A Guide to Inverted Tooth Chains

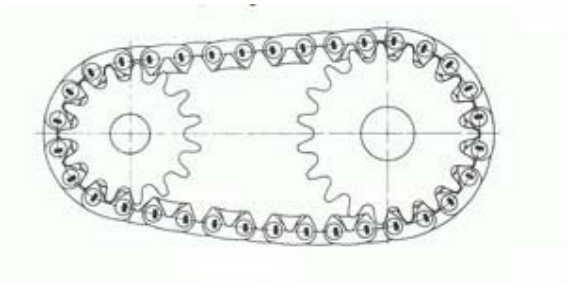
- Steel pintle chain
- Structure of Inverted tooth chains
- Silent drive
- Precise and durable
- Drives and durable
- Drives in comparison
- Features

Steel pintle chains

From the great number of steel pintle chains available, two different designs stand out due to their wide range of applications:
Inverted tooth chains and roller chains.
Whereas roller chains comprise single circular pin joints, the more durable inverted tooth chains are equipped with two-pin rolling pivot joints.

The inverted tooth chain is a positive sprocket driven wrap drive. The toothed plates mesh with the toothing on the sprockets and take up the tension.
The lamellar construction results in a very compact chain, with load-bearing plates making up the entire width. One main design feature of inverted tooth chains is the two-pin rolling pivot joint.

During articulation of the chain, the two pivots roll against each other.
The inverted tooth chain is also known as the silent chain.



Structure of Inverted Tooth Chains

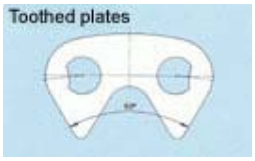
The structural design of inverted tooth chains with two-pin rolling pivots joints is described below, taking the HDL chain, acc. to DIN 8190, as a representative example.
The inverted tooth chain comprises:

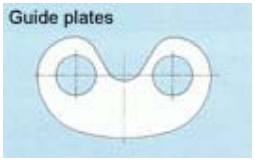
- toothed plate
- guide plates
- rolling pivot joint consisting of 2 profiled pins
- rivet washers

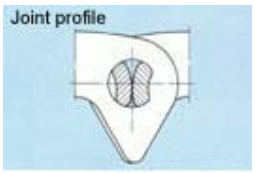
Depending on the chain width, each link will have a certain number of plates arranged in a staggered configuration from link to link. These plates are connected by the rolling pivot joint.
The dimensions of the inverted tooth chain can be adapted to suit the application requirements.
Depending on the required length and width, the chain is composed of multiple link plates and profiled pivots.

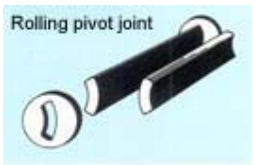
The longer profiled pin is riveted at both ends, thus holding the plates together laterally.
The picture below shows a centre guided HDL chain, i. e., the guide plates are centrally located. In side guided chains, the guide plates are located on the outer sides of the inverted tooth chain.
Force and motion are trans-mitted via the toothed plates, whose outer tooth flanks are oriented at an angle of 60° to each other. These flanks make contact with the sprocket teeth (involutes). Each plate is provided with two joint bores to accommodate the rolling pivot joint.
The guide plates prevent the inverted tooth chain from drifting sideways on the sprocket.
The rolling pivot joint consists of 2 profiled pins. These may be differently shaped according to the type of chain.

Both pins are held captive within the plates. When a joint moves - as the chain enters and exits the sprocket - the two profiled pivots roll against each other, thus avoiding sliding friction within the joint.
The picture below also illustrates that an inverted tooth chain comprises several links, where one link equals one pitch. The chain length, i. e., the number of inverted tooth links, depends on the number of teeth on the sprocket and the shaft-to-shaft distance.









Silent drive

Inverted tooth chains versus other types of chain drives

The cause of operating noise in all chain drives is the entry impact that occurs when the chain members mesh with the sprocket. The intensity of this impact is the product of the mass of the chain link and the impact speed, which is considerably lower in inverted tooth chains than in other types of chain drives.

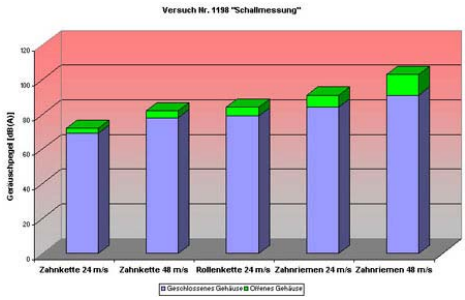
Influencing factors

Flank angle: The flank angle at the point of contact between the chain and the sprocket is much smaller in inverted tooth chains. As a result, the impact speed is nearly half that of roller chains.

Chain pitch: Chain pitches can be sized smaller, achieving a proportional reduction in impact speed. Inverted tooth chains stand out for their compact build and high load transmission capability.

Inverted tooth chains versus other wrap drives

In terms of noise reduction, tooth chains offer major advantages over toothed belts, since they produce none of the characteristic whistling noises due to sudden expulsion of air. At the same time, tooth chains constitute neat and powerful drives with circumferential speeds of currently up to 45 m/s.



Precise and durable

Inverted tooth chains have similar toothing and meshing geometry to gear drives. The top figure shows an inverted tooth chain meshing with the sprocket. The chain links engage so deeply in the tooth gaps that both flanks make contact.
When the chain stretches, both the chain pitch and the pitch circle increase. The chain climbs to a higher pitch circle on the sprocket, which again matches the longer chain pitch. All chain links (joint centres) must again describe a common working circle. If they lay at different heights, the chain strand would develop lateral motion and thus cause oscillations.
The middle figure shows a roller chain consisting of outer and inner links. The pins in the outer links and the bushings on the inner links have worn. The roller centres remain in position on the bushings, i. e., only the pitch of the outer link changes by $2\Delta p$.

Disadvantage in roller chains:
$p_1 = p$, $p_2 = p + 2\Delta p$.

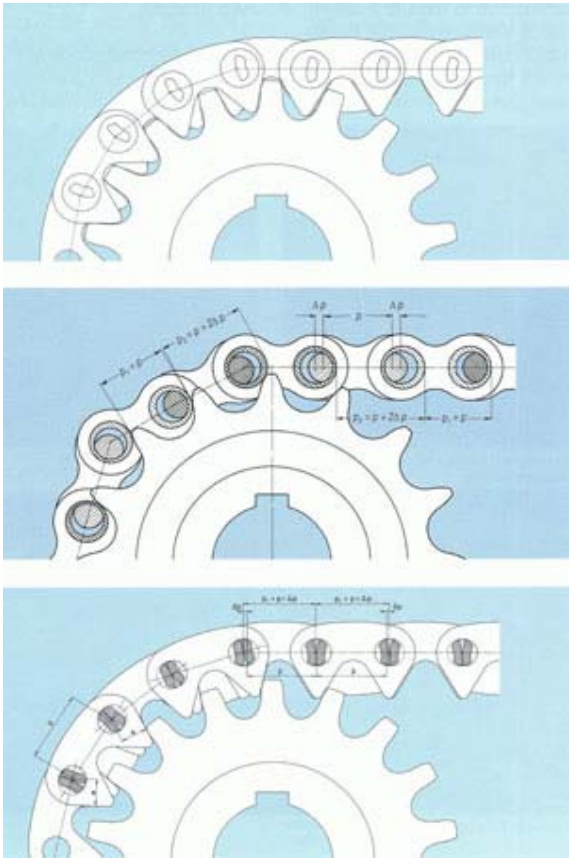
The outer links describe a larger pitch circle than the inner links. This cause the chain to move jerkily and results in irregular loading of the sprocket teeth.

These disadvantages are not present in the inverted tooth chain.

The last figure shows an inverted tooth chain after a prolonged period in service.

The joint pivot and link bores wear gradually at the contact surfaces. The links shift reciprocally. The pitch increases by Δp, thus resulting in the following elongation

inverted tooth chains:
$p_1 = p_2 = p+\Delta p$.



Since all joints wear at the same rate, the pitch will increase uniformly throughout the chain and all links again describe the same, albeit larger pitch circle. Inverted tooth chains therfore ideally combine the benefits of gear and wrap drives.
They are equally suited for short and long shaft center distances, providing a high level of functional safety in all cases.

Drives in comparison

Advantages of Bosch Rexroth inverted tooth chain drives over ...		
... Gears / Transmissions	... Belts	... Roller Chains
Reduced bearing loads	Non-slip	Rolling pivot joint
Insensitive to temperature fluctuations	Higher Speeds	High maximum velocity
No need for intermediate sprocket	Silent - no whistling or humming	Low-noise
Zero tooth flank backlash	Space-saving	Smooth running due to involute toothing running
Larger permissible tolerances for shaft installation	Small sprocket diameters	99% efficiency
Vibration damping	Insensitive to extreme temperatures or humidity levels	Wear-resistant sprockets
Low-cost sprockets	Reduced bearing loads	Vibration damping
	Can be opened, thus easy to install	

Features

Tooth Chains for Drives ...	Conveyor Chains ...
Silent operation	Non-slip
Speeds up to 43 m/s	Dog plates in various designs
High efficiency	Free choice of shape and width
Low maintenance requirement	Reduced elongation
Rolling pivot joint with no sliding friction	Small sprocket diameters
Low wear/high durability	Rugged and temperature resistant
Low lubrication requirement	Ground surface or ground on both sides
Extremely smooth operation	Chains without rigid backing
Zero tooth flank backlash	Stainless version

Space-saving

No projecting pin ends

Features - A Comparison

Characteristics	Tooth chains	Roller chains	Toothed belts	Toothed wheels
Noise behaviour	very good	average	bad	good
Smoothness of running	good	bad	average	good
Temperature sensitivity	good	good	bad	good
Space required	good	average	bad	very good
Wear / elongation	good	bad	average	very good
Large axle bases	good	good	good	bad
Maintenance (Increase of tension)	partly necessary	necessary	not necessary	not necessary
Assembly	dismountable	dismountable	not dismountable	-

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