

ENGINEERING STEEL CHAINS FOR CONVEYING AND POWER TRANSMISSION

By CLIVE G. WILDSMITH
Ewart Chainbelt Co. Ltd., Derby, England

Abstract

Reliability of chain performance, whether in transmitting power or in conveying loads, depends on a wide variety of design, selection and application considerations. While the emphasis is on practical points for the user today — and, still more important, tomorrow — historical developments are quoted where they help to put current technology into perspective.

Introduction

Although the chain principle can be traced back step by step — or, more appropriately, link by link — for many centuries, still there is a great deal of misunderstanding in this area.

When the Egyptians developed a chain-driven bucket elevator around 200 BC, they faced no selection problem: a chain was a chain. And if it failed there was plenty of time and labour to put matters right.

Leonardo da Vinci produced some remarkably advanced designs. Sketches prepared around 1480 show plate chains of the laminated type now common on fork lift trucks, as well as bushed chains. The principles were there, but not the practical experience in applying those principles.

It is still possible to learn from history. Ewart's chief chain designer recently visited Admiral Lord Nelson's flagship 'Victory' and came away with an idea that is now being re-examined. In the bilges of the ship — built in 1765 and now preserved as headquarters of the British Home Fleet — was a toothed chain working on peg sprockets which could offer clear advantages in handling sticky materials.

Cast malleable chains

Main types of cast malleable chain are:—

Ewart detachable — after a century, still in common use today for lighter applications as in agriculture, taking advantage of the chain's self-cleaning action when articulating around sprockets. Ultimate strength up to more than 40 kN; maximum speed, 2 ms⁻¹ on drives and 0,5 ms⁻¹ on conveyors.

Pintle — with longer, heavier pitch and including later types with wear shoes. Maximum speeds similar to those of the detachable chain but ultimate strength up to 170 kN.

Gray pin — edging ultimate strength up to more than 180 kN.

Ley bushed — offering the added advantage of renewable pins and bushes in various metals to meet specific needs and problems.

Expanded width pintle — for drag link applications.

Pin chains with cast rollers — originally used widely in the cane sugar industry, offering ultimate strengths up to 180 kN at conveyor speeds up to 0,5 ms⁻¹.

Steel conveying chains

Earlier this century, steel conveying chains were developed to fill the strength gap between cast malleable and the steel

transmission chains then available. Many of these early steel roller conveyor chains were simple steel fabrications based on cast malleable design principles.

A typical example was the SS996 used widely in the cane sugar industry for many years. This was improved progressively to give greater pitch accuracy and wear resistance. From it were developed the current designs of cane carrier and bagasse chains, culminating in the now widely used 1796 plus chain which was designed specifically to meet the arduous operating conditions encountered in the world's largest sugar mills.

Conveyor chain selection

While chains for conveying loads will be studied first, all engineering steel chains — whether in bucket elevators, chain conveyors or drives — fall into the following main groups:—

Straight sidebar.

Offset sidebar.

Block and bar and leaf chain.

More specialised types to meet the needs of individual industrial applications have been developed from these general engineering steel chains, but the main principles remain unaffected.

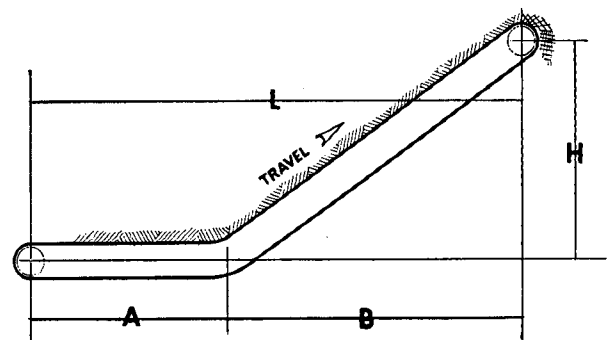
In selecting the correct chain for a particular application, thought must be given equally to the load and the operating conditions, with reliability the ultimate criterion. Otherwise, what may seem a low-cost answer initially will soon turn out to be the most expensive if production is continually interrupted by chain breakage.

Example of Bagasse Conveyor chain selection

Capacity 70 th⁻¹. Chain speed = 0,4 ms⁻¹.

Density of Bagasse 160 kg m⁻³.

2 strands conveyor roller chain, flights at 0,6m pitch.



$$70 \text{ tons/h} = 70\,000 \text{ kg/h} = \frac{70\,000}{60^2} = 19,44 \text{ kg s}^{-1}$$

$$\therefore \text{Mass bagasse conveyed/metre run} = \frac{19,44}{0,4} = 49 \text{ kg m}^{-1}$$

Assume 1,5 m, conveyor width, therefore:

$$\frac{\text{Material Depth}}{160 \times 1,5} = \frac{49}{160 \times 1,5} = 0,2 \text{ m}$$

Double strand chain, attachments, and flights,
Mass/metre run = 65 kg approx.

Chain pull

Where:

$$m = \frac{\text{Mass material/metre length}}{\text{Speed ms}^{-1}} = \frac{0,278 \times \text{capacity th}^{-1}}{0,4} = 49 \text{ kgm}^{-1}$$

$$M = \text{Weight material per metre length} = 49 \times 9,8 = 480 \text{ Nm}^{-1}$$

L = Horizontal centre distance.

fc = Friction coeff. — carrying strand

fr = Friction coeff. — return strand

Both rolling = 0,12.

fm = Friction coeff. on material, sliding = 0,4.

H = Vertical height (10m).

w = Mass/metre of chain and flights (65 kg).

W = Weight/metre of chain and flights = $65 \times 9,8 = 637 \text{ Nm}^{-1}$.

B = Horizontal length of inclined section (23m).

A = Length of horizontal section (15m).

Chain pull =

$$\begin{aligned} & ML fm + MH + W (L fc + H) + 1,2 WA fr + 1,2 W \\ & (Bfr - H) \\ & = (480 \times 38 \times 0,4) + (480 \times 10) + 637 (38 \times 0,12 + 10) \\ & + 1,2 (637 \times 15 \times 0,12) + 1,2 \times 637 (23 \times 0,12 - 10) \\ & = 7296 + 4800 + 9274 + 1375 + \text{zero} = 22,745 \text{ kN.} \end{aligned}$$

Assume duty as follows:—

- (1) Uniform and steady duty.
- (2) Over 10 hours working day.
- (3) Dusty, moderate working temperature.

Therefore, chain factor = 1,4.

Using 10 or 12 teeth sprockets at 0,4 m/sec chain speed, speed factor = 1,1.

Applying above factors

$$\text{Chain pull per single strand:} = \frac{22745}{2} \times 1,4 \times 1,1 = 17,513 \text{ kN}$$

Chain selection would logically be 102 mm pitch No. 0904 steel roller chain with an allowable chain pull of 22 kN, but having regard to previous experience of this duty, the 152 mm pitch equivalent No. 0906 or No. 09060, with their larger diameter pins and rollers, would be recommended.

Power requirement

Where P = chain pull and S = chain speed

$$\begin{aligned} \text{Power at headshaft} &= \frac{S [P - \{W(H - B fr)\}]}{1000} \\ &= \frac{0,4}{1000} [22745 - \{637 (10 - 23 \times 0,12)\}^*] \\ &= \frac{0,4 \times 22745}{1000} = 9,1 \text{ kW} \end{aligned}$$

Earlier designs of steel conveyor chain had flats milled on the bushes and pins to prevent movement in the sidebars. At that time, close enough control of manufacture and tool design was not available to take full advantage of interference fits, which today represent the main method of pin and bush retention.

The importance of controlling the interference fit cannot be over-emphasised. Similarly crucial is the shape of the hole in the sidebars. Earlier flattered designs meant stress-producing changes in shape and sections which led to fatigue problems and chain breakage.

Whereas the ultimate strength of a chain is a measure of the quality of manufacture and heat treatment, the design must also take into account the stresses that will be applied to the chain in service. This is what reliability is all about, and why during its development a new design of chain will be subjected to the most rigorous test procedures.

Modern chain components have yield characteristics approaching 85 per cent of the ultimate strength of the chain. That is to say a chain of balanced design has components with yield to U.T.S. ratios similar to that of the high grade steel from which it is made. Also, the efficiency of the fit of the components in the sidebars is so high that it is not impaired until at least 60 per cent of the U.T.S. figure is reached.

Chain life

Assuming the initial selection has been made wisely, with a sufficient safety factor, the effect of the working load on the chain during its life will be simply to produce progressive wear. Obviously, the higher the loads on the chain, producing high bearing pressures, the greater the amount of wear.

More recent developments in 'hyper' case pins, bushes and rollers will give greater life potential through case depth hardness being increased.

This type of chain will best withstand straight abrasion, but if corrosion is the major problem then stainless steel pins, bushes and rollers must be employed. The quality of stainless steel is such that it can be hardened to 49 RC and is manufactured to close limits chemically. Its physical condition has to be safeguarded during heat treatment.

Temperatures up to 230°C do not normally affect chain strength or life. Above this temperature level, the strength of chain materials is greatly reduced and heat-treated parts lose their hardness. However, this is not a problem normally found in sugar mills.

Key points

A number of key points on chain application that demand the attention of the sugar factory engineer are:—

Chordal action — the effect of the chain when negotiating the sprockets. The lesser the number of teeth, the higher the chordal action which means in turn that the pin is articulated through a larger arc. This leads to greater pin/bush wear. Answer: Use the largest possible sprocket, consistent with the conveyor structure and cost considerations.

Catenary effect — best seen in a sugar factory on main and auxiliary carriers where the natural catenary effect is interrupted by rollers on the return strand. Again this leads to high pin/bush wear as the chain is forced to articulate many more times than if the return strand is either skidded or carried back on outboard rollers.

Shock loading — a serious factor which can shorten chain life and cause breakage. Carriers should be designed wherever

* This section is negative so should be regarded as zero.

possible to have fluid or powder couplings in the drive to absorb start-up shock loads. Also, wherever possible, shock loads from cane knife action and at loading points should be taken by the carrier structure.

Three types of wear

Wear due to rolling — the effect of this is wear on the roller o/d and the roller bore, as well as on the bottom surface of the bush. A well-balanced life for these components is achieved by carefully matching the hardness of the two mating surfaces.

Wear due to sliding — found where use is made of chains not specifically designed for sliding, resulting in reduced chain life. Where the chain is designed for sliding — for example, 907E51 intermediate carrier chain or C132, used on feed tables — it will be capable of resisting wear if the correct materials are selected and the area in contact with the carrier guide rails is also correct.

Wear due to contact with the sprocket — on roller chain the chain gearing on the sprocket is greatly assisted by the chain roller which allows the chain to nestle right into the root diameter of the sprocket then to ride up the working face of the sprocket on to the dynamic pitch circle with the minimum of frictional forces. The main wear pattern will be found on the swept area by the pin/bush interface. On non-roller chain the pattern of wear will be seen also on the bush/barrel o/d. This can, in addition, cause wear on the sprocket if it is not of a hard-tooth type.

Sprocket types

No consideration of chains can progress very far without attention being given to sprockets. Materials used in the manufacture of chain sprockets fall into four main categories:

Cast iron, known as grey iron or common iron. This is normally for the more lightly loaded drive and conveyor or elevator applications.

Special grades of cast iron with additives enabling the sprocket teeth to be hardened by chilling the profile of the mould during casting. These are known as chilled rim sprockets and are the most commonly specified type for medium and heavy applications, with long wearing properties.

Cast or fabricated steel sprockets, used mainly in high shock load applications such as feed tables. Fabricated steel sprockets have certain manufacturing advantages over cast steel ones: they can be flame-hardened on the teeth and therefore give excellent wear life. They are specially suitable for highly loaded drives.

Split versions of all types of sprockets can be supplied, with obvious maintenance advantages on head and tail shafts.

The tooth shape on sprockets is of prime importance. Pressure angles and entry and exit radii must be accurately calculated and manufactured. Allowance for 5 per cent chain wear has been found to ensure long life.

Special needs

The particular difficulties experienced in the sugar industry provided one of the earliest and strongest arguments for developing specialist chains to suit particular needs.

Early use of general engineering chains quickly showed the need for a totally different approach, to meet problems of corrosion, erosion, abrasion and fatigue which are specific to the sugar industry.

Most technical papers and literature available merely outlined the problems and ventured speculative answers. Heavy reliance has had to be placed on feed-back of information on performance from mills in all the main sugar-producing countries.

In this as in so many other applications, a lot of answers came from studying worn samples and undertaking detailed analysis to establish causes of wear, corrosion, erosion and so on. This helped in designing components capable of combating these problems and ensuring very much longer service life.

Still, however, precise information and data on performance, operating conditions and service life are difficult to obtain. Sugar mill engineers, understandably, are busy people with many problems — and many different approaches to the same end.

This makes all the more valuable any comparative information that chain users are able to provide. Experience of installing and commissioning engineers from the major sugar machinery manufacturers to whom chain is supplied has also proved invaluable.

Latest developments

New metallurgical and technological advances are constantly being assessed to see how they can contribute toward an improved product.

One of the most recent developments to emerge — the COBRA or Carrier Out-Board Roller Assembly combines the best features of earlier overlapping tray and slat conveyors with many newer design ideas of particular interest to the cane sugar industry. It is beginning to supersede the conventional two-, three-, four-, and five-strand K attachment chain and slat conveyor.

In fact this type of conveyor is based on principles which date back at least 60 years having proved their rugged efficiency in the handling of materials such as sand, stone and coal. They have worked long and hard under extreme loading conditions in plants where break-downs could not be tolerated; where maintenance has to be kept to a minimum; and where long life is essential.

With the COBRA's rigid platform assembly, the full load is distributed evenly via a square through-rod direct to 150mm dia. outboard rollers, set well clear of possible spillage. This leaves the chain free of all but tensile loading. Jamming and roller damage are reduced, as are power requirements.

Taking a closer look at the chains, the COBRA assembly has two strands of one of the strongest 300mm pitch cane carrier chains yet produced. The large diameter pins have two and a half times greater bearing area than conventional carrier chains and can be supplied equipped for pressure lubrication. A hardened alloy chain roller minimises chain wear on the sprockets.

Coupled with the reduced demands made on the chains, these features make for years of trouble-free service.

The slats are of heavy-gauge plate with generous overlap of the deep corrugations and high, overlapping sideplates. Each slat is fully supported by two 90mm deep angle flanges and braced with a 32mm square through-rod. This prevents distortion and ensures maximum cutting efficiency. Supporting shoes running 1,5 mm above the support rails minimise deflection of the slats and avoid damage caused by impact loading. Slat can be replaced quickly by removing saddle bolts only.

Flanged rollers of 150mm diameter run on standard rails, providing rolling support on both carrying and return strands. This eliminates the need for return idlers and simplifies the supporting structure. The rollers are of heat-treated white iron with large grease reservoir, are readily accessible on removable bushings and offer a greatly increased bearing area.

These features allow the use of a heavy carrier and because of the rollers' large diameter and clog-free action, power requirements are reduced. Plain bearing or sealed-for-life ball bearing rollers are available as alternatives.

There could be no better example of what can be achieved by learning from the past — borrowing from the past — yet applying fresh thinking to every detail: load distribution, spillage, jamming, roller damage, chain loading, power requirements, cutting efficiency, impact loading, plus every possible means of ensuring a long service life with simplest possible maintenance.

Avoiding trouble

All the advances made in the design of chains, conveyors and elevators can still be cancelled out by failure to follow even the simplest maintenance procedures and, of course, by downright abuse of equipment.

Here are some pointers which have proved helpful in minimising problems associated with handling any type of material:

1. Load conveyors with the least possible impact. Ideally the load should be placed or slid on to the conveyor so as to avoid pulsations and surging caused by rough loading.
2. Avoid overloading of running gear by unloading the conveyor before shutting it down. Starting up under full load conditions means extra strain and wear on the equipment.
3. Before starting up, check for any obstructions and clean out any extraneous materials — particularly the kind that tends to pack or harden, such as bagasse or trash.
4. Run the conveyor empty for a short period to ensure that all joints and slats articulate freely and are effectively lubricated.
5. During shut-down periods run the conveyor once a week to keep joints from binding or seizing, thus reducing the risk of overloading when the plant starts up again.

Question of compromise

The purchaser and supplier of carrier chains must agree to compromise on occasions between what is ideally and theoretically the best chain for the job and what reasonably can be afforded or justified. Chains with larger roller diameters and larger bearing areas can always be produced — at a price.

The cane sugar industry has almost universally settled on chains of 150mm pitch using 70mm diameter rollers for main/ancillary and bagasse carriers, although some factories are using 150mm pitch, 76mm rollers on bagasse carriers and 200mm or 300mm chains on cane carriers. Introduction of the chain known as 1796 plus seems to have achieved the

optimum balance of embodying the quality of SS 600 but with the lower-cost straight sidebars helping to satisfy economic considerations.

Standardisation

Standardisation of conveyor chains looks like having reached another landmark with British, Russian, European and North American companies, through the International Standards Organisation having agreed on a new range of chains in metric pitches.

Slat clearances

Worth special mention are slat designs in relation to the successful performance of carrier chains on overlapping slat or tray conveyors. Correct slat profile is crucial. If there is insufficient clearance between the leading edge of one slat and the platform of the preceding slat, severe stresses can be applied to the K attachment of the chain, particularly when the return strand travels over rollers.

Power transmission

Most chains for power transmission are covered by the following groups:

- (1) Low speed and low power — cast malleable detachable and pintle chains.
- (2) Low speed and medium power — heavier malleable and pintle and light duty steel offset sidebar chains.
- (3) Low speed and high power — offset sidebar heavy duty bushed roller chains (crank link).
- (4) High speed and high power — multi-strand BS and ASA roller and inverted tooth chains.

Within each of these groups are to be found variants in metallurgical composition to meet corrosive, abrasive and high or extremely low temperature conditions. A classic case of sub-zero temperature chain application is on excavators operating in Northern Canada.

Increasing use is being made of offset sidebar drive chains in sugar mills — replacing the multi-strand transmission type. Advantages are a considerable increase in resistance to shock loading and they are less subject to clogging in dirty conditions, being used for driving track-mounted earthmoving equipment on which the chains are fully exposed to the worst possible conditions.

Where chain speeds are not high but power or torque is — as in final drives to main carriers — then offset sidebar or crank link chains provide a durable and economic alternative to multi-strand drives or spur gears.

Looking ahead

It is hoped that this paper will help toward greater understanding between the engineer and the chain manufacturer: understanding, above all, that will not rest here but will contribute further in the future to developments which — who knows? — may be quoted even 2 000 years hence, just as this paper began by paying due respects to the pioneering work of the Ancient Egyptians with their chain-driven bucket elevator.