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DEVELOPMENT OF TIMING BELT DRIVES

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INTRODUCTION

Timing belt drive is relatively new conception of power transfer, accepted in all areas of industry today. Actually, they represent a combination of chain and gear transmission. They are flat belts with series of equal spatial teeth inside addendum diameter.Timing belt transfers the torque by means of its shape. The teeth, equally spaced at inner side of timing belts, contact the belt pulley's teeth with their hollows between teeth and, thus, by conjugate gear action, achieve the coupling between the belt and the belt pulley and transfer the torque.

Power transmission through timing belts has a series of good features [1]:

- small amount of slip, constant speed;
- cheap maintenance, because, due to absence of contact between metal parts, there is no need for lubrication;
- possibility for power transfer in a broad range, over 400 kW;
- small load of construction bearings;
- broad range of speeds, from 0.5 m/s to over 33 m/s;
- compact construction, conditioned by small centre distance, small belt width and possibility to transfer large power;
- possibility to simultaneously transfer power to a large number of shafts;
- small heating;
- smoother running in a period of run in;
- small mass of construction, which is sometimes a critical factor (in design of airplanes, hand devices and similar);
- precise kinematic ratio (i=const);
- relatively low level of noise;
- very high efficiency (η=0.99).

Timing belt drives have broad application in industry. They are applied starting from calculation machines, computers and instruments, through machine tools, pumps and compressors, to heavy industrial plants.

Shortcomings of the timing belt drives are:

- expensive manufacture,
- sensitivity to irruption of foreign bodies (possibility of damage during coupling),
- possibility of teeth skipping .

In spite of advantages in operation, timing belt drives have only recently achieved great application. It was yet after their application as IC engine's camshaft drive, that their purposefulness of application had become obvious. Popularity of timing belts in automotive

industry has accelerated their use in other branches of industry. Today, timing belts are applied more and more, especially since technology of manufacture of polyurethane belts has emerged and developed. Market suggests the use of belts of unlimited length and with unlimited number of teeth.

HISTORICAL DEVELOPMENT OF TIMING BELTS

Timing belt is a relatively young drive, firstly designed as a drive for a sewing machine by engineer Richard Y. Case in 1946. It was a rubber belt with trapezoidal teeth profile. After twenty years, in 1962, the timing belt was for the first time built in an automobile, Glas 1004. Engine of Glas 1004 was the first engine where the timing belt was utilized as the camshaft drive (Synchroflex). Valve train was very simple and the timing belt drive had no belt tensioner, Figure 1. Massive use of the timing belts started at the end of 1960's on Fiat 125 and Fiat 128 automobile and, at the beginning of 1970's, on the first Golf automobile.

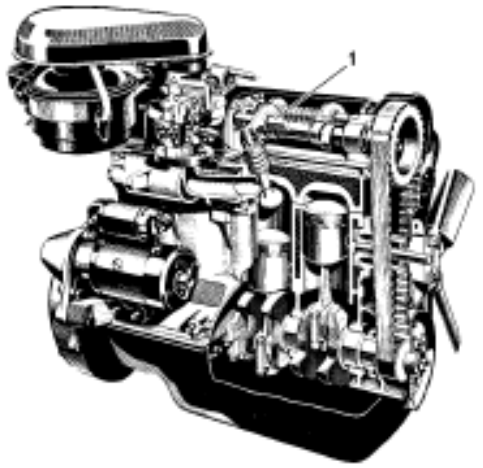

Figure 1: *Engine of Glas 1004 automobile (1962)*

After initial doubt, almost all producers of Otto and Diesel engines for passenger cars have utilized the timing belts. The timing belt is today the most frequently used camshaft drive. Application of the timing belts is mostly linked to automobiles, though just 2% of timing belt production is intended for application in automotive industry.

SUBDIVISION OF TIMING BELTS

There are different types of timing belts in exploitation, differing by construction application, manufacturing technology, materials, teeth profile, etc. There are some attempts to standardize the timing belts. Nevertheless, until today, theses attempts were unsuccessful, because the belts are relatively new, their constructions are special and belt dimensions are determined in different systems, which aggravate their comparison.

The timing belts may be divided according to several criteria:

- According to purpose:

1. Timing belts for energy machines. These are the endless belts with spiral tractive elements. They are used as power transmission between the shafts. Also, they are applied in lathes, sawmills, mills and bakeries, then as drives of pistons, compressors and polygraph devices. The timing belts are used in high-speed gears for driving the grinding wheels, web machines, centrifugal machines and textile and wood-processing machines. Maximal belt length is 22 m.

2. Timing belts for geared transmission and position systems. Their tractive elements are positions parallel to side edges. They are used for realization of linear motion. The timing belts for small transmissions, geared transmissions and position systems are applied in devices for regulation and control of metal rolling machines, power devices and chemical plants. The belt's length is unlimited.

3. Special timing belts. Specially built belts are used for special working conditions. Double-sided timing belts are recommended for reversible transmissions. Belts with modified back surface may be used as transporters for carrying raw materials and final products. Besides, timing belts resistive to high temperatures and lubricants and electric-resistive belts are manufactured.

- According to manufacturing technology:

1. Die casted timing belts. Timing belts manufactured by this method consist from two components – a belt with teeth and a strained tractive element that receives the workload. The belt is manufactured from plastic masses or special texture rubber, therewith the both materials must be highly resistive to wear. The tractive element is manufactured from thin steel wire or from polyetheric ply and it is situated in belt's body. In very small belts, the dilatation is controlled by the tractive element. Mould for belt casting should provide standard dimensions and minimal tolerances of teeth shape for uniform power transmission. Belt's teeth should have a precise shape and should be precisely positioned in order to provide and guarantee quality coupling with belt pulley's teeth.

2. Timing belts obtained by vulcanization. The timing belts are manufactured with the tractive element housed in belt's body, having fibrous film teeth. The belt's body (teeth and back surface) is made of synthetic rubber compound, resistive to wear, which protects the tractive element. This compound should be firm and should poses dimensional stability, so the teeth should reliably receive cross-sectional forces. Protective teeth film is made of wear resistive nylon that has small friction coefficient and protects the teeth and the belt from wear. The film also reduces the noise during operation of belt drive. The belt's body, the tractive element and the belt film join into a set in the mould, during the process of vulcanization.

3. Timing belts obtained by extrusion. Some timing belts are made by method of extrusion. In that case, sections of the belt are obtained which ends may be joined together and, thus, the belt of arbitrary length is obtained. Belt's sections have parallel tractive elements in the shape of steel wire or polyetheric fibre. They also have nylon teeth coatings or back surfaces (or both elements). Timing belts with continuous rolled metal tractive elements, without joints, are manufactured in any length up to 25.5 m. Similar belts made by "*PLASMATIC*" company (USA), are

applied, first of all, in high torque and high speed drives. Belt's body and teeth are made of polyurethane by extrusion method.

- According to measuring units:

1. Timing belts with dimensions given in mm – metric system. The basic parameter of these belts is a modulus or a pitch given in mm.

2. Timing belts with dimensions given in inches ". These belts are mostly made of neoprene and the basic parameter is a pitch in **".**

Both types of belts are not compatible to each other.

- According to material:

The following materials are used for manufacture of timing belts [2]:

- Natural caoutchouc (rubber)
- Neoprene
- Polyurethane (urethane)

Basic characteristics of these materials are:

Natural rubber:

- large elasticity,
- easy design,
- large friction coefficient,
- high bursting stress limit,
- small wear,
- wide temperature range (especially low temperatures),
- small resistance to oils and solvents, especially to acetone and alcohol and
- natural rubber is susceptible to oxidation.

Neoprene:

- large elasticity,
- wide temperature range (especially high temperatures),
- good resistance to external influences (convenient for opened transmissions) and
- small resistance to oils and solvents.

Polyurethane:

- high wear resistance,
- small friction coefficient,
- good resistance to oils and oxidation,
- wide temperature range (especially low temperatures),
- small resistance to high temperatures.

- According to teeth profile shape [3]:

- trapezoidal,
- semicircular (curvilinear),

- semicircular with flat top,
- triangular (saw-timing),
- belt with optimized rounded profile, etc.

Most of the timing belts are made as double-sided constructions, with teeth at both sides of the belt.

TIMING BELT PULLEYS

Belt pulleys are very important and responsible parts of belt transmissions. Synchronicity of transmission and the level of exploitation characteristics largely depend on proper selection, construction and quality of manufacture of belt pulleys [1].

Like timing belts, the timing belt pulleys defer by their construction characteristics. They consist of a certain number of equal hollows between teeth that enable correct coupling with the belt. Belt pulleys are design in such a way that belt teeth enter and leave the hollow between teeth with negligible friction.

Hollows between teeth are manufactured with clearance. The clearance makes the entering and exiting of belt teeth from coupling easier, compensates for cumulative errors of addendum diameter, profile errors of hollows between teeth and belt teeth and for tilting of transmission shaft axles.

According to their construction shapes, timing belt pulleys are made in several different forms. They consist of:

- a rim,
- a hub and
- a plate or a spoke that connect the rim with the hub.

They are made with or without rim rings, with symmetrical or asymmetrical hub.

The rim is connected with the hub with the plate that may be of equal thickness in smaller belt pulleys (up to 100 mm). In larger belt pulleys, the plate is thinner than the rim and it is made with symmetrically drilled holes for weight reduction and for easier capture of the belt pulley during machining. Linking the rim and the hub with spokes is recommended for larger sizes (over 300 mm).

The belt pulleys are made of different materials, resistant to wear, like: steel, cast iron, aluminium alloys, plastic masses – depending on the belt pulley's dimensions and the terms of use. In order to reduce weight, it is recommended to produce the vehicle parts out of new, advanced materials [4,5].

Lately, plastic masses are more frequently used: LEXAN 500, FIBERGLASS (reinfoirced) and DELRIN 500.

The belt pulleys form "MULCO" company for newer belt profiles are made of aluminium alloys (AlCuMgPb, AlZnMgCu0.5-F48) [6].

Flanges are mostly made of carbon steel or aluminium and its alloys.

The timing belt pulleys made from plastic masses and easy alloys are usually manufactured by die-casting. The belt pulley's teeth are threaded with form-growned cutter. The rectilinear part of belt pulley's teeth profile is gained using corresponding form-growned cutter teeth. To facilitate the entrance of the belt teeth into the coupling with the belt pulley,

the teeth head of the belt pulley id rounded. Belt pulley's teeth for belts up to 12.7 mm, due to small height, may be threaded with the gear hobs with rectilinear profile.

Precision of the belt pulley's pitch, small surface roughness and proper shape of teeth guarantee noiseless operation of transmission and a long life time of the belt.

CONCLUSIONS

The timing belt drives are relatively new transmissions, designed in 1950's. Their shape (teeth profile) and materials that they are made of are still changing. Considering that the motion of the belt along the envelope angle of the belt pulley is performed on polygonal profile, by finding the optimal teeth profile, the so called "polygon" effect is reduced and the load is more evenly distributed on all teeth in coupling. At trapezoidal teeth profiles, the first tooth in the coupling, considering that the contact is firstly obtained in a contact point, carries the greatest load.

In production of timing belt pulleys, rubber and steel or tractive elements made of fibreglass were used at first. Today, polyurethane (urethane) and neoprene find bigger and bigger use. New materials have increased wear resistance and wide temperature range.

Trends in development of timing belts are to obtain, by convenient combination of teeth profile shape and the belt materials:

- larger carrying capacity,
- longer life-time and
- smoother load distribution.

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