Brakes for Theatrical Hoists

Introduction

Experience has shown us that terms used to describe brakes on hoists (such as Load Brake, Holding Brake, Secondary Brake, etc.) can have different meanings to the people who are writing the specifications that we see. What follows is an attempt to create a common nomenclature for theatrical hoist brakes that can be used to simplify the dialogue between J. R. Clancy and its customers. We have also included a section on some of the design practices that we feel are appropriate for these devices.

Please note that this is a general discussion of the subject and is not a design manual. You are solely responsible for any designs or specifications you prepare, and for any equipment you manufacture or install. We recommend that any designs, specifications, or equipment you develop be reviewed by a licensed Engineer.

Definitions

The following is a set of terms that can be used to describe types of brakes, their location in the power train, and their means of application. Where possible, we have tried to keep our nomenclature consistent with the American Society of Mechanical Engineers' hoist, elevator, and personnel lifting standards which, currently, are the most comprehensive published standards that govern the design of similar machinery in the U.S. These definitions are also consistent with the most recent draft of ESTA's future ANSI E1.6 "Powered Hoisting Systems for Places of Public Assembly" at the time this is being written.

Brake: (per ASME) "A device used for retarding or stopping motion by friction means." Note that for our purposes we assume that these brake devices will be resisting rotary motion; therefore we will describe the capacity in terms of torque.

Brake Torque: The amount of torque applied to the power train by the brake that acts to decelerate or stop the load. The same brake will make a different amount of torque depending on if the load is moving or not.

Dynamic Brake Torque is produced by the brake while the machinery is in motion, and is usually quite a bit smaller than the **Static Brake Torque** for the same brake.

Fail-Safe (per ESTA draft standard E1.6) [The device in consideration] "Fails to a safe condition." With respect to brakes, this means that if the power or signal to the brake is lost the device will fully engage and resist motion of the system.

Hoist (per ESTA) Power driven machine used for raising or lowering a suspended load using a flexible lifting medium.

Load Side Brake: A brake in the power train of the winch that is attached to the same shaft as the load. This term is contrasted with "Motor Side Brake" to distinguish whether the brake is attached to the motor (on the high speed side of the gear reducer), or the drum (on the low speed side of the gear reducer).

Holding Brake: A brake used only to hold a load in a static condition. This phrase is contrasted with "Stopping Brake" to distinguish whether the device is designed to decelerate and stop a load, or just hold a load once it is at rest.

Mechanical Load Brake (per ASME) "An automatic type of brake that controls the load in a lowering direction. This unidirectional device requires torque from the motor to lower a load, but imposes no additional load on the motor when lifting the load." A "mechanical" brake requires no additional power or control input to function, i.e. it is self-energizing. This is also commonly referred to as a "drive through" brake.

Mechanical Over-speed Brake A particular type of over-speed brake that requires no external power or control applied to it in order to function. Several popular designs make use of centrifugal mechanisms to engage a brake when a preset rotational speed is exceeded. See Over-speed Brake.

Motor Side Brake: A brake in the power train of the winch that is attached on the *motor side* (high speed side) of the gearbox. This term is contrasted with "Load Side Brake" to distinguish whether the brake is attached to the motor or the drum.

Over-speed Brake: Any brake that is designed to automatically arrest a load when the load speed exceeds a preset threshold. Mechanical Over-speed Brakes (see above) require no additional power or control to activate. Many other types of brakes can be combined with electrical load speed sensors to detect runaway conditions and function as an Over-speed Brake.

Parking Brake: See Holding Brake

Secondary Brake: Any additional brake on a hoist for the purposes of redundancy.

Stopping Brake: A brake that is activated while the load is in motion, used to decelerate the load to a controlled stop. This phrase is contrasted with "Holding Brake" to distinguish whether the brake is designed to decelerate and stop a load, or just hold it in place once it is at rest.

Nomenclature Examples

Consider a simple drum winch comprised of a frame, a drum, a gear reducer, and an electric motor with an integral brake. The brake is on the high speed side of the gearbox, so it is a *Motor Side Brake*. If the winch is used with a fixed speed controller, the *Motor Side Brake* is also a *Stopping Brake*. If it is used with a variable speed controller, it is a *Holding Brake*.

Now, take that same drum winch and add an electric brake mounted to the drum shaft. The new brake is a *Secondary Brake* because it is used in addition to the brake on the gearmotor, and it is a *Load Side Brake* because it is on the same shaft as the drum. If this new brake is designed to arrest the load in the case of a runaway, it is a *Stopping Brake*. If it is designed only to be engaged when the load is at rest, it is a *Holding Brake*. If we add an over-speed sensor to the system, and use that sensor to activate the brake, we have an *Over-speed Brake*.

Commentary on Brakes as applied to Theater Hoists

Why use a Secondary Brake?

It is the nature of machinery to fail. Even the most carefully designed and manufactured systems are subject to factors such as material flaws, misuse, or lack of inspection and maintenance. Accordingly, a design for any machine that lifts or holds loads over the heads of people requires consideration of what happens when any one given component in the system fails. Wherever possible, we want to make sure that if a component fails, some other component or feature prevents the load from being released. A design that achieves this is referred to as "single mode failure proof." In many cases the Motor Side Brake is holding the entire load whenever the motor is not energized.

Load Side Brakes versus Motor Side Brakes.

A second brake can provide redundancy to hold the load in case the first brake fails. However, depending on where it is placed in the drive train, it can also provide protection in the case of other drive train component failures. For instance, many gearmotors feature a Motor Side Brake attached directly to the shaft of the rotor. If you take a second Motor Side Brake and put it right next to the first one, you have now added protection in case the first brake fails. But consider this: there are several gear meshes and couplings between the cable drum and these brakes. If any of these fail, the motor shaft will still be locked in place, but the load will fall. In this case, you had better be very confident that the gearbox and intermediate couplings will not fail.

Now, take the second brake and move it onto the end of the drum (or sprocket) shaft so that it is at the opposite end of the mechanical drive train from the motor brake. This is now a Load Side Brake. Now, if one brake fails, the other will still hold the load. Also, if the gearbox or any other coupling or shaft between the motor and the drum fails, the Load Side Brake can still hold the load. The benefit is obvious: the one brake now provides redundancy for two or more power-train components. However this benefit is not without cost. There is no gear ratio between the new brake and the cable drum, so the brake needs to be larger than the one on the motor shaft.

It is interesting to note that the DIN standard for theater winches allows the use of two Motor Side Brakes as long as the design factor on the gearbox is 200%. The idea is that if the gears are made that much stronger than the anticipated load, then there is only a very small chance that it will fail and so a Load Side Brake is not required. The prevailing design philosophy in the U.S. seems to be that the gearbox should be designed for the anticipated loads with a slightly less conservative design factor, and then used in conjunction with a Motor Side Brake and Load Side Brake that will hold the load if the gearbox ever were to fail.

Redundant Gearmotors

As hoists become larger, brake units large enough to be applied as Load Side Brakes become very expensive. In some cases, it can be more cost effective to use two complete sets of motors, gearboxes and Motor Side Brakes than it is to use a single Load Side Brake. The two gearmotors are placed at opposite end of the mechanical drive train for redundancy. The design of these machines is a topic unto itself that we will not explore here. Feel free to contact us if you are interested in learning more about these types of machines.

Holding Brakes versus Stopping Brakes

Holding brakes, also known as Parking Brakes, engage only after the load has come to a complete stop and are designed to hold it in a static condition. This is different from a Stopping Brake, which must actually decelerate the load and bring it to a stop. To the machinery designer these are very different conditions: The dynamic torque from a given brake is usually considerably less than the static torque it can provide, so the brake may need to be larger if it is used as a stopping brake. Also, Stopping Brakes convert the energy of moving systems into heat, so the system must be able to either dissipate that heat or operate at the elevated temperature. Finally, the friction linings of Stopping Brakes will wear over time whereas those on holding brakes will typically not.

Note that when contactors are used to control a fixed speed hoist, the brake will engage at the moment the motor is de-energized, so the brake "catches the load" and functions as a Stopping Brake. Contrasting this is a winch using the same gearmotor but with a variable speed AC motor drive that will decelerate, stop, and hold the load until the brake is engaged. The same Motor Side Brake is now operating as a Holding Brake only.

Over-speed brakes

There are a variety of *mechanical* over-speed brakes in use today. A common design uses a centrifugal mechanism to engage a band type brake. The simple nature of the centrifugal design makes them relatively inexpensive to manufacture. Any brake capable of stopping the load can be combined with a control system that will sense the load speed and used as an over-speed brake. For this type of design, it is important to couple the speed sensor to the drum shaft along in order to effectively monitor drum speed.

It is important to note that over-speed brakes can generate impact loads on the supporting building structure that greatly exceed those of the winch in normal service.

Mechanical load brakes

One simple version of a Mechanical Load Brake is simply a disk brake with a fixed braking torque value fixed to the drum shaft. It is fitted with an over running (“one way”) clutch so that the brake is engaged only when the load is being lowered. These work well on scoreboard hoists and similar machines where the load is known and constant so the brake torque can be properly preset. They have had a reputation for being noisy.

Weston style Mechanical load brakes are in wide use in industrial hoists and have recently come into use in our industry. Like the scoreboard hoist brake, the Weston brake has a ratchet type arrangement so that it is engaged only while the load is being lowered. However, the Weston Brake has a more sophisticated mechanism by which the braking torque generated is proportional to the load.

Unlike over-speed brakes, Mechanical Load Brakes operate every time the load is lowered. Provisions must be made to accommodate the heat generated during normal use. Also, inspection and maintenance of the brake linings becomes an important consideration.

Conditioning the brake lining: “Burn in”

Some brakes require conditioning before they will produce the torque listed in the manufacturers catalog. When selecting a specific brake product, contact the manufacturer to confirm this if it is not specified in their literature. Note that due to the extremely low duty cycle, theatrical brakes will most likely need to undergo a specific procedure to achieve this conditioning at the time of commissioning.

Writing Specifications for Hoist Brakes

JR Clancy manufactures a wide variety of winches to match our customer’s specifications. In order to provide enough information for us to design your machinery, a complete specification for a brake on a theatrical hoist would answer the following questions:

1. Is a Secondary Brake required in addition to the Motor Side Brake?
2. If a Secondary Brake is required, does it need to be a Load Side Brake or a Motor Side Brake?
3. If an additional brake is required, is it a Holding Brake or a Stopping Brake?
4. If it is a Stopping Brake, does it need to trigger in an Over-speed condition?
5. If it is a Stopping Brake, can it trigger only in an Over-speed condition?

Although we will build machinery to match your exact specifications, please consider our recommendations in this paper.

Recommended Design Practices

1. General

a. Unless the rigging system has redundancy built into it in other places, we recommend that hoists that lift or hold loads over the heads of people feature secondary brakes.

b. We recommend that the Secondary Brakes be mounted directly to the drum or drum shaft with no couplers or linkages in between (i.e. as Load Side Brakes)

c. We recommend that all brakes be of Fail Safe design

2. Motor Side Brakes

A Motor Side Brake should produce a minimum of 200% of the full load (nominal) torque produced by the motor.

3. Secondary Holding Brakes

There are some applications where Holding Brakes are appropriate, particularly when it is known that the machinery will not be moving while people are below. However, if people may be standing below the load while it is moving it is more appropriate to use a Stopping Brake. If there is some question as to the application of the winch, we recommend that the Secondary brake be specified as a Stopping Brakes.

The static torque produced by a Holding Brake should be no less than 125% of the torque produced by the maximum load on the hoist. The Dynamic torque produced by that same brake should be no less than 100% of the torque produced by the maximum load on the hoist.

4. Secondary Stopping Brakes

If stopping times or distances are specified, further engineering analysis is required. If no stopping time or distance is specified, a stopping brake should produce a minimum of 130% (dynamic torque) of the torque produced by the maximum load on the hoist. In any case the dynamic torque produced by the brake should typically not exceed 300% of the torque produced by the maximum load on the hoist. This is so the brake cannot transmit forces back into the winch that exceed the design factors of the hoist frame and connections to the building structure. Limiting this value is also important to avoid tearing apart whatever loads are attached to the lifting lines of the winch.

5. Over-speed brakes

Braking Torque design factors for over-speed brakes should be the same as those of any stopping brake. See above. The speed at which the brake engages should be set as close as possible to the operating speed so as to limit free acceleration of the load and resulting impact forces as it is arrested. Both the brake and the over speed sensing device should be directly attached to the shaft to which the lifting load is applied, i.e. the drum shaft.

These are general recommendations that may or may not apply to your project. Each specific hoist and application are different, and you are solely responsible for any designs or specifications you prepare, and for any equipment you manufacture or install. We recommend that any designs, specifications, or equipment you develop be reviewed by a licensed Engineer.

Questions and Comments

We always welcome your comments. Feel free to contact our staff to discuss any of the above topics and how they might apply to your project.