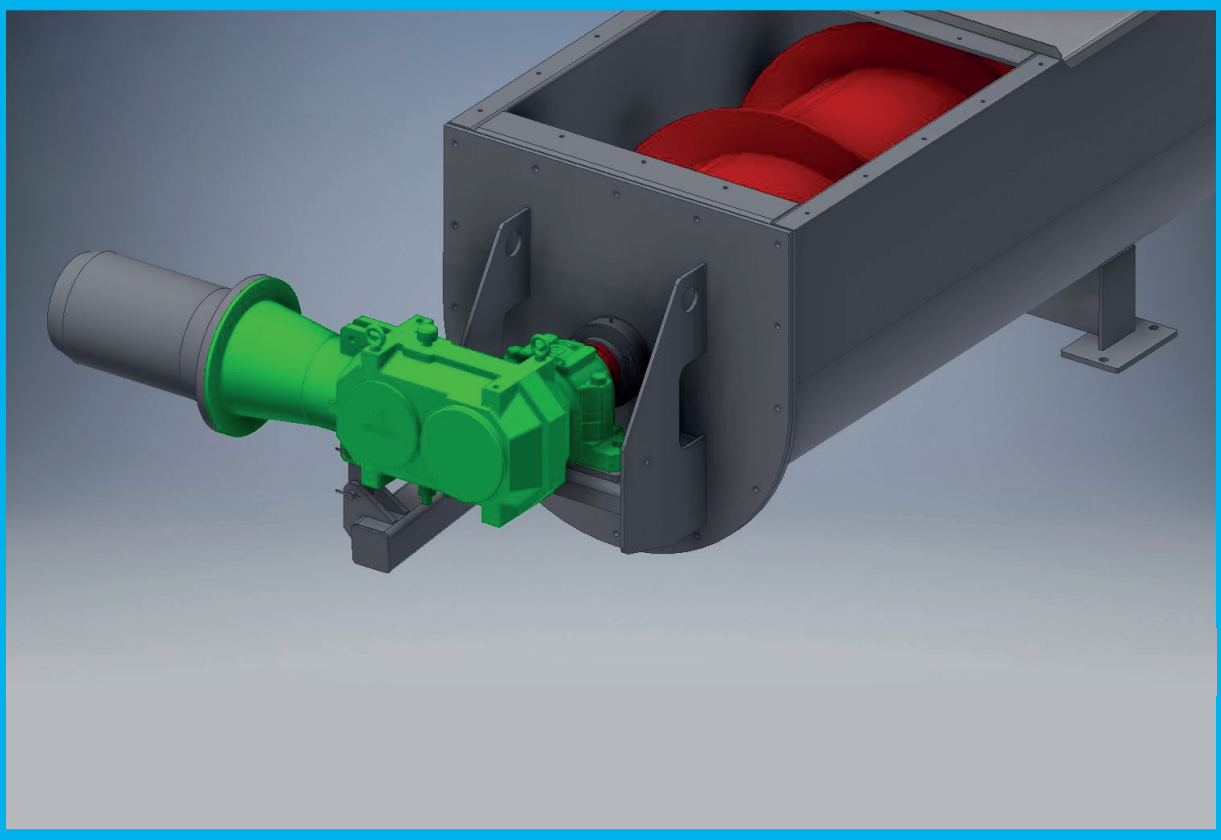
Kosti Koivisto

CONVEYOR ENGINEERING



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PREFACE

Solid material conveyors have always had a very significant role in industry. In power plants, conveyors are needed to transport solid fuel to warehouses and further from warehouses to boilers. In the feed industry, corn is refined into animal feed, flour, malt and so on by transporting raw material from one refinery to another. In the mining industry, long and effective conveyors are needed for the transport of ore. In the process industry, the refining of solid materials into ready-made products is predominantly carried out with the help of conveyors.

Even though the role of conveyors in industry is significant, there is not enough comprehensive literature with clear design instructions on this topic. When I was studying engineering, the syllabus included only very limited instruction in conveyor design. When later I became lecturer of engineering in Technical College, the situation was almost the same. Later, I established a company which designed and manufactured conveyors, and I was a designer there. At the same time, I lectured at the University of Applied Sciences.

Now, with 20 years' experience as a lecturer and 25 years' experience as a designer, I have written this book. The book covers the following conveyor types: chain conveyors, screw conveyors, elevators, belt conveyors and locker belt conveyors. The book examines the utilization of solid material conveyors, their construction and operation with a focus on design, including dimensioning instructions. Additionally, it includes practical examples for every conveyor. These examples further deal with conventional capacity and power calculations as well as strength analysis and dimensioning of axles, bearings, belts, chains and chain wheels. Assembly- and detail drawings are also presented for several of the examples.

The book is intended primarily for engineer level designers, as quite a few engineers work at conveyor design jobs.

My hope is also that conveyor design would be more broadly included in the curriculum of engineering students. This would be of great relief to employers, who nowadays, almost without exception, are forced to train young novice engineers in this area.

Lahti, Finland May 21st, 2018
Kosti Koivisto

CHAIN CONVEYOR

COMMON QUALITIES

Chain conveyors are mainly used for the movement of bulk materials, e.g. powder and granular materials. In the fertilizer and malt industry, chain conveyors are widely used. Similarly, in the food industry, such as in mills, chain conveyors are useful. They are suitable also for the transport of materials of relatively small grain size like wood chips, sand and ash in power plants and for transport of various materials in the chemical process industry. The chain conveyor is not suitable for the movement of sticky, adhesive or clumpy materials.

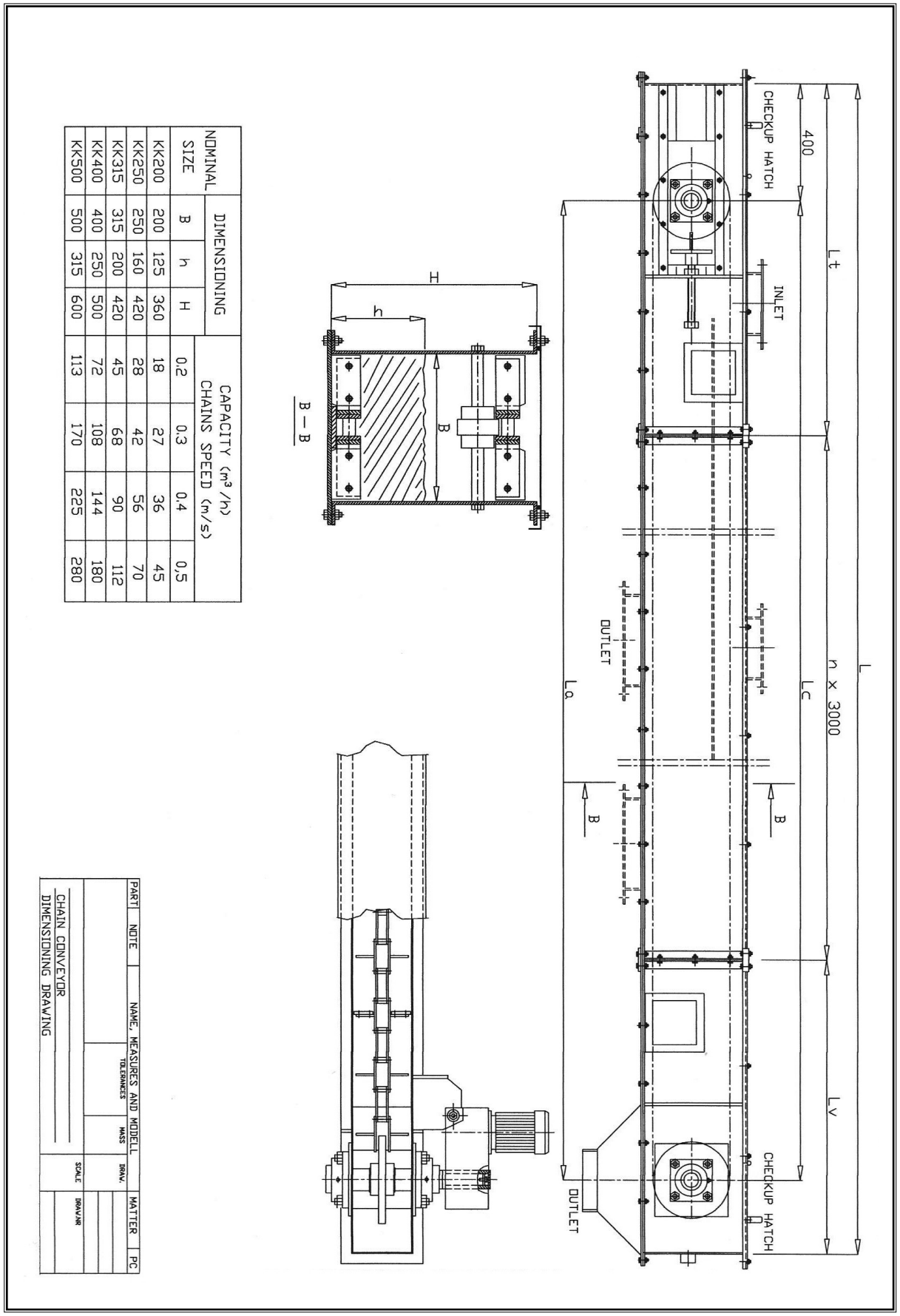
A chain conveyor is used for medium distance material movement. Transport distances are from a few meters to several tens of meters. Conveyor elevation angle can be, depending on material fluidity, as high as 30–40 degrees. For elevation angles over 40 degrees, special scraper constructions are needed. The conveyor is also known as a scraper conveyor or simply chain conveyor.

A chain conveyor's best feature, compared to, for instance, a belt conveyor, is its tight construction, which is a significant advantage in the transport of dusty materials. Transport of materials takes place by dragging with a chain and scrapers attached to it. Thus, friction between construction parts has great significance in choosing the materials rubbing each other and in dimensioning dynamic parts and especially when calculating need of power.

The need of power is significantly higher than belt conveyors, because in belt conveyors, the belt transporting material runs on rolls equipped with effective bearings. The sliding friction of the chain conveyor is many times higher than the rolling friction of bearings.

Physical properties, like particle size, density, fluidity and stickiness of the transported material has essential significance in designing the conveyor. To minimize noise and friction, materials of low friction are used in moving parts. In the same way, cleaning scrapers can be made from plastic, especially in the food industry. PE-plastic panels can be used to cover the whole bottom part. Wear rails and plates are attached by screws, so that they are easily replaceable.

A chain conveyor is suitable for middle distance transport, for several tens of meters, normally for horizontal transportation or elevation angles < 40 degrees. It is best for powdery and granular material like grain, flour, malt, woodchips, sawdust and splints etc.



NOMINAL SIZE	DIMENSIONING			CAPACITY (m^3/h) CHAINS SPEED (m/s)			
	B	h	H	0.2	0.3	0.4	0,5
KK200	200	125	360	18	27	36	45
KK250	250	160	420	28	42	56	70
KK315	315	200	420	45	68	90	112
KK400	400	250	500	72	108	144	180
KK500	500	315	600	113	170	225	280

Picture 1. Dimensioning drawing of basic chain conveyor.

In picture 1 there is a dimensioned drawing for a simple basic mono chain conveyor, which easily shows the conveyor's construction and operation. The dimensioned drawing can be used in offer/tender calculations and in the beginning of the actual design. When transported material and needed capacity is known, by using the table in *pic 1*, can choose the basic dimensions for the conveyor and start designing.

MAIN COMPONENTS OF CONVEYOR

FRAME

The frame consists of the axle housing in drive end and housings in the middle and folding end housing. The frame has a panel construction and is airtight. The aim is to make it partly self-supporting. Support brackets are nevertheless needed, especially for long conveyors, so compromises must be made with self-supporting.

Picture 2. Jam detector in conveyor's driving end.

The material for housing constructions is usually structural steels S235 and S355. Often, in the food industry, stainless steel or acid-proof steels like Aisi304 or Aisi316 are used.
It is worth it to dimension the conveyor housings and especially housings in the middle so that standard sizes of plates can be used. For instance, 3 m plate length is optimum for design and handling of the housings.

DRIVE MECHANISM

The driving mechanism is installed in the drive end. A combination of AC motor and gearing is normally chosen as driving mechanism. Here, the electric motor is compactly attached to the gearbox with a flange mounting. Most often, an alternating current motor is used where a bush ring axle is the secondary axle. This type of gear motor is easy to mount to the driving axle of the chain conveyor. In addition, it is easy to service. Rotation speed can be controlled with a rectifier if needed. In the gearbox, there is a so called torque fitting, from which the gearbox is supported to the corresponding torque fitting in the conveyor. The torque fitting must hold the forces caused by the axial torque forces from the gearbox.
On both sides of the gearbox torque fittings, rubber cushions are mounted, to absorb jerks or shocks, especially in connection to the start up of the conveyor. Also, during running, there are small jerks because of the polygon shape of the chain gear.
Torque fitting in the frame must be designed carefully to avoid possible bending and deformation. The forces caused by torque from the gearbox are directed to frame constructions through the torque fitting. One should not minimize material thickness.
A separate electric motor and gearbox can also be used with a v-belt or chain drive. On the other hand this combination requires more service and a v-belt drive has its own risks. Not recommended.
When choosing the electric motor, one must consider the protective system against fire if the transported material is very dusty.
Rubber absorbers for torque fittings and robust plate construction of torque fittings can be seen in the drive end housing. In addition, it is useful to take the whole support of the axle housing in the drive end into consideration already in the design phase (*pic 3*).
The drive end housing must be designed so no shelves are formed at the front end of the housing, where transported material could accumulate. An ample-sized hole is made in the bottom plate for outlet.
From a manhole attached with protective netting, one can inspect the running of the material and carry out service measures. Protective netting must be installed so that it cannot be opened without extra tools. A jam guard is installed in the front wall of the housing.

Picture 3. Driving end, outlet opening, gear motor and moment support with rubber cushions.

Picture 4. Folding end housing, trimming plate, trimmings screw and collar step bearing.

In the folding end housing for controlling the tightness of the chain, trimming plates and screws and bearing units are attached to trimming plates, axle and chain wheel. The manhole with protective netting should be installed at the folding end cover.

CHAIN WHEELS AND CHAINS

Chain wheel(s) in the drive end are best fastened to the axle with a shaft key. Light and short chain conveyors are made as mono chain and demanding and long conveyors with double chains, depending mostly on capacity and on properties of the transported material.

In the drive end, a gear wheel is used as chain wheel, which converts torque from the drive axle to the chain as the force which transports material further.

In design, it is recommended to consider a few aspects affecting choice of chain wheel. Chain pitch affects considerably on weight. The longer the pitch, the lighter is the chain, and this in turn reduces power required from the motor. One should notice that the number of teeth in the chain wheel affects the size of the chain wheel first and secondly the height of the frame housing. On the other hand, the lower the number of teeth, the more uneven is the running of the chain because the chain wheel is polygonal.The chain does not follow the reference circle but runs at an angle.

The chain wheel can be manufactured as one piece or be divided into two pieces. A divided chain wheel is more expensive to manufacture but replacing it is easier, because you don’t have to dismantle the axle. It is enough to open the cover from the end housing and loosen the bolts that hold the chain wheel halves together.

The chain wheel can also be made as a so-called half-tooth, when for instance, a chain wheel with 6,5 teeth has 13 teeth spaces. There is always one tooth space between every chain bushing.

Because the number of teeth spaces is uneven, the chain bushing touches teeth spaces only on every second round. Thus, wear on the chain wheel is less severe and operating life can even double.

The chain wheel in the drive end is connected to an axle, either with an axle key or with an adapter sleeve. In the key joint fastening axle, key piece and polar is checked according to surface pressure and key piece still according to cutting. When using an adapter sleeve, pay attention that movement of torque is based on friction.

The chain wheel in the folding end does not necessarily need a gear, because its function is only to guide the running of the chain. A so-called disk wheel is enough to guide the running of the chain.

The chain is tightened via trimming tabs/screws, fastened to the folding end.

INTERMEDIATE BOTTOM, LOADING- AND UNLOADING HOPPERS

Mostly material is transported from point A to point B. In these cases, a feeding hopper is placed at the folding end in front of the chain wheel, where material is dropped through the return chain to the bottom and from here, the chain below moves material to the outlet hopper, which is of course placed at the driving end. In these cases, an intermediate floor is not needed.

If material is fed to the conveyor from several points and out from several points, an intermediate floor is needed, along which an upper chain moves material towards the folding end. In this type of case, the lower chain transfers material to outlet hoppers. Depending on the process flow, there can be several outlet hoppers.

When there are several inlet and outlet hoppers, so that materials are fed and removed from the conveyor in several places, but because of process flow factors, not always from the same places, openings can be installed with electric or pneumatic closing devices.

AXLES, BEARINGS AND SEALS

The drive end axle must withstand torque from the driving motor and bending moment caused by the chain force transporting the load.

A collar step bearing unit is normally used as the bearing, or, in more demanding places a pedestal bearing and ball bearing or cylinder bearing. Normally, material is transported only on the bottom plate, thus the lower chain transports material and the upper chain works as an empty return chain. There is no torque in the folding end axle, only friction force caused by the returning chain, so there are hardly any forces affecting the axle, so bearings can be considerably smaller than in the driving end.

If there are several inlet and outlet openings, an intermediate floor is needed, on which the upper chain transports material to the folding end and drops it before the folding wheel on the bottom plate. In this case, bending force caused by drag force from the upper chain affects the axle in the folding end and it can be considerable.

When considering sealing the axle inlet, the harmful properties of dusty material must be considered. Seals are normally tape seals, which are easy to service. Circular radial seals are difficult to change, because it requires considerable dismantling measures.

Sprocket marking model

N1 - 12 - 70 / M224 - A - 160

Hub type

Number of teeth Z

Shaft diameter d (mm)

Chain

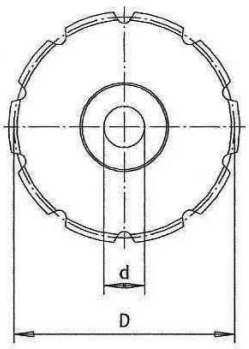
One-piece sprockets

The benefits of a one-piece sprocket are its low purchase price and its simple structure. However, one-piece sprockets are somewhat difficult to replace. During replacement, the shafts have to be removed from their bearings. The sprocket is installed by leading it onto the shaft and locking it into place.

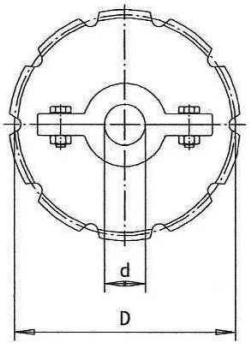
Splittable sprockets

The splittable sprocket is easier to install. As the sprocket consists of two separate halves, the shaft does not have to be removed for its installation. The halves are joined together by a bolt joint in the sprocket.

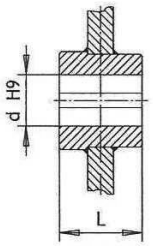
A splittable sprocket is ideal for demanding applications, in which the installation does not require removing the shaft.



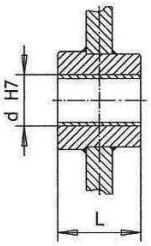
One-piece YN



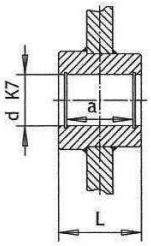
Splittable XN



N 1
Keyway



N 2
Bearing bush



N 4
With ball bearings

Hub types

Picture 5. Hub types of single and two-parts chain wheels and their marking principle.

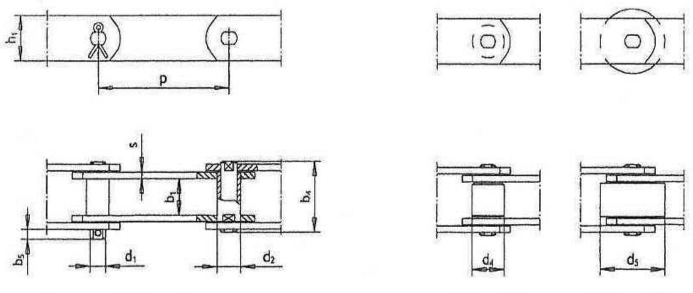
SPROCKET REFERENCE DIAMETERS

Reference diameter D in different size classes

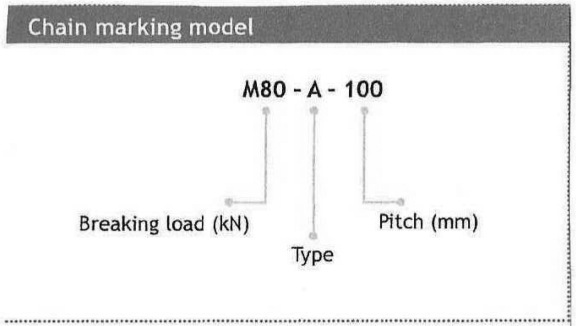
Chain no.	Pitch	Length of hub	8	10	12	14	16
M40	63	60	165	204	243	283	323
	80	60	209	259	309	360	410
	100	60	261	324	386	449	513
M56	63	70	165	204	243	283	323
	80	70	209	259	309	360	410
	100	70	261	324	386	449	513
	125	70	327	405	483	562	641
M80	63	80	165	204	243	283	323
	80	80	209	259	309	360	410
	100	80	261	324	386	449	513
	125	80	327	405	483	562	641
	160	80	418	518	618	719	820
M112	80	100	209	259	309	360	410
	100	100	261	324	386	449	513
	125	100	327	405	483	562	641
	160	100	418	518	618	719	820
M160	100	110	261	324	386	449	513
	125	110	327	405	483	562	641
	160	110	418	518	618	719	820
	200	110	523	647	773	899	1025
M224	125	120	327	405	483	562	641
	160	120	418	518	618	719	820
	200	120	523	647	773	899	1025
M315	125	140	327	405	483	562	641
	160	140	418	518	618	719	820
	200	140	523	647	773	899	1,025
	250	140	653	809	966	1,123	1,281
M450	160	140-160	418	518	618	719	820
	200	140-160	523	647	773	899	1,025
	250	140-160	653	809	966	1,123	1,281
	315	140-160	823	1,019	1,217	1,416	1,615
M630	250	200-240	653	809	966	1,123	1,281
	315	200-240	823	1,019	1,217	1,416	1,615

Picture 6. Chain wheel's reference diameters by teeth count and hub lengths.

CHAINS ACCORDING TO ISO 1977:2006



Type A Type B Type C



	Chain no	Breaking load kN	Allowable load kN	Measuring load kN	Pitch (P)				width b_1 min	Internal Pin d_1	Bush d_2	roller d_4	Small roller d_5	Plain roller d_6 (**	e	External Flanged b_4 (** max	b_5 max	width s	Side plates h_1	h_2	h_3
RIVETED CHAINS	M 40	40	5.7	0.8	63	80	100	125	19	8.5	12.5	18	36	42	13.5	40	9	4 (**	25	35	22.5
	M 56	56	8.0	1.12	63	80	100	125	23	10	15	21	42	50	17	46	10	4	30	40 (**	25 (**
	M 80	80	11.4	1.6	80	100	125	160	27	12	18	25	50	60	20	59	12	5	35	50	32.5
	M 112	112	16.0	2.24	80	100	125	160	31	15	21	30	60	70	22	65	14	6	40	60	40
	M 160	160	22.8	3.2	100	125	160	200	36	18	25	36	70	85	25.5	77	16	7	50	70	45
WELDED CHAINS	M 224	313	44.8 (*	4.5	125	160	200	250	42	21	30	42	85	100	30	89	-	8	60	90	60
	M 315	441	63.0	6.3	160	200	250	315	47	25	36	50	100	120	33	103	-	10	70	100	65
	M 450	630	89.6	9	200	250	315	400	55	30	42	60	120	140	37	121	-	12	80	120	80
	M 630	882	126.0	12,5	250	315	400	500	65	36	50	70	140	170	45	140	-	14	100	140	90
	M 900	1260	179.2	18	250	315	400	500	76	44	60	85	170	210	52	162	-	16	120	180	120

(* 40 per cent greater than that required by the standard, due to having welded bushes.
(** Differs from the standard.

Picture 7. Basic chain types and measurements table.

Although use of conveyors in industry is significant, good and comprehensive literature from the topic is not available.

Now based on 20 years of teaching experience and 25 years of conveyor designer experience I have written the book. In the book following conveyors are covered: chain conveyor, screw conveyor, elevator, belt conveyor and locker belt conveyor. In the book is explained use of bulk material conveyors, structures, operation, and as main topic design with calculation guidelines and in addition there is practical examples from every conveyor. In design and examples are included in addition to normal capacity and power calculations also structural design and dimensioning of axles and bearings and belts, chains, chain wheels and so on. From some of the examples also assembly drawings and technical drawings are made.

The book is written primarily to engineer level designers and in general to conveyor manufacturing companies. The book is also suitable for mechanical engineer students.

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