AUTOMATIC HIGH R.P.M. MACHINE

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Abstract- This paper intends to give proposal, reasoning and quantifiable result of an AUTOMATIC HIGH R.P.M. MACHINE which can be used to obtain very high rpm. A very low constant rpm is given to the machine as input and after some time as output a very high rpm is obtained. The output may be of very high RPM, but it has very low torque. Epicyclic gear train is used with three planet gears one sun gear. A crank and slotted lever assembly is also mounted on the top of Epicyclic gear train to automate and precipitate the process. A ratchet and pawl assembly is playing a very critical role in transferring only the allowed motion in high RPM machine friction is needs to be as low as possible this machine can be solution for very high RPM requirements when cost of such high RPM motor is prohibitive. Motion study in solidworks is also in the scope of this paper.

Key Words- High rpm machine, Epicyclic gear train, Ratchet and pawl. Crank and slotted lever mechanism

I. INTRODUCTION

The appellation “AUTOMATIC HIGH RPM MACHINE” stands for a combination of Epicyclic gear train and crank and slotted lever mechanism connected through ratchet and Paul assembly. An input of low RPM and high torque is given in the crank of crank and slotted lever assembly and after some time the output of the arm of Epicyclic gear train is obtained as of very high RPM and low torque. Usually, Epicyclic gear train require two inputs (one for sun gear and one for its arm), but in this case it only one input, which is given through crank and other generates by itself. Its working principle is based on highly unbalanced centrifugal force which creates angular displacement in the arm of gear train.

II. SPUR GEARS

Spur gears [1] are the most common type of gears. They have straight teeth, and are mounted on parallel shafts. Spur gear teeth are manufactured by either involute profile or cycloid profile. Most of the gears are manufactured by involute profile with 20° pressure angle. A pair of planet and sun gear is shown in Fig. 1 in which both are meshed.

There specifications are:

<table>
<thead>
<tr>
<th>Gear Type</th>
<th>Pitch Circle Diameter</th>
<th>Dedendum Circle Diameter</th>
<th>Addendum Circle Diameter</th>
<th>Base Circle Diameter</th>
<th>Module</th>
<th>Number of Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun Gear</td>
<td>20 mm</td>
<td>19.36 mm</td>
<td>22 mm</td>
<td>18 mm</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Planet Gear</td>
<td>40 mm</td>
<td>38.72 mm</td>
<td>42 mm</td>
<td>38 mm</td>
<td>1</td>
<td>40</td>
</tr>
</tbody>
</table>

\[
R = \frac{\omega_s - \omega_c}{\omega_a - \omega_c}
\]

\(\omega_s\) = Angular velocity of sun gear
\(\omega_a\) = Angular velocity of planet gear
\(\omega_c\) = Angular velocity central arm

Gear ratio \(R = \frac{\text{Number of teeth of planet gear}}{\text{Number of teeth of sun gear}} = 2\) (1)

III. EPICYCLIC GEAR TRAIN

A typical Epicyclic gear train consists of two gears mounted so that the centre of one gear revolves around the centre of the other. An arm connects the centres of the two gears and rotates to carry one gear, called the planet gear, around the other, called the sun gear. The planet and sun gears mesh so that their pitch circles roll without slip. Sun gear has a...
stationary centre while planet gear has a moving centre and its position depends on rotation of arm. A point on the pitch circle of the planet gear traces an epicycloid curve.

Epicyclic gear train has a distinct quality i.e. it can achieve variable gear ratio. It requires two rotation input, one is for the sun gear and second is for the arm. Both input can be changed according to user and gear ratio of this gear train is dependent upon combining effect of angular velocities of sun gear and arm. Epicyclic gear train used in this assembly is shown in Fig. 2, in this all three planet gears are meshed with a common sun gear on the same plane and are connected with a common arm.

IV. CRANK AND SLOTTED LEVER MECHANISM

It is the third inversion of a four bar link mechanism in which third link is fixed and crank is rotated about its revolute pair which has completed rotational motion. The other side of the crank is connected with slider (B1 or B2). Slider is constraint to move in reciprocating motion, or vice-versa. Geometry of this mechanism is shown in fig. 3. This mechanism has a very good mechanical advantage. It has two strokes (B1DB2) and return stroke (B1EB2). When the time required for the working stroke is greater than that of the return stroke, it is crank and slotted lever quick return mechanism.

Crank has constant angular velocity motion while slotted lever motion has varying angular velocity motion. In working stroke, angular velocity is low while in return stroke is angular velocity is quiet high. Time ratio of the mechanism is given as

\[
\frac{\text{Time of forward stroke}}{\text{Time of backward stroke}} = \frac{360 - \alpha}{\alpha}
\]

V. RATCHET AND PAWL MECHANISM

A ratchet consists of a round gear or linear rack with teeth, and a pivoting, spring loaded finger called a pawl that engages the teeth. The teeth are uniform but asymmetrical, with each tooth having a moderate slope on one edge and a much steeper slope on the other edge. When the teeth are moving in the unrestricted (i.e., forward) direction, the pawl easily slides up and over the gently sloped edges of the teeth, with a spring forcing it (often with an audible 'click') into the depression between the teeth as it passes the tip of each tooth. When the teeth move in the opposite (backward) direction, however, the pawl will catch against the steeply sloped edge of the first tooth it encounters, thereby locking it against the tooth and preventing any further motion in that direction. This assembly is shown in Fig. 4.

ASSEMBLY

Assembly 3-D representation is shown in Fig. 5. This assembly is designed and assembled on solidworks. It has four spur gears each having their module as one, three of which are planet gear and one is sun gear. Planet gears are meshed with sun gear with a gear ratio of 2. Sun gear is installed in the central shaft of the assembly having only one degree of freedom as it can rotate in z axis only. Planet gears are mounted on an arm which can also rotate about same axis. On this arm, mounting points of planet gears are at a 120 degree angular difference suspended at centre of the assembly i.e. arm is rotational symmetric at 120 degree. Shaft of each gears is keyed to with their respective gears such that there is no relative motion between gears and their respective shaft. Each planet gear is free to rotate in their own axis and about central axis of the assembly. Epicycle gear train normally needs two inputs of rotation but in this assembly only sun gear needs input. Input for the arm is generated by centrifugal force due to rotation of dead masses placed on each planet gear.

Dead mass are attached on each planet gears equally on both side as shown in Fig. 5. When the planet gear rotates about their own axis dead mass produces some centrifugal force. Dead masses are placed in this
assembly in such a way that summation of their centrifugal forces will provide a constructive effect so that arm can attain high angular velocity in some span of time and this angular velocity will increase continuously as sun gear rotates.

VI. WORKING

The purpose of this analysis is to prove that a continuously increasing angular velocity with non-uniform acceleration can be obtained after some span of time from this assembly as output which has a non-accelerating low angular velocity as input. A low angular velocity, high torque motor is installed on the top of assembly. This motor is directly coupled with the crank and slotted lever mechanism which rotates it with a low rpm input. Output is the angular velocity of the arm. When the crank is in the region of reverse stroke, ratchet and pawl are engaged which led to high speed rotation of sun gear and its shaft. Ratchet and pawl will only remain attach till the half time of reverse stroke i.e. when crank will coincide with the connecting rod. At this point slotted lever will attain maximum speed, after this point ratchet loses mesh with pawl and then retardation starts due to some non-conservative forces. Till next reverse stroke ratchet, central shaft and sun gear will rotate due to their combined inertia. If the input is too low, then in each rotation of crank angular rotation of sun gear decreases due to friction loss in working stroke. Then in second engagement the sun gear achieves its high speed again, this sudden increment in speed will cause jerks in the motion and they are not good for the assembly.

Therefore input should not be very low. If the input is too high, then in each rotation angular velocity of sun gear decreases very less. Therefore there are very less accelerations due to which the assembly will not achieve high speed output in short span of time. This means that input rpm neither should be very less nor it should be very high.

When the sun gear starts moving, with some accelerations and retardations, the planet gears meshed with it starts rotating. With the rotation of planet gears, dead masses on them also rotate. Each mass creates some centrifugal force in its normal direction and by their combined constructive effect a net centrifugal force generates which starts the rotation arm. In each reverse stroke, there is some acceleration in the rotation of planet gears which subsequently increases the centrifugal force of each planet gear and angular velocity of arm. Due to this, the angular velocity of arm will increase continuously with some non-uniform acceleration. But, after attaining a certain angular velocity, arm’s increment in angular velocity for more increment will be countervailed by friction loss of arm. After this point, the output angular velocity will remain constant. Placing the dead weights with respect to the centre of assembly is very important as their position will decide the acceleration magnitude.
After some consideration masses are placed as they are shown in Fig. 7. By this kind of arrangement arm will attain maximum centrifugal force to rotate in very less time.

**ANALYSIS**

Design of crank and slotted lever is shown in Fig. 8. Length of connecting rod is 10 units and length of crank is 9 units. It is shown in the figure that $\alpha/2$ is 25.84 degree.

Therefore, $\alpha = 51.68$ degree

Time ratio: 5.97

More the time ratio, more the relative speed attained in reverse stroke than in working stroke.

Fig. 9 is showing three graphs on one plot i.e. input angular velocity to the crank, angular velocity of slotted lever and angular acceleration of slotted lever (Y axis). Each plot is drawn with respect to time of one revolution of crank (X axis). Scale of Y axis of each plot is different, but they all have a common X axis. Graph in Fig. 9 manifests that there is an apogee in the angular velocity of slotted lever and angular acceleration of slotted lever at the same time. Till this point pawl and ratchet are locked with each other, but after this point pawl speed reduces and it slides freely on ratchet. Analysis is done for first five minutes of the motion only, in which output will increase continuously till it reaches its maximum value. After that, output will have a constant speed. Fig. 10 shows the plot of absolute angular velocity of a planet gear in first five minutes of motion.

Its absolute angular velocity has 2 parts i.e. angular velocity of planet gear with respect to central axis of assembly and angular velocity of planet gear due to its own rotation. Plot of angular velocity of arm (output) of first five minutes of motion is drawn in Fig. 11. Its pattern is almost similar to angular velocity of planet gear (Fig. 10)

Plot of angular acceleration of arm is shown in Fig. 12. All of these plots gives the pattern of output of the assembly. This wave like variation is due to the constantly changing direction of centrifugal force of arm.
CONCLUSION

By analysis it is proved that such an automatic high rpm machine is possible which does not need constant attention but a constant low speed high torque input. If crank and slotted lever mechanism is not installed then high rpm of arm will never be achieved or will be achieved after very long time. Design of crank and slotted lever mechanism is very important as it only decides the magnitude of an accelerating output (angular velocity of arm) from a non-accelerating input. Property of a moving body of being in its state of inertia and centrifugal force are key components of this analysis.

This analysis concludes that centrifugal force of dead mass of each planet gear constitutes in the rotation of arm and this force will increase continuously with respect to time which led to continues increase in velocity of arm till the increment of angular velocity in each rotation is counterbalanced by frictional forces of arm. Same direction of centrifugal forces of dead masses are also necessary so that a constructive effect of all can be achieved as output.

FUTURE SCOPE OF RESEARCH

Solidworks motion study have shown that such the concept is possible. Feasibility of this concept to what extent in practical conditions still needs to be tested. Another addition in this research could be the impact of variation of factors on motion like gear ratio, dead mass weight and planet gear radius etc. Also, a control feedback loop with a velocity feedback and a servo-motor can be installed to maintain the speed of arm in the desired range.

APPLICATIONS

• In situations where very high rpm is needed and torque is not a requirement.
• Where prohibitive cost of high speed motors cannot be accommodated.
• In CNC machines.
• In milling machine.

ASSUMPTIONS

• Friction is as less as possible.
• Carbon steel is used as metal for the whole assembly.
• There is no vibration in any part of assembly.
• Stress and strain in assembly is not considered.

REFERENCES