Appendix E: Torsion calculations

	Maximum Torque [Nm]	Experience d Torque [Nm]	Maximum tangential force [N]	Experience d tangential force [N]	Experience d radial force [N]	Rotational speed [rad/s]
Gear 1 [12T]	3	0.941	450	148.228	53.95	14.537
Gear 2 [36T]	3.4	2.627	700	137.879	50.184	4.508
Gear 3 [24T]	3	2.627	300	206.819	75.276	4.508
Gear 4 [24T]	3	2.489	300	195.99	71.335	4.272
Gear 5 [12T]	3	2.489	450	391.98	142.669	4.272
Gear 6 [36T]	3.4	6.946	700	364	132.709	1.324
Gear 7 [24T]	1	6.946	580	546.923	199.064	1.324
Gear 8 [48T]	1.2	13.269	580	522.417	190.144	0.638
Gear 9 [48T]	1.2	12.922	580	508.74	185.166	0.621

Figure 1: Table from appendix C

The table above shows the summary torque calculated

Torsional shear stress

- We can state the *torsional shear stress formula* as:

$$\tau_{\max} = \frac{TC}{J}$$

$$J = \frac{\pi D^4}{32} \, (\textit{for solid bar})$$

τ = *applied Torque*

C = *radius* of the cross section

J = *Polar moment of ineratia of the cross* section

The above equation from "Mechanic of Materials" 11th edition, written by Russell C. Hibbeler will be used to determine shear strength

Shaft 1

Given yield strength of the shaft:

$$\sigma_{shaft\_1} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft1} := 5\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_1} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_1} := \frac{2 \cdot c_{shaft\_1}{}^4}{6}$$

$$J_{shaft\_1} = 2.13\ mm^4$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft1} := \frac{T_{max\_shaft1} \cdot c_{shaft\_1}}{J_{shaft\_1}}$$

$$\tau_{max\_shaft1} = 3.732\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 1 experienced torque:

$$T_{shaft1\_ex} := 0.941\ N \cdot m$$

Shaft 1 experienced shear stress:

$$\tau_{shaft1\_ex} := \frac{T_{shaft1\_ex} \cdot c_{shaft\_1}}{J_{shaft\_1}}$$

$$\tau_{shaft1\_ex} = 702.295\ MPa$$

Shaft 2

Given yield strength of the shaft:

$$\sigma_{shaft\_2} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft2} := 5\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_2} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_2} := \frac{2 \cdot {c_{shaft\_2}}^{4}}{6}$$

$$J_{shaft\_2} = 2.13\ mm^{4}$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft2} := \frac{T_{max\_shaft2} \cdot c_{shaft\_2}}{J_{shaft\_2}}$$

$$\tau_{max\_shaft2} = 3.732\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 2 experienced torque:

$$T_{shaft2\_ex} := 2.627\ N \cdot m$$

Shaft 2 experienced shear stress:

$$\tau_{shaft2\_ex} := \frac{T_{shaft2\_ex} \cdot c_{shaft\_2}}{J_{shaft\_2}}$$

$$\tau_{shaft2\_ex} = 1.961\ GPa$$

Shaft 3

Given yield strength of the shaft:

$$\sigma_{shaft\_3} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft3} := 5\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_3} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_3} := \frac{2 \cdot {c_{shaft\_2}}^4}{6}$$

$$J_{shaft\_3} = 2.13\ mm^4$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft3} := \frac{T_{max\_shaft3} \cdot c_{shaft\_3}}{J_{shaft\_3}}$$

$$\tau_{max\_shaft3} = 3.732\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 3 experienced torque:

$$T_{shaft3\_ex} := 2.489\ N \cdot m$$

Shaft 3 experienced shear stress:

$$\tau_{shaft3\_ex} := \frac{T_{shaft3\_ex} \cdot c_{shaft\_3}}{J_{shaft\_3}}$$

$$\tau_{shaft3\_ex} = 1.858\ GPa$$

Shaft 4

Given yield strength of the shaft:

$$\sigma_{shaft\_4} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft4} := 13\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_4} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_4} := \frac{2 \cdot {c_{shaft\_2}}^4}{6}$$

$$J_{shaft\_4} = 2.13\ mm^4$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft4} := \frac{T_{max\_shaft4} \cdot c_{shaft\_4}}{J_{shaft\_4}}$$

$$\tau_{max\_shaft4} = 9.702\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 3 experienced torque:

$$T_{shaft4\_ex} := 6.946\ N \cdot m$$

Shaft 3 experienced shear stress:

$$\tau_{shaft4\_ex} := \frac{T_{shaft4\_ex} \cdot c_{shaft\_4}}{J_{shaft\_4}}$$

$$\tau_{shaft4\_ex} = 5.184\ GPa$$

Shaft 5

Given yield strength of the shaft:

$$\sigma_{shaft\_5} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft5} := 15\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_5} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_5} := \frac{2 \cdot c_{shaft\_2}{}^4}{6}$$

$$J_{shaft\_5} = 2.13\ mm^4$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft5} := \frac{T_{max\_shaft5} \cdot c_{shaft\_5}}{J_{shaft\_5}}$$

$$\tau_{max\_shaft5} = 11.195\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 3 experienced torque:

$$T_{shaft5\_ex} := 13.269\ N \cdot m$$

Shaft 3 experienced shear stress:

$$\tau_{shaft5\_ex} := \frac{T_{shaft5\_ex} \cdot c_{shaft\_5}}{J_{shaft\_5}}$$

$$\tau_{shaft5\_ex} = 9.903\ GPa$$

Shaft 6

Given yield strength of the shaft:

$$\sigma_{shaft\_6} := 450\ MPa$$

Given maximum torque the shaft can withstand:

$$T_{max\_shaft6} := 15\ N \cdot m$$

Radius of the cross section:

$$c_{shaft\_6} := 1.59\ mm$$

Polar moment of inertia of a square shaft:

$$J_{shaft\_6} := \frac{2 \cdot {c_{shaft\_6}}^{4}}{6}$$

$$J_{shaft\_6} = 2.13\ mm^{4}$$

Maximum shear stress the shaft can withstand:

$$\tau_{max\_shaft6} := \frac{T_{max\_shaft6} \cdot c_{shaft\_6}}{J_{shaft\_6}}$$

$$\tau_{max\_shaft6} = 11.195\ GPa$$

The shear strength that the shaft will experience will be calculated using the torque it is experiencing from table 1

Shaft 3 experienced torque:

$$T_{shaft6\_ex} := 12.922\ N \cdot m$$

Shaft 3 experienced shear stress:

$$\tau_{shaft6\_ex} := \frac{T_{shaft6\_ex} \cdot c_{shaft\_6}}{J_{shaft\_6}}$$

$$\tau_{shaft6\_ex} = 9.644\ GPa$$