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1.1 Intro

There are so many of us with hobby CNC's out there that i thought i would share some professional knowledge on a topic very seldom covered in our favorite CNC forums. Cable chains carry the power and signals needed to get the job done. Often the cables are cheap enough to replace but it is the hassle of doing the job is time consuming. The bigger problem is when the cables fail during the process, or trying to fault find those missing steps on cables with broken internal cores.

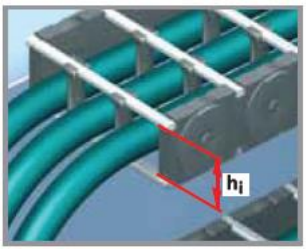
When designing cable chains care needs be taken when selecting firstly the type of chain/carrier and secondly the type of cables to be fitted to the chain, followed by the layout of the cables in the chain. Most of the major chain manufactures have some documentation detailing how to choose and setup their chains to ensure the longest lifetime of both the chain and its contents. Following those guidelines to the letter would ensure lifetimes typically in the 10 of millions cycles range, but would also produce excessively wide chains that we could not easily fit into our applications.

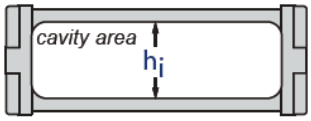
A compromise to having the idea chain is to stack cables on top of another, thereby reducing the overall width of the carrier and cycle life. Stacking cables in a chain is not recommended by the manufactures, but they realize that there are applications that call for the reduced carrier footprint and there design guidelines cover this. The guidelines for stacking ensure cables will be able to move freely with minimum friction and reduce the ability of cables tangling.

I have taken this info from guidelines, emails and face to face meetings from the four major manufactures in Europe so i hope this instructable will help you get the best lifetime out of your chains.

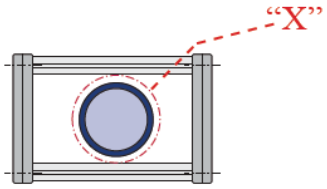
1.1.1 Clearance:

To determine if the required carrier inner cavity height h_i is sufficient.





carrier link cross sectional view



Cables → **Add 10% to the outside Diameter**

Minimum Clearance around O.D = "X" must be >1.0mm

Pneumatic Lines → **Add 15% to the outside Diameter**

Minimum Clearance around O.D = "X" must be >2.0mm

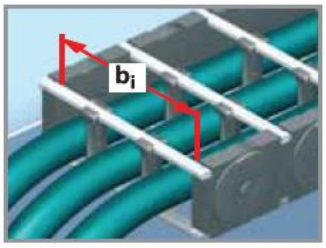
Hydraulic Hoses→ **Add 20% to the outside Diameter**

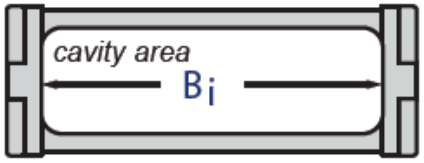
Minimum Clearance around O.D = "X" must be >3.0mm

The largest of these cable, air line or fluid hose outer diameter values, with the safety factor added (Ø+SF), determines the minimum clearance cavity height required (h_i)

1.1.2 Fill:

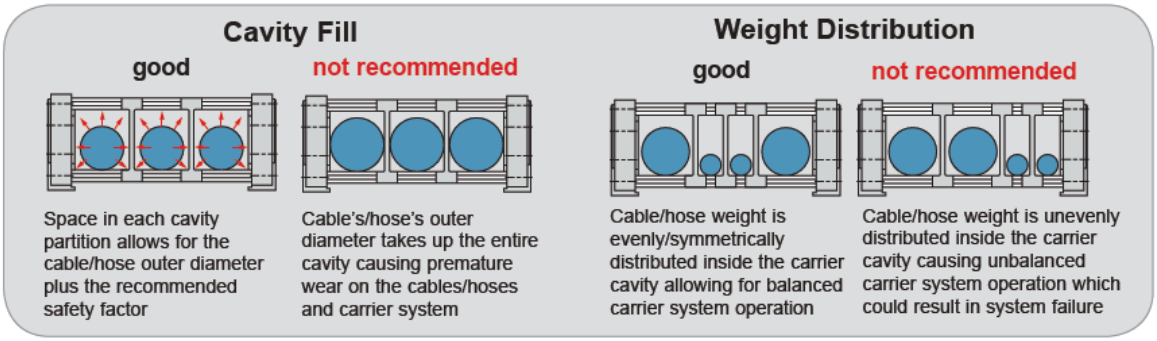
To determine if the required carrier system inner cavity width Bi is sufficient.





For an ideal carrier: sum of all the aforementioned cables, airlines and hydraulic hoses plus there safety factor

$$\sum \text{c } Ø + \text{SF} + \sum \text{pn } Ø + \text{SF} + \sum \text{hyd } Ø + \text{SF} = \sum \text{ALL } Ø$$



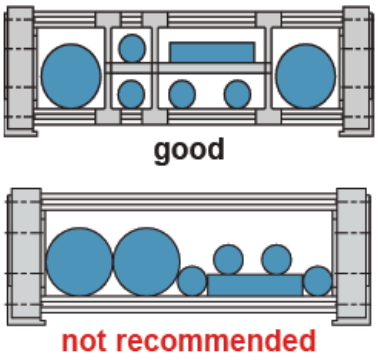
When “not recommended” is stated, it implies that this can be done but it will greatly reduce the lifetime of the cables inside the carrier.

I would also point out that cable chains can have dividers that separate cables for one another. If these dividers are used and i strongly recommend that fixed dividers are used, that is dividers that cant slide by cables pushing on them.

1.1.3 Cavity setup:

In order to achieve the longest possible operating results in conditions where minimum h_i and b_i are not possible it is recommended to use cavity dividers and follow these procedures:

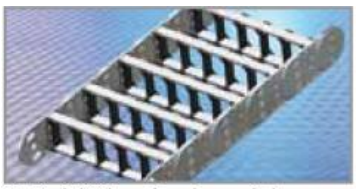
- Keep unlike components apart
- Keep unlike cable or hose jacket materials apart
- When cable or hose diameters are less than 60% of the selected or available inner cavity total height (< 60% of h_i)
- Individual flat cables must be kept separated, in private compartments

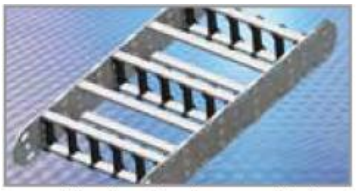


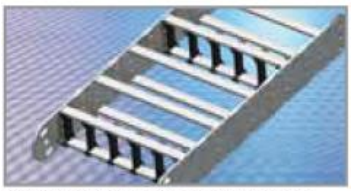
This will

- Prevent cables or hoses from tangling and damage
- Aid in maintaining the best left to right symmetrical weight distribution and balance of the carrier cavity contents
- Ensure maximum cavity fill should be less than or equal to 60% of cavity area

If in accordance with the previously mentioned recommendations it is found that cavity dividers are required the $\sum \mathrm{DIV}\ Ø$ should be added to $\sum \mathrm{ALL}\ Ø$. From this the new b_i can be determined. If this new b_i is wider than allowed, stacking certain cables or hoses is possible using horizontal shelving. It is at this stage that the suppliers usually ask end users to contact them for expert advice, but we dont buy enough from them so the chance of them helping us is slim.


Vertical dividers placed every link


Vertical dividers placed every 2nd link


Vertical dividers placed every 3rd link

If dividers are going to be used it is import to decide how often they are placed, most suppliers default to placing dividers every second link with a maximum separation distance of ½ a meter. The rule of thumb is that the more cables there are the more often divides should be placed.

1.1.4 Bend radius:

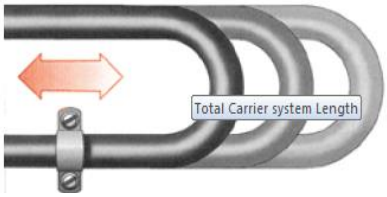
When selecting a cable chain, always chooses a chain that has a minimum bending radius (KR) that is equal to or larger than the largest cables minimum continuous bending radius. So if your largest cable is 15mm the minimum bending radius should be 15mm or bigger. The larger the bend the longer the cables will last. For us this is not usually a problem as our cables are so small, but worth noting

1.1.5 Selecting suitable cables:

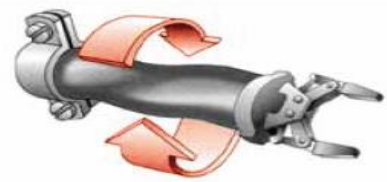
There are many different types of cables on the market today, of all these varieties only a few types are designed and constructed to be used in cable chains. Of which there is only one type and two construction methods. The second method is very expensive so really there is only one type of cable we can use. I have not included cables for fixed installation as these obviously don't work for very long. Also please don't use flexible cables deigned for home use like extension cables, there jackets are not designed for the abrasive environment of a chain,

1.1.6 Types of cable stress:

Cables designed for use in continuous motion applications using a carrier must be specially manufactured to minimize any back-twist on the cable core. When installing new media ensure that it is designed to be used in a cable chain, failure to do this will result in a reduced carrier lifetime. Below are three types of flexing listed with the first two of most importance in robotic applications.



Continuous Flex - In such cases the cable is rolling back and forth in a linear motion resulting in the cable (and the conductors within) to flex in an equivalent way. This is typically the case for all cables that are approved for use within cable carrier systems where required bend radii are typically 10x the cable O.D or less.

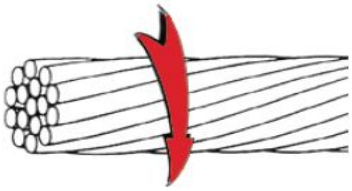


Torsional Flex - In such cases, the cable is being twisted clockwise and counterclockwise off its center-line axis with angles varying from 90 to 360 degrees "rotation". This type of flexing typically occurs on multi-axis robotic machinery that requires constant twisting and flexing over a sustained period of time.

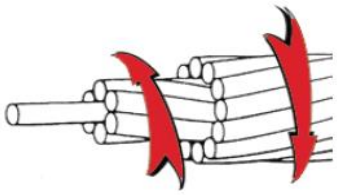
Bending Flex - In such cases, the cable is flexing back and forth off a stationary point. Industry commonly refers to this as a tick tock motion. A vast majority of the stress on the cable in such cases are the two focal points where the bend and load are being applied.

Only continuous Flex cables are recommended for use in cable chains.

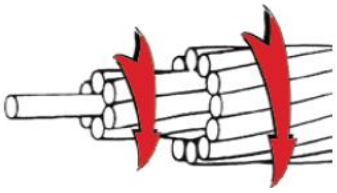
1.1.7 Type of construction



Unilay or Bunch - Cable conductors (copper groups or bunches of wire strands) of any number are twisted together with the same lay direction and the cable lay length. Bunch construction will not have a well feigned geometric configuration and may have a variable cross-section. A Unilay construction will have a well defined geometric configuration and a defined cross-section. This type of cabling technique is usually used in static applications



Concentric Contra-Helical - Conductors are surrounded by well defined layers of helically laid conductors. Each layer has a reversed lay direction and an increasing lay length in each succeeding layer. This type of cabling technique is usually used on continuously flex cable applications and designs (that should be used in cable chains)

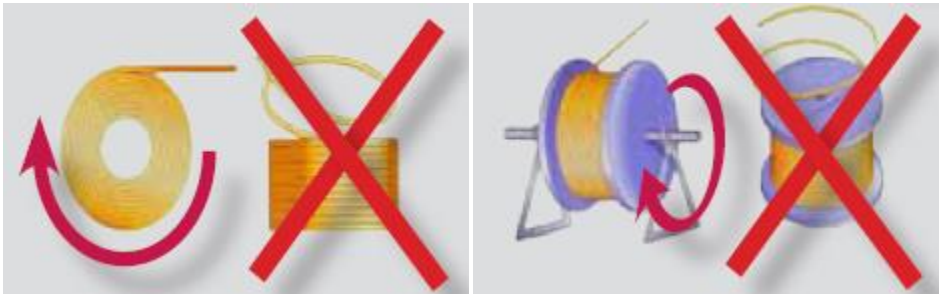


Concentric Unilay – Conductors are surrounded by one or more layers of helically laid conductors with the same direction or lay and increasing lay length in each succeeding layer. This type of cabling technique is usually used in torsional flex applications and designs

The last type that is common and arguably the best is the Chainflex cable from IGUS, super expensive but great lifetimes. If you are that tempted just drop chainflex in google.

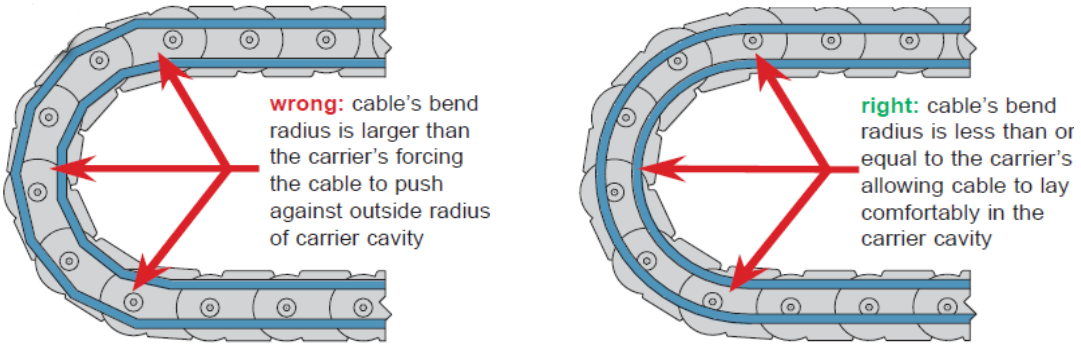
1.1.8 Chain setup

When installing cables or hoses into the carrier system, they should be laid into the carrier without twist and in accordance to the guidelines in the image. Cables or hoses should not be simply pulled off the real. Instead, they should be properly uncoiled from the reel as shown in the illustration below



1.1.9 Installation

- After the carrier system is properly installed onto the machinery and likewise the cables and/ or hoses installed within the carrier system, the entire system should be initially run-off at slow speed to insure that everything runs freely and smoothly without the carrier, cables and/or hoses binding.
- Check that all cables and hoses are not installed too tight (stretched between carrier bars) or too loose (hanging on the carrier bars) inside the carrier system when clamping them into place. Optimally, aim for the “neutral axis” (center line of the link) of the carrier system as shown below.



- Any adjustments to the carrier position or alignment as well as cable and/or hose position and length should be done at this time.
- Once the entire system is double checked, everything should be firmly tightened down. **Important:** Each cable is required to be individually strapped down, and not bunched together.
- Only after this installation and double check procedure is completed should the track be powered up to full speed and duty cycle.

Its always a good idea to recheck the chain after a few hours at full speed incase any of the cables have slipped or stretched while running at full speed.

1.1.10 Failure types

The following information should be used together with other explanations and design recommendations in this section, and is provided to assist fault finding.

Cables that have failed due to incorrect installation typically show the following symptoms

- Corkscrewing where cables twist in themselves
- Knotting of conductors underneath the cable jacket
- Cables twist around one another within a cable carrier system
- Cables are sticking out between the cable carrier crossbars and getting caught in the bend radius
- Cables entangled with other cables and crossbars tearing them apart
- Loss of conductivity through simple breaking of cable conductors

Cable failure showing entangled cables and ruptured jacket.

An example of corkscrewing where cables twist themselves.

Common causes of cable failure when operating in a cable chain

- Cables used are not designed for use in continuous flexing operation
- Cables are packed too tight inside the carrier cavities
- The actual operating bend radius of the application is smaller than the minimum bend radius recommended by the cable manufacturer
- Cable carrier design is not cable friendly or optimal for the types being used.

Catastrophic Cable Failure

Extreme cable movement within carrier system

Possible Causes: incorrect cable for application, missing cable strain relief, insufficient cavity partitioning.

1.1.11 We are done

If you plan on designing a chain in the near future or want to improve your current design I hope you find these tips useful.

If you are serious about dropping some cash into industrial grade chains I would recommend Murrplastic, IGUS or KableSchlepp chains and cables from LappKable or IGUS is you can afford them. Always use open chains and make sure your guide channels with open bottoms so any debris can fall through the chain and channel onto the floor.