Low inertia carbon fiber rollers: a big step in the performance of coating, laminating and printing machines

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Why carbon fibre rollers

Carbon fibre composite rollers are used since many years in many converting applications in the fields of **tissue, non-woven, paper and plastic** film.

In those fields due to the line speed and the width of the web simply **there is no way** to use other types of material to build the rollers. They could not have sufficient mechanical characteristics to guarantee the performance of the line.
Why carbon fibre rollers

This is due to the unique characteristics of the carbon fiber composite which can have **very high stiffness** (up to twice that of steel) and **very low density** (5 times lower than steel).
What is carbon fiber composite

A high performance carbon fiber composite is usually composed by an **epoxy matrix** reinforced with many different types of **carbon fibers** depending from the performance requests of the component.

**PAN fibers**
- High resistance and toughness
- Rt up to 7000 MPa
- E 230-300 GPa

**PITCH fibers**
- Very high modulus but fragile
- Rt up to 3400 MPa
- E up to 930 GPa
At least 90% of the use all over the world of carbon fibers is related to **PAN** fibers. Nevertheless, in roller industry **PITCH** fibers are very important since the stiffness and lightness are more interesting than resistance.

Very long and fast rotating rollers, have a high content of **PITCH fibers** to increase the longitudinal elastic modulus of the whole tube up to values of nearly 300 GPa (1.5 times the steel).
Carbon rollers – summary of the advantages

*Higher speed and lower weight*
Carbon rollers for converting machines usually have twice the critical speed of the corresponding steel rollers, with a weight that is 10-15 times lower.

*Wider formats*
Due to the stiffness and lightness of carbon the film working formats can become wider and increase production.

*Lower starting time*
Thanks to the lower inertia the plant starting time can be overwhelmingly lower with a better efficiency in production.

*Many rollers don’t need to be powered*
Often metal rollers, due to the weight and lightness of the film they carry, need to be powered and controlled by complex electronic systems to avoid stretch or damages. The lightness of carbon allows to eliminate motors, electronic drivers, control systems etc.
Carbon rollers – summary of the advantages

*Better precision in load cells*
Dancing rollers and load cell rollers, if made of carbon fibre, form a lower tare weight. This means the actual film tension can be read with greater precision and quickness from smaller load cells.

*Possibility of diameter reduction*
With carbon fibre the diameters of the rollers can be reduced with many advantages in the geometrical design of the machine which can be more compact and economical.

*Reduction of surface contact*
Another advantage of smaller diameters comes by reducing the contact area between film and roller. This means there are fewer possibilities to damage the film and less interferences during its course.

*Reduction of structural loads on the machine*
The use of carbon rollers in converting machines does not only increase working speed and the width of material but reduces the loads and vibrations on the structure that can become lighter and economical with less electric power involved.
Carbon rollers in coating and laminating machines

Nowadays it’s a **normal and forced choice** the use of carbon fiber rollers in plants with web widths of 2.7 m or more and speeds of at least 6-700 m/min while for lower sizes aluminum rollers are still the standard choice due to their lower cost.

Our experience show now that **even with web widths lower than 2 m** the advantage of using carbon rolls is absolutely effective and can solve many problems particularly with **thin films and metallized films** which can be easily damaged and scratched by high tension or friction on the roller.
Two different operating conditions

1 - Start and stop of the machine

3 parameters have a big influence:

* The moment of inertia of the roller
* The wrapping angle of the web
* The surface friction coefficient of the roller

\[ M = 2 \mu r \, T \sin(\alpha/2) \]
\[ M = J \omega \]

Where:
- \( T \) web tension
- \( r \) roller radius
- \( \mu \) surface friction coefficient
- \( J \) roller moment of inertia
- \( \alpha \) wrapping angle

The most important parameter is the **moment of inertia** of the roller. The **lighter the roller the lower the torque** \( M \) needed and easier to put the roller in rotation and to accelerate.

The carbon roller, in comparison to a classical aluminum roller which it can replace, has a **moment of inertia 2.5 - 3 times lower in average**
Two different operating conditions

2 – Machine operation at working speed

The most important parameter in this phase is the bearing friction. Lower the bearing friction smaller the influence on the web.

Due to the small web tension with delicate films, the weight of the roller is the main parameter for the bearing size and thus affects the friction. Lower weight allows smaller bearing so the friction can be further reduced.

Moreover in many cases, due to their better vibration damping, carbon fiber rollers allow a higher durability of the bearing permitting a longer maintenance intervals in the machine.
Consequences of the use of carbon rollers in start and stop of the machine
Consequences of the use of carbon rollers in the normal operation

- Lighter roller weight
- Smaller bearings
- Lower bearings friction
- No web damages
- Better surface friction coefficient
- No web damages and possible speed increase
- Longer bearing life
- Better vibration damping
Herebelow it can be seen a scheme of a Nordmeccanica Duplex Combi machine.

**Duplex Combi Horizontal**

Red dots are recommended carbon fiber rollers positions.

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Operating applications

In a Nordmeccanica triplex laminator the following rollers have been changed with a very good quality improvement of the web. The rollers are indicated in red in the sketch.

This replacement has consistently improved the rotation of the rollers with stretchable materials like PE or CPP for which very low tension values are used during the process.

All the scratches disappeared after the replacement of the rollers.

We recommend, in case of replacement, to evaluate the possibility to reduce the bearing size replacing also the inner shaft with a smaller one.
Operating applications

Other very important applications have been made completely replacing the idle rollers and guide rollers of a rotogravure printing press in which metallized OPP and PET were heavily damaged and scratched by the slipping of the roller which cannot be put or kept in rotation by the web.

Same operation has led to a very effective improvement in the web quality in a flexographic printing press used for delicate webs.
Problems solution

Air elimination

Fast rollers can drag in rotation air which lifts the web, preventing the contact with the roller, reducing the rotation and creating web damages.

Carbon fiber rollers can be provided with grooves to eliminate the air and, having the possibility to reduce the roller diameter, can be more efficient also in this aspect in front of an aluminum roller.
Problems solution

Wear resistance

If a carbon fiber roller is made with a prepreg wrapping technology can be provided with a carbon fabric surface. In this case its wear resistance is by far better than the aluminum surface and even better than anodized aluminum.

The hardness also is higher that that of an aluminum roller.
Problems solution

Surface coatings

Carbon rollers can be provided with many different types of coatings, from rubber and elastomeric coating up to hard thermal spray coverings.

In coating and laminating machines it is, for some rollers, very important to have the right covering in order to avoid web sticking with the rollers. A high roughness thermal spray with a silicone sealing is confirmed as the best and durable antisticking solution and can be applied on high quality carbon rollers.
Comparison between a typical size aluminum roller and a carbon fiber roller

<table>
<thead>
<tr>
<th></th>
<th>Aluminum roller</th>
<th>Carbon roller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>150 mm</td>
<td>150 mm</td>
</tr>
<tr>
<td>Face length</td>
<td>2500 mm</td>
<td>2500 mm</td>
</tr>
<tr>
<td>Average thickness</td>
<td>5 mm</td>
<td>3 mm</td>
</tr>
<tr>
<td>Roller weight (incl. ends)</td>
<td>17.17 kg</td>
<td>6.89 kg</td>
</tr>
<tr>
<td>Roller Moment of Inertia</td>
<td>879 kg*cm(^2)</td>
<td>345 kg*cm(^2)</td>
</tr>
<tr>
<td>Longit. Young modulus</td>
<td>70 GPa</td>
<td>120 GPa</td>
</tr>
<tr>
<td>Stiffness Ex*Jx</td>
<td>41952 Gpa*cm(^4)</td>
<td>44926 Gpa*cm(^4)</td>
</tr>
</tbody>
</table>

With the same size of a relatively small roller, a carbon fiber roller can have a **reduction of weight and moment of inertia of about 2.5 times** with a higher stiffness.

While aluminum rollers have fixed characteristics, carbon fiber rollers can be designed to meet many different needs, so they can have much higher stiffness or can be even lighter than this here indicated. The difference comes much more evident as the size increases.
Notwithstanding their higher price, carbon fiber rollers can give to the machines so many advantages that its cost increase can be considered negligible in comparison to the lower material waste, better quality and higher production speed which can be achieved.

Conclusion
Thank you for your kind attention

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