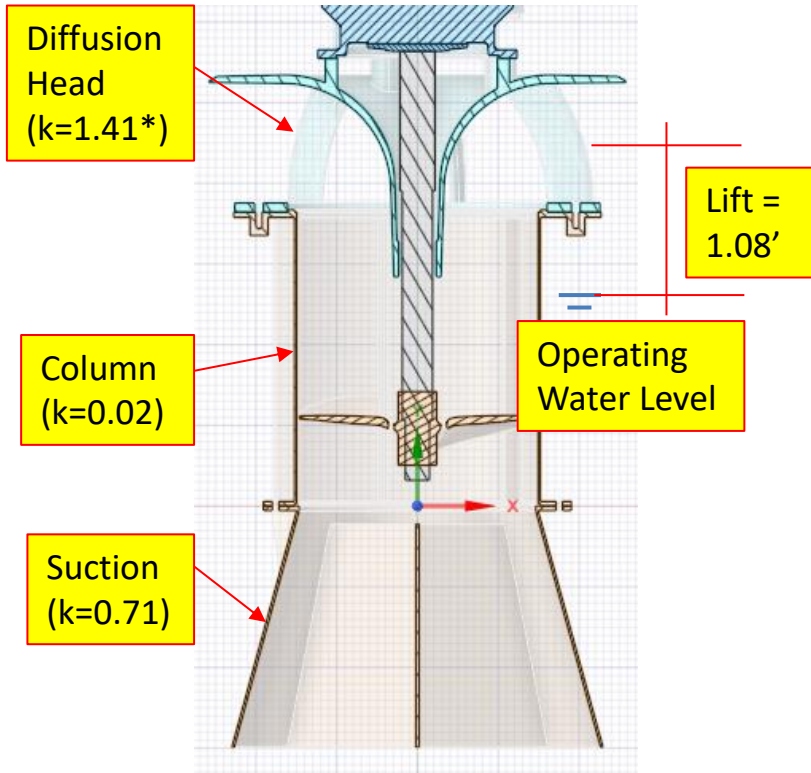
1. 3D modeling of 50HP surface aerator
2. System curve estimation
3. CFD (Computational Fluids Dynamics) setup overview
4. CFD results – effect of flat rake
5. Proposed design updates
6. CFD results – updated propeller
7. Spray pattern simulations and CFD results

First, a simplified 3D model of the 50HP aerator is created to provide geometries and dimensions needed for subsequent simulations



50HP Surface Aerator Assembly

Based on our assumptions, the system curve of the 50HP aerator is plotted out in order to locate its operating point

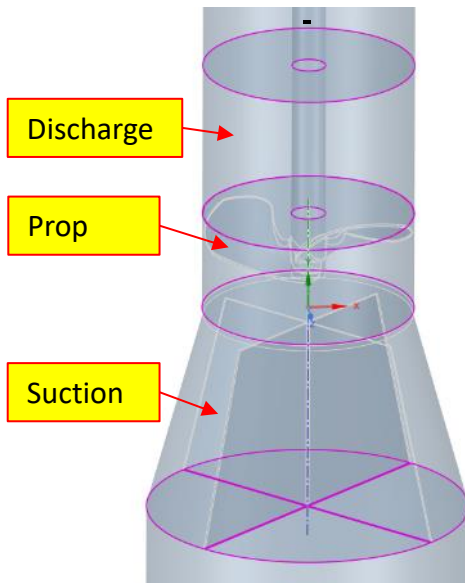


$$K_{total} = K_{suct.} + K_{col.} + K_{disch.} = 2.14$$

** Due to its unique geometry, the K factor of the discharge cone was estimated using CFD head-loss simulation*

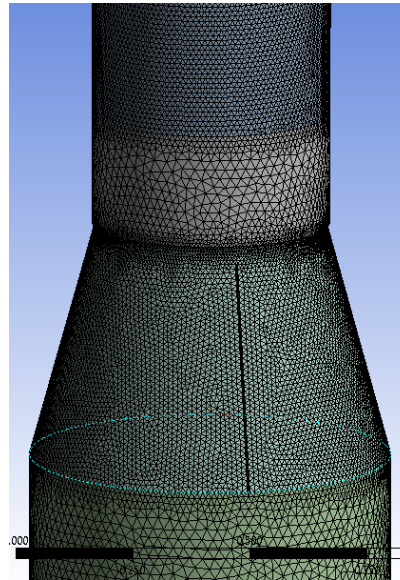
The initial CFD study focuses on simulations of head (pressure) and power of the aerator using a single-phase, steady state setup

Volume Extraction



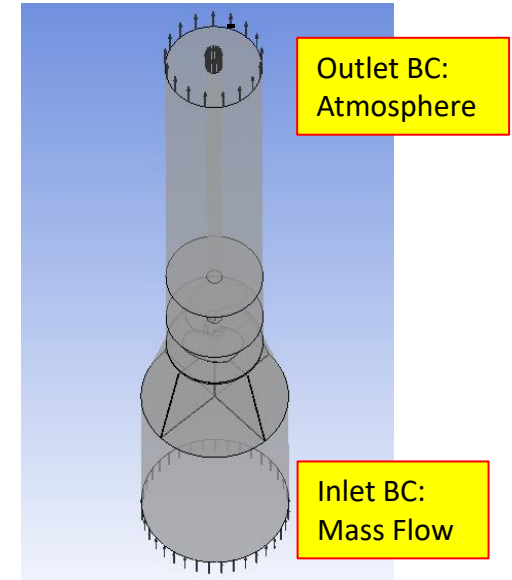
SpaceClaim

Meshing



Ansys Meshing

Boundary Conditions



CFX-Pre

- 2D up / 4D down
- Stationary suction and discharge
- Rotating propeller with counter-rotating shroud

- Tetrahedral, 20mm max.
- 5 layers, 1.2 growth rate
- 0.77 Transition ratio
- Mesh count: 1.2 million +

- Mass flow in + pressure out
- Frozen rotor
- SST (Shear Stress Transport)
- Free-slip wall in & out
- No-slip wall elsewhere

First we simulated the results of our initial sample prop design, and the effect of “pitching” it to provide a constant, flat rake

CFD Results – Current Design (Sample As-built)

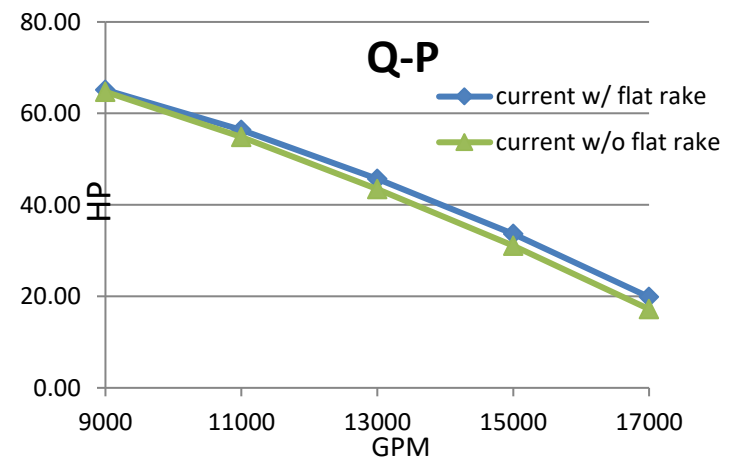
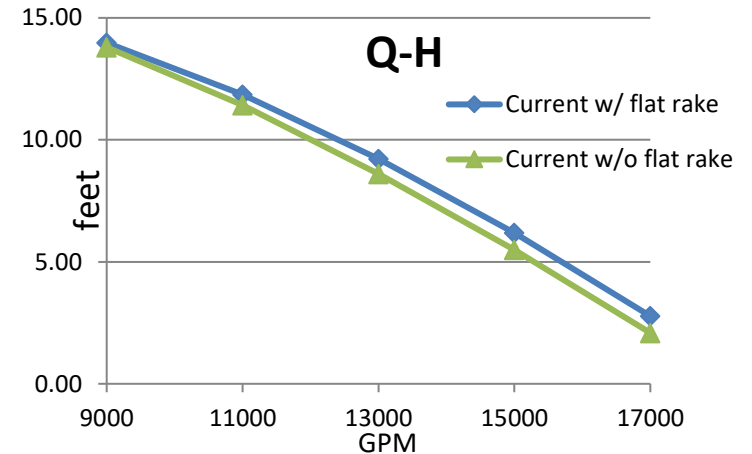
Flow (GPM)	Head (ft)	Power (HP)	Efficiency
9000	13.80	64.73	48.4%
11000	11.43	54.83	57.9%
13000	8.60	43.44	65.0%
15000	5.49	31.07	67.0%
17000	2.09	17.21	52.0%

CFD Results – Current Design w/ Flat Rake Adjustments

Flow (GPM)	Head (ft)	Power (HP)	Efficiency
9000	13.98	65.15	48.8%
11000	11.86	56.36	58.4%
13000	9.22	45.71	66.2%
15000	6.18	33.68	69.5%
17000	2.77	19.85	60.0%

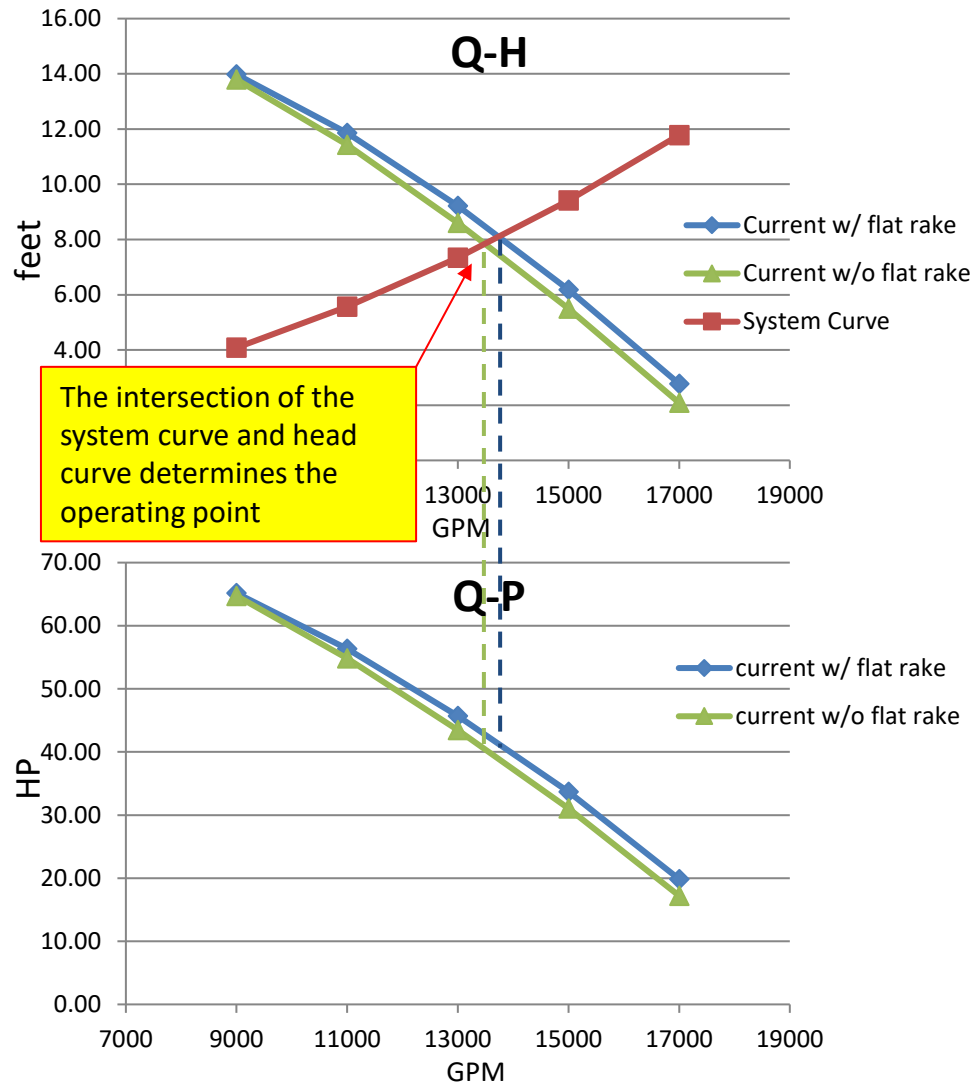
Note: generally speaking, the physical testing results are expected to be somewhat lower than the CFD simulations, which reflect performance in simplified / ideal vs. real-world conditions

CFD suggests that the flat rake adjustments appears to increase the overall output of the propeller. The head, power and efficiency all increased across multiple flow rates



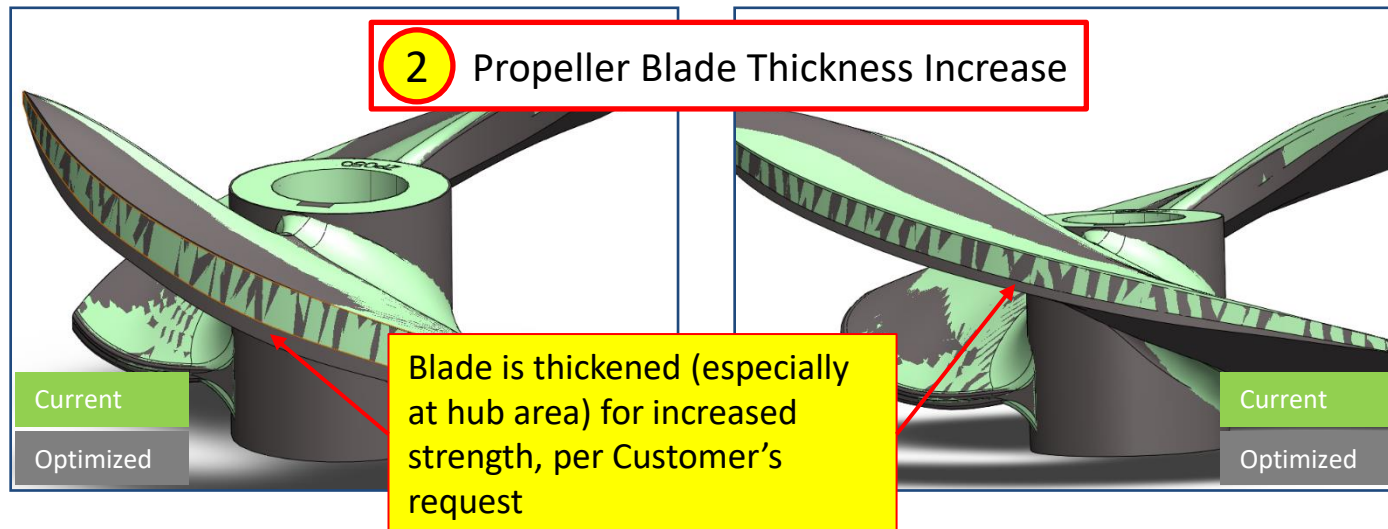
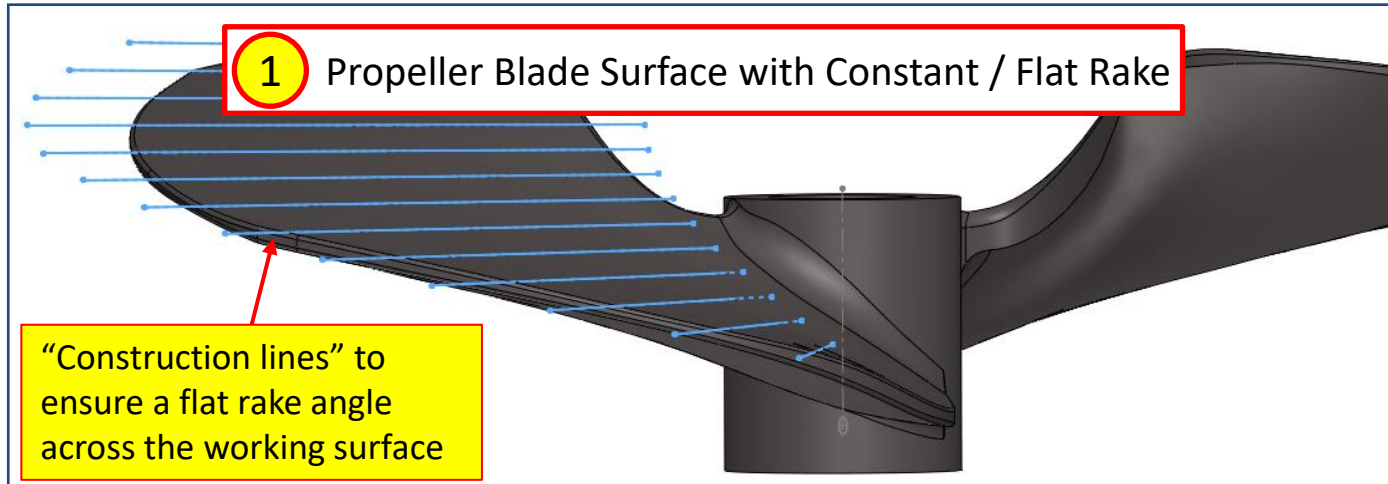
CFD Results – Effect of Flat Rake

Further analysis of our CFD results showed that the simulation closely reflected actual wet-testing data.



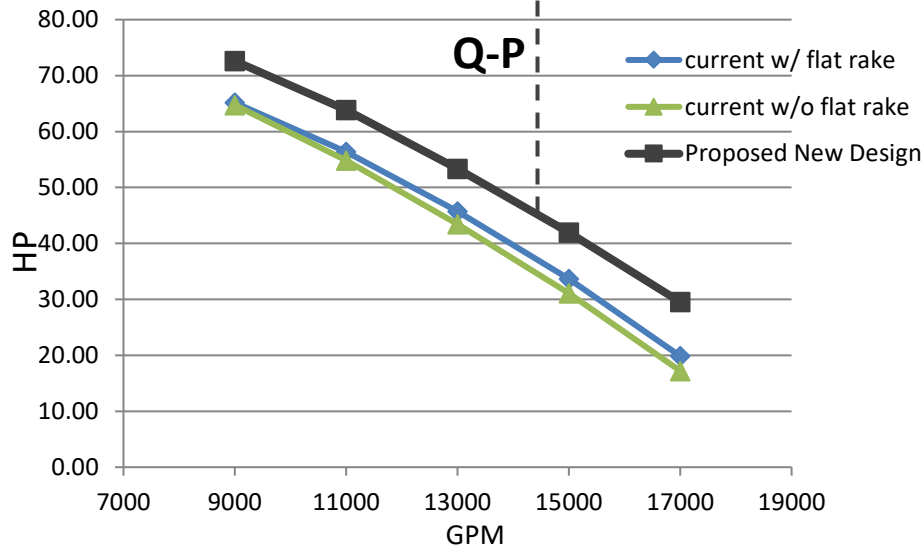
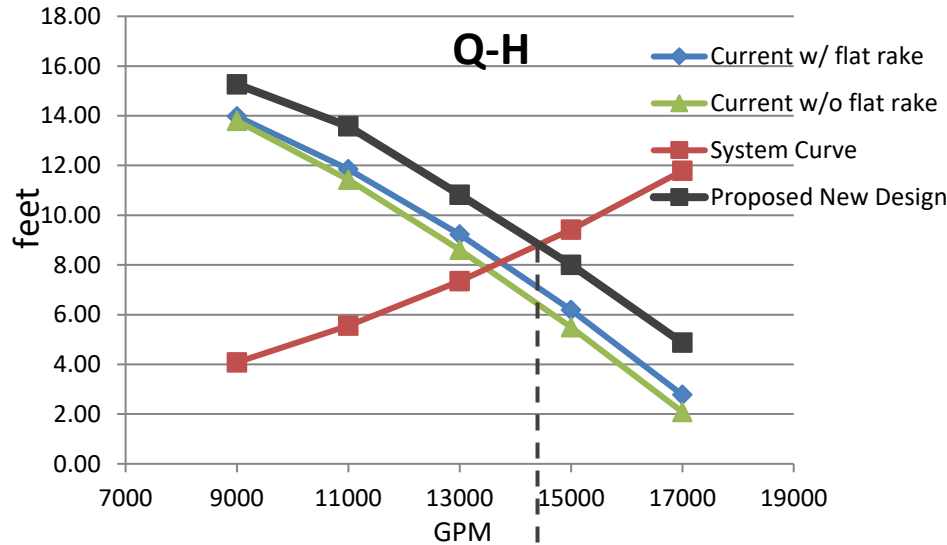
- **CFD estimated duty point:**
 - Current design w/o rake adjustments: 13,500 GPM @ 7.8 feet
 - Current design w/ rake adjustments: 13,750 GPM @ 8.1 feet
- **Takeaways:**
 - The flat-rake design appears to improve both flow and head, which is expected to provide better aeration efficiency
- **CFD estimated power drawn:**
 - Current design w/o rake adjustments : 40.35 HP -> 80.7% HP drawn
 - Current design w/ rake adjustments: 41.2 HP -> 82.4% HP drawn
- **Takeaways:**
 - Simulation results CLOSELY matches testing results (81%-83% power)
 - This indicates that our simulation model can be accurately used to validate prop design updates

After additional design iterations and CFD verifications, GloTech proposes TWO updates to our 50HP prop design



CFD Results – Updated Propeller

Our simulations suggest that the proposed design updates will meet/exceed customer's performance requirements

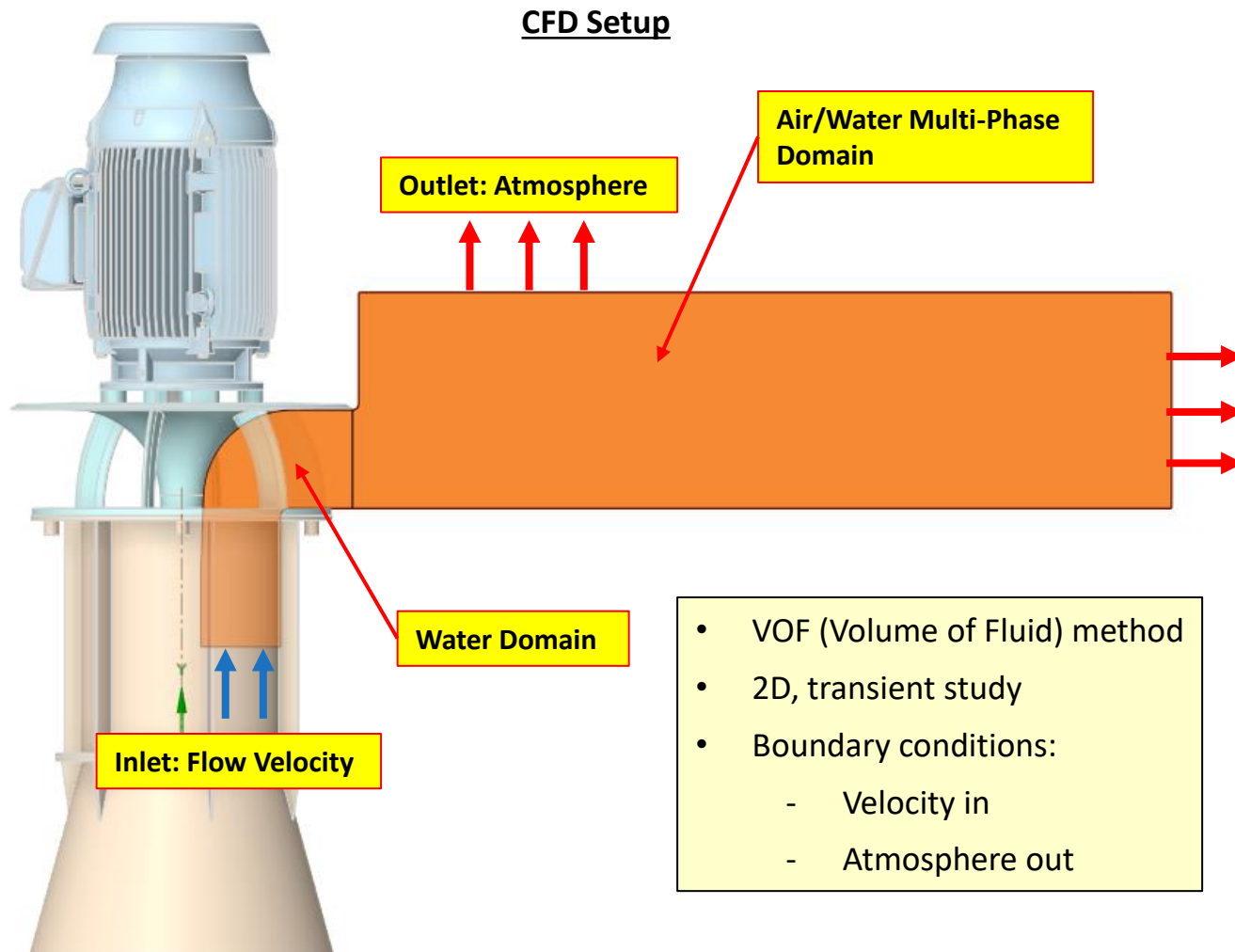


- **CFD estimated duty point :**
 - **Current: 13,500 GPM @ 7.8 feet**
 - **Updated: 14,410 GPM @ 8.8 feet**
- **CFD estimated power drawn:**
 - **Current: 40.35 HP -> 80.7% HP drawn**
 - **Updated : 45.98 HP -> 91.9% HP drawn**

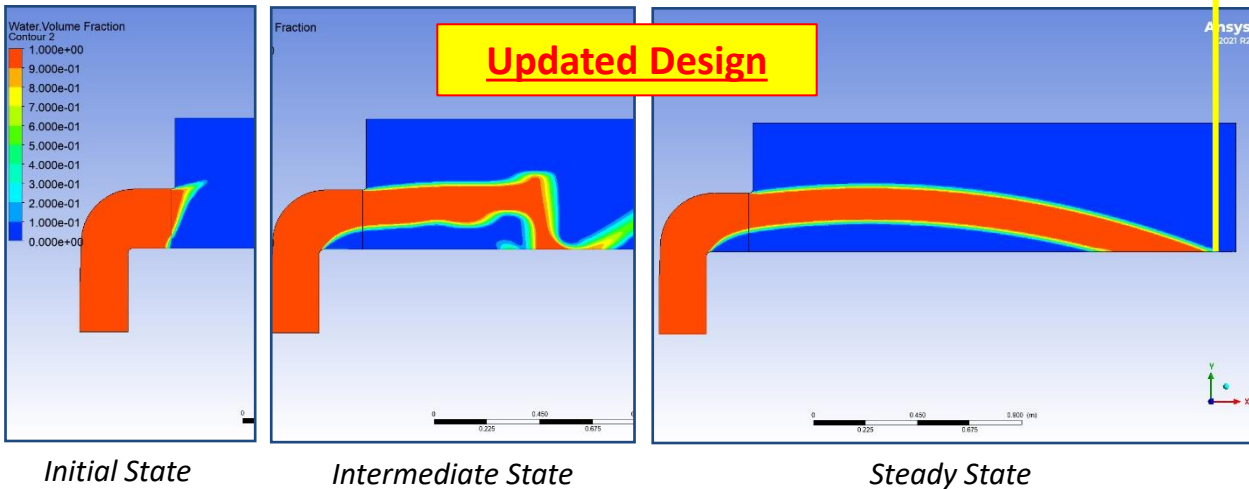
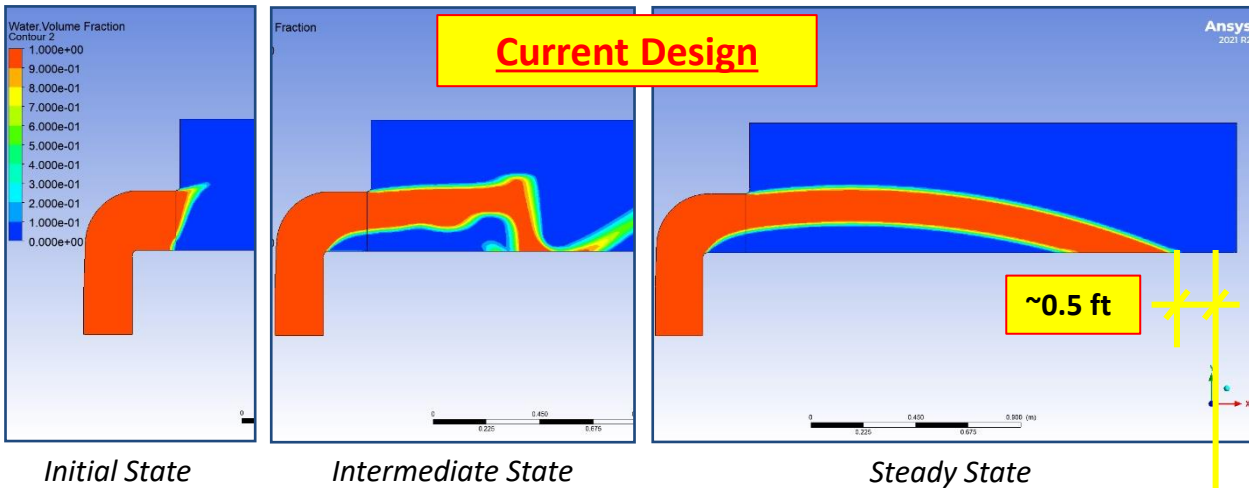
Flow (GPM)	Head(ft)	Power(HP)	Efficiency
9000	15.26	69.90	49.6%
11000	13.57	63.41	59.4%
13000	10.82	53.29	66.6%
15000	8.00	42.93	70.6%
17000	4.87	30.97	67.5%

- Main takeaways:**
1. The proposed design is expected to improve the flow by ~6% and head by ~9%
 2. In the meantime, the power drawn is expected to increase by 14%, which puts it at ~91.9% of the nominal motor HP

We further developed a transient, multi-phase CFD simulation to visualize the spray patterns of the two prop designs



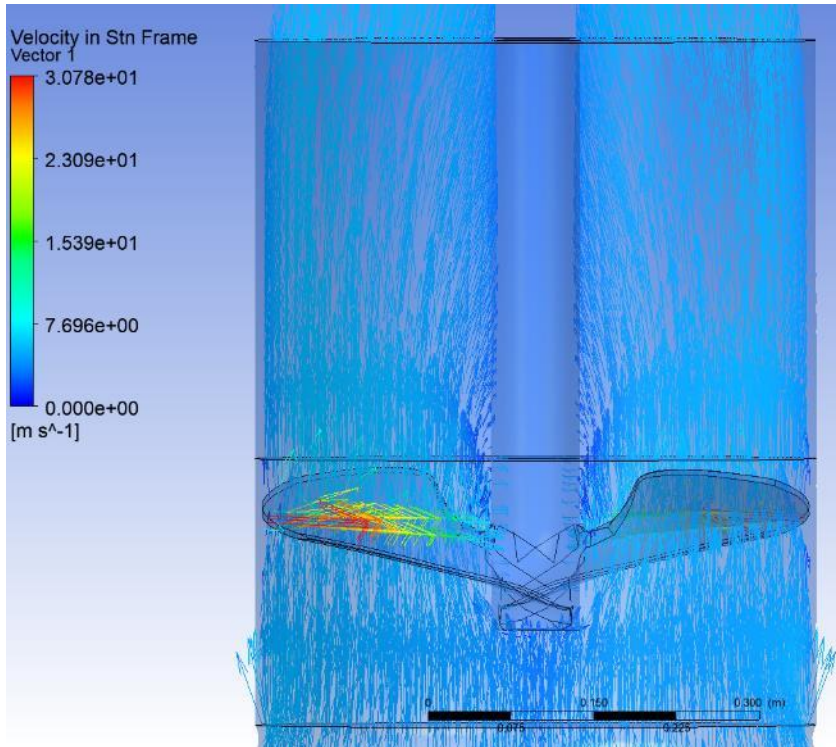
Head-to-head CFD results to show the spray pattern (throw radius) of the current prop design and the updated design



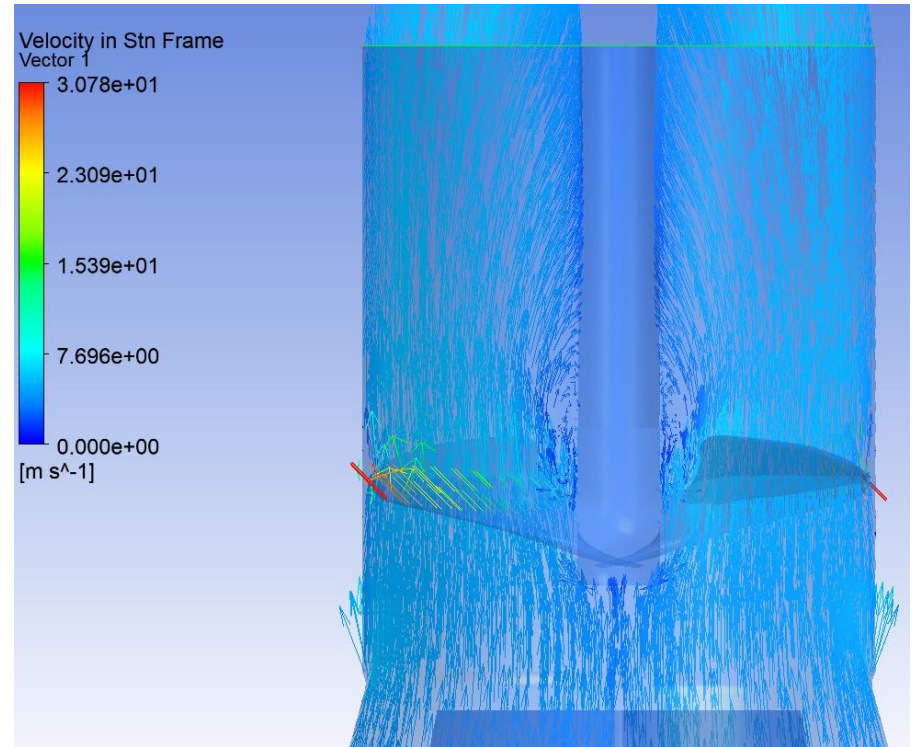
- CFD estimated spray radius:
 - Current: 7.3 feet
 - Updated: 7.8 feet
 - ~7% (0.5 ft) increase
- CFD estimated flow rate:
 - Current: 13,500 GPM
 - Updated: 14,300 GPM
 - ~6% increase
- Conclusions
 - The results of this simulation is preliminary given the assumptions we've had to build in due to our limited exposure to the product application
 - However, we are confident of a *relative* increase both in the spray radius and flow rate, which should lead to more oxygen transfer and aeration efficiency

Summary and technical proposal:

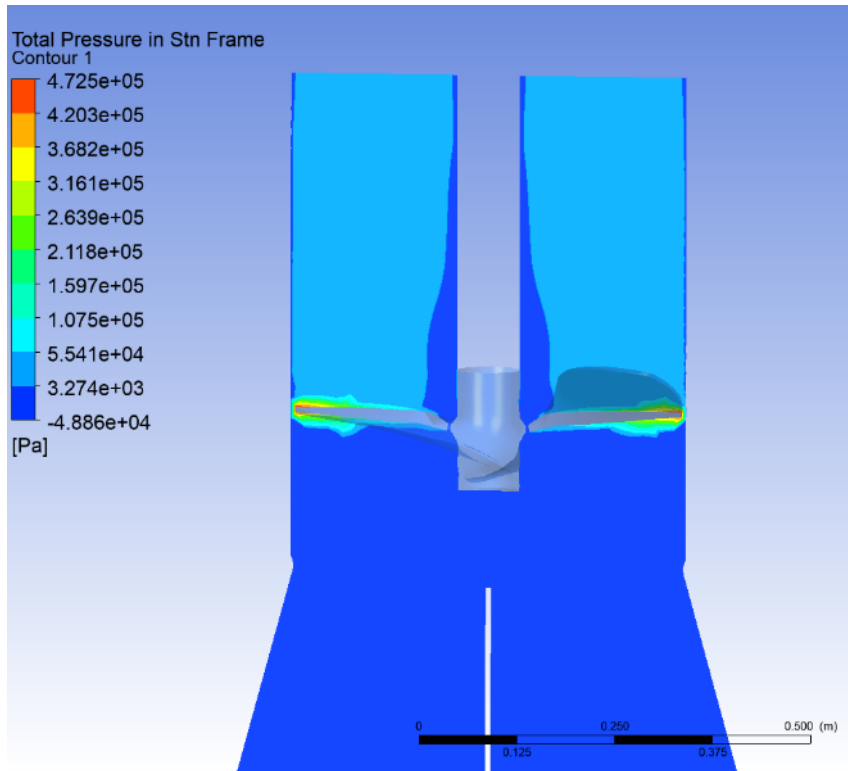
- As was observed during testing, GloTech's initial 50HP props produced a lower power drawn (76% – 82%) than the design target of 88% - 95%
- GloTech built a CFD simulation model that was able to mirror the observed prop performance, as well as the impact of adjusting the propeller rake to be constantly flat
- Via iterative design updates / simulations, we have completed an updated prop design with two main changes:
 1. A constant, flat rake blade surface that is similar to the existing product
 2. Increased blade thickness to further improve mechanical strength and to prevent premature failure
- Our CFD simulations of the updated design suggest that the prop will completely meet customer's product requirements in terms of performance (power draw) and strength, while potentially improving aeration efficiency



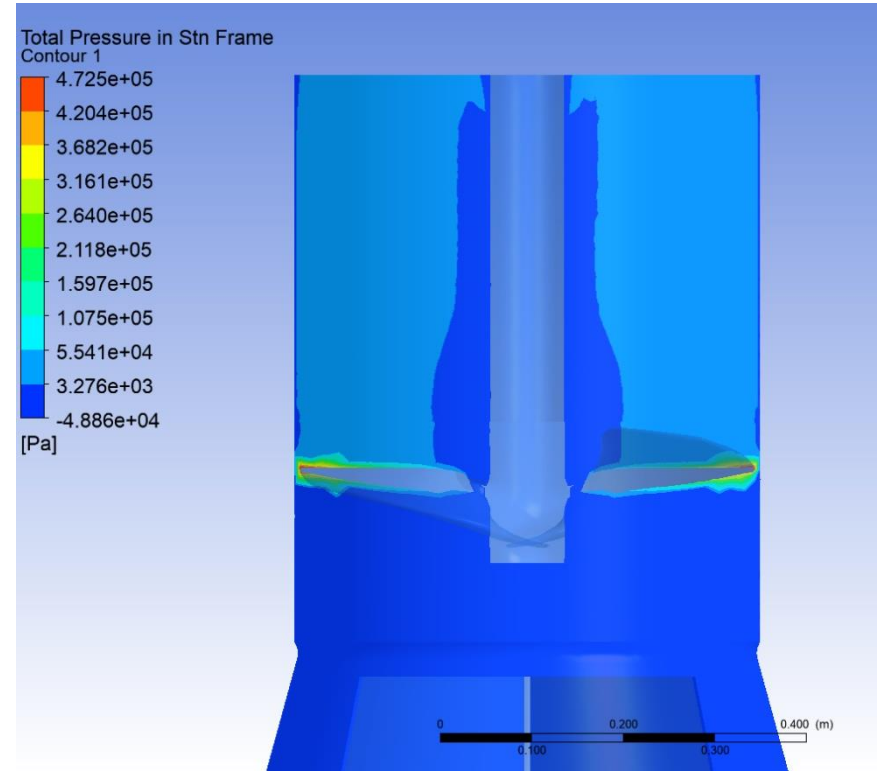
Current Design (As-Built)



Optimized Design

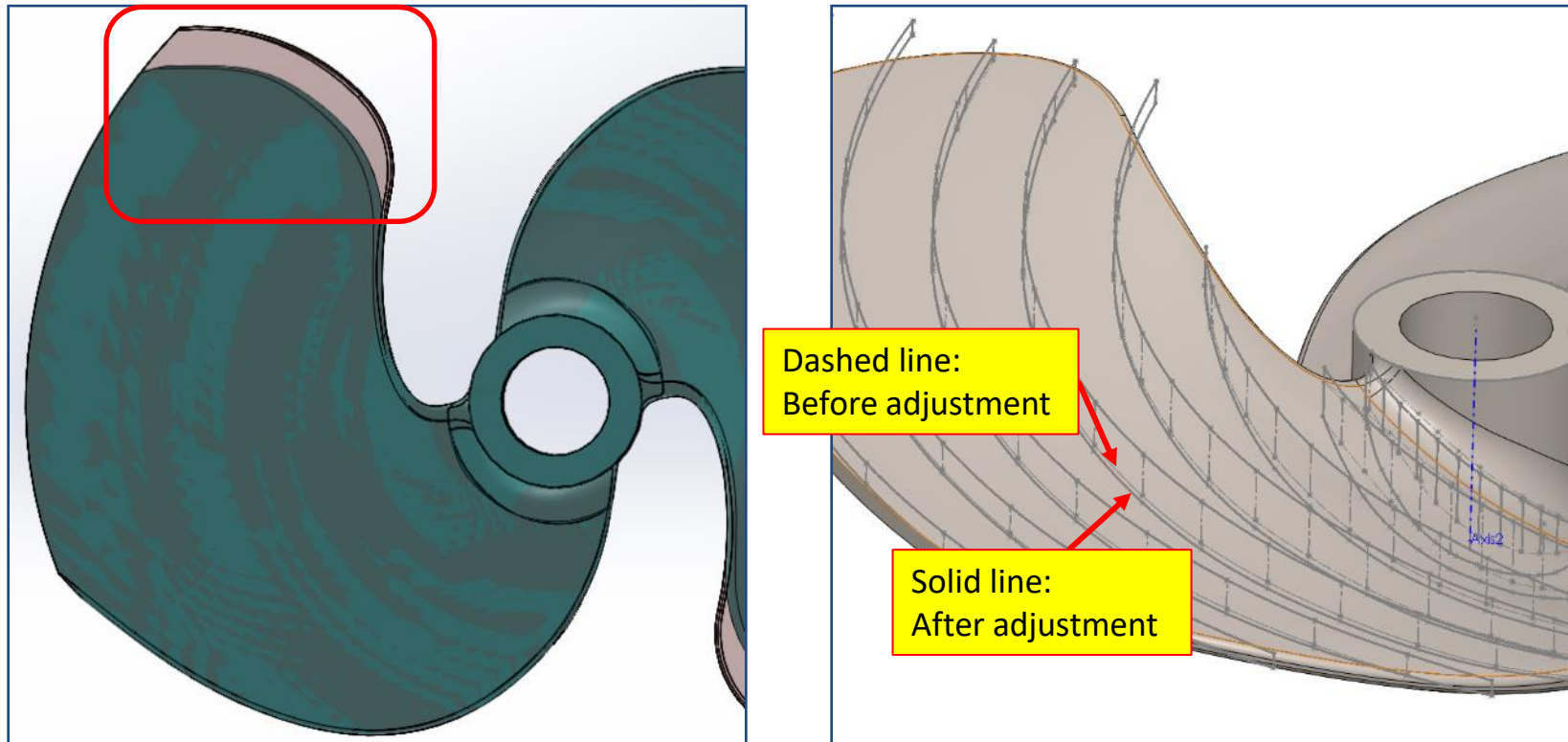


Current Design (As-Built)



Optimized Design

Alternative design option for future considerations: 5% trailing edge extension + slightly thickened blade + flat rake



Future Design Alternative – Trailing Edge Extension (~5%) + Small Increase in Blade Thickness

- A small increase in blade working area can improve the performance including flow, head and power
- CFD predicts ~ 90% of power drawn; 14,200 GPM @ 8.67 feet

Glow Tech Prop exceeds the customer's design targets!

GloTech V3.0 Pototype Prop Evaluation 2600034 PROP (50HP AERATOR)		1/11/2023			
GloTech V2.0-PROP STAMP #1 (316 SS) [33 LBS]					
- AVG FLA%: 95.9 (88%-95% ACCEPTABLE)					
- ODE BEARING VIBRATION: VELOCITY = 0.160-0.195 IN/SEC (≤ 0.300 ACCEPTABLE)					
- DE BEARING VIBRATION: VELOCITY = 0.070-0.090 IN/SEC (≤ 0.300 ACCEPTABLE)					
		<u>LEADING EDGE</u>	<u>ROOT-MIDPOINT</u>	<u>TRAILING EDGE</u>	<u>AVG</u>
BLADE 1: (PITCH)		12.4	12.3	12.5	12.40
BLADE 2: (PITCH)		12.3	12.4	12.4	12.37
BLADE 1 (BLADE OD TIP THICKNESS) [INCH]		0.229	0.307	0.217	
BLADE 2 (BLADE OD TIP THICKNESS) [INCH]		0.236	0.288	0.223	
BLADE 1 (ROOT THICKNESS) [INCH]		1.051		1.135	
BLADE 2 (ROOT THICKNESS) [INCH]		1.024		1.102	
BLADE 1 (RAKE): HUB-CENTER-TIP [INCH]	HUB-CENTER-OUTSIDE	FLAT (-.031) (-.047)	(-.031) FLAT (-.031)	FLAT FLAT (-.031)	
BLADE 2 (RAKE): HUB-CENTER-TIP [INCH]	HUB-CENTER-OUTSIDE	FLAT (-.031) (-.047)	(-.031) FLAT (-.031)	FLAT FLAT (-.031)	
GloTech V2.0-PROP STAMP #2 (316 SS) [32 LBS]					
- AVG FLA%: 95.8 (88%-95% ACCEPTABLE)					
- ODE BEARING VIBRATION: VELOCITY = 0.210-0.255 IN/SEC (≤ 0.300 ACCEPTABLE)					
- DE BEARING VIBRATION: VELOCITY = 0.095-0.150 IN/SEC (≤ 0.300 ACCEPTABLE)					
		<u>LEADING EDGE</u>	<u>ROOT-MIDPOINT</u>	<u>TRAILING EDGE</u>	<u>AVG</u>
BLADE 1: (PITCH)		11.9	12.2	12.8	12.30
BLADE 2: (PITCH)		12.2	12.4	12.3	12.30
BLADE 1 (BLADE OD TIP THICKNESS) [INCH]		0.194	0.274	0.223	
BLADE 2 (BLADE OD TIP THICKNESS) [INCH]		0.183	0.267	0.241	
BLADE 1 (ROOT THICKNESS) [INCH]		1.043		1.121	
BLADE 2 (ROOT THICKNESS) [INCH]		1.036		1.087	
BLADE 1 (RAKE): HUB-CENTER-TIP [INCH]	HUB-CENTER-OUTSIDE	FLAT FLAT FLAT	(-.030) FLAT (-.015)	FLAT (-.015) (-.015)	
BLADE 2 (RAKE): HUB-CENTER-TIP [INCH]	HUB-CENTER-OUTSIDE	FLAT FLAT (-.015)	(-.015) FLAT (-.015)	FLAT FLAT (-.015)	

All Customer design objectives met or exceeded.

- Customer reported Excessive vibration during aerator operation on existing 50HP prop
 - Redesigned prop eliminated vibration effect!
- Customer requested Improved product Quality.
 - Redesigned prop used improved casting methods removing all quality and uniformity issues.
- Customer requested reduction of excessive labor due to pre-pitch balancing.
 - Better manufacturing method and improved design eliminated operation!
- Customer requested their logo/cast letters to be added
 - Logo & casting Letters Added!

We were able to offer a lower cost too!

Customer Purchases redesigned Propeller & started additional projects to improve other propeller sizes!