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Lift and production limits for hoists and belt conveyors in underground mass mining operations

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Abstract

Haulage systems for future underground mass mining projects are likely to be based on current hoisting and belt conveying technologies with multiple streams and multiple flights in each stream.

Hoisting is a batch process. Hoisting systems can incorporate more than one flight in each stream with provisions for buffering and batching in the transfer from one flight to another. These systems are limited in the lift of each flight by the strength and weight properties of the ropes and are limited in production by practical limits on the maximum hoisting speed.

Belt conveying, however, is a continuous process. Belt conveyor systems can incorporate more than one flight in each stream with no interruption to the flow in the transfer from one flight to another. These systems are limited in the lift of each flight by the strength and weight properties of the belt and are limited in production by practical limits on the belt speed.

This paper presents details of current hoisting and belt conveyor systems in underground mass mining operations, and explores the limits of application of these technologies for the increasing demands of future underground mass mining projects.

1 Introduction

The scale of underground mass mining operations is increasing. The International Caving Study (Brown, 2003) identified this trend and categorised current and future underground mass mining operations as 'large', 'bulk' and 'super'. Table 1 presents details of a selection of operations in each of these categories.

The large category was defined as producing 4–6 Mt/a; bulk as producing 10–20 Mt/a; and super as producing or planning to produce greater than 25 Mt/a.

The super mines are addressing production rates exceeding 40 Mt/a and lifts up to 2,000 m. The haulage systems for these super underground mass mining projects are based on current hoisting and belt conveying technologies and incorporate multiple streams and multiple flights in each stream. The proposed Resolution Mine will incorporate three 2,000 m lift hoisting streams in each production shaft for 40 Mt/a (Pascoe et al., 2008). The proposed Chuquicamata Mine will incorporate one stream of three conveyor flights for 45 Mt/a with a total lift of 1,500 m (Pratt, 2008).

This paper presents an overview of current hoisting and belt conveyor systems in underground mass mining operations, and explores the limits of application of these technologies for the increasing demands of future 'beyond super' underground mass mining projects. These limits of application are illustrated with reference to a beyond super haulage system duty of 10,000 t/h (60–70 Mt/a) with 2,000 m lift.

2 Haulage systems for underground mass mining

2.1 Hoisting systems

Ore hoisting systems for underground hard rock mines incorporate crushing stations, skip loading stations, skip hoists and skip dumping stations.

Table 1 Details of large, bulk and super mass mining operations (after Brobst et al., 2008; Brown, 2003; Pascoe et al., 2008; Pratt, 2008; Pratt and Ellen, 2005; Spreadborough and Pratt, 2008)

Class	Name	Annual Production (Mt/a)	Hoist Vertical Lift (m)	Conveyor Vertical Lift (m)	No. of Streams	No. of Flights
Large	Argyle	8.0	-	394	1	1
	Brunswick	3.6	1,125	-	1	1
	Finsch	3.6	763		1	1
	Koffiefontein	1.2	620	-	1	1
	Tongkuangyu	4.0	-	410	1	1
	Mount Isa Copper	7.4	1,073	-	1	1
	Northparkes E26 Lift 2	5.0	505	345	1	3 *
	Cullinan	4.5				
	Ridgeway Deeps	6.4	-	1,058	1	4
	Telfer	5.0	1,113	-	1	1
Bulk	Andina	16.0				
	Cadia East	24.0	-	1,400	1	5
	Freeport DOZ	14.0				
	Henderson	12.0				
	Malmberget	16.0	800	235	1	2
	Olympic Dam	12.0	850	-	2	1
	Salvador	2.5				
	Palabora	10.0	1,290	-	1	1
Super	El Teniente	45.0				
	Chuquicamata	45.0	-	1,500	1	3
	Freeport Grasberg					
	Bingham Canyon	40.0	1,269	-	2	1
	Kiruna	27.0	1,223	-	1	2
	Resolution	40.0	2,000	-	3	1
	Mount Keith					

A crushing station is required to reduce the run of mine material to a size suitable for skip hoisting and to remove tramp material from the ore stream to prevent damage and blockage at other parts of the system. The tramp detection and removal system incorporates tramp magnets, metal detectors and in some cases facilities for manual tramp removal. This equipment is configured appropriately for the size, shape, magnetic properties and quantity of tramp anticipated.

A skip loading station is required to batch load the crushed run of mine material to the ore skips. The system typically incorporates a surge bin, a weigh hopper and interconnecting chutes and gates.

A skip dumping station is required to receive skip loads to a surge bin and to feed this material to the next stage of the system.

The skip hoisting system incorporates a winder, a headframe, a pair of skips and interconnecting ropes. The winder and the interconnecting ropes are arranged to support the skips so that one skip balances the other — one is raised as the other is lowered.

Hoisting systems are driven by either drum or friction winders. These are represented schematically in Figure 1. The head ropes of a drum winder are terminated to the winder drum and coil onto the drum as the associated skip is raised and off the drum as the skip is lowered. The head ropes of a friction winder pass over the drum and are driven by friction between the rope and the drum shell.

Friction winder drums are fitted with multiple head ropes. Friction winder skips are fitted with tail ropes to maintain the rope tension ratio at the drum.

Drum winders are configured with one or two head ropes on each skip. Drum winder skips have no tail ropes.

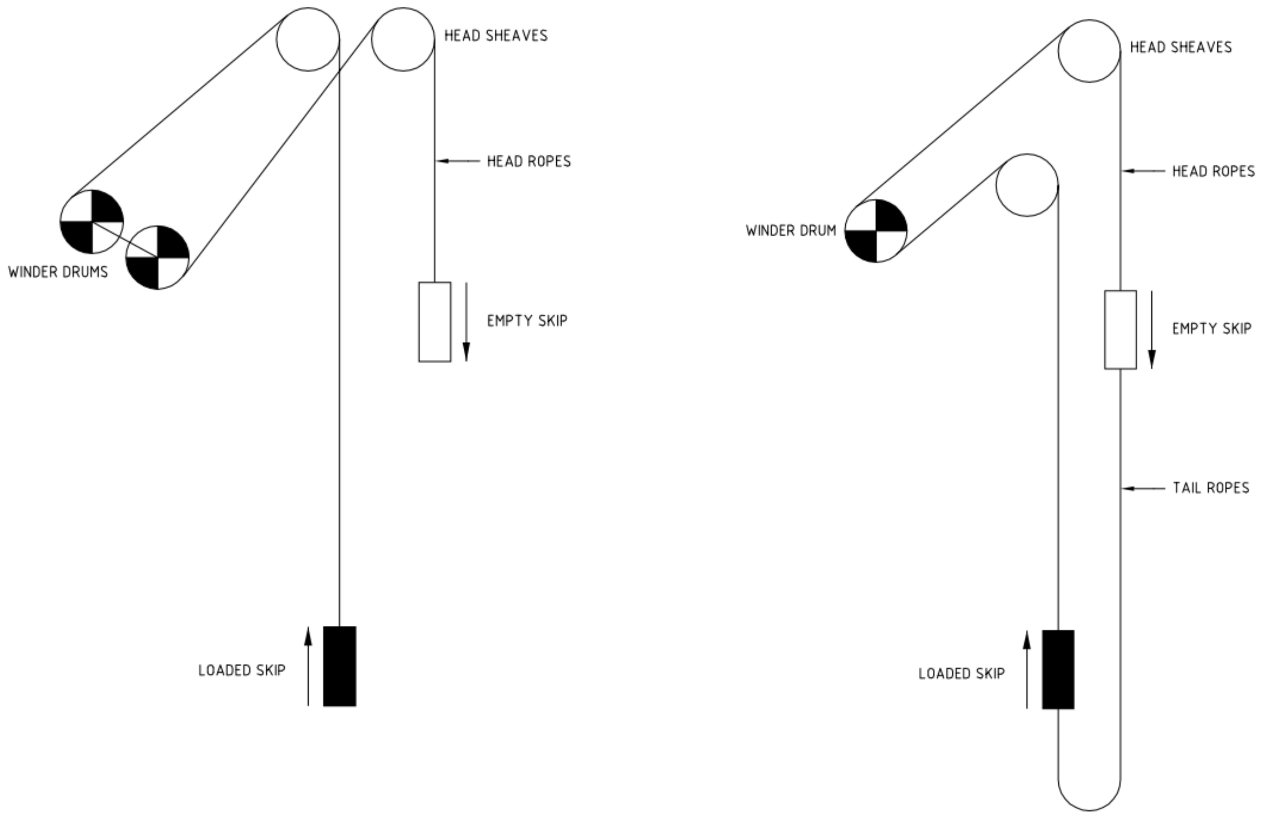

Figure 1 Schematic diagrams – drum and friction winders

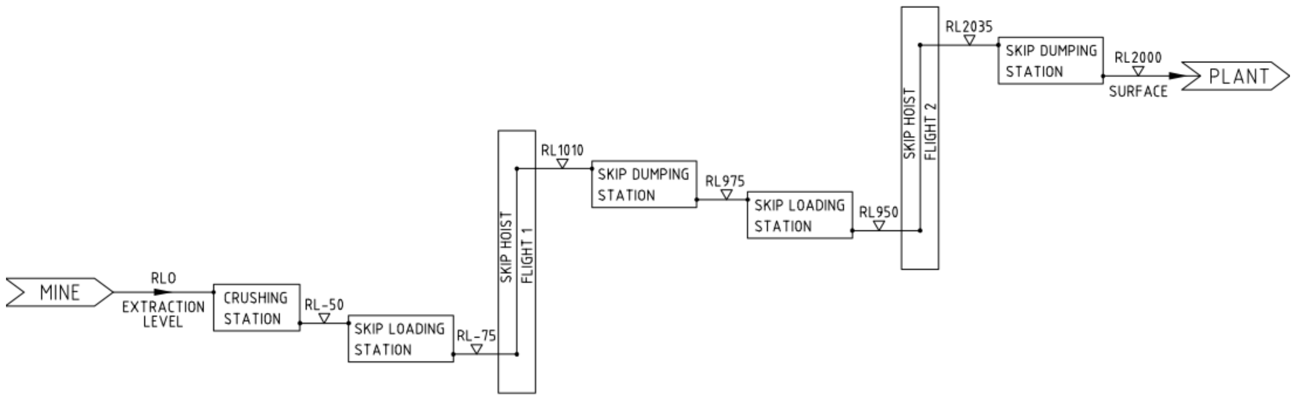

Figure 2 Flow diagram – example of a 2,000 m total lift hoisting system

Hoisting systems can incorporate more than one flight. A schematic diagram of an example two flight hoisting system is presented in Figure 2. This diagram illustrates that the beyond super 2,000 m total lift will require two 1,085 m skip hoists after allowing for lift losses at the crushing, skip loading and skip dumping stations.

2.2 Belt conveying systems

Belt conveying systems incorporate a crushing station similar to that provided for a hoisting system. Each conveyor in a multi flight conveyor stream delivers to the tail of the upstream conveyor.

A schematic diagram of a four flight conveyor stream is presented in Figure 3. This diagram illustrates that the beyond super 2,000 m total lift will require four 520 m flights after allowing for lift losses at the crushing station and transfers.

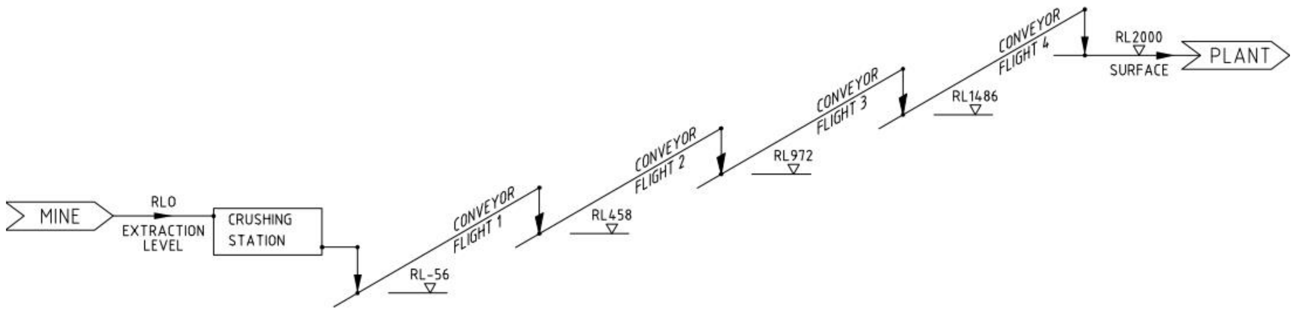

Figure 3 Flow diagram – example of a 2,000 m total lift belt conveying system

3 Lift and production limits

3.1 Hoisting systems

Hoisting systems are limited in the lift of each flight by the strength and weight properties of the ropes. The ratio of the strength of a rope to its weight per unit length is known as the free length of the rope:the maximum length that can support its own weight. The free length of winder ropes is constant across a range of rope diameters at around 17 km (Figure 4).

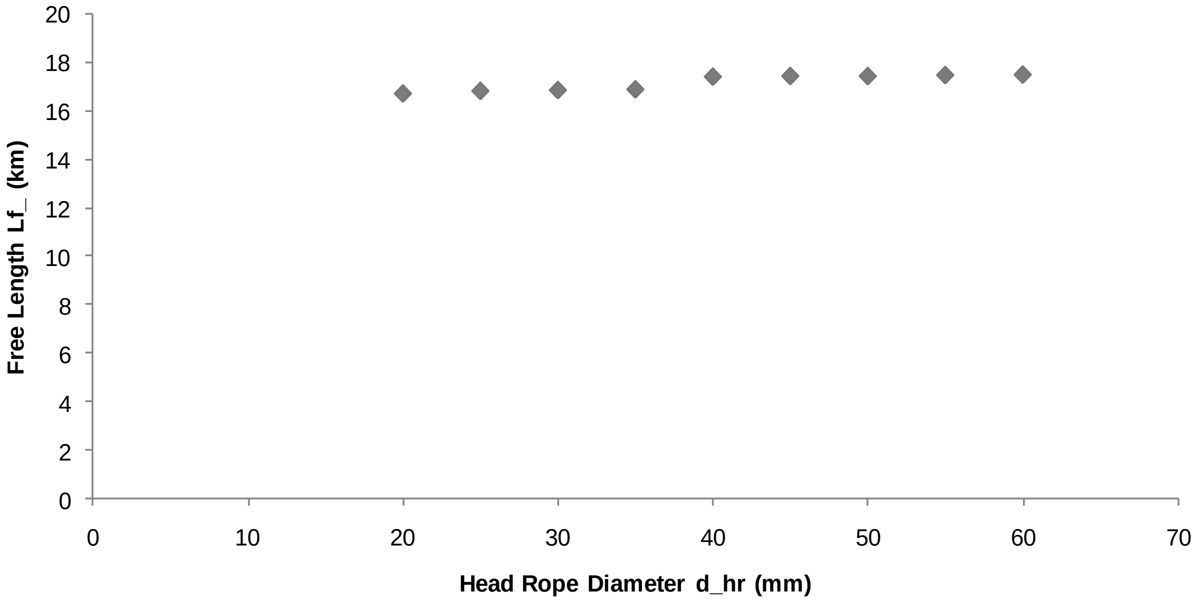

Figure 4 Free length – wire rope

Rope factors of safety for hoisting systems are generally defined by statutory authorities. A rope factor of safety of 5.1 has been applied for this assessment of lift and production limits.

Hoisting systems are limited in production by practical limits on the rope speed. These limitations are associated with rope resonance effects.

Typical lift and production limits are presented in Figures 5 and 6 for two head rope drum winders and six head rope friction winders with head rope diameters from 20–60 mm for two to four streams with one to four flights in each stream. The highlighted duty point addresses the beyond super duty of 10,000 t/h (60–70 Mt/a) with 2,000 m lift in three streams of 3,333 t/h, each with two flights of 1,085 m lift.

Figure 5 illustrates that this duty point is not viable for a two head rope drum winder.

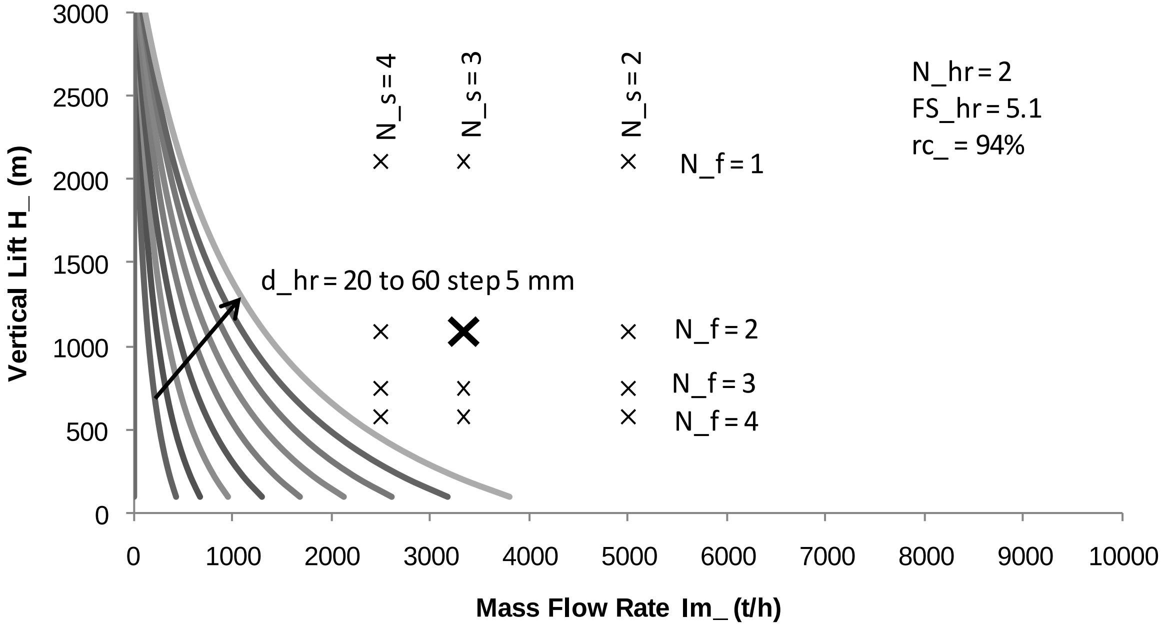

Figure 5 Lift and production limits – drum winder

Figure 6 illustrates the viability of this duty point for a six head rope friction winder with 60 mm head ropes.

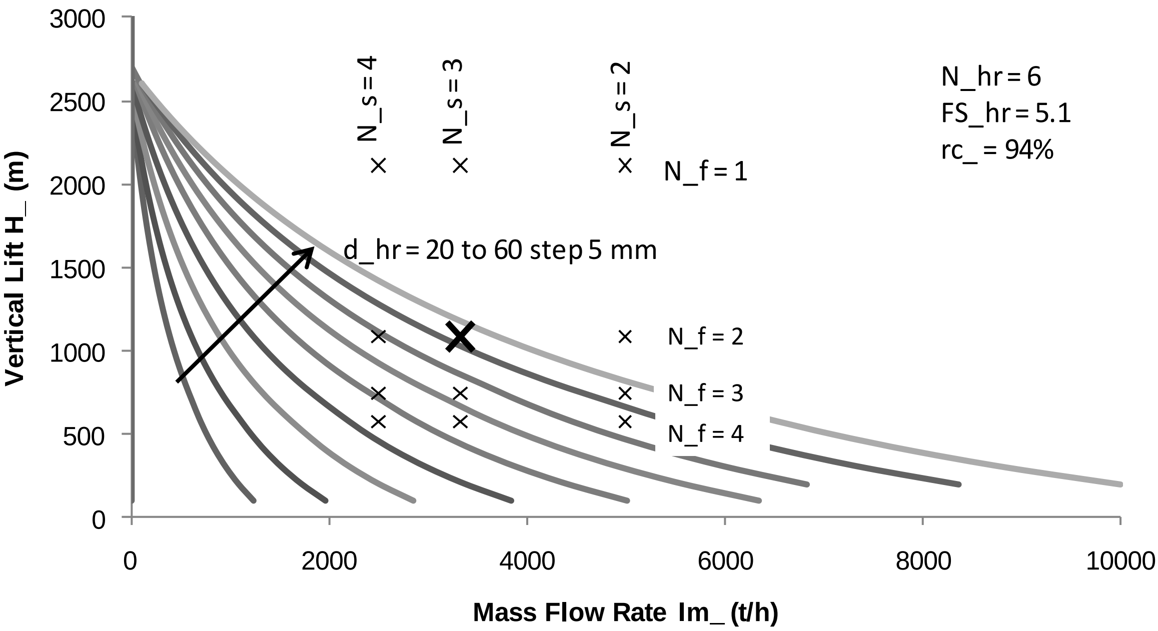

Figure 6 Lift and production limits – friction winder

3.2 Belt conveying systems

Belt conveying systems are limited in the lift of each flight by the strength and weight properties of the belt. The weight of the rubber that encases and protects the belt cords reduces the free length of the belt.

The standard range of steel cord belt constructions defines combinations of cord pitch and cord diameter that provides for greater free lengths for higher belt strengths.

Conveyor belting is also provided with additional cord protection rubber covers at the carry side and at the pulley side. The required cover thickness is assessed with reference to the application loading conditions, loading frequency, material lump size, density and abrasiveness.

An application that is assessed to have a light cover duty will require a belt with lighter covers than that assessed to have a severe cover duty. Hence belt constructions for light duty applications have greater free lengths.

The impact of belt strength and cover duty on belt free length is illustrated in Figure 7 for a range of belt constructions and for two extremes of cover duty. The free length of conveyor belting ranges from around 2 km for low strength carcasses to around 8–10 km for high strength carcasses, depending on the cover duty.

Belt factors of safety are selected for an application with regard to the measures taken to ensure the integrity of the splice fabrication, the fatigue duty to which the splice is subjected, and the additional stresses generated in the belt at the head end transition (DIN22101, 2000).

Splice fabrication is assessed with regard to lack of protection against sun exposure, dust, ambient temperature, worker qualifications, quality of splice materials and the quality of the vulcanising equipment.

The splice fatigue duty is assessed with regard to expected life, consequence of failure, operating conditions (corrosion, impact damage), starting and stopping frequency and the return frequency.

The minimum belt factor of safety for a high lift underground hard rock application will be around 5.2 where:

- the splice fabrication assessment is favourable
- the splice life assessment recognises the issues associated with life expectancy, consequences of failure and the physical demands of the application
- the head end transition geometry is generous.

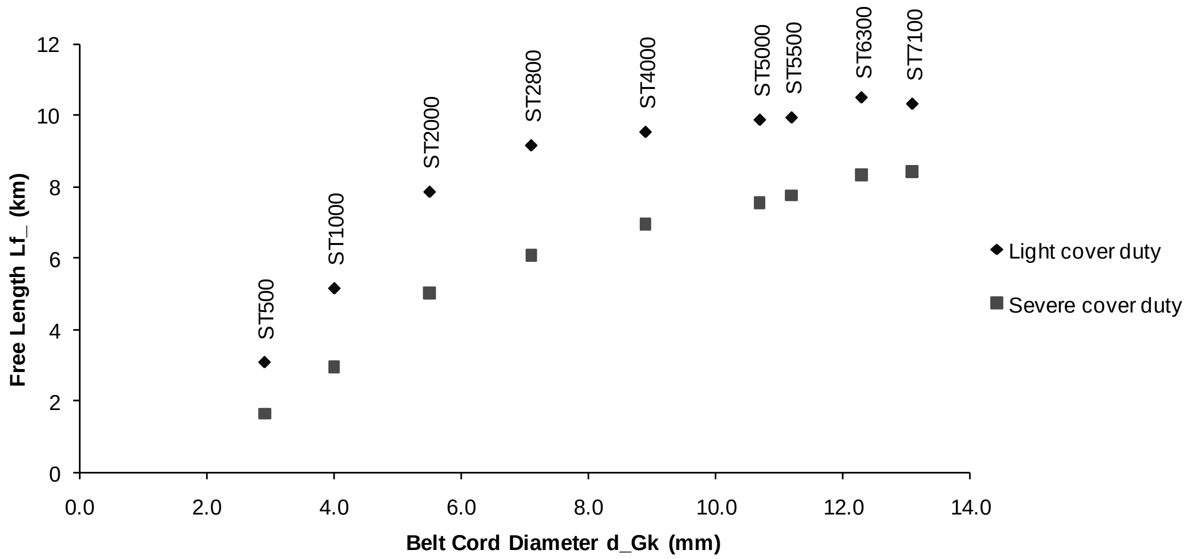

Figure 7 Free length - conveyor belting

Belt conveyors are limited in production by practical limits on the belt speed. These limitations are associated with dust generation and the risk of damage and injury.

Typical belt conveyor lift and production limits are presented in Figure 8 for belt widths from 1.2–3.2 m, belt carcasses from ST500 to ST7100 and for one to four streams with one to four flights in each stream. The highlighted duty point addresses the beyond super duty of 10,000 t/h (60–70 Mt/a) with 2,000 m lift in two streams of 5,000 t/h, each with four flights of 520 m lift. This duty is achieved with a 6 m/s, 2 m wide ST5500 belt.

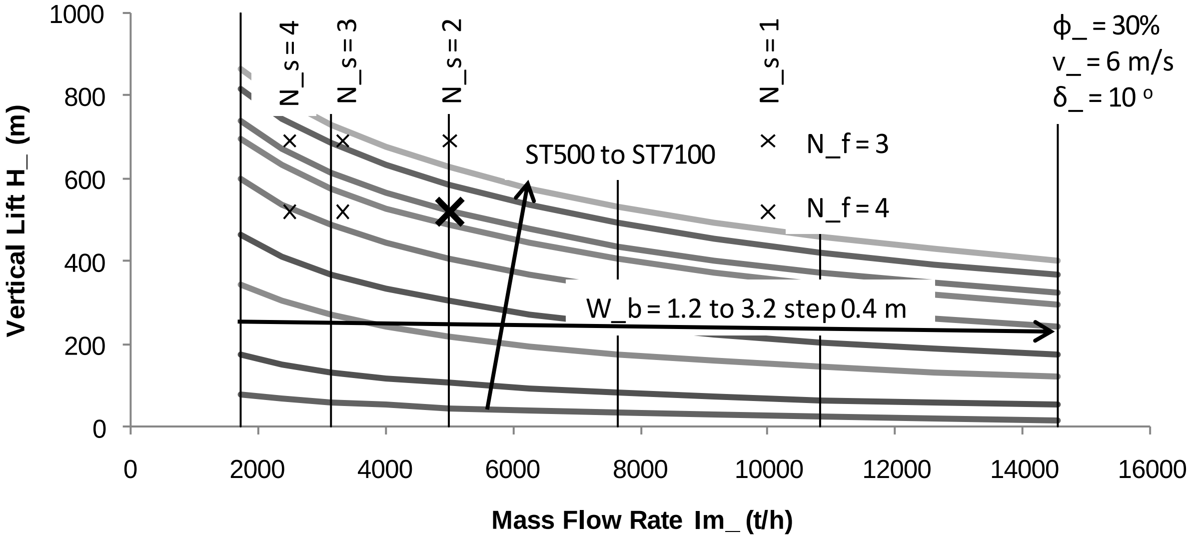

Figure 8 Lift and production limits – belt conveyor

4 Conclusion

This paper has presented an overview of current hoisting and belt conveying technologies and their application to beyond super underground mass mining operations.

The limits of application of these technologies has been illustrated for production of 10,000 t/h (60–70 Mt/a) with a total lift of 2,000 m. These levels of production and lift will require multiple streams and multiple flights.

A hoisting system for this duty will typically require six rope friction winders in three parallel streams of 3,333 t/h, each with two lifts of 1,085 m, and similarly a belt conveying system for this duty will require two streams of 5,000 t/h, each with four lifts of 520 m.

Nomenclature

W_	width
d_	diameter
FS_	factor of safety
H_	vertical lift
Im_	mass flow rate
Lf_	free length
N_	number
rc_	ratio conveyance mass (including attachments)/payload
t_	time
v_	velocity
δ_	slope
φ_	conveyor cross section fill ratio
	postscripts
b	conveyor belt
f	flights
Gk	conveyor belt cord
hr	head rope
s	streams

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