Analysis on the Condition of Motorcycle Using High Speed Climbing

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Abstract. In view of the situation that motorcycle will encounter with climb, the driver will choose to switch into low speed for climbing ahead of time. Drivers can also use high speed inertia force in high gear to increase the throttle for climbing without reducing gear. Using of high speed climbing motorcycle may appear normal engine speed but the actual speed is slow or the engine speed down or engine flue or transmission system tooth phenomenon. These phenomena will cause different degrees of wear or even damage to the corresponding parts. The reasons for above phenomenon of motorcycle climbing with high speed are researched and analyzed from three aspects. They are respectively inside structure of the motorcycle engine, the clutch part and the transmission system. Therefore, reasonable use of gear climbing can effectively extend the service life of motorcycle.

1. Introduction
The speed of the motorcycle is not only related to the output torque of the engine, the load of the car body, the structure of the car body, it also has to do with road conditions. In daily operation, it is inevitable to encounter climbing section, and it is one of the running conditions that the driver uses high-speed climbing without reducing gear. The use of high speed climbing is related to the motorcycle climbing ability, which is related to the problem of whether the motorcycle can climb the slope without extinguishing the fire, involving the motorcycle climbing ability factor. The climbing ability is one of the main indexes to measure the motorcycle dynamic performance. Due to the restriction of engine power and driving resistance, it is possible to increase throttle opening but fail to improve engine speed, engine gradually flamed, transmission gear chain broken, clutch slipping and other phenomena. The emergence of these phenomena and motorcycle climbing ability has a direct relationship, a long time using high-speed climbing will even cause motorcycle engine cylinder, cylinder explosion phenomenon. To sum up, the use of high-speed climbing will shorten the normal service life of the motorcycle, increase safety risks, especially when accelerating the climb flue, will pose a threat to the safety of the driver's life. A large number of examples prove that the use of high-speed climbing will cause motorcycle parts wear or damage, Long term high speed climbing will make motorcycle fuel economy decline and inadequate fuel combustion.

2. Engine Block Analysis
At present, the common motorcycle in the market is equipped with a single cylinder four-stroke self-aspirated air-cooled engine. Considering from the coherence of crankshaft work, the work condition of single cylinder engine is not stable. The rotation speed fluctuates greatly in the working process and it is easy to stall.
2.1. Reasons Analysis for Engine Stalled While Climbing With High Gear

The motorcycle uses the high speed grade to climb the slope, the engine is in the overload condition, at the same time most motorcycle engine use the natural air cooling way to make the engine to dissipate heat, the heat dissipation efficiency is low, and especially in the summer heat dissipation effect is extremely poor. If the engine runs under high load for a long time, the engine temperature will be too high, which will make it difficult to form an oil film between the piston inside the cylinder block and the inside of the cylinder block, resulting in poor lubrication effect. At the same time, under long-term high temperature and high speed operation, excessive thermal expansion of the engine piston makes the friction between the piston and the inner wall of the cylinder increase, which causes the engine to stop working in the light case, and the engine to pull and burst in the heavy case. Figure 1 gives the model of cylinder scoring.

When the engine appears serious pull cylinder, the engine power performance will be significantly reduced, the engine noise, and will be accompanied by a pungent burning odor. If the piston works under high pressure, high speed and high temperature for a long time without timely lubrication, friction will increase and eventually the engine will stall.

2.2. Power Requirements for High Gear Climbing

Motorcycle generally adopts the layout mode of engine mid with rear drive. While it is actually driving, the road driving equation is as following.

\[ F_t = \sum F \]  

(1)

Where \( F_t \) is the driving force, \( \sum F \) is the sum of the running resistance. In the actual driving process, the driving resistance includes rolling resistance, air resistance, acceleration resistance and slope resistance. The force diagram of the driving wheel is shown in figure 2.

![Figure 1. Model of cylinder scoring](image1)

![Figure 2. Force diagram of driving wheel](image2)

Here, \( F_t \) is driving force which obtained from the crankshaft of the motorcycle engine via the transmission system to the rear wheels. The torque \( T_t \) acting on the rear wheel generates a pair of circumferential forces \( F_0 \) on the ground. The reaction force of the ground facing the rear wheel, namely the static friction force \( F_s \), is the external force driving the motorcycle forward. Its value is:

\[ F_t = \frac{T_t}{r} \]  

(2)

Here, \( r \) is the wheel radius. \( T_{tq} \) is the engine torque, \( i_g \) is the transmission ratio, \( i_0 \) is the primary transmission ratio, \( i_l \) is the final transmission ratio, \( \eta_T \) is the mechanical efficiency of transmission system.

\[ T_t = T_{tq}i_gi_0i_l\eta_T \]  

(3)

According to equations (1) and (2), it is necessary for the engine to output enough power to overcome the driving resistance in climbing. Taking the following WuYang 125-20B motorcycle as an example, its transmission is shown in Table 1.
Table 1. Transmission Ratio of Model Wu Yang 125-20B Motorcycle Transmission

| type                  | \(i_m\) | \(i_0\) | \(i_1\) |
|-----------------------|---------|---------|---------|
| Primary ratio         | 4.056   |         |         |
| First speed ratio     | 2.769   |         |         |
| Second speed ratio    | 1.882   |         |         |
| Third speed ratio     | 1.400   |         |         |
| Fourth speed ratio    | 1.130   |         |         |
| Fifth speed ratio     | 0.960   |         |         |
| At the end of the class ratio | 2.800  |         |         |

Here, \(i_g\) is the primary transmission ratio that is the speed ratio of the engine crankshaft to the gearbox input shaft. \(i_0\) is the gear ratio that is ratio of gear speed on driving shaft to gear speed on driven shaft. \(i_1\) is the final transmission ratio that is speed ratio between the gearbox output shaft and the motorcycle rear wheel chain plate. So, the driving force can be calculated as following.

\[
F_t = \frac{T_{shk}l_i i_0 i_1 \eta_r}{r} \tag{4}
\]

Formula (4) shows that a larger driving force \(F_t\) can be obtained under the same engine torque and the low speed gear can meet this requirement. But in order to achieve high speed, the high speed gear can meet this requirement. The relationship between engine power \(P_e\), torque \(T_tq\) and engine speed \(n\) is expressed by curves as shown in figure 3.

![Figure 3. Relationship between torque and engine speed](image3.png)

![Figure 4. Change of driving force in each gear with speed](image4.png)

In the figure 3, the \(n_{min}\) is the minimum stable speed of the engine. \(n_{max}\) is the maximum engine speed. It can be seen from figure 3 that with the increase of the engine speed, the power and torque of the engine are both increasing. While the maximum torque is \(T_{tq \ max}\), the engine speed is \(n_{sq}\). With \(T_{tq}\) decreases, the power increases until the maximum power \(P_{e \ max}\) are obtained. At this moment, the engine speed is \(n_P\). The power is down with speed increasing. The relationship between engine power and torque is as follows.

\[
P_e = \frac{T_{tq}}{9550} \tag{5}
\]

While the actual speed is \(u_a\), it can be calculated by formula 6.

\[
u_a = 0.377 \frac{r n}{i_g i_0 i_1} \tag{6}
\]

According to the functional relationship between the driving force of the engine and the speed, \(F_t \cdot u_a\) curve was used to comprehensively represent the driving force of each gear. It is shown in figure 4.
Figure 4 shows that the driving force of each gear increases with the increase of motorcycle speed and tends to decrease. The driving force of high speed increases with the increase of motorcycle speed and its range of change is smaller than that of other gear. Therefore, when a motorcycle climbs a slope with high speed, the change range of driving force is small and the change range of motorcycle acceleration is also small. While motorcycle climbing, it must overcome the rolling resistance between the tire and the ground, body air resistance, climbing slope resistance and acceleration resistance. Therefore it is easy to stall with high gear climbing.

Figure 5 gives the force diagram of the motorcycle while climbing. The motorcycle weight needs to be overcome by engine torque during climbing. It results in slow speed. So, the acceleration can be calculated by formula (7).

\[
ma = Ft - F_{\text{resistance}}
\]  

(7)

Based on the law of conservation of energy, the output power of the engine is the summary of rolling resistance power, air resistance, slope resistance and acceleration resistance power.

\[
P_{\text{reserve}} = P_e - \frac{1}{\eta}(P_{\text{air}} + P_{\text{roll}})
\]  

(8)

Formula (8) represents the backup power of the motorcycle. It refers to the maximum output power that the engine may increase in order to overcome potential road resistance when the motorcycle travels at a constant speed on a flat road. The change of backup power of each gear with the speed is shown in figure 6.

Figure 6. Variation of backup power at each gear with speed

The engine power required to maintain the motorcycle moving forward on a flat road is not large and the throttle opening is small. While climbing, the throttle needs to be stepped up to make the engine backup power play a role. As can be seen from figure 6, the backup power of low speed gear is large while the motorcycle speed is low, while the backup power of high speed gear gradually decreases as the motorcycle speed increases. At this time, the engine speed is too slow to stall easily if using high gear.

3. Reason for Clutch Slip

Friction plate is the main part of the clutch. Its main role is to cut off or transfer power of the crankshaft box to the transmission. It also helps the motorcycle start smooth or smooth shift. After the clutch slips, the dynamic performance of motorcycle will decline but its fuel consumption will rise.

Clutch slipping is the phenomenon that the engine speed is higher but the actual speed is slower. It is caused by driver’s operation. There are some reasons for clutch slipping. First, failure of clutch handle free travel leads to friction slip caused by low pressure on the clutch plate. Second, the clutch spring will become soft with heat and slip during long time running under high load. Third, the engine speed was increased instantaneously but the actual wheel motion speed lagged while climbing which caused slipping. Last, the clutch driving plate is made of asbestos composite material, while the driven plate is
made of iron. In the process of mutual friction, the friction loss of the driving plate will be more serious and friction and slip will occur in long term use. The reason of the actual slow speed is directly related to the slip of clutch. The wear diagram of the clutch driving plate is shown in figure 7.

![Wear of clutch driving plate](image1)

**Figure 7.** Wear of clutch driving plate

![Fuel consumption with various speeds at highest constant speed](image2)

**Figure 8.** Fuel consumption with various speeds at highest constant speed

Here, $T_C$ is the static friction torque between the friction surface of the main and slave parts of the clutch. $f$ is the static friction factor. $F$ is the working pressure exerted by the pressure disc on the friction surface. $Z$ is the number of friction surfaces; $R_C$ is the average friction radius of the friction plate. So the friction torque can be calculated by formula 9.

$$T_C = fFZR_C$$  \hspace{1cm} (9)

$P_0$ is the unit pressure borne by the friction surface, $d_S$ is the unit friction area, $\rho$ is the radius of curvature. The friction torque generated on the unit area is as formula 10.

$$dT = P_0d_S\rho$$  \hspace{1cm} (10)

According to formulas (9) and (10), the cause of clutch slipping is insufficient static friction torque. The factors causing insufficient static friction torque include friction sheet material, working pressure, number of friction sheets and radius of friction sheets.

4. Reasons For Fuel Economy Decline

Engine fuel economy refers to the performance of maintaining normal running with as little fuel consumption as possible on the premise of ensuring motorcycle power performance. There are two indexes to measure. First is constant speed 100 kilometers fuel consumption. Second is certain fuel mileage. The working condition of motorcycle using high speed gear can be regarded as constant speed climbing. Driving with various speeds at highest constant speed, the fuel consumption curve at each speed is shown in figure 8. It can be seen from figure 8 that the motorcycle climbs the slope with high gear, its fuel consumption increases with the speed increasing. The fuel consumption of the engine at a constant speed of 100km can be calculated by formula 11.

$$Q_s = \frac{CFb}{\eta_T}$$  \hspace{1cm} (11)

Where, $C$ is a constant. $F$ is composed of rolling resistance and air resistance. $b$ is fuel consumption rate. $\eta_T$ is the mechanical efficiency of the transmission system. The fuel consumption of the engine at a constant speed of 100km is directly proportional to the driving resistance. And it is inversely proportional to $\eta_T$. While climbing with high speed gear, the increase of air resistance and slope resistance leads to the increase of driving resistance and fuel consumption at a constant speed of 100km. The clutch slipping leads to the reduction of transmission efficiency and the actual speed during slipping is less than the engine speed. At the same time, the climbing time increases which will cause to the increase of engine fuel consumption.
5. Wear Analysis Of Transmission System
The model of chain sprocket engagement of motorcycle is shown in figure 9.

![Model of chain sprocket engagement](image)

Figure 9. Model of chain sprocket engagement

![Broken of gear tooth](image)

Figure 10. Broken of gear tooth

The advantage of chain driving is simple structure with extremely high transmission efficiency. The disadvantage of chain driving is that the force between the driving gear and the chain is tight. The output shaft of active gear needs to run on the same side as the chain tray. The parallelism deviation of the front and back shafts of outer driving chain is large. The meshing clearance between chain and sprocket is too large. Phenomenon of chain gluing appeared by poor lubrication. Engines endured long term high speed and heavy duty operation. These will result in broken teeth or wear of chain sprocket wheel. Figure 10 gives the schematic diagram of gear teeth broken. Broken teeth are usually caused by insufficient fatigue strength, accelerating moment and load suddenly increases. Because the intensity of tooth chain plate is low, the teeth are easy to be pulled.

6. Conclusion
By analyzing the influence of engine, clutch and transmission system of motorcycle climbing with high gear, the following conclusions are drawn. By climbing with high grade, the engine speed was low and output torque was small. It is characterized by insufficient power or flameout. It is possible to pull or explode the cylinder while it is serious. Running under the condition of high throttle for a long time caused the clutch spring to become soft with heat and slip. It also resulted in insufficient fuel combustion and reduced fuel economy. The wear of the transmission system is intensified while climbing at a high speed with high speed gear. Therefore, it is hard to avoid the phenomenon of broken teeth in a long time. Considering the various characteristics of the motorcycle, the selection of gear should be combined with the actual road conditions. The motorcycle in good running condition can be obtained by choosing the best gear.

7. References
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