BISHOPWISECARVER

Guide Wheel System Properties, Selection & Sizing

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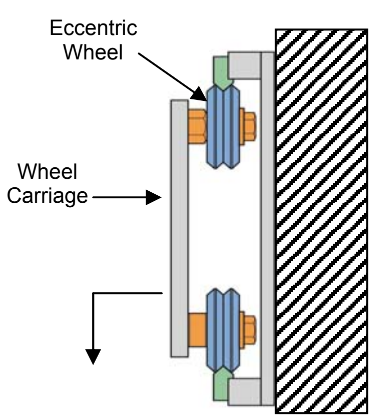
Paper dust particulates wreak havoc with just about every aspect of paper converting machinery, and especially the bearings. Linear guides, planar bearings and shafts, even with wipers, lubricators, scrapers or bellows, tend to draw particulates into the bearings. Without adequate protection, paper dust mixes with bearing lubricant and damages bearing raceways and balls. We found Bishop-Wisecarver's DualVee® guide-wheel carriages protected the bearings and track from particulates, resulting in higher machine performance ratings without sacrificing accuracy.

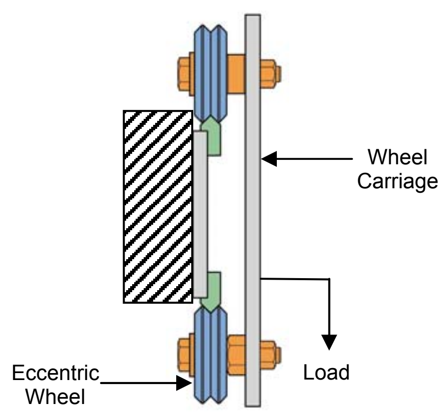
A moving carriage may be unable to distribute loads equally. A guide-wheel carriage system handles these unequal load distributions – as much as two to three feet – by utilizing four high-capacity wheels/bearings with a relatively small separation distance. Planar bearing shafts can bend under such conditions.

Even when the mounting surface of the track is uneven, we can hold tight tolerances and the guide-wheel carriage functions properly, providing a smooth rolling motion. Additionally, parallel tracks are easier and faster to assemble because guide-wheel track alignment is very forgiving.

Wheel Carriage Configurations

Using the correct combination of eccentric and concentric guide wheels in the guide-wheel carriage configuration ensures a robust design. Linear systems always have two concentric wheels and the remaining guide wheels are eccentric. The eccentric wheels remove the play (preload) between the wheels and track, equally loading all the wheels so they roll instead of sliding or skipping on the track during acceleration or deceleration. When the wheel carriage is loaded in the radial direction, the concentric wheel carries the primary load.

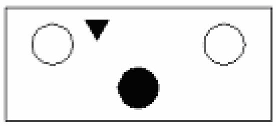




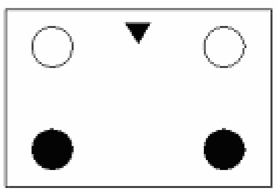
Load

Diagram Symbols:
○ = Concentric guide wheel symbol ● = Eccentric guide wheels are marked by:
▼ = Radial loading directions

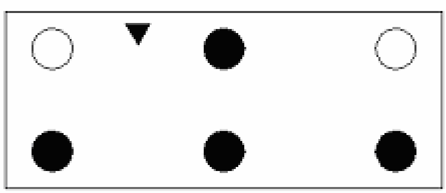
It is important to note the location of the eccentric wheel is dependent on whether the track guide way is on the outside or inside of the wheel carriage. Below are several wheel carriage configurations:



3 Wheel Carriage



4 Wheel Carriage



6 Wheel Carriage

Loads

We start by determining the type of loads – radial and/or axial. A radial load (L_R) is applied perpendicular to the bearing shaft, while an axial load (L_A) is applied parallel to the bearing shaft. We have found the formulas provided by BishopWisecarver for determining lifespan and sizing to be easy to apply.

Axial loading on a guide-wheel is a moment load, because it is on one side. Since the ball bearing elements are not equally loaded, one side of the wheel is free, while the other side interacts with the track. This creates a moment load on the wheel and, in turn, the bearing. To offset the moment load, we increase the radial preload, allowing higher axial loads. However, by increasing the radial preload the wear rate increases.

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Load/Life Equation – Size and Selection

To estimate load/life requires an understanding of the principles of statics. For example, the ability to analyze free-body diagrams and the capability to transfer externally applied forces on the carriage into radial and axial reaction forces at each guide wheel. To calculate system life, we use the wheel with the heaviest load.

The process for sizing and selecting a wheel carriage assembly includes three steps:

1. Determine radial and axial loads
2. Calculate load factor for wheel with heaviest load
3. Apply safety factors to compensate for speed, vibration, shock and environment

Typical Guide Wheel Load Ratings

Part Number	Radial Dynamic Load (N)	Radial Dynamic Load (lbf)	Radial Static Load (N)	Radial Static Load (lbf)	Axial Dynamic Load (N)	Axial Dynamic Load (lbf)	Axial Static Load (N)	Axial Static Load (lbf)
W0	1050	236	500	112	135	30	123	28
W1	2180	490	1110	250	277	62	252	57
W2	4700	1057	2780	625	688	155	625	141
W3	9150	2057	5050	1135	1871	421	1701	382
W4	12800	2878	7900	1776	4401	989	4001	900

Step One

Calculate the radial (L_R) and axial (L_A) loads on each bearing element in the guide wheel system design. This is computed by applying statics to the application.

Step Two

All standard statics calculations must be considered, including inertial forces, gravitational forces and such external forces as tool pressure, bearing element spacing and payload magnitude and travel direction. Additionally, external forces generating a reaction through the wheel-track interface must be considered:

$$L_F = L_A / L_{Amax} + L_R / L_{Rmax}$$

Where :

L_F = Load Factor
L_A = Axial load on guide wheel
L_{Amax} = Maximum axial working load capacity of wheel
L_R = Radial load on wheel
L_{Rmax} = Maximum radial working load capacity of wheel

Bearings should be sized such that $L_F \leq 1$.

A safety factor must be applied to the maximum axial (L_{Amax}) and radial (L_{Rmax}) working load capacities. This is because load, speed, shock, vibration, contamination and duty cycle requirements may vary.

Safety Factors*	Application Requirement
1.0 – 0.7	Clean, Low Speed, Low Shock, Low Duty
0.7 – 0.4	Moderate Contaminants, Medium Duty, Medium Shock, Low to Medium Vibration, Moderate Speed
0.4 – 0.1	Heavy Contamination, High Acceleration, High Speed, Medium to High Shock, High Vibration, High Duty Cycle
Safety Factors applied to the maximum axial (L_{Amax}) and radial (L_{Rmax}) working load capacities.	

*The ratings and calculations are theoretical values based on ideal conditions. Most of our applications involve less than optimum conditions. Hence, we use the next largest size, ensuring the machines never reach the critical limits of a guide-wheel.

Step Three

The Load factor is applied to the equation below for determining system life expectancy:

DualVee Size	Life Constant (L_C)	
	Inches of travel	Kilometers of travel
1	2.19×10^6	55
2	3.47×10^6	87
3	5.19×10^6	130

Life = $L_C / (L_F)^3$

Where:

L_F = Load Factor

L_C = Life Constant

Calculation Example:

$L_A = 50\ lb_f$
$L_R = 200\ lb_f$
Wheel Size: 2

Environment: Moderate shock loading and contamination with intermittent motion
What is the expected wheel life?

Following the outlined procedure, we know the information from Step 1, radial (L_R) and axial (L_A) loads on each wheel, therefore we are ready to calculate:

L_A = 50 lb_f
L_{Amax} = 140 lb_f
L_R = 200 lb_f
L_{Rmax} = 625 lb_f
L_F = 50/140 + 200/625 = .68
Life = $3.47 \times 10^6 / (.68)^3 \times 0.6 = 6.21 \times 10^6$ Inches of travel

*Note an adjustment factor of 0.6 was used because of environmental issues.

Conclusion

Speed, productivity, reliability and durability are crucial factors for buyers of such capital equipment as paper converting machinery. However, higher speeds also lead to durability and reliability issues. We found the Bishop-Wisecarver DualVee guide-wheel carriage to be very efficient. They exhibit less friction, allowing higher speeds with practically no impact on accuracy. The wheel bearings resist paper dust, while reducing maintenance, dramatically improving machine design robustness and durability.

To achieve even higher productivity, our new paper converting machines are migrating from reciprocating motion to circular or elliptical motion that moves in one direction. The Bishop-Wisecarver guide-wheel ring and track system allows the next generation machines to achieve even higher productivity, while improving reliability and durability.

Authors Bios:

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Brett is a specialist in the Material Handling Section at Bretting Manufacturing. Brett is a graduate of Milwaukee School of Engineering and has been with Bretting for 14 years.

Kevin Kegel, Machine Assembly Specialist, C.G. Bretting Manufacturing

Kevin holds the title of Machine Assembly Specialist at Bretting Manufacturing. Kevin has brought 18 years of experience to the Bretting environment to date.