1. Introduction

OHC engines use ribbed belts or chains to transmit rotation of crank shafts to camshafts and synchronize the timing of all these units. The auto tensioners are used to keep adequate tension of these ribbed belts and chains which contribute to longer life and the quietness of engines.

For engines of motorcycles, chains are used more often than ribbed belts for the above synchronization. As such, auto tensioners for chains of motorcycles (hereafter, chain tensioners) are required to meet certain functionality particular to motor cycle engines. NTN has been developing and commercializing chain tensioners that meet these requirements. This article introduces the structure and characteristics of chain tensioners for motorcycle engines.

2. Current situation of chain tensioners for motorcycle engines

2.1 System configuration and required functionality

When a chain is used for the above mentioned synchronization of rotation, the chain is slide guided by a chain lever and chain guide (Fig. 1). The sliding resistance between those slide guides and the chain creates friction loss; therefore, adequate chain tension is critical. When the chain tension is too high, the friction loss becomes larger, resulting in deterioration of fuel efficiency, low output and, at worst, chain rupture.

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NTN has developed the hydraulic auto tensioner of timing belt drive and timing chain drive unit for engine camshaft drive application. Since 2004, NTN has started to supply timing chain tensioner for motorcycle engine application.

Today I would like to introduce new technology of auto tensioner to reduce engine noise and increase durability performance.

On the contrary, if the chain tension is too low, chain fluttering becomes larger, resulting in larger noise and vibration, as well as wear elongation. Therefore, the optimized design of the chain tensioner, which adjusts chain tension, is critical, requiring optimization of damping force, etc. for each engine.

Usually, there is a time lag between the starting of an engine and when lubricant oil reaches each component.

Chain tensioners with hydraulic damping mechanisms may produce abnormal noise due to chain fluttering after starting the engine until oil is filled into the high pressure chamber. Therefore, a no-back mechanism is required to prevent the chain from being pushed in when the engine stops.

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In addition, chain tensioners for motor cycles are required to have the following functionality since they are often installed by being inserted from outside of the engine.

1) Initial setting release mechanism from outside the engine
A chain tensioner is delivered with the initial setting where the internal component is pushed into the cylinder. The initial setting needs to be released, after the tensioner is installed to the engine, to allow the internal component of the tensioner to be extended until it is in contact with the chain lever. Therefore, a mechanism to release the initial setting (being pushed in) is required either manually from outside or automatically (Fig. 2).

2) Prevention of fallout of internal components
A mechanism to prevent fallout of internal components into the engine is required in case chain tensioners are removed for maintenance, etc.

2.2 Chain tensioners of other manufacturers
Mechanical chain tensioners have been used for motor cycle engines with simple structures of springs and ratchets or damping with friction force of screws.

3. NTN chain tensioners
NTN has tackled the following challenges of the chain tensioners.
(1) Improvement of quietness and reliability
(2) Compact/lightweight
(3) Improvement of workability
(4) Stability of hydraulic damping force

3.1 Improvement of quietness and reliability
There are two types of structures to achieve a no-back mechanism regarding quietness and reliability. These structures are introduced in this paper.

1) Buttress thread type chain tensioner
The no-back mechanism (Fig. 3) utilizing a buttress thread with NTN proprietary technology makes it possible to reduce chain fluttering. This is even possible with no oil supply to the chain tensioner immediately after the engine starts and when no damping force exists from oil hydraulics (Fig. 4 and 7).

The buttress threads enable the no-back mechanism, regardless of the position of the tensioner tip when the engine stops; significantly contributing to quietness of the engine when it starts.

In addition, the frictional force of the buttress threads also work as a part of the damping force during normal operation, and not only when the engine starts (Table 1). In recent years, the load on...
the chain tensioners immediately after starting the engine increases due to the increase in driving torque of cam shafts, higher power output of engines, and downsizing of oil pumps. In response to these trends, NTN is marketing products with increased load capability while maintaining the conventional functionality of tensioners by reexamining the buttress thread specifications.

2) Register ring type chain tensioner

NTN is also marketing chain tensioners with simplified buttress thread functions with a structure that allows a stepped no-back mechanism using the grooves of the plunger outer perimeter and the register ring (freed on the extended direction by the grooves of the plunger outer perimeter and latched on the return direction). As opposed to other products with ratchet structure for the stepped no-back mechanism in the market, NTN products are characterized by the compact design by utilizing elasticity of the ring placed concentrically with the chain tensioner plunger (Fig. 5).

![Fig. 5 Ring type chain tensioner](image)

The traveling line of the chain (plunger position of the tensioner) can vary depending on the temperature and rotational speed. With the register ring type no-back mechanism, the backlash amount until the no-back mechanism starts functioning needs to be set so that the axial movement of the plunger can follow the variation of the traveling line of the chain. Caution to this point is particularly needed for the motorcycle engines which allow high-speed rotation range, and therefore, produce significant variations of rotational speed (Fig. 6).

The register ring also prevents the plunger to fall out from the cylinder when it is completely extended, an important role for motor cycle engines from a maintenance standpoint, for which installation is often accomplished from outside the engines.

![Fig. 6 Structure of ring type](image)

3.2 Compact/lightweight

NTN has long been working on lightweight chain tensioners by adopting cylinders made of aluminum; however, we developed even lighter and more compact chain tensioners which can be directly installed on the engine with threads (self-mount type chain tensioners,) and started marketing them in 2010 (Fig. 8). This product comes with male threads on the cylinder outer perimeter which can be screwed into the female threads on the engine for installation. Therefore, bolts and washers for installation of the conventional products are no longer required, contributing to space saving, reduced weight and labor for installation on the engines. This product is particularly effective for motor cycle engines because they have limited space in the engine, and chain tensioners are often installed from outside the engine. In addition, this product can be used both for the aforementioned buttress thread type and register ring type.

![Fig. 7 Engine startup characteristic of each no-back mechanism](image)

![Fig. 8 Self-mount type chain tensioner](image)
3.3 Workability

1) Automatic release of initial setting

For engines of four-wheel vehicles, the release of the initial setting after installation of chain tensioners is accomplished by removing the set pin of the chain tensioner and then installing the front cover (Fig. 9).

However, motorcycle engines do not have working space for removing the set pin after installation; therefore, an easy and secure releasing mechanism is required. NTN addresses these challenges by adopting the mechanism shown in Fig. 10.

- Set pin
- The snap ring is shrunk and set into the grooves on the plunger outer perimeter and cylinder inner perimeter.
- The plunger is pushed in the extended direction by the internal return spring (Fig. 8) and kept in the initial setting position.

(Releasing initial setting)
- With the load applied to the plunger, the snap ring moves in the axial direction along with the groove of the plunger as they move in the pushed-in direction.
- As the snap ring moves toward the cylinder groove on the larger diameter side, the snap ring is expanded.
- When the snap ring is expanded, it cannot prevent the plunger from being extended, releasing the initial setting.

(Reapplying initial setting)
- After the chain tensioner is removed from the engine for maintenance, etc., the initial setting can be reset with the snap ring in place by pushing the plunger to the initial setting position.

This structure allows automatic release of the initial setting by applying load with engine cranking, which causes displacement after the chain tensioner is installed onto the engine.

2) Prevention of fallout of internal components

With the register ring type chain tensioner, the register ring works as a prevention mechanism against fallout of the internal components. However, since the said component does not exist with the buttress thread type, another snap ring shown in Fig. 11 is provided separately from the snap ring for initial setting.
3.4 Stability of hydraulic damping force

1) Relief valve setting

For higher power output, motorcycle engines have higher permitted rotational speed than four-wheel vehicles. It is necessary for the hydraulic damping mechanism to restrain the chain tension because of the tendency of excessive damping force in the higher rotational speed range. By controlling leak gaps with the conventional simple hydraulic damping mechanism, it is difficult to optimize the damping force in the lower and higher rotational speed ranges. NTN addressed these challenges by integrating a compact relief valve in the chain tensioner (Fig. 12). The open valve pressure of a relief valve can be changed with the internal spring setting, allowing adjustments for damping force appropriate to different engines. This mechanism supports engines with higher permitted rotational speed such as large and sports type motorcycles; therefore, NTN chain tensioners are often adopted.

Fig. 13 and 14 show the verification results of relief valve effects. The tuning of damping force was conducted under conditions of 100˚C/200 Hz.

Compared to the case when damping force is adjusted only by the leak gap (Fig. 13), adding a relief valve produces stable damping force against variation of oil temperatures and frequency (=engine rotational speed) (Fig. 14).

The comparison of the characteristics in the actual test is shown in Fig. 15. Reduction of load in the higher rotation range can be expected with the relief valve setting.

2) Bleed mechanism setting

Hydraulic chain tensioners cannot satisfy the function if air is present in the oil pressure chamber. Therefore, NTN has adopted various bleeding mechanisms so that they can be added to the best location depending on usage (Fig. 16 and 17).
4. Conclusion

We have been developing chain tensioners for motorcycle engines, particularly for higher power output and sport vehicles, to satisfy requirements for functionality and reliability. Going forward, it is expected that the requirements for chain tensioners will be diversified, even for motorcycles possessing environmental concerns.

NTN will continue to address these requirements while developing chain tensioners for applications to broader vehicle types.

References