Creative Design of Three-speed Automatic Speed Changer

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Abstract

The bicycle is constantly being updated in order to meet market needs, the developing trend of bicycle shifting gear has changed from manual shifting fashion into automatic shift fashion. In this paper, a systematic approach is proposed to synthesize the design concept of the three-speed automatic speed changer. In this paper, we accord to the design concepts of planetary gear trains with two degrees of freedom, which are proposed by Hong-Sen Yan and Long-Chang Hsieh. By applying the TRIZ creative design method to centrifugal clutch, one-way clutch, and brake, 10 kinds of creative design concepts of three-speed automatic speed changer was created. The results not only can serve as a teaching tool for creative design courses, but also can provide as a reference to industrial circles for development of the three-speed automatic speed changer of bicycle, electric motorcycle, and electric scooter.

Keywords: automatic speed changer, planetary gear trains, centrifugal clutch, one way clutch, TRIZ creative design.

I. Preface

How well the bicycle speed shift mechanism is designed usually has influence on the performance and comfort of the bicycle. Over time, the bicycle has gradually adopted the automatic shift fashion by following the path of a motorcycle or automobile. By referring to such related patents as those on the external speed changer, internal shifting back axle, and bicycle automatic shift [1-26], and the studies on planetary gear trains construction analysis and synthesis [27-42], we form the following ideas: (1) most bicycle external speed changers now available adopt the parallel four-bar linkage as the main body of shifting; (2) most bicycle internal speed changers now available adopt planetary gear trains as the main body; (3) as to the internal speed changer, both SHIMANO and SACHS use the sun gear (engaging or separating) that controls the planetary gear train to obtain the shifting effect; (4)SHIMANO obtains the shifting effect by turning around the central axis; whereas SACHS obtains the effect of shifting control by pulling or pushing the central axis; (5) as to the external speed changer, most devices obtain the shifting effect by controlling the parallel four-bar linkage; (6) the bicycle automatic speed changer device can obtain the effect of automatic shift by using the mechanical device with centrifugal clutch or by using central process unit (CPU) with speed sensor and torque sensor.

By referring the related patents and literature above, we select the fairly simple planetary gear trains as the reference basis of designing the three-speed self-shifting gear mechanism. It has also used the TRIZ creative design method as the basis of designing the creative program of the bicycle three-speed automatic speed changer. This is according to the planetary gear trains design concepts, proposed by Yan, Hong-Sen and Hsieh, Long-Chang [27-28]. The results not only can serve as a teaching tool for creative design courses, but also can provide as a reference to industrial circles for development of the three-speed automatic speed changer of bicycle, electric motorcycle, and electric scooter.

II. Basic Concepts

1. The composing elements of bicycle speed changer

The bicycle speed changer can be divided into chain-driven external speed changer and internal speed changer. The external speed changer in turn is divided into front external speed changer and back external speed changer. A complete speed changer needs to contain the speed changer entity, shifting control device and shifting steer device.

(1) The speed changer entity: that part inside the speed changer in charge of transmitting the power while the bicycle is running is called the main body of speed changer. The chain-driven external speed changer is comprised of three parts, i.e. front chain wheel group, chain, and back chain wheel group. These provide different kinds of speed changer, including ten speed, twelve speed, fourteen speed, fifteen speed, sixteen speed, eighteen speed, twenty-one speed, twenty-four speed, and twenty-seven speed. The internal speed changer may be divided into three speed, four speed, five speed, seven, twelve speed, and so on.

(2) The shifting control device: this is used in controlling the operation of each gear position of bicycle speed changer entity, (shifting control device). It is not responsible for transmitting the driving power, usually located inside or nearby the speed changer entity. The chain-driven external speed changer contains the front chain-shifting mechanism and back chain-shifting mechanism. The internal speed changer, including the control mechanism inside the axle, is divided into the following: revolving model and translating model, and revolving plus translating model. The control mechanism of SACHS twelve

speed changer [4], as shown in Figure 1, is a translating control device. It uses the shifting line to control the draw rod and pushing rod so as to allow the clutch bind or separate.

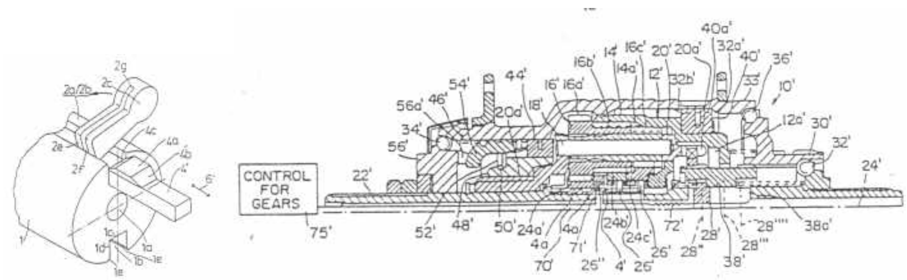


Figure 1: The control mechanism of SACHS twelve speed changer [4]

(3) The shifting steer device: this is used to steer the shifting control device and does not transmit the driving power. It is usually installed in a position far away from the speed changer entity, and can use the shifting line or other means to connect with the shifting control device. As to the internal and external speed changers, there are two shifting types, manual and computer. Manual shifting includes the shifting line and revolving handle. Computer shifting uses CPU to control the shifting control device.

Separate studies can be made on the three parts of speed changer entity, shifting control device and shifting steer device when designing a bicycle, before combining them into a complete bicycle speed changer. The compatibility between each other should be taken into consideration. Generally speaking, the speed changer entity and shifting control device of different types of bicycle speed changer are usually not exchangeable.

2. Bicycle speed changers now available

(1) The chain-driven external speed changer

The chain-driven external speed changer is usually divided into front external speed changer and back external speed changer and may contain the following components:

(a) The front external speed changer can be fixed on the bicycle frame, while the back external speed changer is fixed on the back wheel central axis.

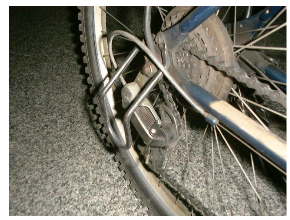
(b) Parallel four-bar linkage is used to change the chain guide and the back guide pulley position.

(c) The chain wheel group is installed on the pedal central axis and the back wheel central axis. It revolves around this central axis to transmit the driving power to the chain and bear the driving power transmitted by the chain.

(d) One or several groups of control devices, such as the parallel four-bar linkage, skid rail apparatus and other devices are used to achieve the purpose of changing the speed ratio.

In Figure 2(a), the bicycle front external speed changer is shown, and in Figure 2(b), the bicycle back external speed changer is shown. Both of these make use of a parallel four-bar linkage. This is controlled by the shifting line, which causes the guide pulley and the chain guider to move, shift the position of chain, further drive the chain, and change the reduction ratio.

(a) Front external speed changer



(b) Back external speed changer

Figure 2: Chain-driven external speed changer

(2) The internal speed changer

The internal speed changer may contain the following components:

(a) One central axis can be fixed on the bicycle frame.

(b) One driving unit is installed on the central axis, revolving around it to transmit the rider's drive.

(c) One planetary gear train is installed on the central axis to provide the shifting of all kinds of speed ratios.

(d) One output unit is installed on the central axis, revolving around it to bear the drive power transmitted by the planetary gear train and pass it to the wheel.

(e) There are several groups of clutch that can separate or joint the driving unit, output unit, and a certain component of the planetary gear train.

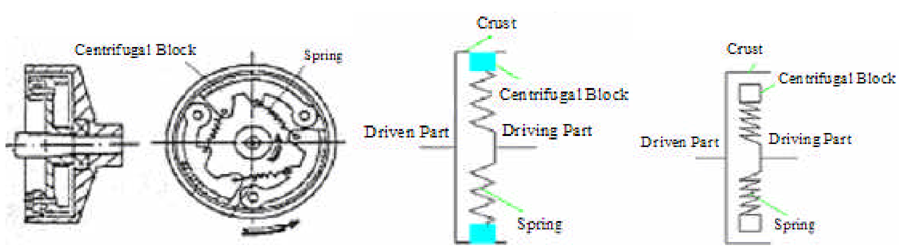
(f) One shifting control device is used to control the clutch (or brake) for the purpose of shifting the speed ratio.

3. Automatic speed changer

Generally speaking, the automatic speed changer includes the shifting control devices (centrifugal clutches), planetary gear train, clutches (including one way clutch), brakes, and so on. The centrifugal clutch can be roughly divided into two categories: (1) radial motion centrifugal clutch, shown in Figure 3, (2) axial motion centrifugal clutch, respectively shown in Figure 4. The radial motion centrifugal clutch plays the role of engaging or divorcing by using the centrifugal block to make the radial motion, respectively shown in Figures 3(b) and 3(c). The axial motion centrifugal clutch makes use of axial displacement caused by the additional weight movement, as shown in Figures 4(b) and 4(c). Due to speed change, the centrifugal clutch draws or pushes the shifting control device to realize the purpose of automatic shift.

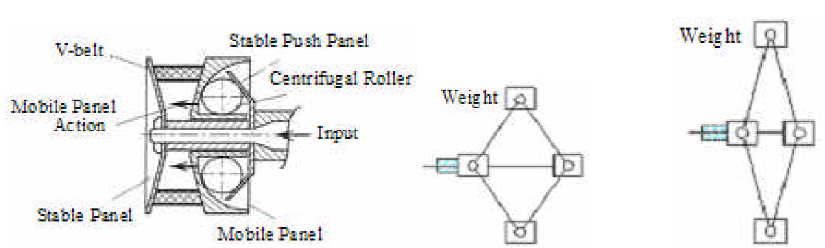
(1) Motorcycle automatic speed changer

The motorcycle automatic speed changer can be divided into step speed changer and continuously variable speed changer. In turn the step speed changer can be divided into the fixed-axle gear type and the planetary gear type according to the gear train mechanism used in it. The automatic step speed changer uses the centrifugal clutch inducting the engine speed to change the gear position. The automatic speed changer is composed of several clutches, brakes and shifting control device and its whole operating process uses the clutch (or brake) to automatically change the reduction ratio. Thus provide the motorcycle with better maneuvering. Most of the continuously variable speed changers adopt rubber V-belt devices. Their structures and working principles will be illustrated individually in the following.



(a) Structural Drawing (b) Engaging state (c) Separating state

Figure 3: Radial motion centrifugal clutch

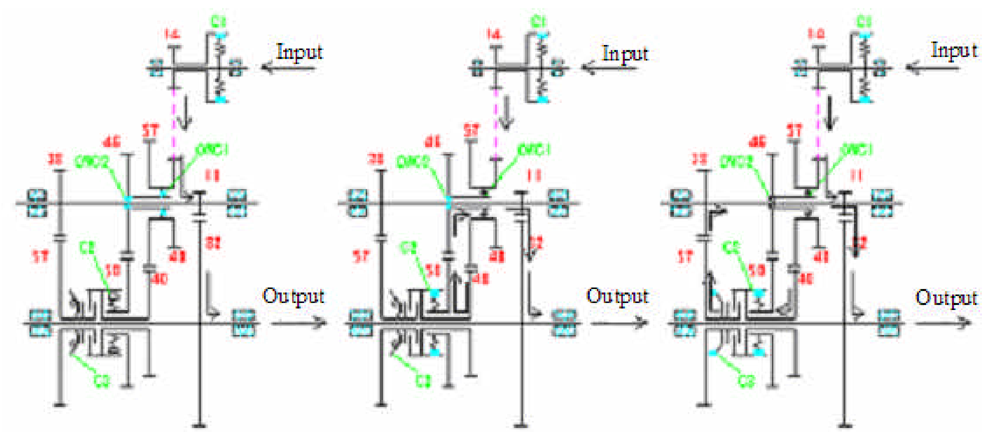


(a) Structural Drawing (b) Low Speed (c) High Speed

Figure 4: Axial motion centrifugal clutch

(a) Fixed-axle gear type automatic speed changer

The fixed-axle gear type automatic speed changer is also called the parallel-axle gear type automatic speed changer. This kind of automatic speed changer is composed of an ordinary gear train and several clutches (including one-way clutches). Shown in Figure 5 is the sketch map of the fixed-axle gear type, three-speed, and automatic speed changer. When the engine rotation speed reaches the preset level, the first clutch C1, one-way clutch OWC1, and one-way clutch OWC2 are engaged. The driving power is then transmitted by 14T chain wheel via the chain to 40T chain wheel of the secondary axle. It is then output via 11T gear from the fixed axle of 82T gear, and its reduction ratio is 21.298. With the boosting of the engine speed, clutch C2 also engages, but the one-way clutch OWC1 separates. The driving power is then transmitted to the output axle by the chain device via the one-way clutch OWC2 and three gear groups. Its reduction ration is 13.75. If the engine speed is again increased, the clutch C3 engages, but the one-way clutch OWC2 also separates. The driving power is transmitted to the output axle by the chain device via the clutch C3 and three gear groups, and its reduction ratio is 9.96.

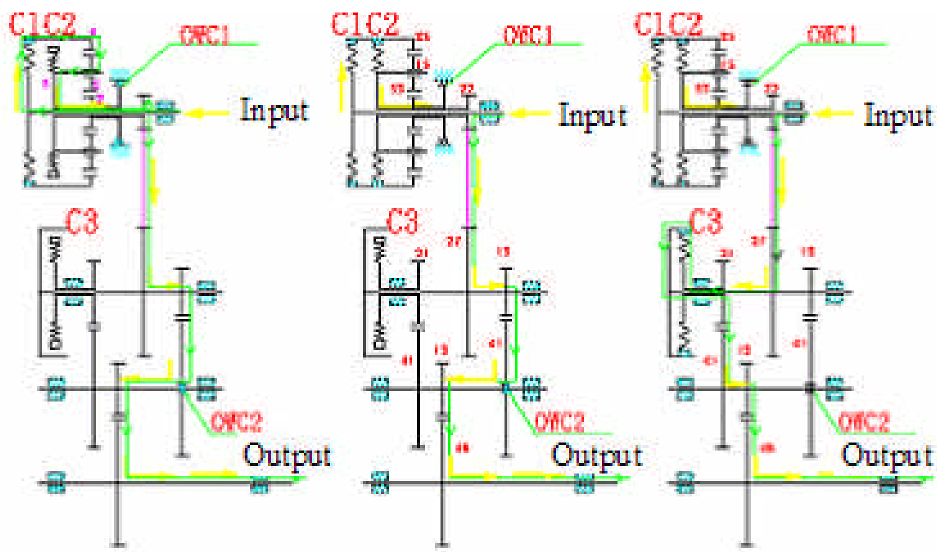


(a) First gear (b) Second gear (c) Third gear

Figure 5: The fixed axle type, three-speed, and automatic speed changer

(b) Planetary gear type three-speed automatic speed changer

The drive system of the planetary gear type automatic speed changer is composed of planetary gear trains and several clutches (including one-way clutches). Shown in Figure 6 is the sketch map of the planetary gear type three-speed automatic speed changer. When the engine speed reaches the preset level, the clutch C1, one-way clutch OWC1, and one-way clutch OWC2 are engaged. The sun gear of planetary gear trains is then fixed by the one-way clutch OWC1. The driving power is transmitted to the chain device via the ring gear, planet gear, and arm of the planetary gear train. It follows on to the output axle via the one-way clutch OWC2 and two reduction gear sets, its reduction ratio is 22.236. With the boosting of engine speed, the clutch C2 also engages, but the one-way clutch OWC1 separates. The sun gear of planetary gear train is then locked. The driving power is transmitted to the chain device via the planetary gear train, then to the output axis via the one-way clutch OWC2, and two reduction gear sets, and its reduction ratio is 13.696. If the engine speed is increased again, the clutch C3 engages, but the one-way clutch OWC2 separates. The driving power is transmitted to the chain device by the planetary gear train, then to the output axle via the clutch, C3 and two reduction gear sets, and its reduction ratio is 8.478.



(a) First Gear (b) Second Gear (c) Third Gear

Figure 6: The locomotive three-speed automatic speed changer

(c) V-belt type continuously variable speed changer

Shown in Figure 7 is the working principle sketch map of a V-belt type continuously variable speed changer. On the belt pulley respectively of the drive axle and the driven axle is a mobile panel, the motion of which causes the application pitch circle's diameter of the V-belt pulley to be changed. When the drive belt is in low speed or the driven is under high load, the system will be placed in the state of high reduction ratio. Yet, on the contrary, when the engine speed increases or the load lowers, the system reduction ratio will continually change with the changing of the mobile panel position. The reduction ratio tends to be low. Shown in Figure 7 is the sketch map of the drive axle belt pulley mechanism of the motorcycle CVT shifting system. Here the mobile panel plays the role of inducing the engine speed with the centrifugal roller and moving. When the drive axle rotation rate increases, the centrifugal roller applies an axial force on the mobile panel. It causes the application pitch circle diameter of the drive axle belt pulley to enlarge, and make the system tend towards low reduction ratio. As a result, it raises the motorcycles running speed. The mobile panel plays the role of inducing the load with the torsion cam mechanism shown in figure 8. When the load increases in the running process, the axial force applied by the mobile pane twisting cam, plus the relationship of speed difference between the mobile panel and the stable panel, will force the mobile panel to move inwards. Thus causing the application pitch circle diameter of the driven axis belt pulley to enlarge, so the system tends to have a high reduction ratio and balance with the load, causing the motorcycle maintain the original rotate and run smoothly.

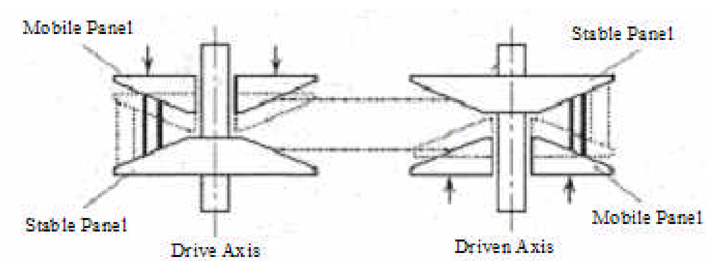


Figure 7: The working principle of a V-belt step-less speed changer

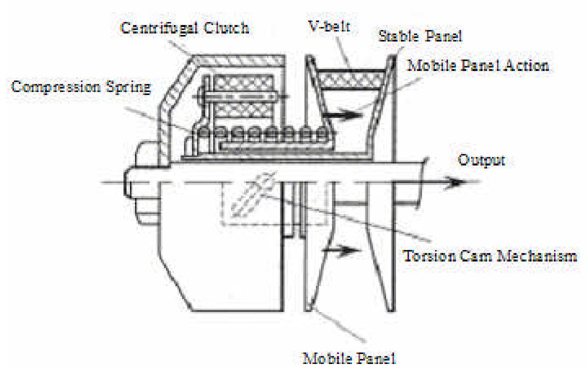


Figure 8: The driven axis belt pulley mechanism

4. Clutch and brake

The five-bar planetary gear trains with two degrees of freedom are shown in Figure 9. The brake must be used to fix one of the planetary gear train, turning the planetary gear train into a mechanism with one degree of freedom. The actuation of a clutch must also be used to realize the function of shift. Considering the space and cost, most motorcycles use the one-way clutch as a brake and the centrifugal clutch to induce the engine speed and load and change the reduction ratio.

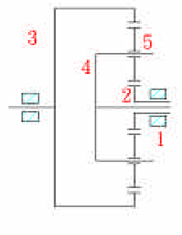
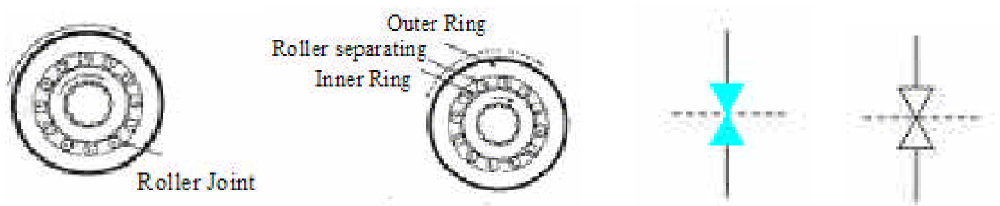


Figure 9: The five-bar planetary gear trains

Shown in Figure 3(a) is the construction drawing of a centrifugal clutch which is composed of the clutch crust, centrifugal clutch blocks and clutch springs. The input axle and output axle are respectively connected with the clutch's centrifugal clutch blocks and crust. Thus make use of the centrifugal force caused by the clutch rotation to transfer the drive to the driven axle. Since the centrifugal clutch determines the opportunity for engaging according to the magnitude of centrifugal force, in design via the clutch's centrifugal clutch block weight and the coefficient of clutch spring, the opportunity for the clutch to engage can be determined. The shift opportunity is controlled by the engine speed. In this paper Figure 3(b) is included to show the centrifugal clutch in the engaging state, whereas Figure 3(c) is included to show the centrifugal clutch in the separate state.

Shown in Figure l0(a) is the construction drawing of a one-way clutch (OWC), composed of an inner ring with a slanting flange, an outer ring, and several rollers placed between the inner ring and outer ring. If the one-way clutch inner-ring is the driving part, the outer ring is the driven part. When the inner-rings rotation speed is larger than that of the outer ring, the roller will move to the high end of the inner ring, slanting flange. Thus causing the inner ring, outer ring, and roller of the one way clutch to join in one, and transferring the driving power from the inner ring (driving part) to the outer ring (driven part), as shown in Figure 10(a). When the inner-ring rotation speed is lower than that of the outer ring or has stopped, the roller will move the lower end of the inner ring, slanting flange. Thus cause the inner ring, outer ring and roller that have surpassed the clutch to separate. The outer ring can then rotate freely in the same direction (or make circular movements) as shown in Figure 10(b). In this paper Figure 10(c) is included to show the one-way clutch in engaging state; Figure 10(d) the one-way clutch in separate state. Moreover, if the outer ring (or inner ring) is fixed with the machine frame, the inner ring (or outer ring) will be locked and used as a brake.



(a) Structural Drawing 1 (b) Structural Drawing 2 (c) Binding state (d) Separating state

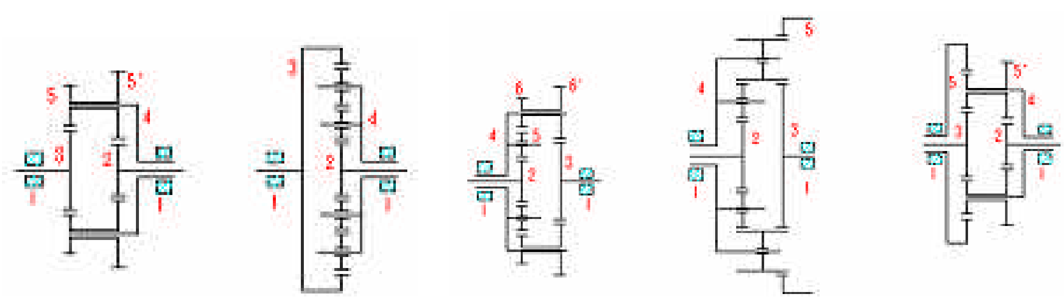
Figure 10: One-way clutch

III. Creative Design of Automatic Speed Changer

In this paper, we make use of the planetary gear trains now available so as to pick out the better planetary gear trains design concepts. Also, combine with the one-way clutch and the centrifugal clutch and by applying the TRIZ method, to conceive the creative concepts of three-speed automatic speed changer.

1. The design concepts of planetary gear trains

There are numerous concepts about planetary gear trains, but in this paper, we chose the fairly simple design concepts to act as the reference basis for our design of the automatic speed changer. According to the design concept of planetary gear trains with two degrees of freedom conceived by Hsieh & Yan [27-28], the five planetary gear trains shown in Figure 11 are chosen. Different input bar, fixed link, and output bar are adopted, and the centrifugal clutch is collocated, including one-way clutch and brake, to obtain the automatic shift function. Figure 11(a)~(b) is a five-bar planetary gear train with two degrees of freedom, and Figure 11(c)~(e) is a six-bar planetary gear train with two degrees of freedom. We have also referred to bicycle internal speed changers, motorcycle automatic speed changers, and the automobile automatic gearboxes now available to make an innovative design of the three-speed automatic speed changer.



(a) (b) (c) (d) (e)

Figure 11: Five planetary gear trains

2. The design constraints

After deciding on the planetary gear mechanism, the conceptual design can be carried out on the automatic speed changer. On conceiving the feasible design concept, the design constrains of the three-speed automatic speed changer should be taken into consideration, so as to make the composed mechanism to meet requirements. The three-speed automatic speed changer in this paper has the following design constrains:

(1) It must possess the automatic shift function that can replace computer control, which belongs to mechanical automatic shift mechanism.

(2) It needs to possess three-speed automatic shift function.

(3) Its automatic internal speed changer can be divided into (a) front internal speed changer: its foot-board axle can be connected with the shift mechanism's input axle; (b) back internal speed changer: it is fixed on the central axle of back wheel.

(4) The centrifugal clutch needs to adjust its elasticity setting value and control its tossing order.

(5) Considering the effect of output axle, the characteristic of one-way clutch is that the fast one-way clutch acts as the output; considering the effect of input axle, the slow one-way clutch acts as the input.

3. TRIZ fundamental theory and creative design concept

With the development of science and technology, the life cycle of any industry has been drastically shortened. With fierce competitive pressure, new products are constantly put on the market. One of the most important subjects in industrial circles has become, how to research and develop rapidly, new products which are low cost, high quality, and innovative. The twenty-first century is a century of creative products, and so only by updating the products constantly can an enterprise maintain its competitiveness and obtain profits. In order to attain the objective of promoting product quality, shortening research and development time, and reducing cost, it has become an important means to apply the creative design method.

In 1946, Russian scientist G. Altshuller proposed the TRIZ method after analyzing four hundred thousand patents. From numerous patents, Altshuller came to a conclusion: a creative problem contains at least one contradiction. The creator need not read all the patent papers; he can make improvements by merely putting the problem into a contradiction table [43-44]. Therefore, the contradiction matrix has become well known when finding creative solutions that are mostly often adopted. By means of analysis and induction, Altshuller obtained 39 engineering parameters of technical contradictions that are commonly met with, as shown in

Table I. These will be turned into a contradiction matrix when the corresponding solving theorems are arranged into a matrix. On the contradiction matrix axis of ordinate, is the feature that want to be improved. On the axis of abscissa, is the feature that does not want to be worsened. Imagine that when the designer wishes to improve the feature A, feature B worsens, however, via the contradiction matrix [45], he can quickly find creative principles to solve the problem, as shown in Table II. The creative principle is one paragraph of illustrative narration, which guides the direction for the designer to solve the problem. The 40 principles are shown in Table III.

Table I. 39 Parameters

1. Weight of moving object	14. Strength	27. Reliability
2. Weight of non-moving object	15. Durability of moving object	28. Accuracy of measurement
3. Length of moving object	16. Durability of non-moving object	29. Accuracy of manufacturing
4. Length of non-moving object	17. Temperature	30. Harmful factors acting on object
5. Area of moving object	18. Brightness	31. Harmful side effects
6. Area of non-moving object	19. Energy spent by moving object	32. Manufacturability
7. Volume of moving object	20. Energy spent by non-moving objects	33. Convenience of use
8. Volume of non-moving object	21. Power	34. Repairability
9. Speed	22. Waste of energy	35. Adaptability
10. Force	23. Waste of substance	36. Complexity of device
11. Tension, pressure	24. Loss of information	37. Complexity of control
12. Shape	25. Waste of time	38. Level of automation
13. Stability of object	26. Amount of substance	39. Productivity

Tables II. Contradiction Table

Undesired Result / Feature to Change		1	...	13	...	39
		Weight of moving object	...	Stability of object	...	Productivity
1	Weight of moving object			1,35, 19,39		
...	...					
39	Productivity					

Tables III. 40 Principles

1. Segmentation	11. Beforehand cushioning	21. Skipping	31. Porous materials
2. Taking out	12. Equipotentiality	22. 'Blessing in disguise'	32. Color changes
3. Local Quality	13. 'The other way around'	23. Feedback	33. Homogeneity
4. Asymmetry	14. Spheroidality	24. 'Intermediary'	34. Discarding and recovering
5. Merging	15. Dynamics	25. Self-service	35. Parameter changes
6. Universality	16. Partial or excessive actions	26. Copying	36. Phase transitions
7. 'Nested doll'	17. Another dimension	27. Cheap short-living	37. Thermal expansion
8. Anti-weight	18. Mechanical vibration	28. Mechanics substitution	38. Strong oxidants
9. Preliminary anti-action	19. Periodic action	29. Pneumatics and hydraulics	39. Inert atmosphere
10. Preliminary action	20. Continuity of useful action	30. Flexible shells and thin films	40. Composite material

According to planetary gear trains now available, we pick out the better planetary gear trains design conception. In collocation with the one-way clutch and centrifugal clutch, we have designed the three-speed automatic speed changer. In this paper, we adopt the technological contradiction table solution in the TRIZ theory so as to construct the design problem of three-speed automatic speed changer into a technological problem. Attempt to discover the plans that meet the creative design need. First we will apply the engineering parameters to be improved and those not wanted to be worsened into the contradiction table. According to these parameters the contradiction table is arranged into a matrix, which will provide 1201 problem solutions. Each of these solutions can be worked out according to one of the 40 principles sorted by Altshuller from numerous patents. If the parameters are not similar to those 39 engineering parameters in the contradiction table, they will be transformed into the similar parameters. This will show the appropriate creative theory to carry out creative amelioration. When the sought principles are empty from the contradiction matrix, the parameters wished to be improved and those that do not wish to be worsened have to be defined again so as to find out other creative principles.

In this paper, we apply such principles as transformation, replacement, and combination in TRIZ creative design method, by which we have created 10 types of innovative three-speed automatic speed changer.

(1) Plan 1

Shown in Figure 6 is the motorcycle three-speed automatic gear changer with planetary gear train. This plan will to some extent change the locations of its one-way clutch and centrifugal clutch. It will enlarge the original two gear positions of the planetary gear train to a three-speed automatic speed changer that possesses three automatic gear positions. The parameter 1 [weight of moving object] wished to be improved and the parameter 13 [stability of object] not wanted to worsen will be defined. The contradiction table will be used to find out principles 1,19,35,39, whose contradiction matrix is shown in Table II. The principles cited in the matrix are the ones that have been most popular for solving the problem, in this plan, we adopt principle 35 (transformation of physical and chemical states of an object) to find the solution, as a result of which the design plan is obtained in Figure 12. The actuating maps of these three gears are shown in Figure 13(a), Figure 13(b), and Figure 13(c).

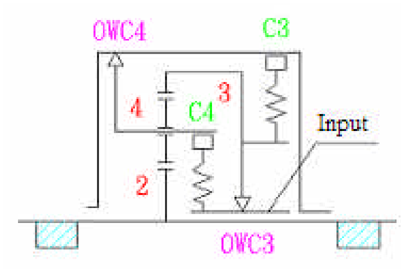
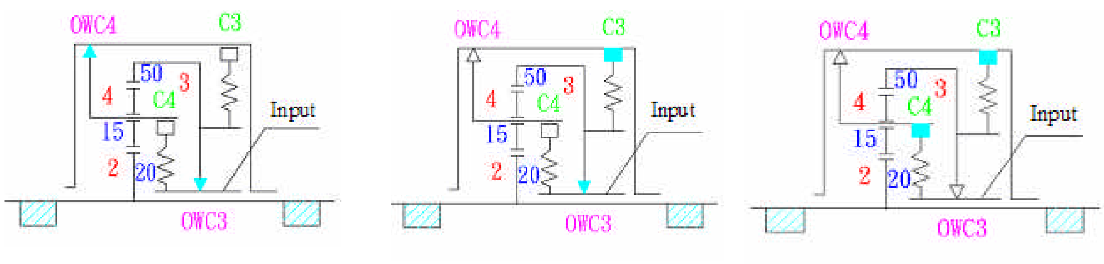


Figure 12: Plan 1



(a) First Gear (b) Second Gear (c) Third Gear

Figure 13: Three gear positions of Plan 1

(2) Plans 2 and 3

These plans adopts other planetary gear trains to achieve the following: replace the automatic three-speed back internal speed changer in Figure 12, define the parameter 36 [complexity of device] wished to be improved and the parameter 12 [shape] not wanted to be worsened, and make use of the contradictory table to find out principles 13,15,28,29, whose contradiction matrix is demonstrated in Table IV. The principles cited in the matrix are the ones that have been most popular for solving the problem, in these plans, we adopt principle 28 (replacement of a mechanical system) to find the solution, obtain design plan 2, as shown in Figure 14, the actuating maps of these three gears are shown in Figure 15(a), Figure 15(b), and Figure 15(c). Meanwhile we obtain design plan 3, as shown in Figure 16, the actuating maps of these three gears are shown in Figure 17(a), Figure 17(b), and Figure 17(c).

Tables IV. Contradiction Table – Plan 2, 3

Feature to Change \ Undesired Result		1 Weight of moving object	...	12 Shape	...	39 Productivity
1	Weight of moving object					
...	...					
36	Convenience of device			29,13 28,15		
...	...					
39	Productivity					

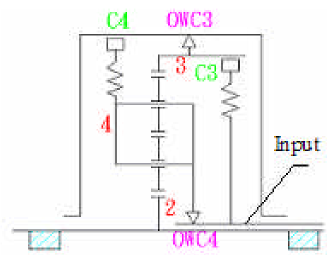
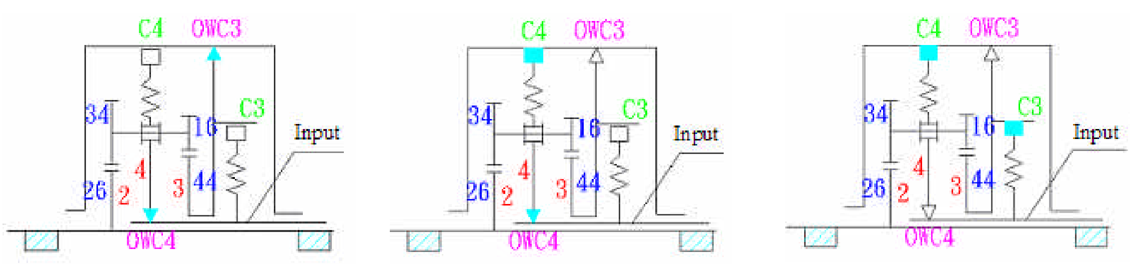


Figure 14: Plan 2



(a) First Gear (b) Second Gear (c) Third Gear

Figure 15: Three gear positions of Plan 2

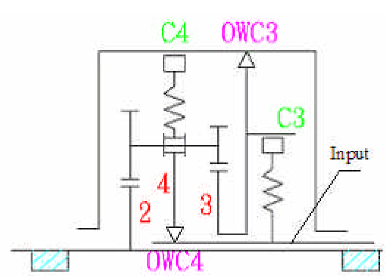
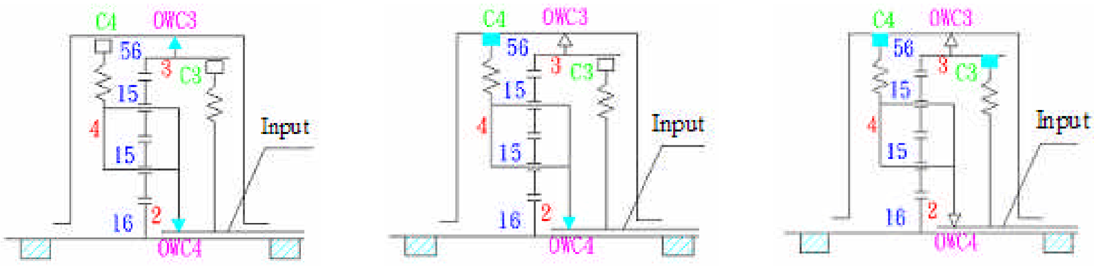


Figure 16: Plan 3



(a) First Gear (b) Second Gear (c) Third Gear

Figure 17: Three gear positions of Plan 3

(3) Plans 4, 5, and 6

These plans change the three-speed automatic speed changer in Figure 12, Figure 14 and Figure 16, replace the back wheel central solid axle of the back speed changer with the foot board rotation axle, and use it as the input axle of the automatic speed changer. We also define the parameter 13 [stability of object] that we wish to improve and the parameter 35[adaptability] we don't want to worsen. We make use of the contradiction table to find out principles 2,30,34,35, whose contradiction matrix is shown in Table V. The principles cited in the matrix are the ones that have been most popular for solving the problem, in this paper, plans 4,5,6 make use of principle 35 (transformation of physical or chemical states of an object) to find the solution. The design plans of the automatic three-speed front internal speed changer are shown in Figure 18, Figure 19 and Figure 20.

Table V. Contradiction Table – Plan 4, 5, 6

Undesired Result / Feature to Change		1	...	35	...	39
		Weight of moving object	...	Adaptability	...	Productivity
1	Weight of moving object					
...	...					
13	Stability of object			35,30 34,12		
...	...					
39	Productivity					

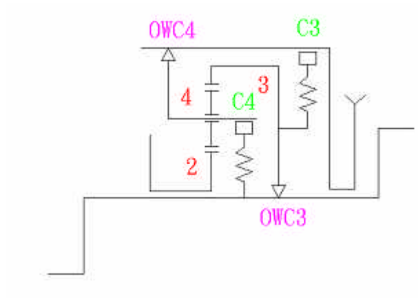


Figure 18: Plan 4

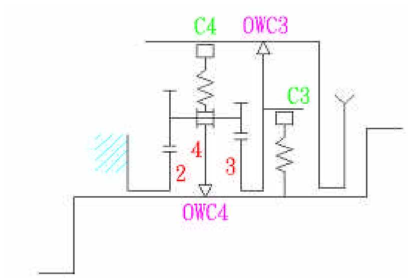


Figure 19: Plan 5

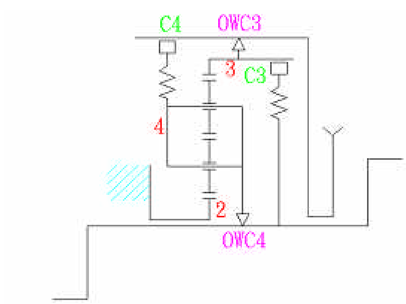


Figure 20: Plan 6

Until now the automatic internal speed changer has introduced and designed is a combination of radial motion centrifugal clutch, planetary gear train (PGT) and one way clutch (?), as shown in Figure 21.

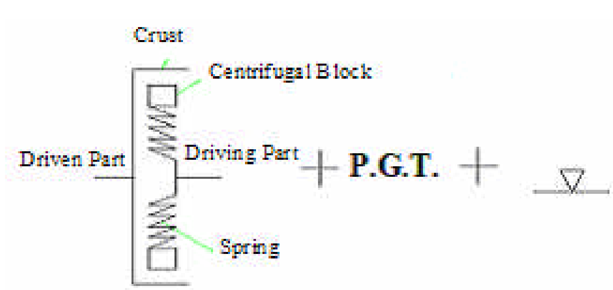


Figure 21: The automatic internal speed changer design (1)

(4) Plans 7, 8, 9, and 10

These plans will fit together the axial motion centrifugal clutch and planetary gear trains, one way clutch, and external control clutch (arrester), so as to attain the effect of bicycle automatic shift. The axial motion centrifugal clutch makes use of acceleration to increase the centrifugal force. This causes the centrifugal block (balance weights) to throw off the axial displacement, further pulling or pushing the control mechanism, and to realize the purpose of automatic shift. We define the parameter 37 [complexity of control] wished to be improved, and the parameter 33 [convenience of use], making use of the contradiction table to discover principles 2, 5, whose contradiction matrix is shown in Table VI.

Table VI. Contradiction Table – Plan 7, 8, 9, 10

Feature to Change \ Undesired Result		1	…	33	…	39
		Weight of moving object	…	Convenience of use	…	Productivity
1	Weight of moving object					
…	…					
37	Complexity of control			2,5		
…	…					
39	Productivity					

The principles cited in the matrix are the ones that have been most popular for solving the problem, in these plans, principle 5(combining) will be used to find the solution. Also, to fit together the axial motion centrifugal clutch, planetary gear train, one-way clutch and external control clutch (or brake), as shown in Figure 22. By this combination means four types of three-speed automatic speed changer are obtained, as respectively shown in Figures 23, 24, 25, and 26. Shown in Figure 23 is the three-speed automatic speed changer design plan 7, the actuating maps of these three gears are shown in Figure 24(a), Figure 24(b), and Figure 24(c). Shown in Figure 25 is the three-speed automatic speed changer design plan 8, the actuating maps of these three gears are shown in Figure 26(a), Figure 26(b), and Figure 26(c). Shown in Figure 27 is the three-speed automatic speed changer design plan 9, the actuating maps of these three gears are shown in Figure 28(a), Figure 28(b), and Figure 28(c). Shown in Figure 29 is the three-speed automatic speed changer design plan 10, the actuating maps of these three gears are shown in Figure 30(a), Figure 30(b), and Figure 30(c).

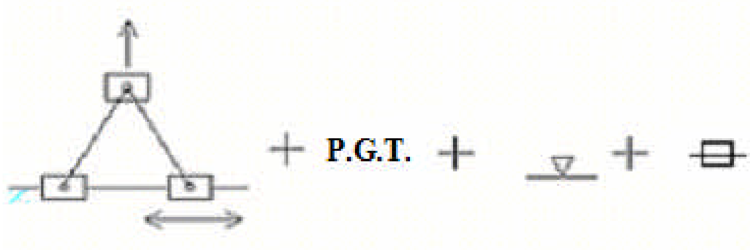


Figure 22: The automatic internal speed changer design (2)

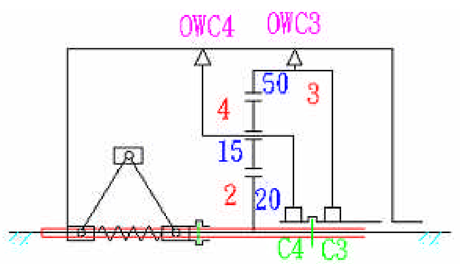
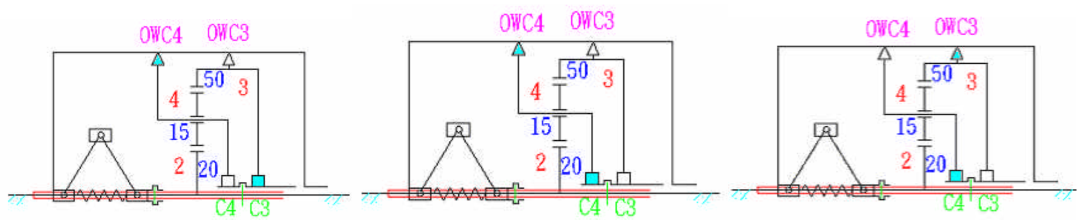


Figure 23: Plan 7



(a) First Gear (b) Second Gear (c) Third Gear

Figure 24: Three gear positions of Plan 7

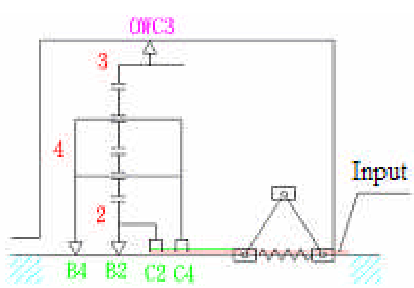
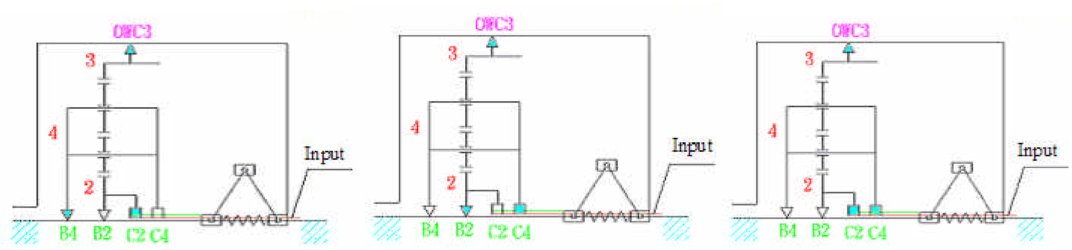


Figure 25: Plan 8



(a) First Gear (b) Second Gear (c) Third Gear

Figure 26: Three gear positions of Plan 8

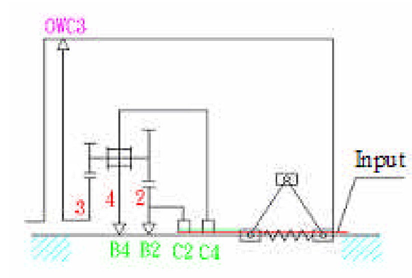
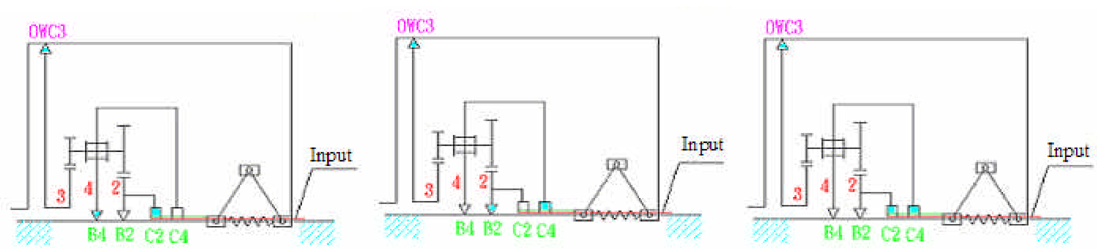


Figure 27: Plan 9



(a) First Gear (b) Second Gear (c) Third Gear

Figure 28: Three gear positions of Plan 9

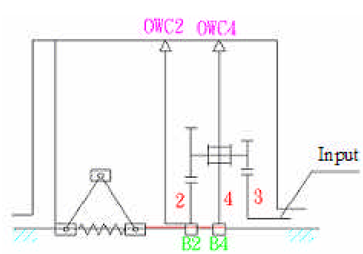
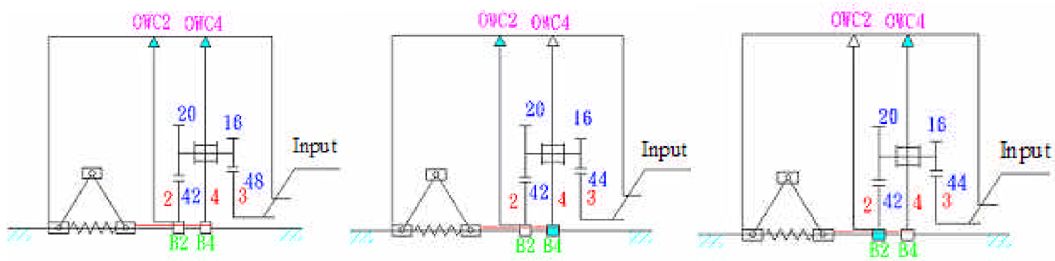


Figure 29: Plan 10



(a) First Gear (b) Second Gear (c) Third Gear

Figure 30: Three gear positions of Plan 10

IV. Conclusion

Each planetary gear train chooses different links via centrifugal clutch, one-way clutch and external control clutch (or brake) to respectively act as the input link, fixed link, or output link. That is, to obtain several design concepts of three-speed automatic gear changer. In this paper, a systematic design method is proposed to design three-speed automatic speed changer. Several examples are used to illustrate this approach. Be referring to the methods in this paper, more design concepts of three-speed automatic speed changer will be conceived. These will be the basis on which to develop a subsequent embryo machine. As a result of creative research 10 kinds of three-speed automatic speed changer are designed. The results not only can serve as a teaching tool for creative design courses, but also can provide as a reference to industrial circles for development of the three-speed automatic speed changer of bicycle, electric motorcycle, and electric scooter.

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