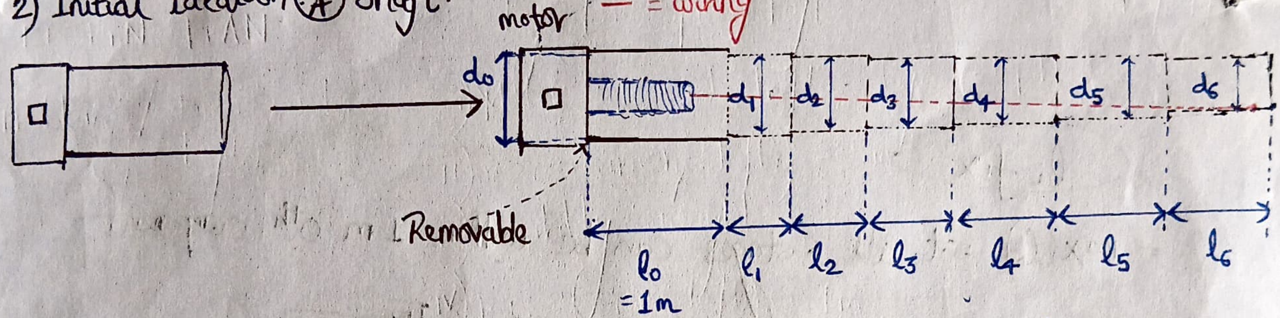
PRE-DESIGN PLAN — 6 stage telescopic shaft 18/07/2024

1) Problems/Characteristics of shaft —
i) Motor — solid shaft 6 stage — tip blades
ii) max(extension(shaft)) = 5m
iii) Flexibility & Weight
iv) min(extension(shaft)) = 1m
v) Tank diameter = 0.4m > shaft diameter (Consider blades/folded-blades)
vi) Underwater & sludge resistant
vii) User-friendly → one button control.

Primary Goal → Telescopic shaft design

Secondary Goal → Electronics of blades

2) Initial ideation Ⓐ Shaft.



$d_i > d_j \quad \forall\, i<j$

$l_i < l_j \quad \forall\, i<j$

$\sum_{i=0}^{6} l_i = 5m \Rightarrow \boxed{\sum_{i=1}^{6} l_i = 4m}$

what if : $l_1, l_2, \ldots, l_6$ is in A.P.

$l_1 = l_1$

$l_2 = l_1 + \delta$

$\vdots$

$l_6 = l_1 + 5\delta$

$\Rightarrow 6l_1 + 15\delta = 4$

let $l_6 = l_0 = 1$

$l_1 + 5\delta = 1$

$\rightarrow 3l_1 + 15\delta = 3$

$\Longrightarrow \boxed{l_1 = 1/3\ m}$

$\boxed{\delta = 2/15\ m}$

stage	l_i	d_i
0	1000	150+30
1	333.33	135+30
2	466.66	120+30
3	599.99	105+30
4	733.32	90+30
5	866.65	75+30
6	1000	60+30
	4999.95	

180 mm

80 mm

mm

✗ wrong bcuz of $i=6$ can't be 1m

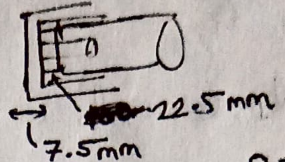
Actual $\phi(O_i) = d_i + A$

$A = 2.5mm$

Actual $\phi(I_i) = d_i - 5mm$

li fix

$l_6 = \max(l_6)$ s.t. all 6 stages can be within 1 m 0^{th} component.



$l_6 \le 1000 - (30 \times 6)$

$\le 1000 - 190$

≤ 810 mm

Actual length of stage 6 shaft

But extension of stage 6 shaft will be < 810 mm

0-1
1-2
2-3
3-4
4-5
5-6

If L_i = actual stage length
l_i = actual stage extension $\boxed{l_i < L_i}$

$l_0 = L_0 = 1m$ $L_1 = 970$ mm $L_2 = 940$ mm $L_3 = 910$ mm $L_4 = 880$ mm $L_5 = 850$ mm
$L_6 = 820$ mm

$$\frac{\partial l_1}{\partial l_0} < \frac{\partial l_2}{\partial l_1} < \frac{\partial l_3}{\partial l_2} \cdots < \frac{\partial l_6}{\partial l_5} \rightarrow \text{Thus } \boxed{l_6 > l_5 > \cdots l_2 > l_1}$$

But l_i?

$\boxed{l_6 = 780 \text{ mm}}$

$L_6 - f_6$

factor
(ensures actuator stage does not leave the spline screw)

let $f_6 = 40$ mm

$f_5 = 50$ mm

$f_4 = 60$ mm

$f_3 = 70$ mm

$f_2 = 80$ mm

$f_1 = 90$ mm

$\sum_{i=1}^{6} L_i = 5370$ mm

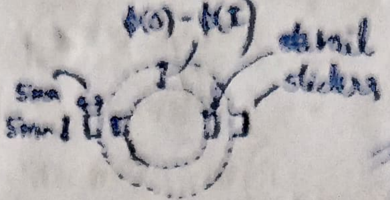
So for $\sum_{i=1}^{6} l_i = 4000$ mm

We leave 1370 mm to compensate as non-free length of the stages.

$d_0 = 15\text{ cm} = 150\text{ mm}$

common difference

15 mm



C.S. of stage

$\phi(O)$ = outer diameter
$\phi(I)$ = inner diameter

$$\begin{cases} +\psi \text{ RPM} \longrightarrow +\gamma \text{ mm/s extension,} \\ -\psi \text{ RPM} \longrightarrow -\gamma \text{ mm/s} \end{cases}$$

$\forall$ stage i ; $\phi(O_i) - \phi(I_i) = (5+\alpha)$ mm

Adjust α according to required strength.

we take $\boxed{\alpha = 2.5\text{ mm}}$

153.325 rev needed.

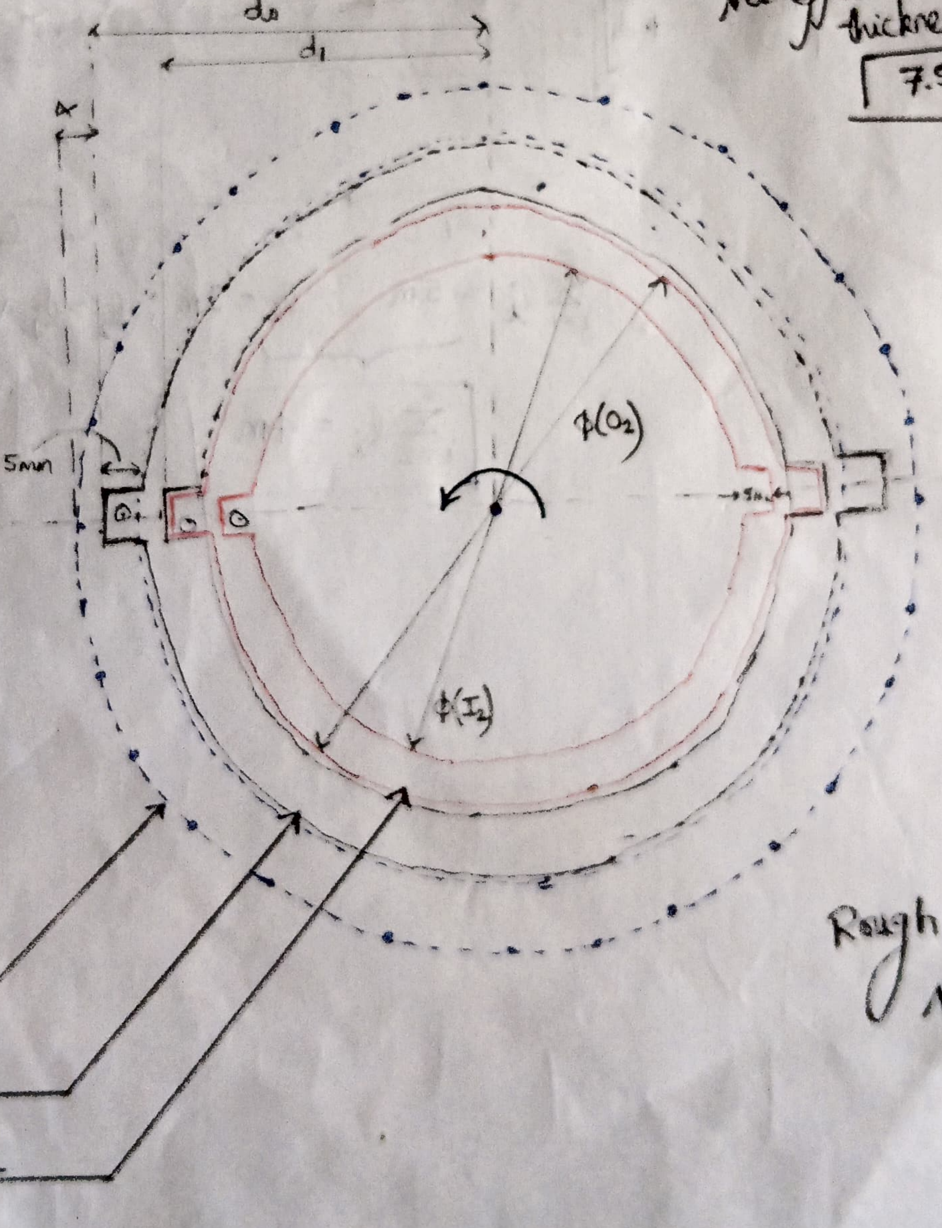
$\gamma = \dfrac{613.3}{T}$

$\boxed{\psi = 153.3\text{ RPM}}$ $\boxed{\gamma = 10.22\text{ mm/s}}$

$\boxed{T = 60\text{ s}}$

Net effective thickness is always $\boxed{7.5\text{ mm}}$

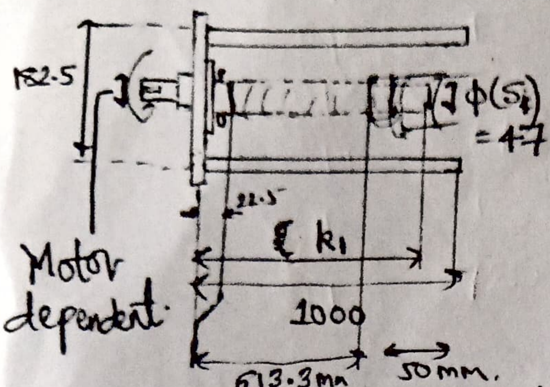
1cm/s



Rough idea of CS
Not to scale.

Product design of shaft (mm)

i) $i=0$



screw thickness = 7mm

5mm dead space b/w adjoining screws to avoid friction.

$k_i > l_i$

(Introduce dead length for safety and distribute the bending moment)

spline screw diam = $\phi(S_i)$

~~$\phi(S_6)$ =~~

$\phi(S_6) = 85 - 3$ mm

= 82 mm

v

$\phi(S_5)$ = ~~80~~ ~~75~~ 70 mm

v

$\phi(S_4)$ = ~~70~~ ~~68~~ 63

v

$\phi(S_3)$ = ~~61~~ 56

v

$\phi(S_2)$ = ~~54~~ 49

v

$\phi(S_1)$ = ~~47~~ 42

~~15 mm to support screw joint~~

15 mm joint for screws

$$k_i = l_i + \underbrace{22.5}_{\text{for screw joint}} + \underbrace{7.5\text{mm}}_{\text{next stage thickness}} + 50\text{mm}$$

At end ~~k_6 = 900 mm~~

k_6 = 800 mm

At retracted state 20 mm dead space left in stage 6

↓

For motors / mechanism for blades at the tip pitch → dist trav in one rotation. (mm)

n rotations for fully expanding the shaft

dist needed to travel $= l_i$

$np_1 = 613.3$

$np_2 = 634.6$

$np_3 = 656$

$np_4 = 677.3$

$np_5 = 698.6$

$np_6 = 720$

(td Thread depth $\approx 0.51 \times$ pitch for (M1-M100 screws))

$\because k_j > k_i \ \forall \ j > i$

$\Rightarrow$ More the longer is the screw, more pitch it should have & more thread depth

$td_1 = 2.44$ $p_1 = 4$ mm $n =$ ~~150 revs~~ 153.325 revs

$td_2 = 2.53$ $p_2 = 4.14$ mm

$td_3 = 2.61$ $p_3 = 4.28$ mm

$td_4 = 2.70$ $p_4 = 4.42$ mm

$td_5 = 2.78$ $p_5 = 4.56$ mm

$td_6 = 2.87$ ~~p_6 = 4.70 mm~~

Using a motor of 153 RPM will extend the shaft in 1 min

1m to 1.6m 1 stage telescopic actuator

1m to 2.25m 2 stage telescopic actuator

1m to 2.9m 3 stage telescopic actuator

1m to 3.6m 4 stage telescopic actuator

1m to 4.3m 5 stage telescopic actuator

1m to 5m 6 stage telescopic actuator

$f_1 + f_2 + \cdots + \underset{\substack{\downarrow \\ 100\,mm}}{f_6} = 1370$

Let $f_5 = f_6 + \Delta f$

$f_4 = f_6 + 2\Delta f$

$\vdots$

$f_1 = f_6 + 5\Delta f$.

30

$f_1 + \cdots f_5 = 1270$

$\therefore 1270 = 5f_6 + 15\Delta f$.

$254 = \underset{\substack{\downarrow \\ 100}}{f_6} + 3\Delta f$

$154 = 3\Delta f \Longrightarrow \boxed{\Delta f = 51.33\ mm}$

After extension.
The depth reached
is ~~8~~ 4.9998 m
↑
slight diff to
allow gap between blades
and tank surface.

$\boxed{mm}$

w 15 mm screw joint

stage	L_i	f_i	l_i	d_i	$\phi(O_i)$	$\phi(I_i)$	$\phi(S_i)$	k_i	Screw depth or pitch
0 (base)	1000	-	1000	180	182.5	175	~~42~~	-	
1	970	356.65	613.35 = 613.3	165	167.5	160	42 ~~49~~	693.3	
2	940	305.32	634.68 = 634.6	150	152.5	145	49 ~~56~~	714.6	
3	910	253.99	656.01 = 656	135	137.5	130	56 ~~63~~	736	
4	880	202.66	677.34 = 677.3	120	122.5	115	63 ~~56~~	757.3	
5	850	151.33	698.67 698.6	105	107.5	100	70 ~~49~~	778.6	
6	820	100	720	90	92.5	85	82 ~~42~~	800	
			~~5~~000.05						

↓
Rounding off l_i
~~[illegible]~~
Total
~~4~~999.80
(0.2 mm)

No need of screw joints here