Review on Effects of Various Geometrical Parameters on the Performance of External Gear Pump

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Abstract : *This paper reveals the study of effect of various parameters on the performance of the external gear pump along with its flow characteristics. The two externally meshed spur gears plays a very important role in proper functioning of the gear pump as per its designed performance. Hence, it is very important to control the various parameters of the gear. The effect of variation of such parameters like pressure angle, module, number of teeth, correction factor, span, etc. on the output of the gear pump is analyzed. Also, the graphs for such parameters are plotted against discharge of the gear pump, which is referred as flow characteristics of the gear pump. The performance characteristics of the gear pump for various parameters are also studied for the case having unequal number of teeth on each gear. With the increase in parameters such as module, no. of teeth, face width, the discharge of the gear pump increases. While, the discharge increases with increase in pressure angle upto certain value and then it decreases. As the flow pulsation factor decreases, discharge increases. Excessive axial and radial clearance beyond certain limit causes leakage, which reduces the discharge.*

***Index Terms* – External gear pump, Spur gear, Geometrical parameters, Discharge.**

I. INTRODUCTION

External gear pump consists of a pair of externally meshed spur gears, out of which one is the driving gear and the other is the driven gear. This pair of driving and driven gear is enclosed in a casing or body. The input to the gear pump is provided by means of rotations from shaft having splines, which is given to the driving gear. The casing of the pump consists of two ports, which allows the inlet and outlet flow of the hydraulic oil. As, the two externally meshing gears drives the whole system, they are the most critical components responsible for acquiring the designed optimum output of the gear pump, which is the flow rateVarious parameters of gear like, pressure angle, addendum, dedendum, PCD, span etc. which affects the flow rate of the gear pump, as the clearances in the internal body of the gear pump are in micro level. Hence, it is very necessary to control these parameters of the gear as per the design to achieve the designed output of the pump. The effects of such parameters on the output of the gear pump are of most importance, to maintain the optimal flow characteristics of the gear pump. This study reviews on the various parameters affecting the output of the externally driven gear pump consisting of unequal sizes of driving gear (Larger) and driven gear (smaller) with different number of teeth. Prof. Dr. Ahmed M. et.al[1] analysed the effect of gear geometry like change in module, no. of teeth, pressure angle, face width on the performance of gear pump is discussed. It concludes that, discharge increases with increase I module, no. of teeth and face width. Also discharge increases with increase in pressure angle up to certain value then decreases with increase in pressure angle. Xiaoru Hao. et.al[2] investigated the volume change law of trapped fluid in the meshing process and the flow characteristics of external gear pumps under the two cases: the pump design with and without relief grooves. It concludes that, in above both cases trapped volume decreases with increase in no. of teeth. Durmus Gunay.et.al[3] in the method of changing the pressure angle, tooth thickness is increased by increasing the pressure angle and resulting in decease of root stresses of tooth. From this, it is observed that, stress concentration increases with increase in addendum modification coefficients. Ahmed M. Saleem, et.al[4] the capability to use unstandardized gears and their effect on the performance of the gear pumps are investigated. These effects include pump flow rate, trapped volume between two meshing gears, and pulsation flow rate factor. This study concludes that, unstandard gear pump give higher flow rate than standard gear pump. Emiliano Mucchi, et.al[5] Effect of variations in operational parameters like output pressure, rotational speed and oil viscosity are analysed. Also effect of size of relief groove is discussed, larger the relief groove higher will be vibration. It concludes that, decrease in rotational speed, oil viscosity and increase in output pressure increases the eccentricity modulus of gear centre with respect to housing centre. Prof. C. Ragunathan, et.al[6] Effect of pressure speed and friction, also the influence of clearance in the hydrodynamic bearing and between tooth tip and pump case are discussed. This study concludes that, in order to increase the performance and to reduce vibration of gear pump the value of clearance must be optimum. E.A.P. Egbe, et.al[7] The design of pump considered with relevant theories and principles which affect the performance of the pump. This paper concludes that the discharge dropped with increase in pressure head due to increase in losses.

II. External Gear Pump

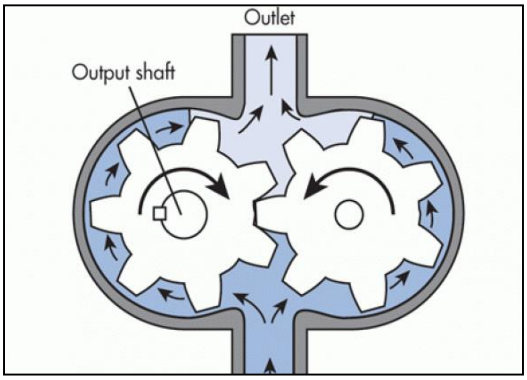

Fig.01. Working principle of external gear pumps

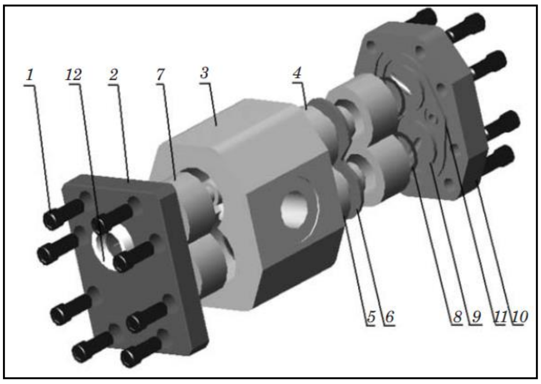

Fig.02. Components of external gear pump

Components:

Table 1 Components of the gear pump

1.Bolts	7. Bearing Sleeve
2. Front End Plate	8. Thrust Ring
3. Casing	9. Seal Under Driven Wheel
4. Driving Wheel (Drive Gear)	10. Rear Endplate
5. Driven Wheel (Idler Gear)	11. Large Seal
6. Resistance Filler	12. Shaft End Seal

III. Terminologies of External Spur Gear

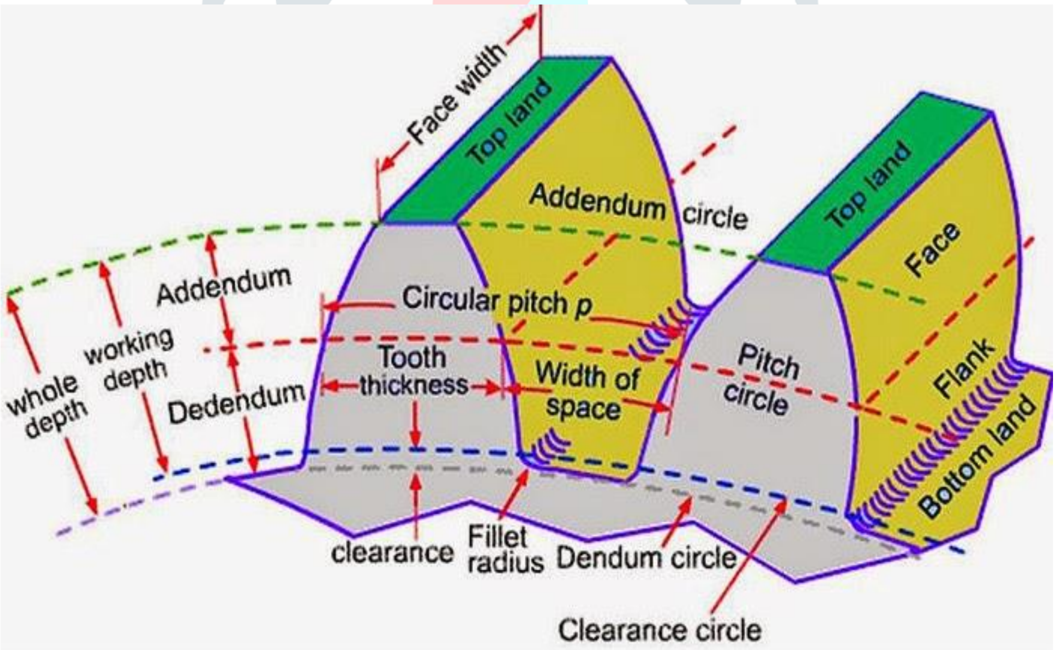

Fig.03. Terminologies of external spur gear

Nomenclatures related to gear parameters:

m=Module of gear in mm
D=pitch circle diameter in mm
Z=number of teeth
Q= Discharge in cm^3/rev
α= Pressure angle in degree
b= Face width in mm
x= correction factor

1. Pitch Circle diameter:

Pitch circle is the apparent circle that two gears can be taken like smooth cylinders rolling without friction. It is diameter of pitch circle. The size of gear usually defined by pitch circle diameter.

2. Addendum Circle diameter:

Addendum circle is the outer most profile circle of a gear. Addendum is the radial distance between the pitch circle and the addendum circle. Addendum circle is circle drawn through top of teeth which is concentric with pitch circle. It is diameter of addendum circle.

3. Dedendum Circle diameter:

Dedendum is the radial distance between the pitch circle and the dedendum circle. Dedendum Circle is circle drawn from bottom of teeth. It is diameter of dedendum circle.

4. Base circle diameter:

It is a circle from which the involute profile of tooth profile is generated.

5. Root circle diameter:

It is the diameter of circle at root of gear tooth spaces

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IV. EFFECT OF VARIOUS GEOMETRICAL PARAMETERS ON FLOW RATE OF GEAR PUMP

By studying research papers on the hydraulic gear pump, the effects of various geometrical parameters on the discharge of gear pump and which formula is used for that purpose are discussed below:

A. .Effect of module on discharge:

Module is the unit of size that indicates how big or small a gear is. It is ratio of pitch circle diameter to number of teeth on gear (m=D/Z).

Fig.04. indicates that discharge increases with increase in module at various number of teeth. If we increase module of both gears of pump then it affects the tooth depth and dimensions. Both combinations will lead to increase the spaces between the gears. More space between gears increase the discharge for same number of teeth. The calculation of amount of discharge for module 2mm to 16mm is given by the formula

$$Q = (3.64 \text{ to } 6.83)m^2 \quad ...(4.1)$$

i.e. if m=2 and number of teeth=8, then discharge is given by $Q=3.64*m^2= 14.56$ cm^3/rev.
if m=2 and number of teeth=10, then discharge is given by $Q=4.46*m^2=17.84$ cm^3/rev.

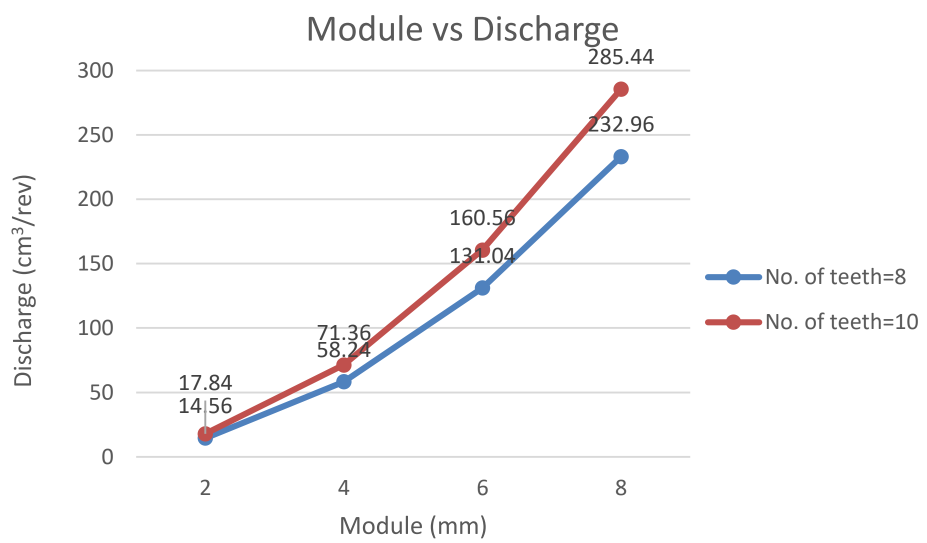

Fig 04: Effect on discharge with the change in module at various number of teeth

B. Effect of number of teeth on discharge:

It indicates the amount of number of teeth the gear has. It is indicated by z. To avoid phenomena, like under cutting of gear, it is suggested that number of teeth should be less than 17. Fig.05 indicates that the discharge increases with increase in number of teeth for all values of module. Increase in number of teeth, increases the space between adjacent teeth. According to this discharge per revolution is increase for same module value. The calculation of amount of discharge for number of teeth from 8 to 20 is given by formula

$$Q= (2.21 \text{ to } 20.46)z^{(0.895 \text{ to } 0.907)} \quad ...(4.2)$$

i.e. if z=8 and m=2, then $Q= 2.21*z^{0.895} = 14.21$ cm^3/rev.
if z=8 and m=4, then $Q=8.97*z^{0.9} = 58.28$ cm^3/rev.
if z=8 and m=6, then $Q= 20.46*z^{0.907} = 134.89$ cm^3/rev.

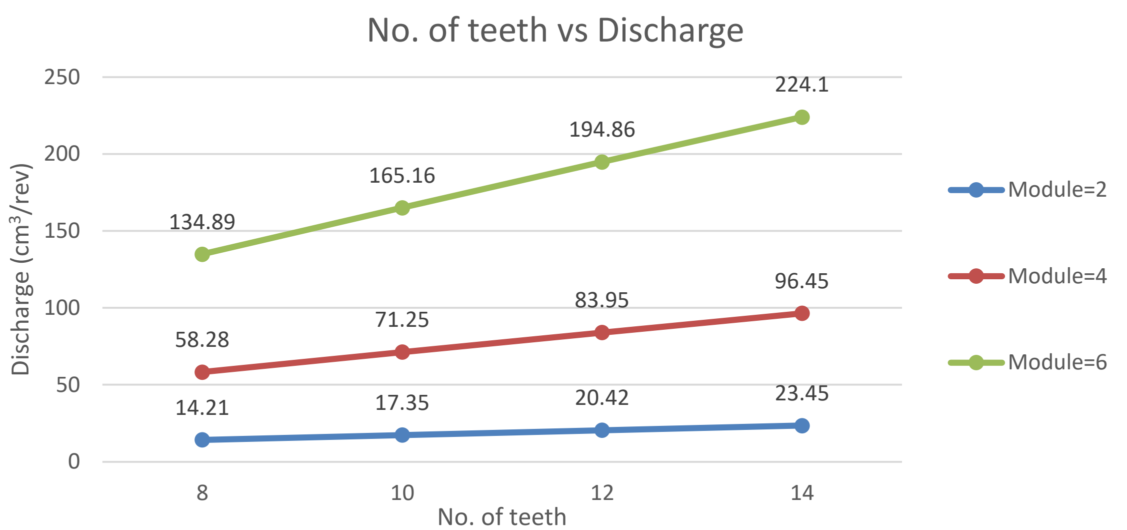

Fig 05: Effect of number of teeth on Discharge at different module

C. Effect of pressure angle on discharge:

Pressure angle refers to the angle through which forces are transmitted between meshing gears. The pressure angle gives the direction normal to the tooth profile. The pressure angle is equal to the profile angle at the standard pitch circle and can be termed the "standard" pressure angle at that point. Standard values are 14.5, 20 and 25 degrees. Increasing pressure angle improves the tooth strength also result in smaller base circle so more portion of tooth becomes involute thus can eliminate interference. Fig.06. indicates that the discharge increases with increasing pressure angle at different number of teeth. When pressure angle increases the radius of curvature of tooth get increased, resulting into increased area between addendum circle and base circle. Effect of pressure angle on discharge is up to a certain limit. Discharge increases with increase in pressure angle till 30^0 then it may decrease for further increase in pressure angle. With the increase in pressure angle, base circle radius decreases so area between base circle and root circle increases. The calculation of amount of discharge for pressure angle is given by formula

$$Q= (120.2 \text{ to } 240.6)e^{(0.0041 \text{ to } 0.0001)\alpha} \quad ...(4.3)$$

i.e. if $\alpha = 10$ and z=8 , discharge is given as $Q= 120.2*e^{0.0041\alpha} = 125.23$ cm³/rev.
if $\alpha = 10$ and z=10 , discharge is given as $Q= 149.6*e^{0.0031\alpha} = 154.31$ cm³/rev.

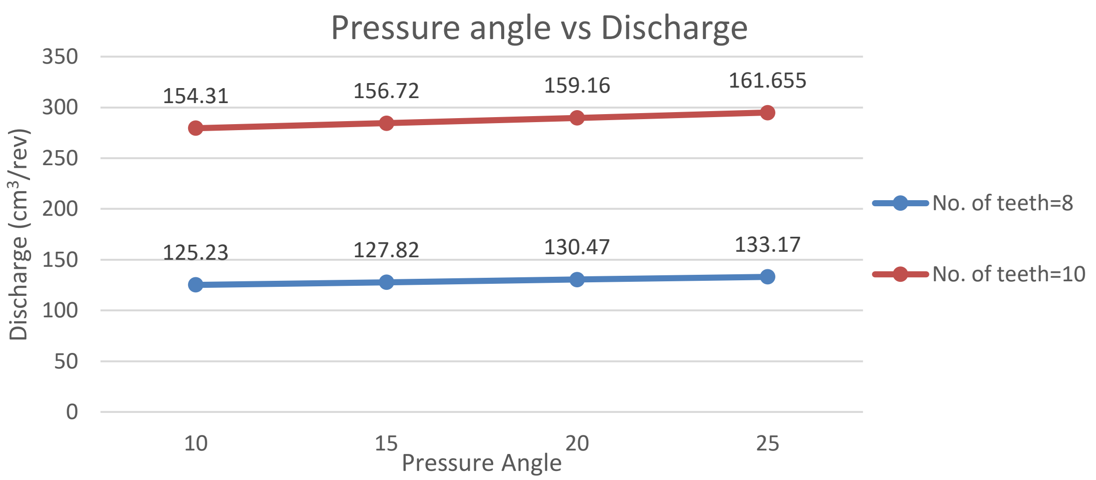

Fig 06: Effect of pressure angle on discharge at different number of teeth

D. Effect of face width on discharge:

The face width of a gear is the length of teeth in an axial plane. When the face width is too small, the gear has poor capacity to absorb the shock loads and vibrations. Further, teeth wear at a faster rate. Fig.07. indicate that discharge is increase with increase in face width at different number of teeth. This occurs due to more trapped volume of oil between teeth. The amount of discharge for face width 20 mm to 60 mm is given by formula.

$$Q = (2.2 \text{ to } 4.09)b \quad ...(4.4)$$

i.e. if b=20 and z = 8, the amount of discharge is given by Q = 2.2*b = 44 cm³/rev.

if b=20 and z= 10, the amount of discharge is given by Q= 2.67*b = 53.4 cm^3/rev.

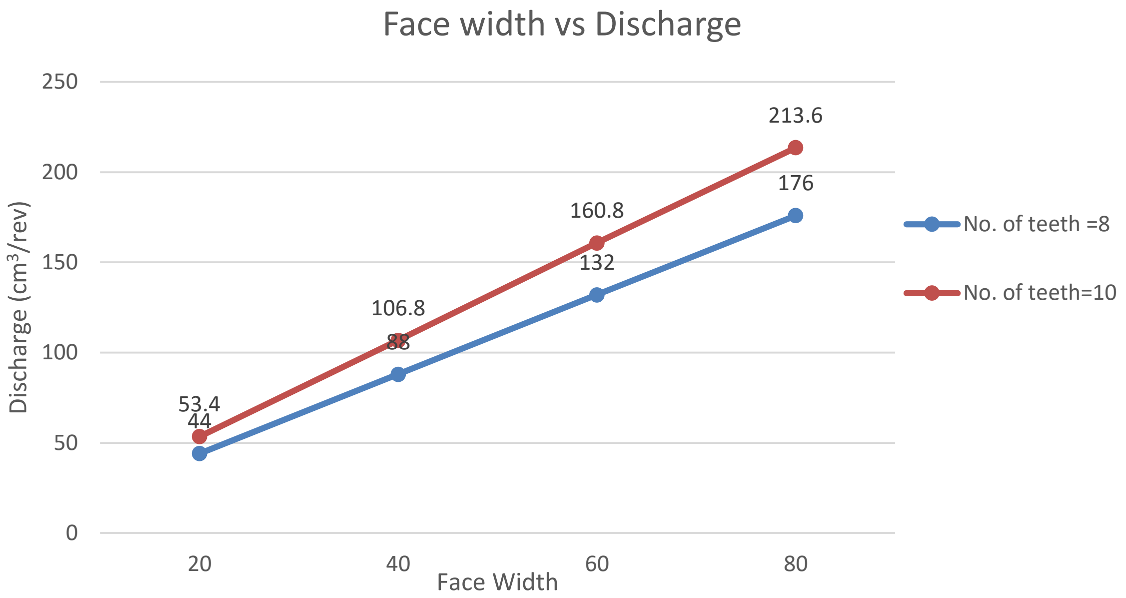

Fig 07: Effect of face width on discharge number of teeth at different number of teeth

E. Effect of correction factor on discharge:

Spur gear teeth are manufactured by either involute profile or cycloidal profile. When two gears are in mesh at one instant there is a chance to mate involute portion with non-involute portion of mating gear. This phenomenon is known as "interference" and occurs when the number of teeth on the smaller of the two meshing gears is less than a required minimum. To avoid interference we can have undercutting, but this is not a suitable solution as undercutting leads to weakening of tooth at its base. In this situation Corrected gears are used. In corrected gears, cutter rack is shifted upwards or downwards. There is both positive and negative shifting. There will be change in tooth thickness; In the case of positive shifting (+), tooth thickness will become thicker, while in the case of negative shifting (-), it will become thinner. The tooth depth will not change. It is observed that increase in positive correction factor increases the tip circle diameters of gears.

Fig.08. indicate that discharge increases with increase in positive correction factor with different number of teeth. Tip circle increases according to (mz+2m(1+x)). This increases space between adjacent teeth and discharge will increase. Appropriate value of Positive correction factor also leads to reduction in tooth deformation and increase in tooth stiffness. Correction factor generally with 0 and 0.5 combination gives optimum performance for discharge. The calculation of amount of discharge for correction factor is given by formula

$$Q = (123.74 \text{ to } 261.71)e^{(0.1585 \text{ to } 0.032)x} \quad ...(4.5)$$

i.e. if x = -0.2 and z = 8, then discharge is given by Q= $123.74*e^{(0.1585*x)}$ =119.87 cm^3/rev.
if x= -0.2 and z= 10, then discharge is given by Q= $151.90*e^{(0.113*x)}$ = 148.50 cm^3/rev.

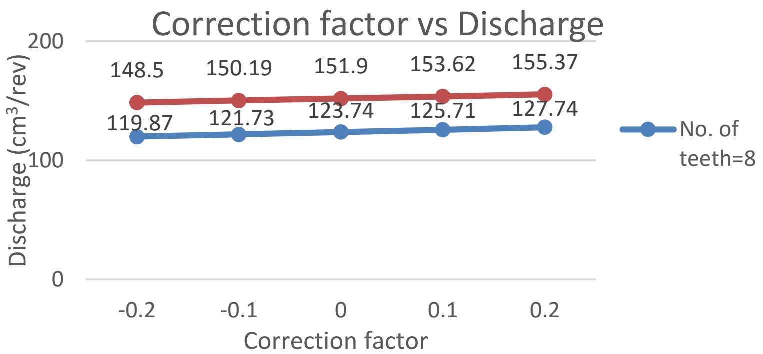

Fig 08: Effect of Correction factor on discharge at different number of teeth

F. Effect of relief groove on discharge:

An elongated groove is provided in the gear pump to equalize pressure, this groove is called relief groove. Relief groove is used to stop undesired material removal and melting of base material in meshing gears in case of excessive pressure. If pump does not have any relief groove, then discharge decreases with increase in number of teeth. Therefore, pump should have relief groove, this will increase discharge gradually. The designer has to reduce gear vibration then relief groove length has to be reduced but one can increase the length in order to increase volumetric pump efficiency.

G. Effect of aeration:

Excessive noise in a hydraulic system can be caused by the presence of air in the hydraulic oil. Introduction of air into the system can be the result of a leak in the suction line, air bubbles entrained in the oil, or insufficient pump or motor inlet flow which results in a vacuum. This increases the suction time of oil which decreases the flow rate per minute.

H. Effect of excessive inlet pressure:

When pump is operated at high temperatures, pressure is built up with increase in temperature. Sometimes inlet pressure goes out of rated pressure and system operated under high pressure and temperature are called as Excessive pressure. Pressure and hydraulic shocks are also responsible for pump failure. Pumps operating under a continuous load at high pressure and for extended periods are susceptible to premature wear and failure. Excessive pressure takes some time to suction of oil and hence less discharge is obtained per unit time. Forces are generated by outlet pressure and gear area causes deflection of gears. It starts the degradation of bushes and clearances will increase. This ultimately results into decrease in discharge due to leak from sidewalls.

I. Effect of slip:

Small amount of oil leakage from outlet port of hydraulic pump is nothing but Slip. This Slip is generally provided for lubrication purpose. The Slip is defined as the quantity of fluid which leaks through internal clearances of a pump per unit of time. But slippage increases the system pressure and leads to wear of casing parts.

The factors which influences on slip are Bore clearance, side clearance, oil viscosity, differential pressure. Therefore, less flow is coming out from outlet of pump and more goes to inlet or leak. Discharge reduces for increase in slip factors. Generally, 0.8 to 0.9 slip factor suitable for Pump Designs. This parameter is used in design of centrifugal pumps.

J. Effect of flow pulsation factor:

As gears rotate teeth carry constant discharge per revolution. Gear pumps can produce a high frequency pressure pulsation and thus increase of fluctuations of delivery flow 'flow rate ripples' in suction and impulsion chambers, which tends to damage pressure gauges. Vibration in the pump leads to generate pulses. This flow pulsation amplitude disturbs constant flow rate at the output of pump.

As the number of teeth increases, flow pulsation factor decreases and efficiency of pump increases. With greater efficiency pump can delivered expected rated pressure. Flow pulsation is more in spur gear pumps as compared to helical and herringbone gear pumps.

Flow pulsation can be find out by

$$Q_{sh} = \frac{1}{2} B\omega_1 [2R_1(h_1 + h_2) + h_1^2 + h_2^2 \frac{R_1}{R_2} - (1 + \frac{R_1}{R_2}) f^2] \qquad \text{...(4.6)}$$

Where,

R= the reference radius,

ω= angular velocity of the driving gear,

H= the tooth height,

B= the width of the gear teeth,

f= the distance between meshing and pitch point.

K. Effect of clearance modification on discharge:

Clearance may define as the small gap between mating body parts and rotating parts. While manufacturing of any parts clearances are must for smoothing of operation between parts. Clearance is very crucial and important factor when we design pump flow rate. There are two types of clearances i.e. radial and axial.

Clearances are different when the gears are rotating and stationary in case of pump. At the stationary position of gears of pump as the nominal clearance increases, stationary position of centres comes closer as well as eccentricity between centres increase. As distance between parts vary, gears stars rotating eccentrically and runout goes increasing. This will lead to removal of material from body and effect on discharge of pump. Generally, value of nominal clearance between tip of teeth and casing kept as 0.0245 mm.

V. CONCLUSIONS:

From this study, the effect of various parameters affecting the performance of the gear pump is reviewed. The graphs for various geometrical parameters are plotted against the discharge of the pump, by evaluation of the formulated data. Thus, the variations of certain parameters on the discharge of the pump are as follows:

1. With the increase in module or number of teeth, the discharge increases.
2. The discharge increases with the increase in pressure angle upto a pressure angle 30^0, and then it decreases for further increase in pressure angle
3. Increase in parameters like, face width or positive correction factor increases the discharge of the gear pump
4. Presence of relief groove on the pump body, increases the efficiency of the pump by delivering the fluid or oil at the desired flow rate
5. With the increase in certain undesirable operating parameters like, aeration, excessive inlet pressure, slip causes a decrease in discharge of the pump, which fails to perform as per its rated output
6. The flow pulsation factor decreases with the increase in number of teeth, which increases the efficiency and hence the discharge of the gear pump.
7. The values of radial or axial clearances beyond specified limits, causes leakages in pump. This reduces the flow rate by affecting the performance of the gear pump

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