HANDS ON LAB : ME 371

HOW THINGS WORK : PULL BACK CAR

PROJECT MEMBERS:

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PROJECT REPORT:

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INTRODUCTION

It started at the age of five , when we used to play with this toy,we pulled it,we pushed it ,we threw it,we crushed it and sometimes we even slept with it .And now fourteen years hence, we are looking at the same object but in an entirely different perspective.The pull back car is one of the most common childhood toys , with which almost all of us must have played.The car , when pulled backward by some distance on a surface and left goes forward a distance greater than the backward one , but the reverse does not happen.This mechanism is also employed in the toys driven by keys but with a slight difference.The basic cause and effect are the same.
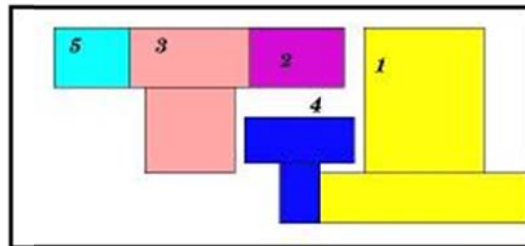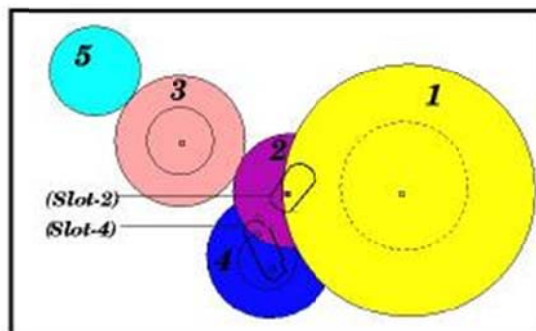
COMPONENTS

The mechanism consists of five gears , and a torsional spring whose engagements in the normal position are shown in the figure given below.

GEARS

The specifications of the gears are given below.The subscripts "a" and "b" represent parts of the same gear with different radii and hence different number of teeth , where "a" refers to the part with larger number of teeth.

GEAR 1 :

- **Status : Fixed**
- **Connected to : Torsional Spring**

1. **1a:**
   - **No. of teeth - 40**
   - **Connected to - Gear 4b(always)**
2. **1b:**
   - **No. of teeth - 14**
   - **Connected to - Gear 2(backward motion)**

GEAR 2 :

- **Status - Movable(in slot 2)**
- **No. of teeth - 10**
- **Connected to -**
  - **Gear 1b(backward motion)**
  - **Gear 3a(always)**

GEAR 3 :

- **Status - Fixed**

1. **3a :**
   - o **No. of teeth - 12**
   - o **Connected to -**
     - ▪ **Gear 2(always)**
     - ▪ **Gear 5(always)**
2. **3b :**
   - o **No. of teeth - 10**
   - o **Connected to -Gear 4a(forward motion)**

GEAR 4 :

- **Status - Movable**

1. **4a :**
   - o **No. of teeth - 19**
   - o **Connected to - Gear 3b(forward motion)**

2. **4b :**
    o **No. of teeth - 10**
    o **Connected to - Gear 1a(always)**

GEAR 5:

- **Status - Fixed**
- **Mounted on shaft connecting the rear wheels**
- **No. of teeth - 9**
- **Connected to - Gear 3a(always)**

TORSIONAL SPRING

- **Spiral**
- **connected to - Gear 1**

REAR WHEEL SHAFT

- **Connects the two rear wheels.**
- **Has Gear 5 attached to it**

MATERIAL OF COMPONENTS

GEARS

The gears are made up of a thermosetting plastic.This material has its advantages that it is lightweight , and has a high stiffness which are the essential requirements for this usage.Besides for such an accuracy ,it is very cheap as compared to other gear materials like steel etc.

TORSIONAL SPRING

The torsional spring is spiral in nature , and is made up of spring steel.this material is quite stiff for the present usage.

REAR WHEEL SHAFT

The shaft is made up of mild steel and is about 2mm in diameter.The material has its advantage over other probable elements that it does not buckle or twist at this diameter.

MECHANISM

The mechanism is basically a GEAR TRAIN mechanism.It can be divided into three modes:

- Normal or the No-Working mode
- Backward or Input mode
- Forward or Output mode

NORMAL OR NO WORKING MODE

This is the mode in which no energy storage or release occurs in the spring.That is to say that none of the movable gears , namely Gear 2 and Gear4 experience any tangential force and are present in the no force positions,that is the normal positiins in their slots.The gear connections can be written as:

- GEAR 5 - GEAR 3a - GEAR 2
- GEAR 1a - GEAR 4b

The Normal mode is shown in the figure given below:
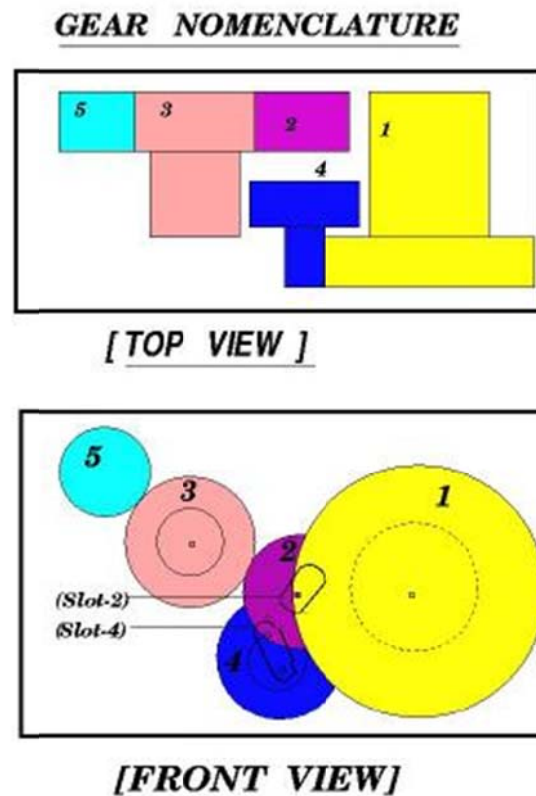
This mode also explains why the car does not return when moved in the forward direction.Here the Gear connections as shown above indicate that moving the forward causes only gears 5, 3 and 2 to move.Also the force exerted on Gear2 by Gear3 is antiparallel to the orientation of its slot,so it does not get connected to Gear 1. hence no energy storage in the spring,and so no backward motion.
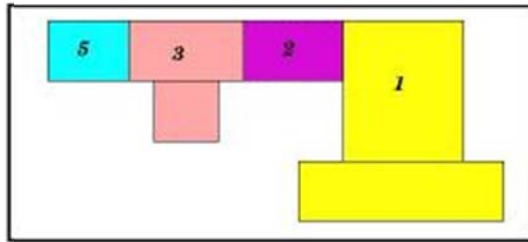

BACKWARD OR INPUT MODE

This is the ENERGY STORAGE mode.The Gear train in this mode can be written as:
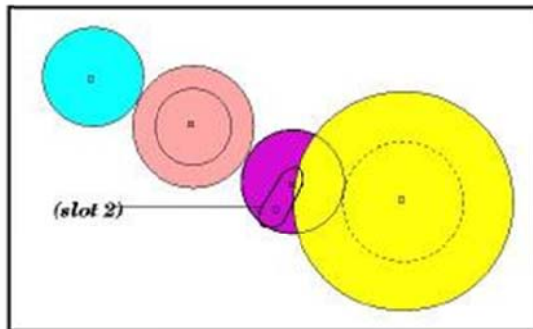
- GEAR 5 - GEAR 3a - GEAR 2 - GEAR 1b

The backward gear train is as shown below:

BACKWARD GEAR TRAIN

[TOP VIEW]

[FRONT VIEW]

The tyres are rubbed against a surface in the backward direction.Now ,due to the no slip condition the tyres start rotating.The rotation is being viewed from such a direction that the tyres move clockwise in this view.Gear 5, which is connected to the rear wheel shaft also starts rotating clockwise.Now Gear 3a,which is meshing with Gear 5 starts rotating in the counter-clockwise direction.This gear is meshed with Gear 2 ,and so Gear 2 rotates clockwise.Also in this mode, Gear 3 exerts tangential force on Gear 2 in the direction of orientation of Gear 2's slot so that under this force Gear 2 moves in its slot and changes its axis and so gets connected to Gear 1b.So Gear 1b rotates counter-clockwise .Now as it is connected to the spring the spring twists and energy is stored in it.

It is important to note that Gear 4 is connected to Gear 1.But it does not form a part of the Gear Train.Gear 1 exerts a force on it , but the direction of the force is perpedicular to the antiparallel to the direction of orientation of slot 4.So it does not move in the slot and does not get connected to Gear 3.It does rotate,which is due to its meshing with Gear 1 , but does not serve any purpose in this motion.
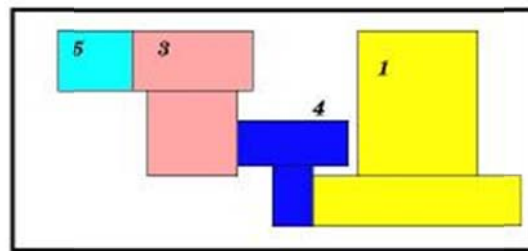

FORWARD OR OUTPUT MODE

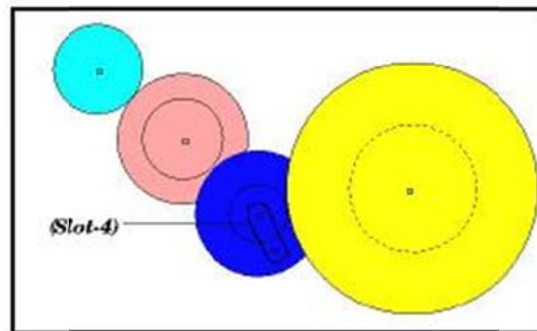This is the ENERGY RELEASE mode .The Gear Train can be writen as:

- GEAR 1a - GEAR 2b / GEAR 2a - GEAR 3b / GEAR 3a - GEAR 5

The forward gear train is as shown below:

FORWARD GEAR TRAIN

[TOP VIEW]

[FRONT VIEW]

Once sufficient energy is stored,the car is left on the surface. The spring in this stage is in a twisted(deflected) state.Hence it tries to restore its natural shape.As it does so,being in connection with Gear 1,rotates it clockwise.This is meshed with Gear 4a , so Gear 4 starts rotating counter-clockwise.Also, Gear 1 exerts a tangential force on Gear 4 in a direction parallal to the direction of orientation of slot 4.Gear 4, under this force moves in its slot and changes its axis , thereby gets connected to Gear 3b through 4a.Thus Gear 3 rotates clockwise , and since it is connected to Gear 5 through Gear 3a , Gear 5 starts rotating counter-clockwise.Gear 5 is attached to the shaft joining the rear wheels.So the wheels rotate and the car moves forward.Also after the spring regains its original shape,Gear 1 and Hence Gear4 stop moving,and gear 4 gets disconnected from Gear 3.But the car moves forward some more distance because of momentum stored in it.Then the connections after the spring has regained its shape are that of the normal mode.

Here again it is important to note that though in this case Gear 2 is connected only to Gear 3b and does not form part of the train.As soon as the car is left after the input motion , the force on Gear 2 due to Gear 3 changes sign and is now in a direction antiparallel to orientation of slot 2.So Gear 2 gets disengaged from Gear 1 an moves back in its slot to its normal position.It does rotate due to its engagement with Gear 3b ,and like Gear 4 in the backward motion does not serve any purpose.

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GEAR RATIO

BACKWARD RATIO

(Rotation of Spring/Rotation of Gear 5)=

$(n5/n3a)*(n3a/n2)*(n2/n1b)=$

(n denotes no. of teeth in the gear)

$(9/12)*(12/10)*(10/14)=$

(9/14)

FORWARD RATIO

(Rotation of Gear 5/Rotation of spring)=

$(n1a/n4b)*(n4a/n3b)*(n3a/n5)=$

$(40/10)*(19/10)*(12/9)=$

(152/15)

OVERALL RATIO

Forward Ratio * Backward Ratio=

$(152/15)*(9/14)=$

6.5

This value of overall ratio nearly equal to 6.5 shows that for one rotation of the tyre in the backward direction,the tyres of the car rotate 6.5 times and hence the car moves 6.5 times the distance travelled in the backward direction.This clearly explains why the car goes a larger distance in the forward direction.

IMPROVEMENT IN DESIGN

As we have analysed, it is quite an efficient system within itself.Possible improvements in design are based on increasing the gear ratio. The possible improvements are:

1. **Either the no. of teeths on gear 1(b) should be decreased or the no. of teeths on gear5 should be increased in order to increase the gear ratio in backward motion.**

2. In the gears having two radii the ratio of teeths on (a) vs (b) should be increased as it will improve the gear ratio in forward motion.
3. By insertion of another gear between gear3 and gear4 having two different radii with (a) in contact with (b) will improve the gear ratio in forward gear train by no. of teeths on (a) divided by the no. of teeths on (b).In this case the position of gears will change.