ACCOUNTING FOR LOST MOTION

Backlash and deflection are critical factors when designing mechanical control cables.

Mechanical control cables feature either a solid-wire or wire-cable core housed within a conduit. They provide a simple and reliable method to activate throttles, latches, and other mechanisms.

Mechanical control cables provide a simple, lightweight, economical, and reliable way to activate throttles, latches, gas springs, electromechanical devices, and many other mechanisms. They're widely used in office furniture, recreational vehicles, lawn mowers, and medical devices, as well as in adjustable seats in cars and planes.

The basic design features a movable core — either a solid-wire or braided wire-rope cable — that's free to travel axially inside a conduit. Actuating a lever or similar device at one end of the cable assembly produces output force and motion at the other end.

Solid-core controls are generally used to transmit force in both push and pull directions. The ends of solid wires can be formed to eliminate the need for separate fittings and terminations. But the solid wire requires large bend radii and simple routing to avoid kinds, drag or surface friction, and permanent set. All push-pull controls have greater load capacity in tension than compression — they can pull more than they can push.

In some cases, stiff, small-diameter wire-rope cables can be used in push-pull applications, provided push loads are light, and the cable and conduit are carefully matched. However, these so-called flexible-core controls are usually found on pull-pull controls that transmit tensile force in both directions. For high-load, push-pull applications, specially designed wire cores are available that maintain high flexibility yet permit loads to 100 lb.

In general, more-flexible conduits and cores provide greater routing freedom and smaller bend radii in restricted installations. They often feature return springs, which maintain specified loads on the cables and return mechanisms to their original position after activation.

Design Factors

Engineers should consider parameters such as load, routing, friction, stretch, permanent set, lost motion, temperature, environment, and exposure to contaminants when specifying cables. Here's a look at these critical factors.

Load factors. For push-pull controls, the cable assembly's rated working loads should be in the pull or tension model. Push, or compression, loads should be ≤50% of pull loads.

Werner Steuernagel
Vice President — Engineering

Cable Manufacturing & Assembly Co.

Edited by Kenneth Korane

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Reducing the push load minimizes a core's tendency to displace the conduit and, more importantly, reduces the potential for the unsupported core outside the conduit to kink, bend, or distort.

Base maximum pull-pull working loads on the cable's minimum breaking strength, plus a safety factor. Also consider the conduit's resistance to deflection and compressive forces, and cable-assembly end-fitting selection. High loads and cycles can cause the cable to stretch and wear through the conduit liner. Core and conduit must remain as originally routed for an assembly to function properly.

Travel. Experts recommend 5-in. maximum travel for most light and medium-duty push-pull applications. This minimizes lost motion and potential for the core to buckle. Use even shorter travel lengths with small-diameter cores.

Travel in pull-pull applications has fewer restrictions and can generally exceed 5 in. However, if the core is subject to hostile environments, minimize the stroke to limit exposure outside the conduit.

Lost Motion

Perhaps the least-understood design factor is lost motion. All push-pull controls lose some motion between input and output sides when applying a load to the system. Lost motion increases with higher loads, more bends, and longer assembly lengths. It can be overcome by designing overtravel into the system at the input or output ends, or at both ends.
Lost motion is caused by deflection and backlash.

Backlash is caused by the clearance between the core OD and conduit ID, and is present in both push and pull operating modes. It is proportional to the number and length of bends in the installed assembly, and the clearance between core and conduit. Calculate backlash B by using:

$$B = X\pi R2/180 - X\pi R1/180$$

where R1 = centerline of core in tension (no load); R2 = centerline of core in compression (no load); and X = total angular degrees of bend in the routing.

Deflection comes from elastic strain caused by tension and compression loads on the control. Calculate deflection ΔL as:

$$\Delta L = FL/AE$$

where F = average force, or one-half output load + one-half input load; L = length of active inner core; A = core cross-sectional area; and E = core's modulus of elasticity.

Note that the actual deflection of a control in compression may vary from calculated values based on the column strength of the core and

Werner Steuernagel
Vice President — Engineering

Cable Manufacturing & Assembly Co.

Edited by Kenneth Korane

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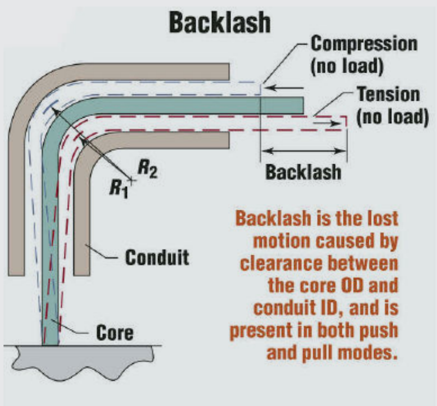

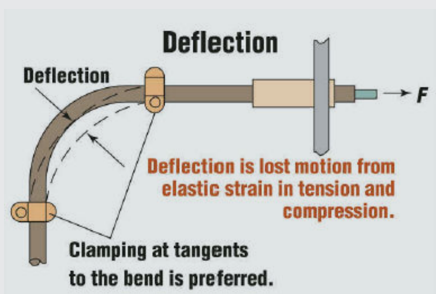

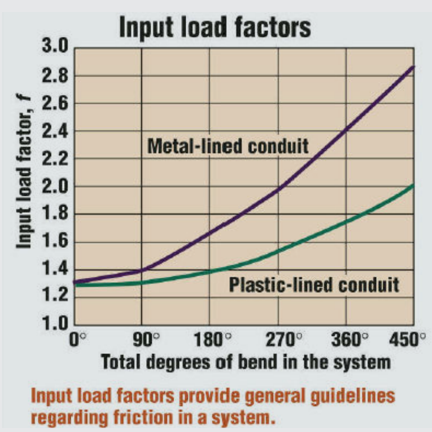

conduit and the buckling potential. And lost-motion calculations assume that control is securely mounted on the ends, and that the conduit is firmly held in its routed position.

Lost motion is also a factor in pull-pull controls. They typically have little backlash because they operate under tension. However, these controls are subject to the same deflection factors as the push-pull controls. And routing always affects the travel length. In some cases, lost motion can be accurately calculated. In others, installing a prototype in the system to confirm correct design length and travel is highly recommended.

Friction Considerations

Efficiency. The conduit, core, and number of bends, as well as the relative friction between core and conduit, determine a push-pull control's efficiency. Depending on the materials, good practice is a 2–10-in. minimum bend radius. Estimate the minimum bend radius by multiplying the core diameter by 100.

Bends in the system create friction and reduce efficiency. Estimate frictional effects from:

$$I = Pf$$

where I = actual input load; P = output load; and f = input load factor, found in the accompanying graphic. Percent efficiency η is then determined from:

$$\eta = (P/f) \times 100.$$

In pull-pull controls, cable cores generate more friction than solid-wire cores. Most cable controls use 1 × 19 cable because it has a relatively smooth OD and is more flexible than solid-wire cores. For applications requiring more flexibility, specify 7 × 7 cable, higher loads reduce efficiency and can subject the liner to undue wear and damage.

Werner Steuernagel
Vice President — Engineering

Cable Manufacturing & Assembly Co.

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Proper alignment and mounting also help increase efficiency and cycle life and reduce working loads. In cases in which a lever arm moves, mount the control to minimize the angular deflection of the core. If possible, specify a fitting or assembly that rotates at the mounting point.

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Conduit and core selection

Most applications use braided, reinforced conduits. Braided conduit is generally coated with polypropylene (relatively stiff) or nylon (more flexible and heat resistant). The accompanying tables list some common conduit designs and offer core recommendations for various applications.

All conduit and core combinations should include a reasonable clearance between the conduit ID and core OD. For most light- and medium-duty pull-pull applications, a 0.015–0.025-in. clearance is recommended. Note that decreasing the clearance to minimize the effects of lost motion can dramatically increase operating forces.

Core Characteristics

Characteristic	Material	Highest performance	⟶		Lowest performance
Corrosion resistance	Wire or cable	Type 302/304 stainless steel	Copperized steel, Galvanized steel		Bright music wire, oil tempered spring steel
Flexibility	Wire	Small diameter			Large diameter
	Cable	7 x 19	7 x 7	1 x 19	1 x 7
Efficiency	Wire	302/304 Stainless steel			Hard-drawn galvanized
	Cable	1 x 19	7 x 19	7 x 7	1 x 7
Compression loads	Wire	Large diameter			Small diameter
	Cable	1 x 7	1 x 19	7 x 7	7 x 19
Tensile loads	Wire	Large diameter			Small diameter
	Cable	1 x 19	1 x 7	7 x 19	7 x 7

Werner Steuernagel
Vice President — Engineering

Cable Manufacturing & Assembly Co.

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Conduit Comparison

	Conduit type	Cost rating factor	Features	Typical uses
	Tubing	1	Lightweight, flexible assemblies	Light-duty seat releases, vent controls
	Braided reinforcement	2	Lightweight, with liner braid for stiffness and fair crush resistance	Seat latches, window mech-anisms, release assemblies, gas-spring controls
	Bowden	3	Good flexibility, compressive strength, and crush resistance	Medium-duty lower-efficiency throttle controls, PTO controls
	Flat-wire Bowden with liner	4	Fairly flexible, high efficiency, good compressive strength and crush resistance	Remote latch, deck, and push-pull controls
	Long lay	5	Relatively stiff, high compressive strength, good crush resistance	Clutch and brake cables, heavy-duty push-pull controls, marine throttles, shift-control cables

Questions: Contact CMA

If you have questions or are interested in speaking with us about a custom cable assembly, we are happy to help. Please contact us by email or phone.

Cable Manufacturing & Assembly Co. Inc.
10896 Industrial Parkway N.W.
PO Box 409
Bolivar, Ohio 44612-0409

Toll-Free: (800) 586-8404
Phone: (330) 874-2900

Email: cmaoh@cmacable.com

Werner Steuernagel
Vice President — Engineering

Cable Manufacturing & Assembly Co.

Edited by Kenneth Korane