6-Stage Telescopic Actuator

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***Abstract*—This report aims to showcase the Computer Aided Design of a 6 Stage Telescopic Actuator Shaft with extension capability of 1 meter to 5 meter. Firstly, we present the main problem about this idea, think and evaluate the metrics and calculations to support the solution. Followed by this, we present 1 Stage, 2 Stage, 3 Stage, 4 Stage, 5 Stage and Finally the 6 Stage Telescopic Shaft CAD assemblies and Drafts.**

VARIABILITY IS THE CORE of any machinery. The fact that machines automate tasks doesn't negate this principle; it thrives on it. A loom, for example, can be adjusted for different fabric widths and thread types. A car engine alters its fuel mixture based on sensor readings. This adaptability allows a single machine to perform a wide range of functions or excel at a specific task under ever-changing conditions. It's this very ability to vary its behavior that takes a machine from a fixed tool to a dynamic partner, capable of responding to our needs and the ever-shifting world around us.

This Report presents the solution to the problem of homogenizing solid waste for a tank of depth 5 meter and diameter 0.4 meter. The main characteristics should include a telescopic shaft (Actuator) with extension from 1 meter to 5 meter. The shaft must be portable, flexible and weight-efficient. This paper focuses on the actuator mechanism.

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SOLUTION SUMMARY

After planning and computing the configurations and measurements of all the 6 stages, we can obtain 6 different telescopic actuator shafts with different extensions. (The normal length of the shaft is 1m)

n-Stage	Product Name	Max. Extension
1-Stage	Alpha	1.6m
2-Stage	Beta	2.25m
3-Stage	Gamma	2.9m
4-Stage	Delta	3.6m
5-Stage	Sigma	4.3m
6-Stage	Epsilon	5m

Table 1. Products

Based on the requirement of depth, the shaft can be reconfigured. A standalone blade rotor can then be connected to the end of any stage along with a vaccuum rubber attachment to make the agitator shaft waterproof. The choice of material will depend on the water and sludge viscosity.

All the product .par designs and .asm assemblies can be found here: Click Here

PRE-PLANNING AND CONFIGURATION

The construction of any machine or a device requires one to keep in mind the practical constraints and requirements. Configuring the device through calculations and ensure that the production of the machine could* be flawless.

Prerequisites include basic understanding of inequalities, algebra, approximations, SolidEdge CAD and the fundamentals of telescopic shafts.

*no real-life machine can be 100% perfect or efficient because of unavoidable errors.

Notations

We will consider the following diagram of the Rough Sketch to understand the notations used:

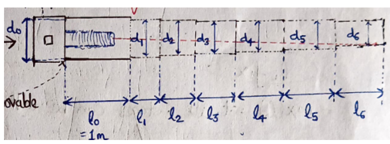

Figure 1. Rough Side View

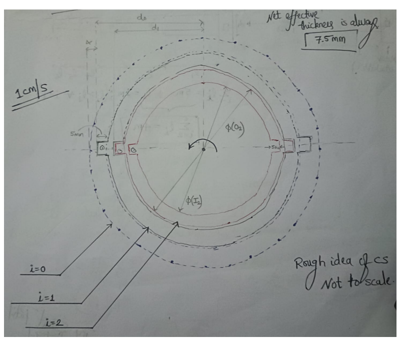

Figure 2. Rough Cross-Sectional View

Let the normal state of the actuator when not extended that is 1m be referred to as the **regressed state** whereas let the entire extended state be called as **extended state**. Let stage i = 0 refer to the base stage, i=1 refer to the 1^{st} stage and so on for all 6 stages. The actual length of each stage is L_i, the maximum length of each stage actually visible when extended i.e. extension of i^{th} stage be l_i. Let f_i be a factor having the dimensions $[M^0L^1T^0]$. d_i is the diameter of cross-section measured for the rails(crevices) on each i^{th} stage on which the next $(i+1)^{th}$ stage will be constrained to slide with only one degree of freedom along the cylindrical axis. Let α also be another factor having the dimensions $[M^0L^1T^0]$. Let $\phi(O_i)\ and\ \phi(I_i)$ be the outer and inner diameters of the i^{th} stage. Let $\phi(S_i)\ and\ k_i$ be the diameter and the length of the spline screws respectively such that, the i^{th} stage traverses on the i^{th} spline and has the $(i+1)^{th}$ spline to continue the previous spline. Let there be n revolutions for shaft to change from regressed to extended state. Each spline has a pitch p_i and thread depth t_{d_1}. All other standard mathematical notations are used.

Following now, All length dimensions are in mm unless otherwise specified.

Configuring for L_i and l_i

Each subsequent spline will be connected through a connector of thickness 15mm and length 22.5mm Now, $L_0 = 1000mm$ as the regressed state has to be unit metre. Subsequently, $L_i > L_{i+1} \forall\ (i \geq 0)$ We will take L_i in an arithmetic progression such that,

$$L_i = L_{i-1} - 30 \quad \forall (i > 0)$$

Thus we obtain,

L_1	L_2	L_3	L_4	L_5	L_6
970	940	910	880	850	810

Table 2. Configurations for L_i

For the shaft to expand such that the equivalent of all different extensions of each shaft be 5000mm exactly at same time T;

$$\frac{\partial l_1}{\partial l_0} < \frac{\partial l_2}{\partial l_1} < \frac{\partial l_3}{\partial l_2} < \frac{\partial l_4}{\partial l_3} < \frac{\partial l_5}{\partial l_4} < \frac{\partial l_6}{\partial l_5}$$

Assuming that the pitch of spline i ($0 \leq i \leq 5$) is related as:

$$p_i < p_{i+1} \quad \forall (spline\ i)$$

We can saw from the above two relations that:

$$l_6 > l_5 > l_4 > l_3 > l_2 > l_1 \tag{1}$$

Obviously, $l_0 = L_0$ as there is no extension in base stage.

Considering the constraints of unit metre and the length occupied by spline joints, we consider a factor $f_i \quad \forall (i > 0)$ such that,

$$l_i = L_i - f_i \tag{2}$$

Now before we proceed, let us look at the net length of all stages we have;

$$\sum_{i=0}^{6} l_i = 5000 \text{ As required}$$

$$\sum_{i=1}^{6} l_i = 4000 \ \ \{l_0 = 1000\}$$

However, we have

$$\sum_{i=1}^{6} L_i = 5370 \ \ \{L_0 = 1000\}$$

$$\sum_{i=1}^{6} L_i - \sum_{i=1}^{6} l_i = 1370$$

So we have 1370mm as the extra length which need not be extended and hence be considered for our factor calculation. So,

$$\sum_{i=1}^{6} f_i = 1370 \ \ \{L_0 = 1000\}$$

For simplicity and symmetric nature, let f_i be in an arithmetic progression such that, assuming $f_6 = 100$, $f_5 = f_6 + \Delta f,\ f_4 = f_5 + 2\Delta f$ ...., $f_1 = f_6 + 5\Delta f$. On calculating we obtain

$$\Delta f = 51.33$$

Finally, we can obtain l_i through eq. (2) as,

L_i	f_i	l_i
1000	-	1000
970	356.65	613.3
940	305.32	634.6
910	253.99	656
880	202.66	677.3
850	151.33	698.6
820	100	720

Table 3. Configurations for l_i

Configuring for $\phi(O_i)$, $\phi(I_i)$

Each stage will be constrained to slide on a rail of the crevices on the previous stage. We will assume the rail is a cuboidal space of cross section 5mm x 5mm. Let us define;

$$\phi(O_i) = d_i + \alpha$$

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

. So effectively, we always are left with a thickness of

$$\phi(O_i) - \phi(I_i) = \alpha + 5$$

where, α is a parameter depended of required strength, weight and the build of stages. Now considering portability as well as a herculean task of extending the shaft to 5m, we will take $d_0 = 180mm$ and consider d_i to also be in an arithmetic progression such that

$$d_{i+1} = d_i - 15$$

. Let us also assume $\alpha = 2.5$ Finally, we obtain;

d_i	$\phi(O_i)$	$\phi(I_i)$
180	182.5	175
165	167.5	160
150	152.5	145
135	137.5	130
120	122.5	115
105	107.5	100
90	92.5	85

Table 4. Configuring for $\phi(O_i)$, $\phi(I_i)$

Configuring for $\phi(S_i)$, k_i, p_i and t_{d_i}

For $\phi(S_i)$, we did a brute force approach to find the right diameter of splines for each stage as; As you

$\phi(S_i)$
42
49
56
63
70
82

Table 5. Configuration for $\phi(S_i)$

can observe, all are in arithmetic progression except the $\phi(S_6)$. This is because we have no new spline arising for i=6 and thus its only a revolving stage rather than an extender.

Now to adjust k_i, we will consider the following logic;

$$k_i = l_i + 22.5 + 7.5 + 50$$

Here, any stage will obviously need to traverse $l_i + 22.5 + 7.5$ mm so that it extends according to the configuration. An extra 50mm is considered as a safety as well as to somewhat reduce the bending moment and shearing stress. We get; Now we know that we need

k_i
693.3
714.6
736
757.3
778.6
800

Table 6. Configuration for k_i

to achieve the extension or regression in n revolutions (Using a motor of n RPM will extend or regress the shaft in 1 minute). Also, pitch is the distance travelled in one revolution. So we can mathematically say,

$$np_i = l_i$$

To make the production efficient, we will hope to ue industry ISO Metric Standard M1-M100 Spline Screws. As a standard, let us assume the pitch $p_1 = 4$. Thus we obtain that $n = 153.325revs$. (Using a motor of 300 RPM will extend or regress the shaft in 30s only!). Thus we get all the pitches as: For ISO Metric

p_i	t_{d_i}
4	2.44
4.14	2.53
4.28	2.61
4.42	2.70
4.56	2.78
Not Applicable for i=6	-

Table 7. Configuration for k_i

M1-M100, we approximately have

$$t_{d_i} = 0.61 \times p_i$$

With this, we have successfully configured all the metrics and dimensions of our product.

EPSILON

We will be looking at the main product. A 6-stage telescopic actuator shaft with extension capability from 1m to 5m. Refer to the link given in the solution summary to look at the product CAD.

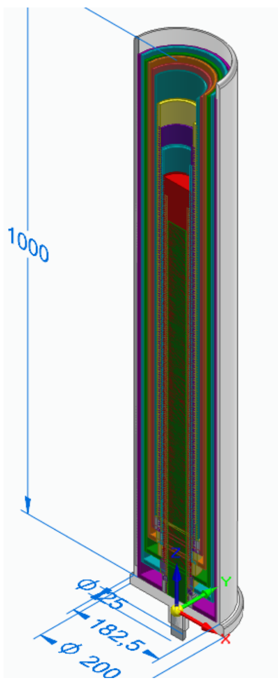

Figure 3. Medial Section 3D View in Regressed State

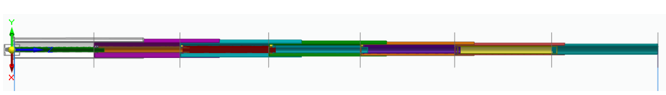

Figure 4. Medial Section Isometric View in Extended State

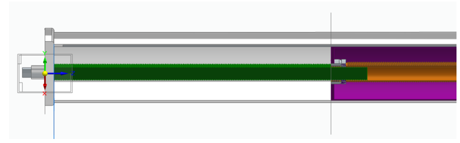

Figure 5. Focus View of Figure 4

PROJECT

Submitted by © Sonit Nitin Patil and the corresponding all products and their assemblies can be found at Click Here