CHAPTER 4

DESIGN VOLUMERIC FAUCET PROTOTYPE

4.1 Find out purpose of prototype and plan

Proof-of-product prototype is build according to the selected concept. It is needed to know how feasibly this concept can work. Development proof-of-concept is the choice to answer the question.

The volumetric faucet prototype develop for proof-of-product and concept. Plan and purpose of the prototype show in table 4.1.

Name of prototype	Volumetric Faucet
Purpose	How relationship of volume and flow rate? How much turn on faucet handle torque require? How much torque of rdelease ratchet lock require? Proof working feasibility.
Quantity to be built:	1 sets of volumetric faucet
Outline of test plan:	Test in different flow rate vary from 1 - 10 litre/minute
Schedule	2 week for parts available 1 week for assemblies 1/2 week for tests competes 1 week for Analysis of results completed.

Table 4.1. Prototype purpose and plan development

Refer to the purpose of prototype, physical prototype will be developed from testing all of these purpose.

Primary mechanical theory is derived and calculated for designing and building prototype.

4.2 Design volumetric prototype

According to purpose of prototype and plan the data that need to collection from testing are torque of turn on, torque release ratchet, and relationship of flow rate and water volume flow through faucet. There are two parts of volumetric prototype need to analyses and design. The other parts are not focus at this time because it does not affect the purpose of prototype.

4.2.1 Torsion spring design

Because faucet needs energy to rotate ball valve back to close position, torsion spring is used to store this energy. Before starting to calculate torsion spring, it needs to know the moment to open ball valve. This data can get from ball valve testing refer to (Chonwilai, 1995) average moment to rotate ball valve is 0.238 newton-metre.

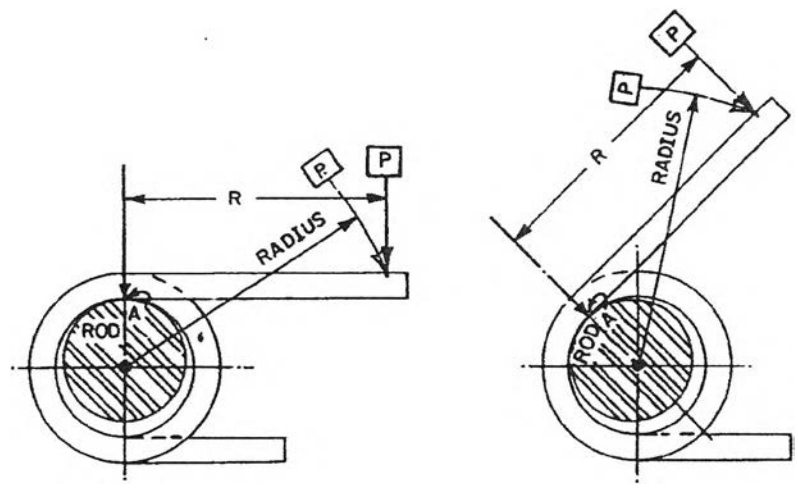

Figure 4.1 Force apply on torsion spring

Torque equation

$$T = P.R$$

T = Torque

P = Tangent force on spring

R = Length that perpendicular point P

According to formula of torsion spring (circular wire) show below (Waitl, 1987)

$$N = \frac{EdF^{o}}{392S_{b}D}$$

$$S_{b} = \frac{10.18T}{d^{3}}$$

$$ID = \frac{N(ID_{free})}{N + \frac{F^{0}}{360}}$$

$$D = ID + d$$

where,

d = Wire diameter (mm.)

E = Modulus of Elasticity (MPa)

S_{b} = Bending stress (MPa)

N = Number of active coils

F^{o} = Angle deflection

T = Torque = $P.R$ (N.mm)

ID = Inside diameter after deflection (mm.)

ID_{free} = Inside diameter before deflection (mm.)

Calculation step

1. Torsion spring stores energy from rotation faucet handle clockwise and from existing data averages rotation ball valve moment equal 0.2387 newton-meter

2. Requirement

   2.1 Number of active coils

   2.2 Inside diameter before deflection

   2.3 Spring thickness

3. Spring diagram

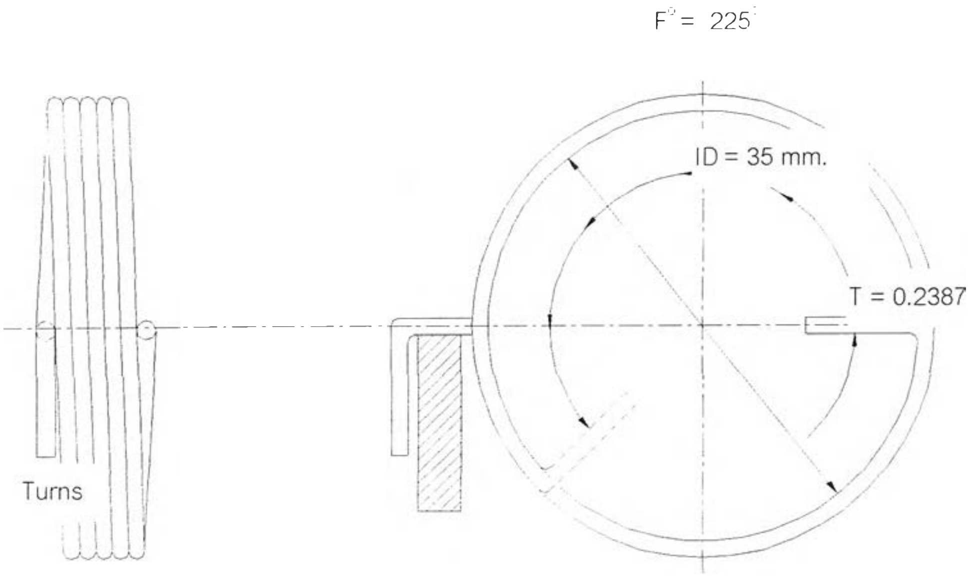

Figure 4.2 Free body diagram of torsion spring in volumetric faucet

4. Spring mater is music wire diameter 1.4 mm.

5. Basic assumptions

5.1 No friction force between spring surface

5.2 Center of rotation not change

5.3 Overestimate 30% to compensate imperfect build prototype

6. Analysis

6.1 Calculate bending stress (Mpa)

$$S_b = \frac{10.18 \times 0.31031 \times 1000}{1.4^3} = 1151.22 \text{ Mpa}$$

$$D = 35 + 1.4 = 36.4 \quad \text{mm.}$$

6.2 Calculate number of active coils refer modulus of elasticity of music wire diameter = 1.4 mm. from appendix B = 200,000 Mpa

$$N = \frac{200000 \times 1.4 \times 225}{392 \times 1151.22 \times 36.4} = 3.83 \quad \text{turns}$$

6.3 Torsion spring thickness equal diameter size time active coil turns = 1.4 x 3.83 = 5.362 mm.

6.4 Inside diameter before deflection (mm.)

$$ID_{free} = \frac{35(3.83 + \frac{225}{360})}{3.83} = 40.71 \quad \text{mm.}$$

4.2.1 Ratchet design

Ratchet working in 2 dimensions so the theory used in the calculation on considering force in 2 dimension. Refer on equilibrium of rigid body.

$$\sum F = 0 \qquad \sum M = 0$$

F = Force apply to rigid body (newton)

M = Moment (newton-metre)

$$M = r \times F$$

$$M = rF \sin\theta = Fd$$

Rigid body in 2 dimension equilibrium

$$F_z = 0 \qquad M_x = M_y = 0 \qquad M_z = 0$$

And

$$\sum F_x = 0 \qquad \sum F_y = 0 \qquad \sum M_o = 0$$

Calculation step

1. Gear moment (M_d) applied on outer gear counter clockwise till tip of inner gear attaches on ratchet mechanism. Moment of torsion spring (M_l) applied on pin of ratchet clockwise show in figure 4.3

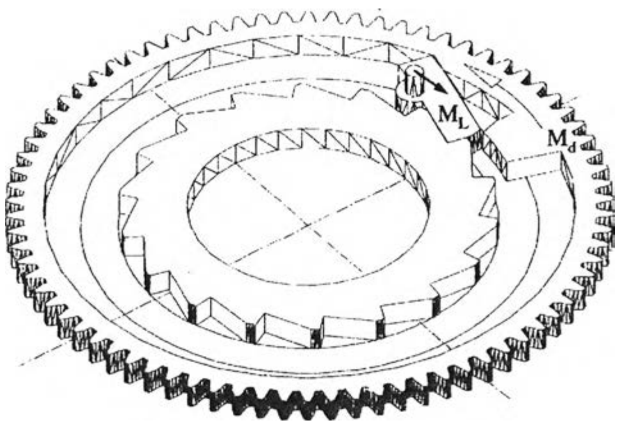

Figure 4.3 Drawing for ratchet gear

2. Requirement

Moment to release ratchet

3. Free body diagram and basic information

l_l = Perpendicular distance of F_l from ratchet lock tip to rotation center = 0.005 m.

l_{bp} = Perpendicular distance of F_{bp} from ratchet lock tip to rotation center = 0.006 m.

l_b = Perpendicular distance of F_b from ratchet lock tip to rotation center = 0.00034 m.

l_d = Perpendicular distance of F_d from ratchet lock tip to rotation center = 0.00026 m.

r = Distance from faucet center to center of ratchet lock = 0.017 m.

r_d = Distance from faucet center to position of F_d apply = 0.021 m.

μ = Friction coefficient taken from appendix C = 0.6

θ = Angle of ratchet pin = 77°

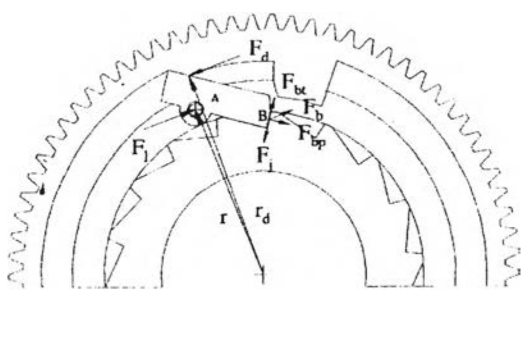

Figure 4.4 Free body diagram of gear and lock ratchet

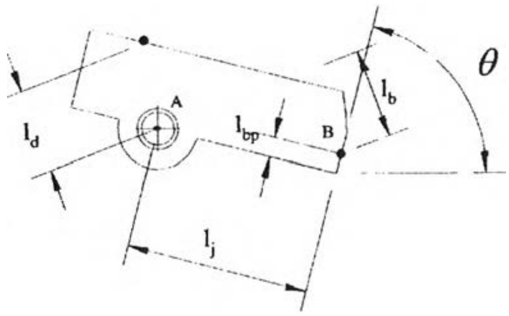

Figure 4.5 Free body diagram of lock ratchet

4. Basic assumption

4.1 No friction force between ratchet gear and hosting

4.2 Consider on 2-dimension force

4.3 Ignore force from spring apply to ratchet pin

4.4 Ignore stress in axis ratchet pin

5. Analysis

5.1 Moment of spring on ratchet

$$F = \frac{M}{r} = \frac{0.3103 N.m}{0.017 m} = 18.25 N$$

5.2 Transfer force from point A to point B and calculate F and moment M

$$F_b = 18.25 N$$

$$M_b = F_l \times l_b$$

$$M_b = 18.25 \times 0.00346 = 0.062 Nm.$$

5.3 Divide force around rotation point

$$F_{bt} = F_b \cos\theta = 18.25 \cos 77^\circ = 4.10 N$$

$$F_{bp} = F_b \sin\theta = 18.25 \sin 77^\circ = 17.78 N$$

$$F_l = \mu F_{bp} = (0.6) * (17.78) = 10.66 N$$

5.4 Moment around point A

$$F_d l_d - (F_j - F_{bt}) \cdot l_j - M_b - F_{bp} \cdot l_p = 0$$

$$F_d = \frac{(F_j - F'_{bt}) \cdot l_j + M_b + F_{bp} \cdot l_{bp}}{l_d}$$

$$F_d = \frac{(10.66 - 4.10) \cdot (0.005) + 0.062 + (17.78) \cdot (0.0006)}{0.0026}$$

$$F_d = 40.56N$$

5.5 Moment to release ratchet

$$M_d = F_d \times r_d$$

$$M_d = (40.56) \cdot (0.021)$$

$$M_d = 0.85N.m$$