

WHITE PAPER

# Determining Gearbox Service Factors for Overhead Crane Applications

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## Introduction

One of the most important aspects to consider when sizing or selecting power transmission products adequately is the suitable service factors for various applications. *Service factors* are basically periodic overload capacities that components such as speed reducers can operate at without damaging or shortening the lifetime of the product.

A service factor higher than 1.0 with no overloading, implies an increased reliability and lifetime of the product. Ideally, engineers would always apply high service factor values in order to guarantee reliable and durable products. However, these service factors must be optimized so that manufacturers do not lose their competitive edge in the market by offering an over-sized product. How then, are service factors that yield reliable yet competitive products being determined? Large associations such as the American Gear Manufacturers Association (AGMA) and the Crane Manufacturers Association of America (CMAA) help quantify numerical service factors for specific applications, generally determined through theoretical testing data as well as real application data through numerous years of experience. The focal point of this article is to reveal the importance of pre-established selection criteria, as well as the collaboration between the speed reducer manufacturer and the crane manufacturer in selecting a product that meets the end-user's needs.

Per AGMA, there are several different factors that go into determining the appropriate service factor of an application such as:

### Load characteristics:

- Uniform vs. moderate vs. heavy shock load
- Light vs. medium vs. heavy inertial load

### Motion characteristics:

- Frequency of start and/or reversal

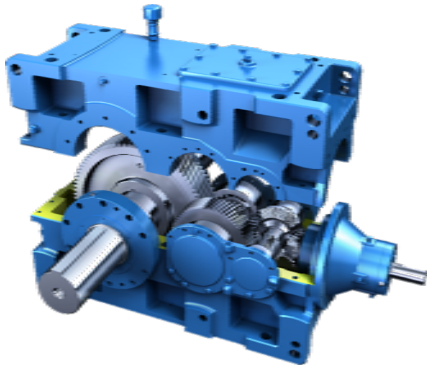
### Operating hours:

- Intermittent duty vs. Medium duty vs. Continuous duty

Although the conditions mentioned above are the most common factors for establishing service factor criteria, special consideration must be given when the following conditions are present:

- Extreme temperature and/or environmental conditions
- Equipment operation involving human safety
- Misalignment or unstable foundations
- Lubrication or variable mounting positions
- Brake Equipped Applications
  - When an application requires a “working brake” because deceleration of motion is required, it is necessary to consider the brake rating as part of speed reducer selection and or service factor.

*Figure 1. Bevel Helical Reducer – Paramax®: A commonly used drive for large industrial crane hoist applications.*



Further consideration must be given to the characteristics of the prime mover for a speed reducer selection, i.e., electric motor vs. internal combustion engine vs. hydraulic motor. The load characteristics transmitted by the different types of prime movers must be carefully and meticulously taken into account in order to offer a durable and robust speed reducer that meets the job requirements in all normal operating circumstances. For instance, it is generally expected that a speed reducer driven by an internal combustion engine be sized with a higher degree of service factor as compared to an electric motor. Unlike an electric motor whose torque output is comparatively smooth, internal combustion engines have multi-cylinder/piston type motions that produce varying torque. This varying torque will ultimately result in shock loading for the driven equipment. Even within electric motors, there are distinct operating characteristics that must be taken into account when sizing the speed reducer for the application.

The importance of the prime mover for sizing the reducer becomes particularly apparent in applications with a large frequency of starts/reversals. In many applications, an intermittent duty with multiple starts/stops/reversals may require a significantly higher service factor than a continuous running, occasional shock load application. One application with numerous starts/stops/reversals is the overhead crane application. A simple bridge crane often has three main drives that are frequently starting, stopping, and reversing during its operation. As is shown in Figure 2, a bridge crane consists of the following drives:

- Bridge travel drive
- Trolley travel drive
- Hoist drive

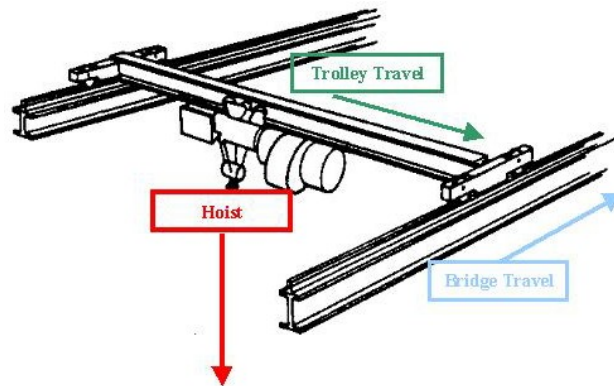
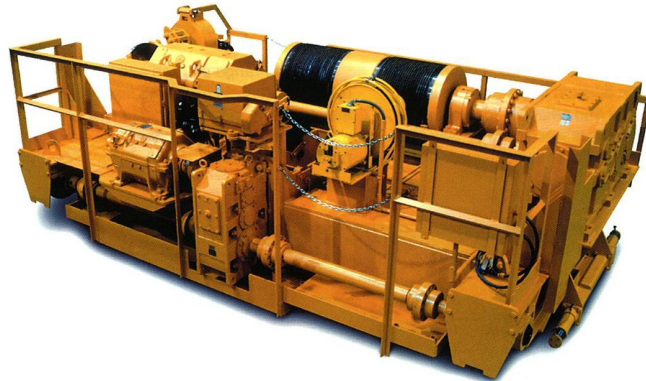


Figure 2. General Schematic of a simple overhead bridge crane <sup>1</sup>

<sup>1</sup> R.E. Ward. Material Handling Equipment Taxonomy. September 30, 1999  
<<http://www.ise.ncsu.edu/kay/mhetax/TransEq/Crane/>>.  
Modified on March 4, 2010 by Danilo Lai



**Figure 3.** This 35-ton capacity DC Trolley Hoist incorporating Sumitomo Paramax® reducers<sup>2</sup>



**Figure 4.** 100' span bridge crane with Sumitomo Paramax® reducers<sup>3</sup>

As the name itself implies, the travel drives are used for traveling and guiding the hoist drive to its intended location, and is generally distinguished into two components: the bridge travel drive offers “longitudinal” motion while the trolley travel drive offers “latitudinal” motion. Furthermore, the hoist drive is used to hoist or lift the material/product. These drives are designed to operate with frequent starts, stops, and reversals. If we take a typical assembly operation as an example, these operating conditions become quite clear. In order for a simple pick and place operation to occur, the operator must maneuver the travel drive towards the material, come to a full stop while the hoist is operating, and reverse back to its original location. Within this short period of time, the travel drive has gone through multiple stages of acceleration, deceleration, stops, and reversals.

These motion characteristics may in turn lead to overloading of the reducer through the prime mover. In order to better clarify this concept, a typical electrical AC induction motor start-up curve is shown in the Figure 5 below

<sup>2</sup> “35-ton capacity DC Trolley Hoist.” Photograph. Virginia Crane, Ashland, VA

<sup>3</sup> “100’ span bridge crane.” Photograph. Virginia Crane, Ashland, VA

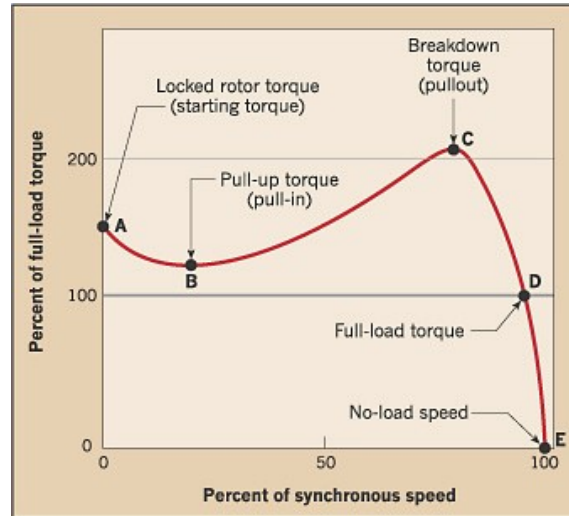


Figure 5. Motor Start-Up Curve <sup>4</sup>

Without going into the details of the motor start-up curve shown above, it is evident that prior to reaching its nominal operating speed at point “D”, the torque transmitted can reach values greater than 200% of the full-load torque. This in turn, means that every time the travel drive is operated, these torque overloads will be transmitted by the motor and transferred to the speed reducer. Speed reducer manufacturers are well aware of these overload conditions and therefore design their products to be capable of withstanding a limited number of overloads over a span of time. However, as mentioned above, the main operation of a travel drive includes repeated starts/stops/reversals, which in turn means that the speed reducer is frequently being overloaded.

There are two possible solutions to ensure the reducer performs adequately under these overloads: upsize the reducer to increase the load carrying capacity or utilize a “torque smoothing” control method. Modern motor technologies can be employed to ensure that the ramp-up characteristics of the motor are not so abrupt by smoothing out the acceleration nature of the driver. There are several control methods such as Variable Frequency Drive (VFD) and Flux Vector Motor Controls for AC drives and Digital DC controls for DC drives. An AC Variable Frequency Drive can moderate the characteristic high starting currents of AC induction motors during the ramp-up period described above by varying the line frequency, and therefore the synchronous speed (Ref. Figure 5), during acceleration. Because the motor is always operating near synchronous speed, the torque is kept to a value near the full-load torque. This feature assures smooth transitions between speed steps, which in turn minimize the effects of shock on the driven equipment. On the same note, digital logic controllers for DC drives deliver precise and repeatable controls for the application, with increased reliability and performance. Many of the features of current DC control technology are similar to those described for AC Variable Frequency Drives.

Due to a smoother ramp-up characteristic of the prime mover through the controls mentioned above, the service factor requirements for the speed reducers become less stringent. The crane manufacturers also take such conditions into close consideration. According to the Association for Iron and Steel Engineers (AISE), travel drive speed reducers that will be operated with “torque smoothing” control methods can be selected with a lesser amount of service factor: *“Travel drive gear ratings for bending strength and pitting resistance shall be based on 2 times the 60-minute motor rating for series wound constant potential DC drives, and 1.7 times the 60-minute motor rating for AC motors and adjustable voltage DC drives”* <sup>5</sup>

<sup>4</sup> Ed Cowern. Understanding Induction Motor Nameplate Information. May 1, 2004 <[http://ecmweb.com/mag/electric\\_understanding\\_induction\\_motor/](http://ecmweb.com/mag/electric_understanding_induction_motor/)>.

<sup>5</sup> Anon (1966), AISE Standard No.6, Specification for Electric Overhead Traveling Cranes for Steel Mill Service, Association of Iron and Steel Engineers.



**Figure 6.** Overhead Crane Application. Courtesy of Virginia Crane <sup>6</sup>

Other associations like the CMAA develop specifications that are intended to ensure a balance between cost and performance, based on the projected use and duty-cycle of the equipment. There are other crane specifications in use, including AISE Specification No. 6, and various European and worldwide specifications as well. CMAA designates six crane duty classes, from A to F, with F being the most heavily operated under the most severe conditions. Class F cranes incorporate features that ensure long life and expedite required maintenance. Customers who purchase Class F cranes usually do so because they require high in-service time, expect equipment life measured in decades, and understand that reducing maintenance costs yields significant savings in lifetime equipment costs.

During the design process, loads are calculated and speed reducer torque requirements are determined, under normal operating conditions as well as under extraordinary load conditions, such as crane collisions or emergency stops. When the speed reducer torque requirement is known, a speed reducer capacity is selected based on a minimum speed reducer service factor determined primarily by CMAA design class, but influenced by the actual in-use conditions, and other factors including prime-mover type, electric motor type, control design, ambient temperature, etc. For crane specific applications, the CMAA Class is a determining factor. However, for other factors, a consultation with the speed reducer manufacturer is required.

CMAA does not mandate, or even suggest, speed reducer service factors when buying speed reducers from gear manufacturers as they state that all commercial speed reducers are to be sized according to the manufacturer's recommendation. Consequently crane builders should meet with their speed reducer suppliers to determine suitable service factors based on CMAA Class designations. Years of reliable service later, the service factors chosen have proved to be an effective balance of cost and performance.

Open communication between the speed reducer manufacturer and the crane manufacturer is essential to ensure that the product is being sized adequately for its intended application. It is also very important to purchase components from manufacturers that are part of large associations such as AGMA and CMAA that develop specifications based on numerous years of experience as well as proven theoretical data. This level of commitment from the manufacturer ensures that the end-user will receive an adequately sized product that meets all requirements set forth by the application.

<sup>6</sup> Virginia Crane. 2010. <<http://www.virginiacrane.com>>



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4. "100' span bridge crane." Photograph. Virginia Crane, Ashland, VA
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**Biography:**

Danilo Lai is a Product Engineer with Sumitomo Drive Technologies. He has a Bachelor's Degree in Manufacturing Engineering from Boston University and a Master's Degree in Mechanical Engineering from Tufts University. Danilo's interests are in the areas of Engineering Operations Integration and Global Knowledge Management

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