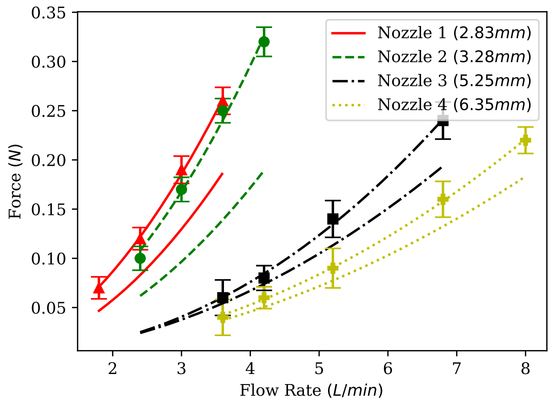
Pressure Profile

Team 2

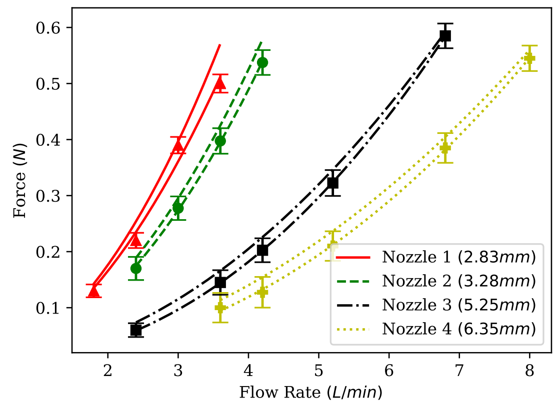
February 28, 2020

An increasing flow rate of a water jet impinging on multiple angles of objects correlates to an increasing force on that object. As fluid hits an object, it changes directions based on the angle of the object, therefore the object exerts a force on the fluid which is seen in the general momentum equation (Equation 8). This principle of conservation of momentum can be seen in some examples such as billiard balls bouncing off one another where the sum of the products of mass and velocity are conserved before and after a collision. In fluids, mass flow rate is used instead of mass and is a product of the velocity and cross sectional area. The rearranged momentum equation for the scenario of a water jet, Equation 9, has $\dot{V}^2$ in the numerator which means that as the volumetric flow rate doubles, the force on the object quadruples. Thus the force required to redirect the stream increases as the flow rate of that stream increases.

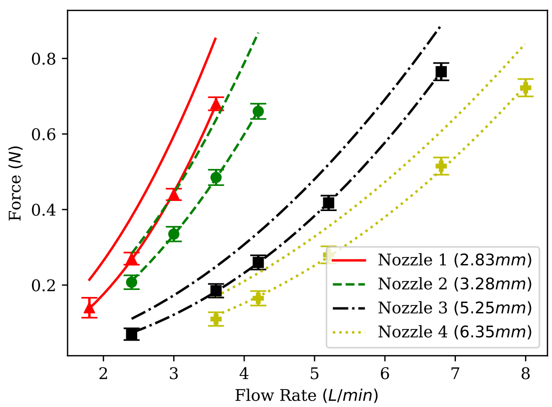
Theoretical projections of force on multiple objects based on volumetric flow rate exhibit similar attributes to the measured data. The measured data has been tabulated for four different angles of targets in Table 1.These measured values for flow rate versus force applied have also been plotted for several object angles and are seen in Figure 1 where four nozzle diameters are shown on each plot for comparison. In addition, the theoretical forces are compared to their respective measured force, the same nozzle size having similar line patterns. The trend line for the data was modeled with a power law curve where the power coefficient for the plots is seen in Table 2 and the theoretical equations yielded results that were quite similar in shape and general direction as the power curve trend line. Additionally, the prediction of the force quadrupling as the flow rate doubles is also seen to be true based on the plots general trend. This implication is that our theoretical model does



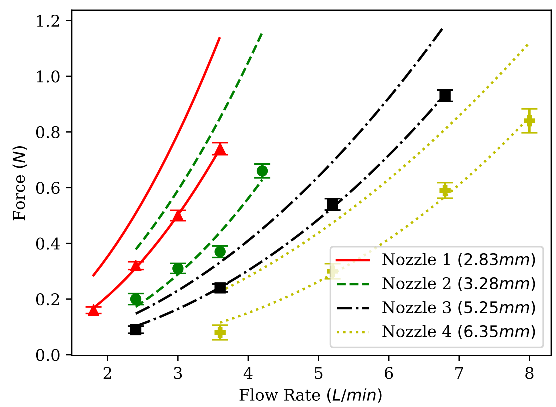
(a) 47.7°



(b) 90°



(c) 120°



(d) 180°

Figure 1: Plots

indeed model our data well and can be used.

Table 1: Force measured on four different target angles at various flow rates and nozzle diameters

		Target Angle							
		47.7°		90°		120°		180°	
D_N (mm)	$\dot{V}\,(L/m)$	F (N)	$\sigma(N)$	F (N)	$\sigma(N)$	F (N)	$\sigma(N)$	F (N)	$\sigma(N)$
2.83	1.8	0.07	0.0025	0.013	0.0028	0.14	0.0122	0.16	0.0032
	2.4	0.12	0.0026	0.22	0.0046	0.27	0.0063	0.32	0.0049
	3	0.19	0.0048	0.39	0.0054	0.44	0.0057	0.5	0.0078
	3.6	0.26	0.0047	0.5	0.0064	0.68	0.0071	0.74	0.0096
3.28	2.4	0.1	0.0034	0.17	0.009025	0.2075	0.007675	0.2	0.0086
	3	0.17	0.0036	0.2775	0.00925	0.335	0.0083	0.31	0.0075
	3.6	2.5	0.0036	0.3975	0.010225	0.485	0.00885	0.37	0.0091
	4.2	0.32	0.0055	0.5375	0.0099	0.66	0.008775	0.66	0.0113
5.25	2.4			0.06	0.0036	0.07	0.0059	0.09	0.004
	3.6	0.06	0.0075	0.145	0.00975	0.185	0.007475	0.24	0.0051
	4.2			0.2025	0.009425	0.26	0.00795		
	5.2	0.14	0.0079	0.3225	0.0104	0.4175	0.008275	0.54	0.009
	6.8	0.24	0.008	0.585	0.009825	0.765	0.0103	0.93	0.0089
6.35	3.6	0.04	0.0076	0.1	0.0122	0.11	0.0075	0.08	0.0121
	4.2			0.1275	0.01275	0.165	0.008175		
	5.2	0.09	0.0087	0.21	0.0122	0.28	0.0101	0.3	0.0126
	6.8	0.16	0.0076	0.385	0.0123	0.515	0.01025	0.59	0.0131
	8	0.22	0.0045	0.545	0.0102	0.7225	0.010375	0.84	0.0209

Table 2: Power coefficient for various angles of object

D_N (mm)	47.7°	90°	120°	180°
2.83	1.884	1.922	2.295	2.138
3.28	1.971	2.014	2.042	2.312
5.25	2.179	2.200	2.249	2.124
6.35	2.067	2.198	2.262	2.504
Average	2.025	2.083	2.212	2.269