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ANALYSIS OF DYNAMIC LOAD FACTOR IN A FAIL-SAFE CRANE EQUIPPED WITH A HYDRAULIC EQUALIZING CYLINDER

{ AMIREHSAN GHASEMI, RON GOULET, JAMES C. NEWMAN III, B. BROOKES BACON AND MARK RAY } UTC & TVA

ABSTRACT

A model is proposed for the dynamic behavior of an equalizing cylinder when coupled to a fail-safe crane mechanism. The constitutive equations involve the continuity of the fluid in the equilizing bar and time-dependent incompressible one-dimensional Navier-Stokes equations for the detailed motion of the cylinder coupled with the dynamics of the traveling block and the elastic cable. These yields a nonlinear 2^{nd}-order ordinary differential equations. The results for the Dynamic Load Factor (DLF) is presented.

INTRODUCTION

A previous study of double-safety crane mechanism was done by Edmondson [1] without considerig the effect of the equilizing cylinder. The TVA double safety crane system can be modeled using the configuration shown in Fig. (1).

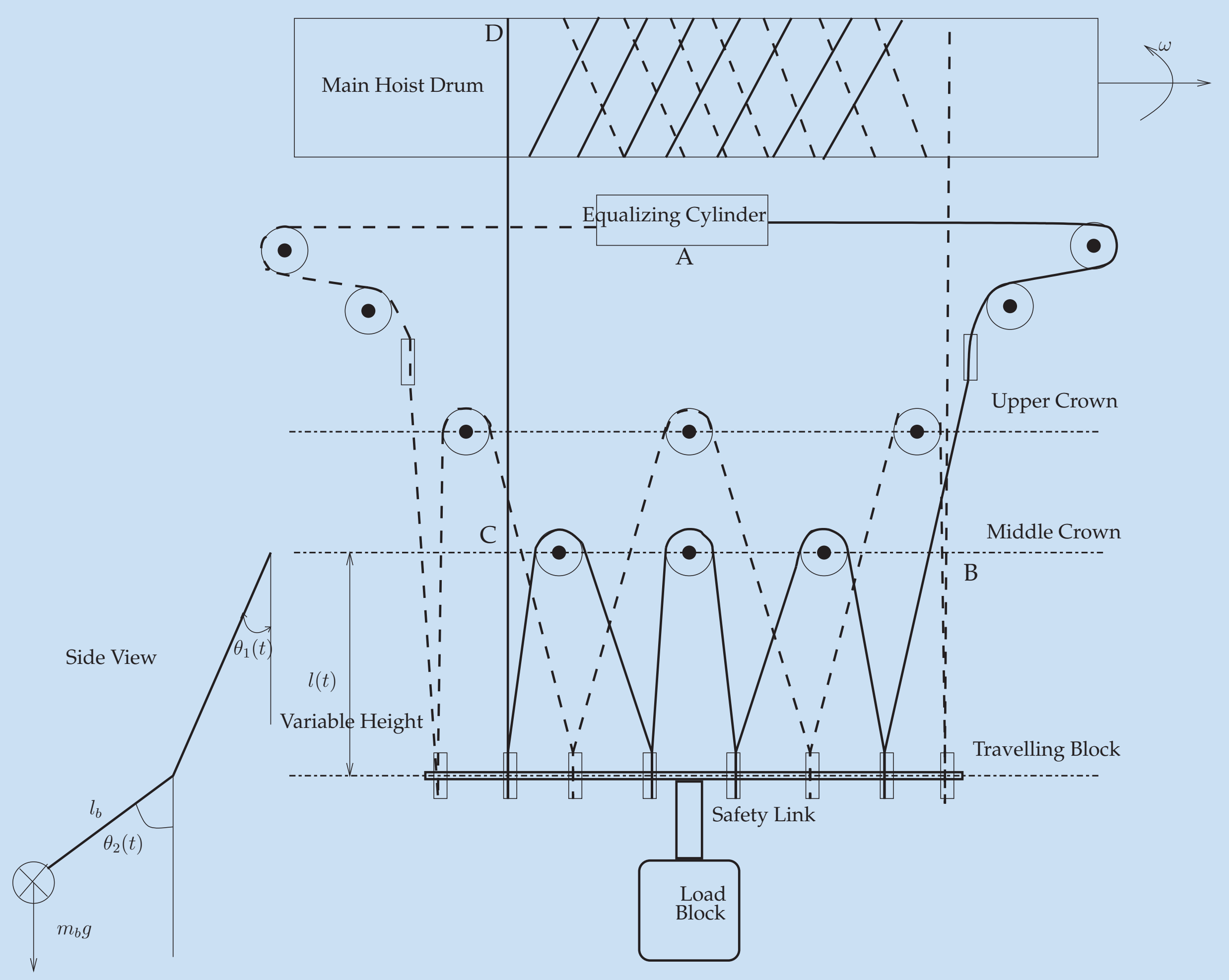

Figure 1: The crane-pulley model used in the current work.

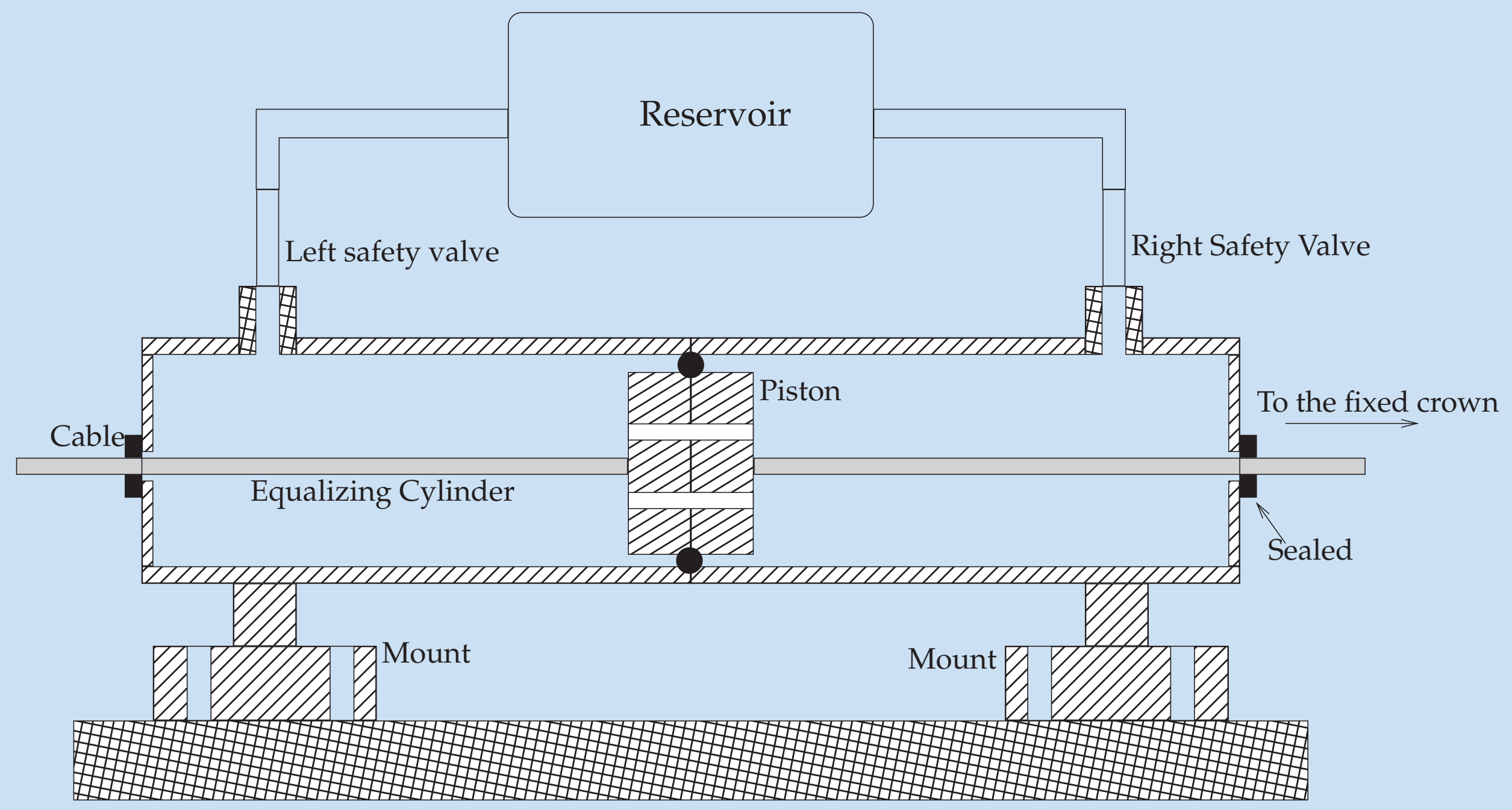

Figure 2: The configuration of the equilizing bar.

It includes 8 stages on each side integrated together and each stage takes half the payload. In the event of breaking a cable on one side, the other side undergoes full loading plus a transient dynamic load. The ends are connected to the equiliing cylinder which is designed to damp the dynamic loading. The details of this part is shown in Fig. (2). The piston is sealed using an O-ring. We also investigated the case where the O-ring breaks and causes tolerance sealing as shown in Fig. (3).

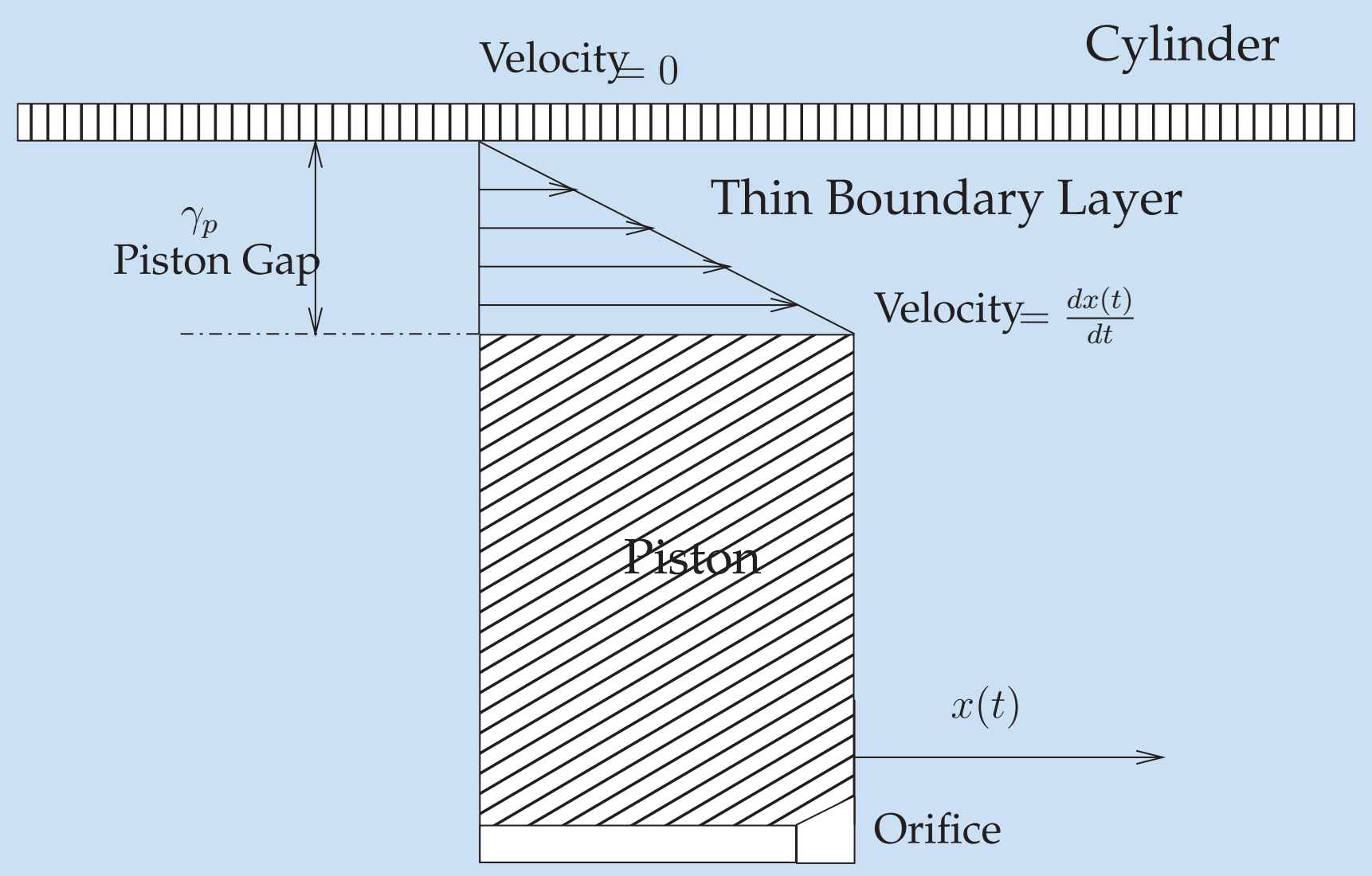

Figure 3: Tolerance Sealed equilizing bar.

In the loading part, where moving mechanisms exist, the behavior is modeled usig a combination of a pendulum and a fixed arm as shown is Fig. (4).

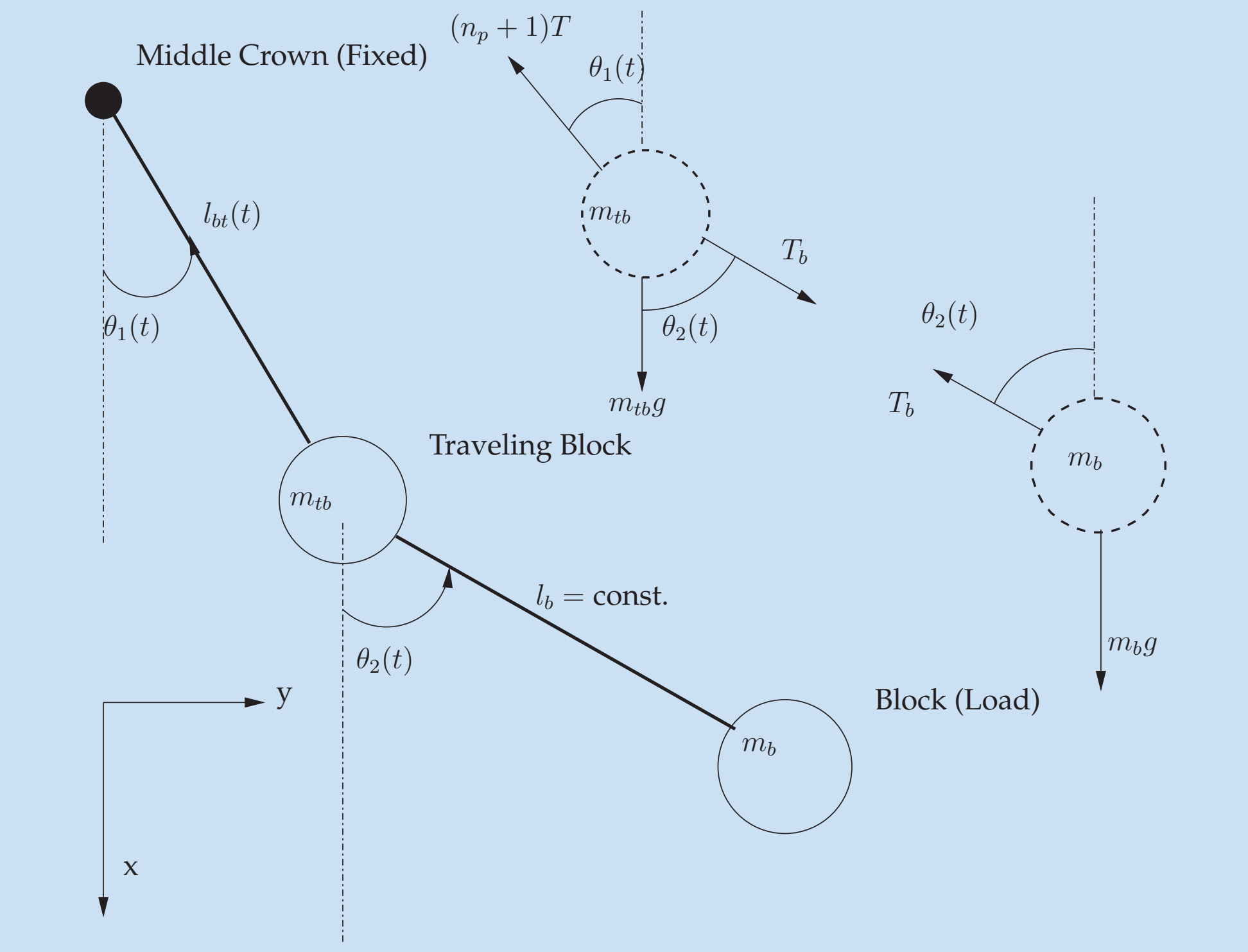

Figure 4: Free body diagrams of the loading.

DERIVATION

We use Navier-Stokes eqs. in the control-volume form for the hydraulic cylinder as shown in Fig. (5).

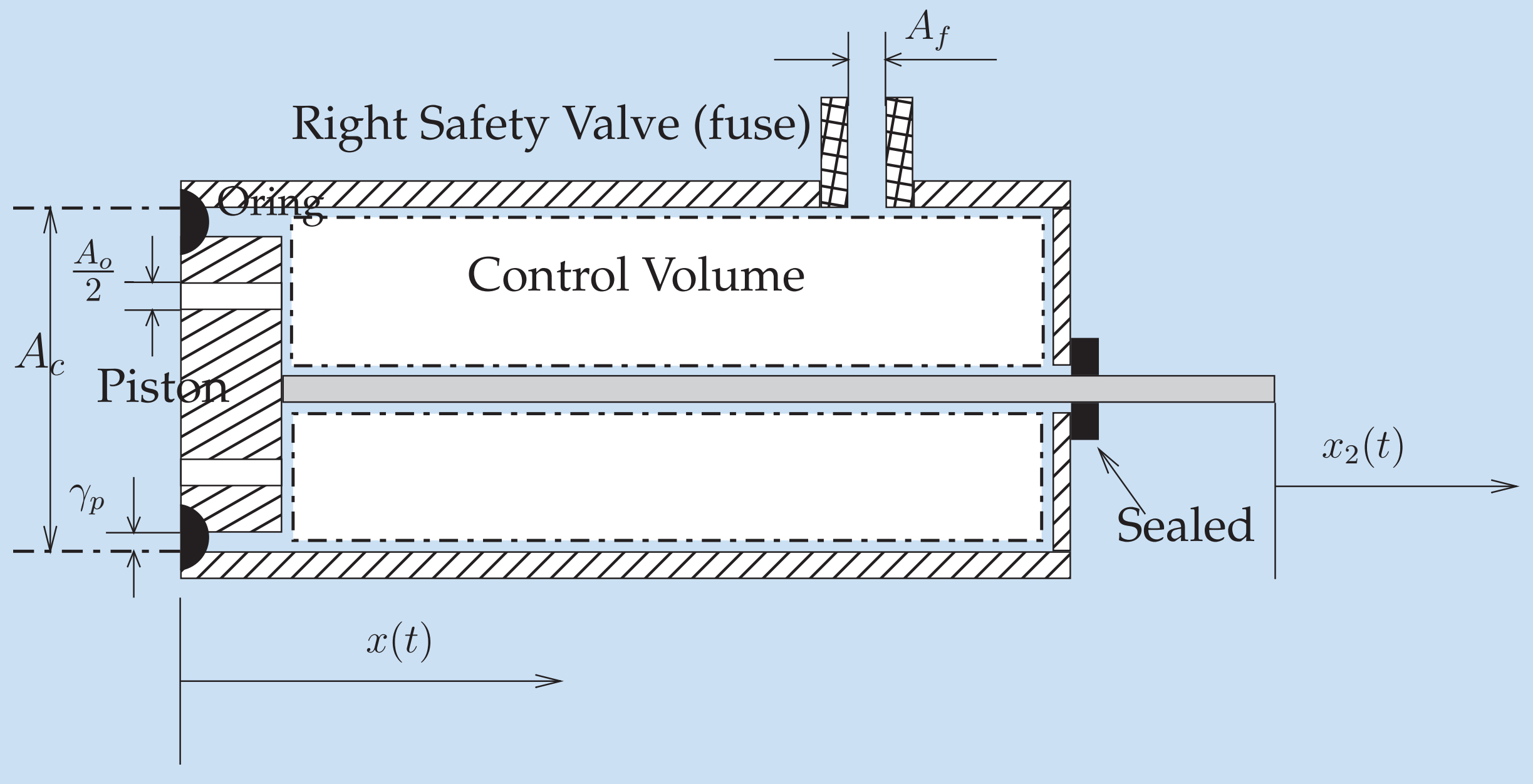

Figure 5: Details of the control volume analysis.

A control-mass method for the dynamics of moving poston is shown in Fig. (6). The results of combining these equations is $\frac{d^2x(t)}{dt^2} + \beta_1 \left(\frac{dx(t)}{dt}\right)^2 = f$. which yields the solution for displacement of the piston after the failure of one cable where the impact velocity when the piston reaches to the end is obatined as

$$v_f = \frac{\kappa \left(\mathrm{e}^{\eta\,\beta_1}\sqrt{\mathrm{e}^{2\,\eta\,\beta_1}-1} + \mathrm{e}^{2\,\eta\,\beta_1} - 1\right)\mathrm{e}^{-\eta\,\beta_1}}{\left(\mathrm{e}^{\eta\,\beta_1} + \sqrt{\mathrm{e}^{2\,\eta\,\beta_1}-1}\right)\beta_1\,(np+1)} \quad (1)$$

where $\kappa = \sqrt{\beta_1 f}$ and $\beta_1 = \frac{g}{\frac{(n_p+1)m_p}{m_b+m_{tb}} + \frac{1}{n_p+1}}$ and n_P number of pulleis on one side, m_p mass of payload, m_b mass of block and m_{tb} is the mass of traveling block. The final closed form solution for DLF is

$$\mathrm{DLF} = \frac{(m_b + m_{tb})g + \sqrt{(m_b + m_{tb})\frac{A_{\text{Cable}}E_{\text{Cable}}}{L_{\text{Cable}}}}\,v_f}{(m_b + m_{tb})g} \quad (2)$$

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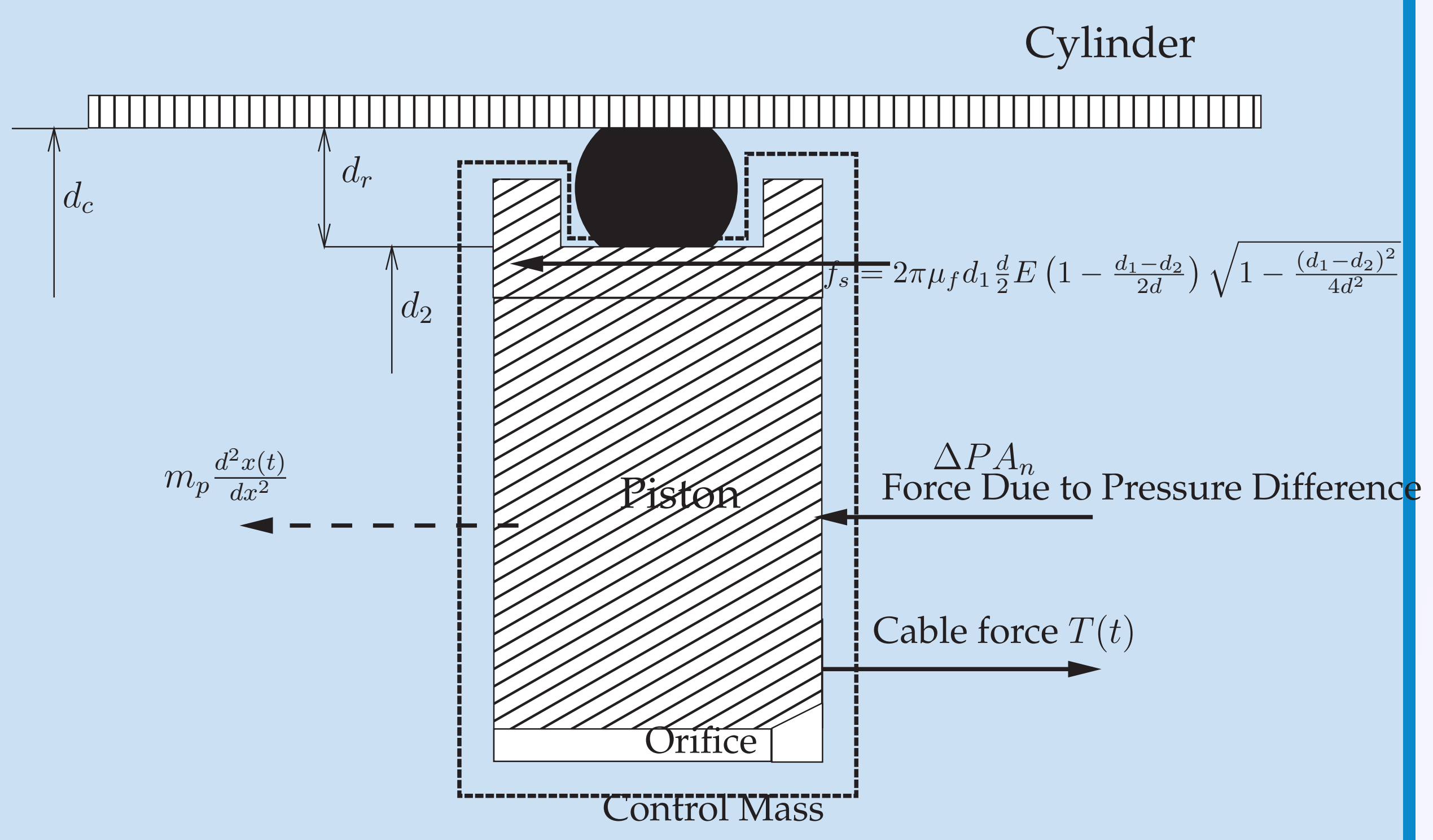

Figure 6: Details of the control mass analysis.

RESULTS AND CONCLUSION

The DLF is evaluated for the system configuration shown in the following table.

Parameter	Value	Unit
Cylinder Diameter	5	inches
Connecting Rod	2.5	inches
Orifice Diameter	0.02	inches
Cable Modulus of Elasticity	200	GPa
Diameter of the cable	4.	centimeters
Effective cable Length	100.	meters
Coefficient of discharge of the orifice	0.7	-
Expansibility Factor	1	-
Mass of the piston	2	Kg
Mass of the Traveling Block	15	Kg
Number of pulleys n_p	7	-
Fluid Density	872	kg/m^3
Half length of the cylinder	10	centimeters
Block Mass	2000	kg
Calculated Impact Time	10.97	sec.

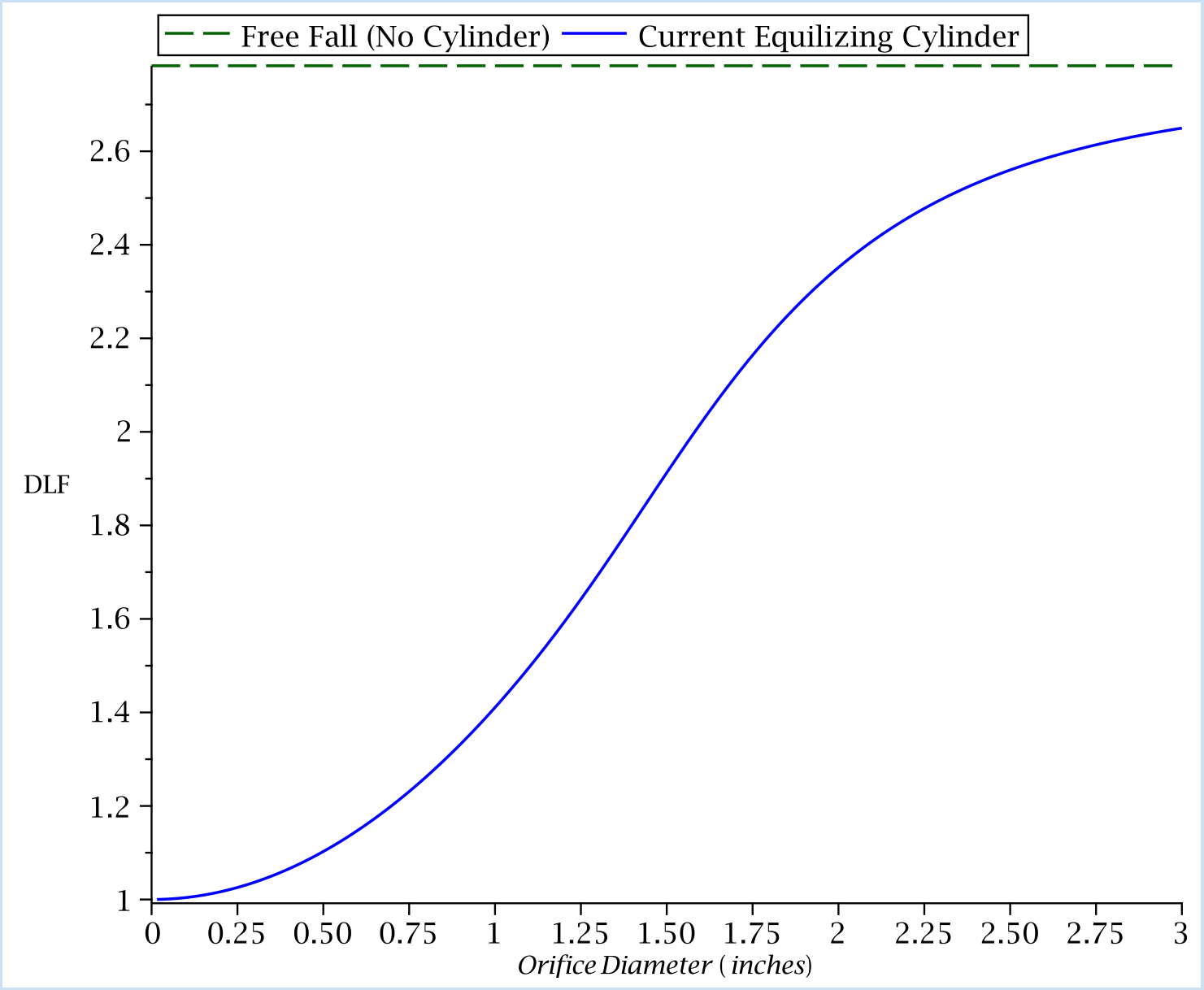

Figure 7: The dynamic load factor versus the diameter of the orifice. The actual diameter is 0.02 inches.

REFERENCES

[1] A. J. Edmondson. Failure Analysis of a Redundant Reeving Hoist. *ASME Journal of Eng. for Ind.*, 13(52):1166–1169, November 1976.

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