IVT vs. V-Roller

A Technical Comparison Between Integral-V™ Technology (IVT) and V-Roller System with Steel Rails

Kevin Bischel
Sr. System Design Engineer
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Historically, one of the more common linear guidance systems used has been bearing blocks containing re-circulating ball bearings running on profiled steel rails that are fastened to a structure. In recent years, PBC Linear has introduced another type of linear guidance system called Integral-V™ Technology (IVT). In these systems, cam rollers of v-profile run on steel raceways that are mechanically fixed into a structural aluminum component to form a unified rail component.

Introduction

Historically, one of the more commonly used linear guidance systems has been cam rollers of v-profile running on separate steel rails fastened to a structure. In recent years, PBC Linear has introduced another type of linear guidance system called Integral-V™ Technology (IVT). In these systems cam rollers of v-profile run on steel raceways that are mechanically fixed into a structural aluminum component to form a unified rail component.

The purpose of this paper is to describe the two systems, some of their important features and differentiators, and provide a relative cost comparison given a common application.

Overview of V-rollers with Steel Rail

Introduced in the early 1970's, these products consist of cam-rollers with v-profiles that run on matching steel rails as shown in Fig.1.

Two disadvantages of such linear guidance systems are:

1. The rails must be fastened with multiple fasteners to the supporting structure. The standard holes are spaced at 2 inch (51mm), 3 inch (76mm), or 4 inch (102mm) intervals depending on the rail size. The fasteners add labor cost, assembly time, and increase the possibility of assembly error or fastener failure.

2. The accuracy of the system is dependent on the flatness, straightness and parallelism of the supporting structure. Most v-roller applications do not require high accuracy. It is adequate in many applications to attach the rails directly to cold finished or extruded material. Rails are supplied with shoulders to mount against the square edges of plates or bars.

For designs requiring accuracy levels of ±.005inch/ft (±.13mm/300mm) and better, the mounting surfaces must be prepared appropriately flat, straight, and parallel Reference edge assemblies should also be used. Greater accuracy can be obtained by fastening the rails to a plate or bar that has been prepared by milling or grinding the mounting surfaces flat and parallel.

Fig. 1: V-roller rails and steel rail

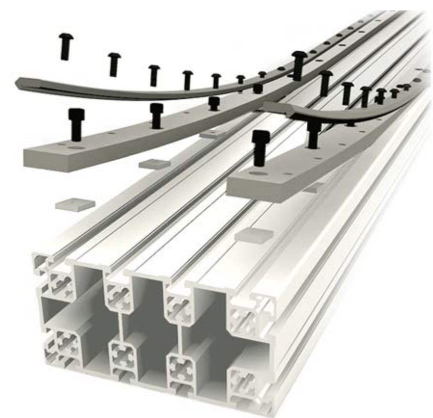

Fig. 2: V-roller rails often require many fasteners

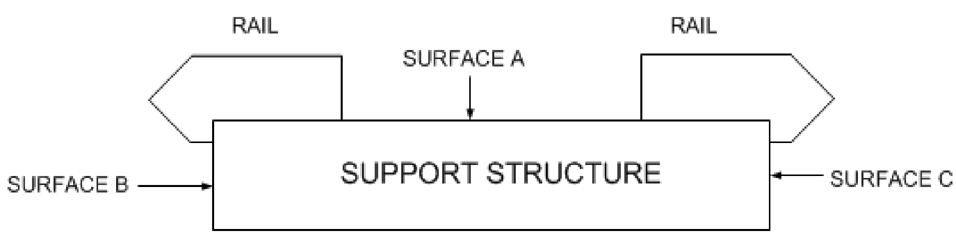

Fig. 3: The accuracy of v-roller rails is largely dependent on the flatness, straightness and parallelism of the surfaces to which they mount.

In the diagram above, surface A should be flat; surfaces B and C should be flat and parallel. One also wants the support structure to be straight with minimal twist or camber.

The following table contains dimensional tolerances that one can generally expect for extruded aluminum. [1]

Camber (Bar)

Wall Thickness	Per Length
to 0.094 in (to 2.5mm)	.0125 in/ft (1mm/m)
over .094 in (over 2.5mm)	.05 in/ft (4mm/m)

Twist (Bar)

Widest Dimension	Per Length	Maximum
to 1.5 in (40mm)	1º / ft (3º / m)	7º
1.5 - 3.0in (40-75mm)	1/2º / ft (1.5º / m)	5º
over 3.0in (75mm)	1/4º / ft (3/4º / m)	3º

Flatness (Bar)

Minimum thickness of metal forming the surface	WIDTH		
	Up to 5.999in (152.4mm)	6.000in (152.4mm) to 7.999in (203.2mm)	8.000in (203.2mm) to 9.999in (254.0mm)
to .124in (3.15mm)	.004in (.10mm)	.006in (.15mm)	.010in (.25mm)
.125-.187in (3.15-4.75mm)	.004in (.10mm)	.006in (.15mm)	.008in (.20mm)
.188-.249in (4.76-6.32mm)	.004in (.10mm)	.006in (.15mm)	.008in (.20mm)
.250-.374in (6.33-9.50mm)	.004in (.10mm)	.006in (.15mm)	.006in (.15mm)
.375-.499in (9.51-12.67mm)	.004in (.10mm)	.004in (.10mm)	.006in (.15mm)
.500-.749in (12.68-19.02mm)	.004in (.10mm)	.004in (.10mm)	.006in (.15mm)
.750-.999in (19.03-25.37mm)	.004in (.10mm)	.004in (.10mm)	.006in (.15mm)

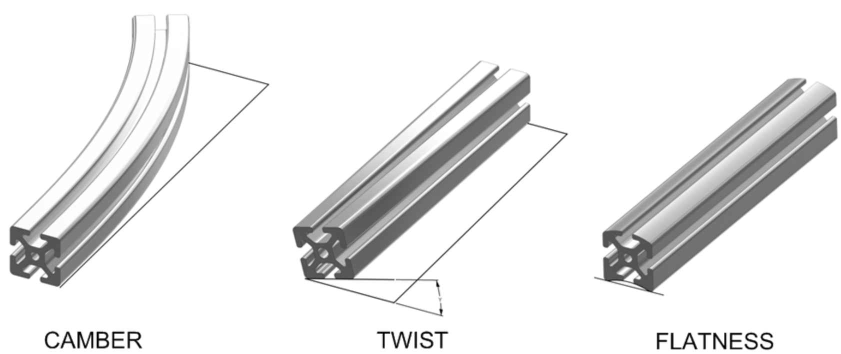

Fig. 4: Illustration of camber, twist and flatness.

When preparing mounting faces by machining, the amounts of deviation from flatness one can generally expect are within:
- Face Milling[2]: 0.005 in/ft (0.4mm/m)
- Surface Grinding[2]: 0.001 in/ft (.08mm/m)

The fasteners along the length of the v-rails allow some tolerance variations that occur in long wavelengths to be removed during assembly. This is done by shifting and aligning the v-rails within the clearances of the fastener holes and tightening the fasteners. But tolerance variations that occur in short wavelengths cannot be adjusted out during assembly because of the stiffness of the v-rail and the spacing of the fasteners.

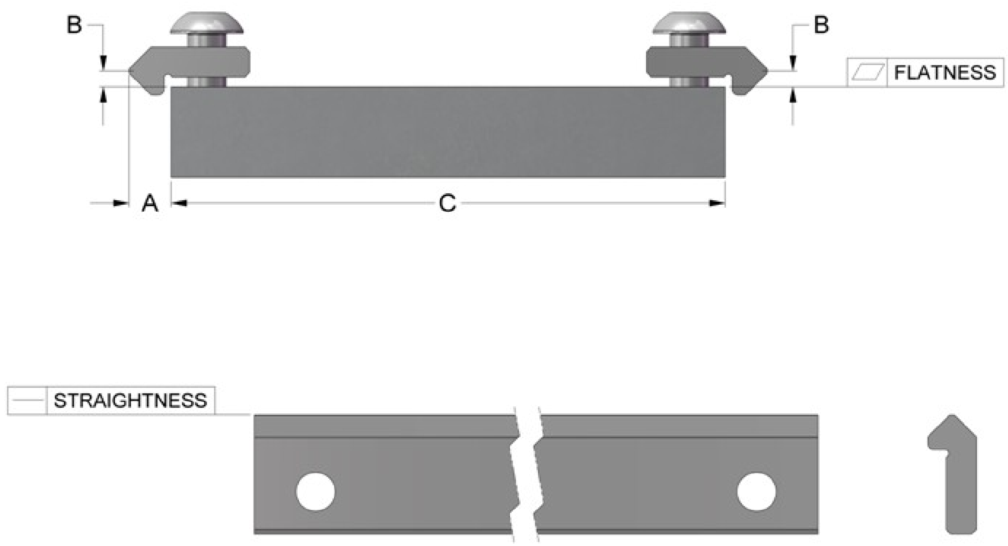

Fig. 5: Stack-up of tolerances affects the location tolerances of steel v-rail assemblies

Before PBC Linear developed the IVT system, manufacturers tried several methods to improve the dimensional tolerances of the steel rail systems and to provide a rail assembly that did not require fasteners.

One method tried was to insert steel v-rails directly into extruded pockets in an aluminum extrusion. However, the dimensional tolerances of such rail assemblies depended on the as-extruded tolerances of the aluminum extrusion which are unacceptably high for many applications.

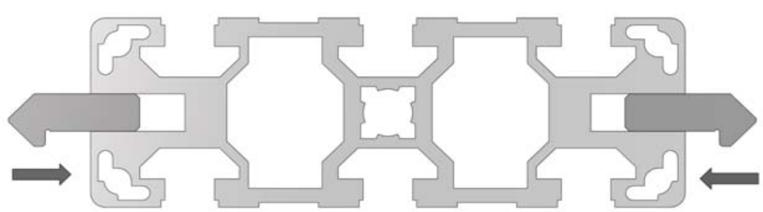

Fig. 6: Steel v-rails inserted into extruded pockets in an aluminum structure.

Another method is to have aluminum fingers extruded within the pockets. The fingers are designed to deform and support the steel v-rails when they were pressed in. Rollers are used during the assembly process to insert the steel v-rails a controlled amount. The location tolerances for the steel v-rails were improved, but location tolerances are still dependent on extrusion tolerances such as twist and flatness. The stiffness of the steel rails themselves still prevents short wavelength dimensional variations from being removed.

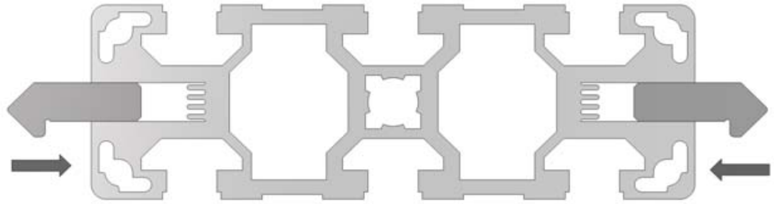

Fig. 7: Steel v-rails inserted in extruded or machined pockets containing fingers in an aluminum structure.

To reduce the effect of the extrusion tolerances on the final rail tolerances, the pockets and fingers in the aluminum structure can be machined rather than extruded. This reduces the effect of variations in an extrusion's camber, twist, and flatness; but short wavelength variations can still not be removed by the assembly process due to the stiffness of the steel v-rail.

Integral-V™ Technology (IVT) Systems

This is a product recently introduced by PBC Linear in 2008. Cam rollers with a "v" profile run upon rails that are constructed of angled hardened steel raceways mechanically fixed into an anodized aluminum rail. Parallel raceways can be combined into one rail structure rather than being separate components that must be fastened in place with screws. PBC Linear's SIMO® (Simultaneous Integral Milling Operation) process provides precise rail surfaces that are accurately aligned to one another.

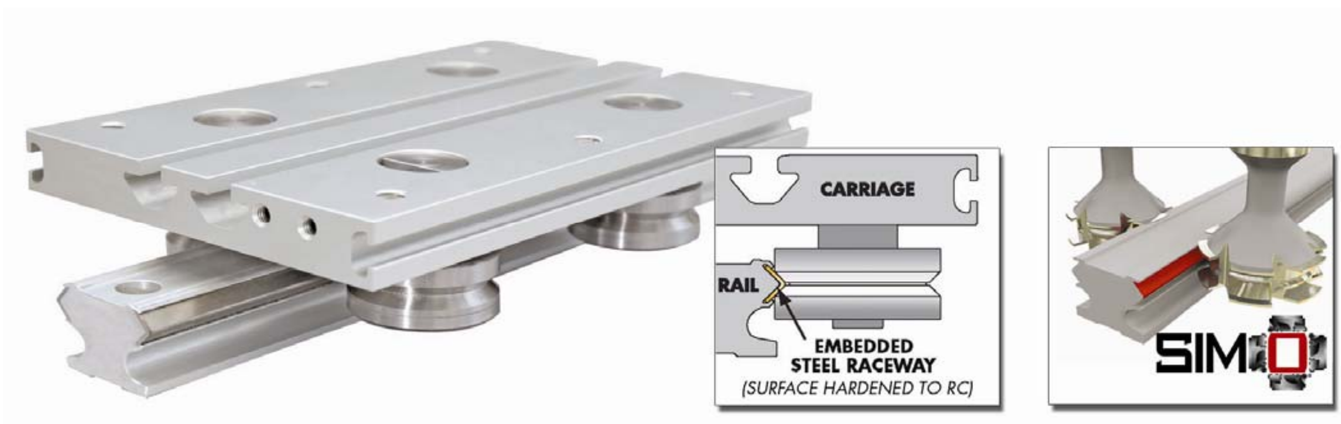

Fig. 8 Example of an IVT Rail and Carriage System with schematic of IVT system

The rated precision of the IVT rails is as follows:

- Raceway to raceway ±.001"
- Raceway to surface ±.002"
- Straightness ±.002"/ft.
- Flatness .002"
- Parallelism ±.001"
- Twist < 1/4°/ft.

The design of the IVT rail system allows for the contact stresses created by the rollers on the outside surface of the steel v-race to be dispersed to much lower levels before they are transmitted to the supporting aluminum structure.

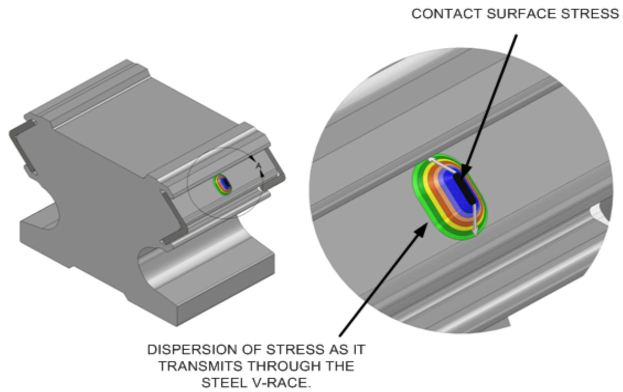

Fig. 9: Steel v-race shown transparent so that the dispersion of the contact surface stress as it progresses through the steel v-race can be seen.

During manufacturing of an IVT rail, the supporting structure for the v-races is first machined into the aluminum substructure using PBC Linear's SIMO™ process.

Fig. 10: The supporting structure for the IVT v-races

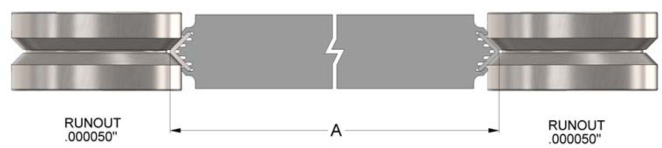

Fig. 11: IVT v-races being swaged into place.

The final assembly tolerances for IVT rails are controlled by rollers that simultaneously press the steel v-races in place during manufacturing. Be carefully designing the v-races to be more flexible while retaining the strength necessary to disperse contact stresses, tolerance variations of shorter wavelength can be eliminated during assembly.

The IVT product allows great design flexibility as the IVT raceways can be built into an endless variety of structural shapes. Standard configurations are available that fit a variety of size envelopes, load capacities, and mounting arrangements. Rail designs are available to conform to the same size envelope as steel profile rails. Custom IVT shapes and carriages have been exclusively supplied to particular customers. Such designs have allowed those customers to reduce the part count, the fastener count, and the assembly labor of their designs.

When an IVT rail with dual raceways is fastened in place, it will be influenced by the flatness and straightness of the mounting surface(s) to which it is attached. However, the raceways remain precisely spaced from each other as they follow the irregularities of the mounting surface. The machined parallelism of the rails promotes smoother carriage travel than if the individual raceways were each located separately.

The IVT linear guidance system has several advantages:

- The number of fasteners for a dual IVT system is one half or less than the number of fasteners necessary in a v-roller system with two separate rails that must be aligned and screwed in place.
- Custom IVT designs can be created that combine parallel steel raceways with a custom structural member allowing a user to drastically reduce their part count and fastener count.

Cost Comparison of the Two Systems

Assume linear guidance is needed for 1m stroke and that both types of systems are capable of meeting the accuracy and load requirements. Assume the v-roller system will require a plate to which its (2) rails will be mounted and a carriage. Assume the IVT system will require an integrated dual raceway rail and a carriage. V-roller systems often require the user to design the carriage while predesigned carriages are offered for the IVT product line.

1. Designing the System

Designing a linear guide system can take hours of engineering and drafting time. Obviously, the time involved could vary widely depending on the complication of the design. However, it is not a cost factor that should be overlooked so a simple estimate was made.

		
Design Steps	**V-Roller System**	**IVT System**
	Labor (min)	Labor (min)
1. Select and source components	30	10
2. Download model/drawings	5	5
3. Design carriage	60	0
4. Build and cost BOM	25	10
5. Manufacture/procure carriage	20	20
6.Manufacture/procure rail	20	20
7.Quality assurance	20	5
Total Time (hours)	3 hours	1.17 hours
Design Cost Sub-total ($60.00/hour)	**$184.80**	**$70.20**

2. Material Costs

A v-roller rail system requires many more components than an IVT system.

V-Roller System BOM	Quantity	Cost
Rail	2	$39.38
Carriage Assembly	1	$87.12
Mounting Plate Assembly	1	$16.34
Fasteners	56	$0.13
Material Quantity & Cost Subtotal:	**60**	**$142.97**

IVT System BOM		
IVTAAF Rail	1	$71.60
Carriage Assembly	1	$113.17
Fasteners	26	$0.13
Material Quantity & Cost Subtotal:	**28**	**$184.90**

3. Installation Labor

	V-Roller System	IVT System
Design Steps	Labor (min)	Labor (min)
Drill/tap machine plate	10	10
Clean/align rail with reference surface	30	N/A
Loosely fasten rail to machining surface	10	N/A
Secure side plates	10	N/A
Repeat steps for secondary rail	50	N/A
Securely fasten system	10	15
Total Installation Time:	120	25
Assembly Cost Sub-total ($35.00/hour)	**$70.00**	**$14.60**

Total Cost Comparison Results	V-Roller System	IVT System
Design Cost Sub-total ($60.00/hour)	$184.80	$70.20
Material Cost Subtotal	$142.97	$184.90
Assembly Cost Sub-total ($35.00/hour)	$70.00	$14.60
Total Cost	**$397.77**	**$269.70**

The above estimates are approximate, but the v-roller system was found to be about 1.5 times higher in cost than an IVT system.

CONCLUSION

For most applications where an IVT system or V-roller system with steel rails are being considered, the IVT system has advantages. The design flexibility of the IVT system lends itself to simple clean designs that minimize part count, assembly labor, assembly time, and assembly weight. The accuracy of the IVT system is normally better than that of the v-roller system with steel rails, and an IVT system’s total cost (including design and assembly) is lower.

References

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(McGraw Hill, 1986) p. 130

3. Tedric A. Harris and Michael N. Kotzalas, *Essential Concepts of Bearing Technology* (CRC Press: Taylor and Francis Group, 2007) p.136

Further Information

If you're still having difficulties, contact a PBC Linear Application Engineer to discuss your application. You can contact an engineer directly by calling 1.800.962.8979 (from within the USA) or +1.815.389.5600 (from outside the USA). If you prefer e-mail, e-mail an engineer at: appeng@pbclinear.com

Worldwide Headquarters

PBC Linear, A Pacific Bearing Co.
6402 E. Rockton Road
Roscoe, IL 61073
USA

Toll-Free: +1.800.962.8979
Office: +1.815.389.5600
Fax: +1.815.389.5790
sales@pbclinear.com
www.pbclinear.com

European Branch

PBC Lineartechnik GmbH, A Pacific Bearing Co.
Niermannsweg 11-15
D-40699 Erkrath
Germany

Office: +49.211.416073.10
Fax: +49.211.416073.11
sales_gmbh@pbclinear.de
www.pbclinear.de