WP0305
Dodge® conveyor pulleys: life comparison
Dodge Customer/Order Engineering
10-25-2019

The belt conveyor marketplace is full of pulley end disc terminology such as weld-in hub, integral hub, and profiled. There are also different classes of pulleys such as CEMA, Heavy Duty, and Mine Duty. These terms are used to differentiate between products within a pulley manufacturer's product line. Though, these terms don't explain how these designs compare with other products in the marketplace. Recently, ABB analyzed standard end disc designs in a side-by-side comparison, to allow customers to make better decisions about their conveyor pulley needs. Through finite element analysis, ABB compared the theoretical fatigue life of four common pulley designs: Heavy Duty with weld-in hub, Heavy Duty with integral hub, Mine Duty with weld-in hub, and Mine Duty with integral hub. The results of the study show the increased value of the Mine Duty pulley class with an integral hub.

Pulley Construction:

Typically, a manufacturer's lightest conveyor pulley design will be a pulley that adheres to the CEMA B105.1 standard for Welded Steel Conveyor Drum Pulleys. Along with dimensional tolerances, this standard provides minimum load rating capabilities for welded steel conveyor drum pulleys. This helps ensure that U.S. pulley manufacturers offer pulleys that meet these minimum standards. Generally, pulley designs that meet CEMA load ratings are referred to as Heavy Duty. Some conveyors require pulleys to handle more load than CEMA publishes. In these cases, pulley manufacturers have created designs that are a step above CEMA requirements. These designs are typically referred to as Mine Duty. There are no standards or restrictions for Mine Duty pulleys, so each manufacturer internally defines Mine Duty. Generally, the Mine Duty design has a thicker rim and end disc than the Heavy Duty design, which allows the pulley to withstand heavier loads.

End Disc Designs:

Welded steel conveyor pulleys have been common in the United States for nearly 70 years. During that time, the most common end disc design was the weld-in hub end disc, **Figure 1**. The weld-in hub end disc design is a two-piece assembly where a steel hub is welded to a thin, plate steel disc. This assembly is then welded to the pulley rim to complete the pulley construction. This design is typically referred to as a standard CEMA pulley. Notice in Figure 1, the red areas are fillet welds. At a minimum, this pulley design would have 7 different welds.

The next pulley end disc design we will consider is the profiled/integral hub end disc, **Figure 2**. This style of end disc has only been around about 30 years. With this one-piece design, the hub is made into a thick, plate steel disc; therefore, the hub is integral to the end disc. This eliminates the hub to end disc weld that exists on the previous weld-in hub design. Pulley weld locations have been known to have a greater potential for cracks to form. Therefore, to improve the load carrying capability of a conveyor pulley, the number of welds must be minimized. Moving to the integral hub eliminates 4 of the 7 welds from the traditional weld-in hub design.

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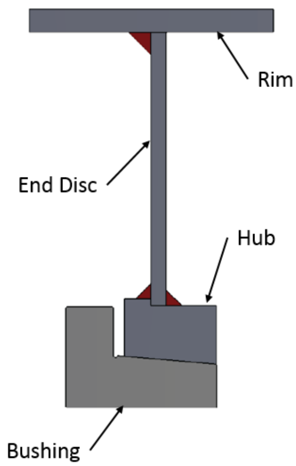

Figure 1. Weld-in hub design

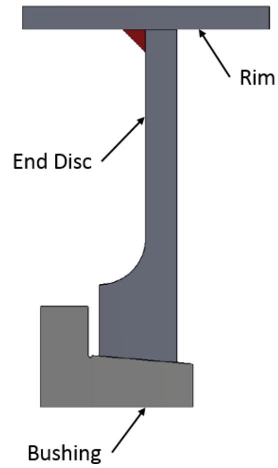

Figure 2. integral hub design

Test Set-up:

ABB performed two comparative tests under the same application loading and pulley dimensions. The first test was intended to compare the Heavy Duty integral hub and Mine Duty integral hub designs. ABB selected five of the most common pulley sizes to analyze using Finite Element Analysis (FEA). The approach taken was to determine the number of design cycles at critical locations on the pulley cross-section using the fatigue standard BS-7608. The five pulley designs analyzed can be found in **Tables 1 through 4**.

Table 1. Heavy Duty integral hub samples

Dia	FW	Example Description	PIW (lb/in)	Tension (lb)	Shaft Diameter	Bearing Centers
12	32	12X32 CR DR XT30	125	3750	2.9375	38
14	32	14X32 CR DR XT35	160	4800	3.4375	38
16	32	16X32 CR DR XT35	195	5850	3.4375	38
18	32	18X32 CR DR XT40	230	6900	3.9375	38
20	32	20X32 CR DR XT40	275	8250	3.9375	38

Table 2. Mine Duty integral hub samples

Dia	FW	Example Description	PIW (lb/in)	Tension (lb)	Shaft Diameter	Bearing Centers
12	32	12X32 CR DR XT30	125	3750	2.9375	38
14	32	14X32 CR DR XT35	160	4800	3.4375	38
16	32	16X32 CR DR XT35	195	5850	3.4375	38
18	32	18X32 CR DR XT40	230	6900	3.9375	38
20	32	20X32 CR DR XT40	275	8250	3.9375	38

Table 3. Heavy Duty weld-in hub samples

Dia	FW	Example Description	PIW (lb/in)	Tension (lb)	Shaft Diameter	Bearing Centers
12	32	12X32 CR DR XT30	125	3750	2.9375	38
14	32	14X32 CR DR XT35	160	4800	3.4375	38
16	32	16X32 CR DR XT35	195	5850	3.4375	38
18	32	18X32 CR DR XT40	230	6900	3.9375	38
20	32	20X32 CR DR XT40	275	8250	3.9375	38

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Table 4. Mine Duty weld-in hub samples

Dia	FW	Example Description	PIW (lb/in)	Tension (lb)	Shaft Diameter	Bearing Centers
12	32	12X32 CR DR XT30	125	3750	2.9375	38
14	32	14X32 CR DR XT35	160	4800	3.4375	38
16	32	16X32 CR DR XT35	195	5850	3.4375	38
18	32	18X32 CR DR XT40	230	6900	3.9375	38
20	32	20X32 CR DR XT40	275	8250	3.9375	38

Each of the pulleys were modeled in ANSYS software and represents ½ symmetry along the axial direction of the pulley assembly. The FEA model for the 12x32 Heavy Duty pulley is shown in **Figures 3 and 4**. The bushing is not explicitly modeled, but is assumed to be integral to the shaft and end disc. All components are modeled using linear material properties of steel:

Elastic Modulus = 29E6 psi
Poisson's ration = 0.3

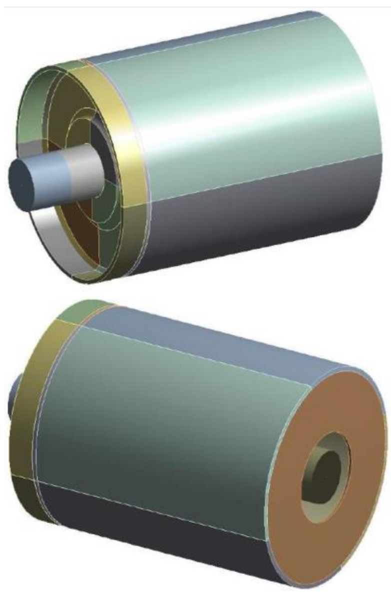

Figure 3. FEA model 12 x 32 Heavy Duty (full)

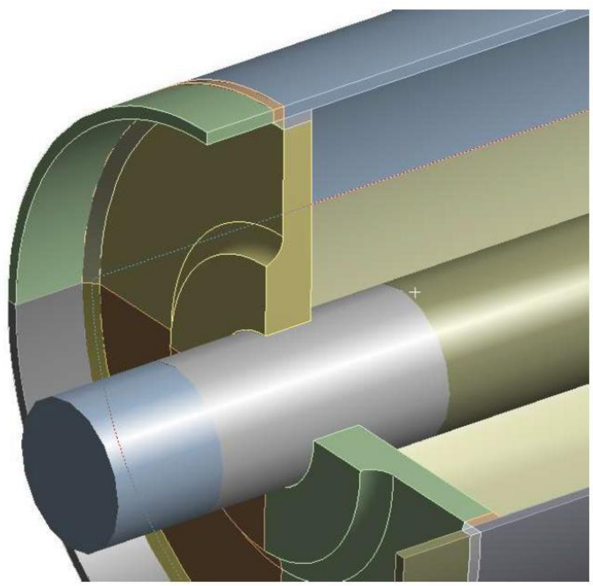

Figure 4. FEA model 12 x 32 heavy duty (hub)

The belt load is applied as a uniform pressure over a belt wrap angle of 180 degrees. The pulley is assumed to be a driven or non-drive pulley where the incoming belt tension and the outgoing belt tension are equal. The pressure load is calculated as,

$$P = T/RW$$

Where

T = belt tension (1/2 the total tension given in Tables 1-4)
R = outside radius of pulley rim
W = belt width

We applied the belt load over a shorter area than the typical belt load due to meshing considerations (see **Figure 5**). This causes the belt force to be applied over a smaller surface area, thus the pressure loading is a little on the high side.

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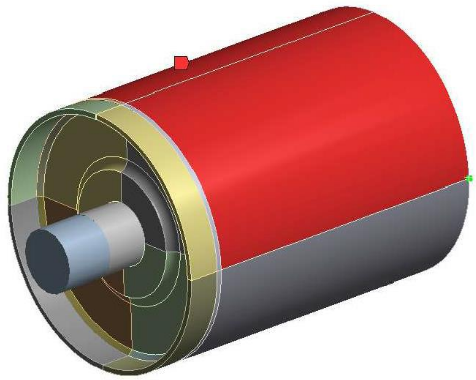

Figure 5. Location of belt pressure load

Based on past conveyor pulley stress analyses, it was determined that there are six critical locations of our model to consider. Historically, cracks have initiated in these locations after the pulley experiences overloads, thus the locations shown in **Figure 6** are critical for conveyor pulley design. These locations are discussed in more detail in **Tables 5 and 6**.

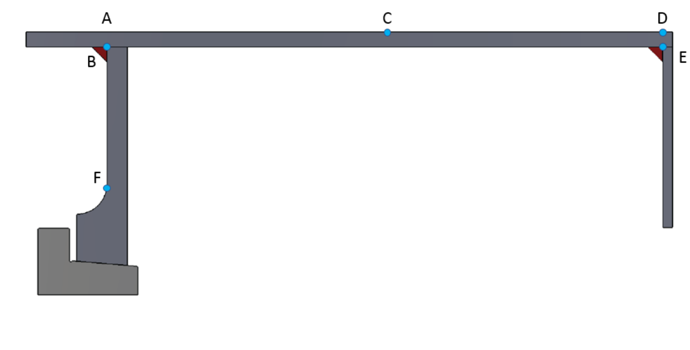

Figure 6. Critical stress locations

Table 5. Critical stress locations of an integral hub pulley

Location	Weld Area	Description
A	End Disc to Rim Fillet	Weld Root Through Rim
B	End Disc to Rim Fillet	Weld Toe Through End Disc
C	Rim Seam	Mid-Span Between End Disc and Center Disc
D	Rim Seam	Pulley Mid-Span at Center Disc
E	Center Disc Fillet	Rim at Center Disc
F	End Disc at Hub radius	Base metal

Table 6. Critical stress locations of a weld-in hub pulley

Location	Weld Area	Description
A	End Disc to Rim Fillet	Weld Root Through Rim
B	End Disc to Rim Fillet	Weld Toe Through End Disc
C	Rim Seam	Mid-Span Between End Disc and Center Disc
D	Rim Seam	Pulley Mid-Span at Center Disc
E	Center Disc Fillet	Rim at Center Disc
F	Hub Fillet	Weld Toe at Hub

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The three weld locations are evaluated using BS-7608, "Fatigue Design and Assessment of Steel Structures". According to the standard, the appropriate weld fatigue curve is based on the weld classification. Where square fillet welds occur, such as around the circumference of end discs and center discs, BS-7608 denotes them as class "F". Each location was evaluated for stress using FEA and the expected fatigue life was determined using BS-7608.

Results:

The results from all pulley fatigue life calculations are displayed in **Tables 7 and 8**. In all ten of the pulleys designed with integral hub, the limiting location of the pulley is determined to be the center disc weld. We also see that in all ten of the pulleys designed with weld-in hubs, the limiting location of the pulley is determined to be the hub fillet weld. Therefore, these weld locations determine the overall effective pulley fatigue life. **Tables 9 through 11** show a comparison of overall pulley fatigue life between the different pulley construction and end disc designs.

Table 7. Fatigue life (cycles) results for integral hub pulleys

Location	12x32		14x32		16x32		18x32		20x32	
	HD	HDX	HD	MDX	HD	MDX	HD	MDX	HD	MDX
E	9.30E+07	2.00E+08	1.10E+08	2.10E+08	1.60E+08	2.7R+08	1.90R+08	4.20R+08	1.10E+08	2.90E+08

Table 8. Fatigue life (cycles) results for weld-in hub pulleys

Location	12x32		14x32		16x32		18x32		20x32	
	HD	HDX	HD	MDX	HD	MDX	HD	MDX	HD	MDX
E	4.10E+05	1.60E+06	9.30E+05	7.90E+06	8.20E+05	7.70E+06	2.10E+06	8.90+06	1.80E+06	8.50E+06

Table 9. Fatigue life comparison

ODxFW	Class	Life Comparison
12x32	HD-WIH	1
	MD-WIH	3.9
14x32	HD-WIH	1
	MD-WIH	8.5
16x32	HD-WIH	1
	MD-WIH	9.4
18x32	HD-WIH	1
	MD-WIH	4.2
20x32	HD-WIH	1
	MD-WIH	4.7

Table 10. Fatigue life comparison between HD and HDX integral hub designs

ODxFW	Class	Life Comparison
12x32	HD-IH	1
	MDX-IH	2.2
14x32	HD-IH	1
	MDX-IH	1.9
16x32	HD-IH	1
	MDX-IH	1.7
18x32	HD-IH	1
	MDX-IH	2.2
20x32	HD-IH	1
	MDX-IH	2.6

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Table 11. Fatigue life comparison between MD weld-in hub and MDX integral hub designs

ODxFW	Class	Life Comparison
12x32	HD-IH	1
	MDX-IH	125
14x32	HD-IH	1
	MDX-IH	26.6
16x32	HD-IH	1
	MDX-IH	35.1
18x32	HD-IH	1
	MDX-IH	47.2
20x32	HD-IH	1
	MDX-IH	34.1

When we compare the overall effective life cycles between HD and MD construction (integral hub), we see that the MD construction offers at least 1.7x fatigue life of the HD construction. When we compare the overall effective life cycles between HD and MD construction (weld-in hub), we see that the MD construction offers at least 3.9x fatigue life of the HD construction. When we compare the overall effective life cycles between the two MD designs, we see that MDX construction with an integral hub offers at least 26.6x fatigue life of the MD construction with a weld-in hub. When considering the theoretical fatigue life of a pulley, the MDX integral hub design becomes the best choice.

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