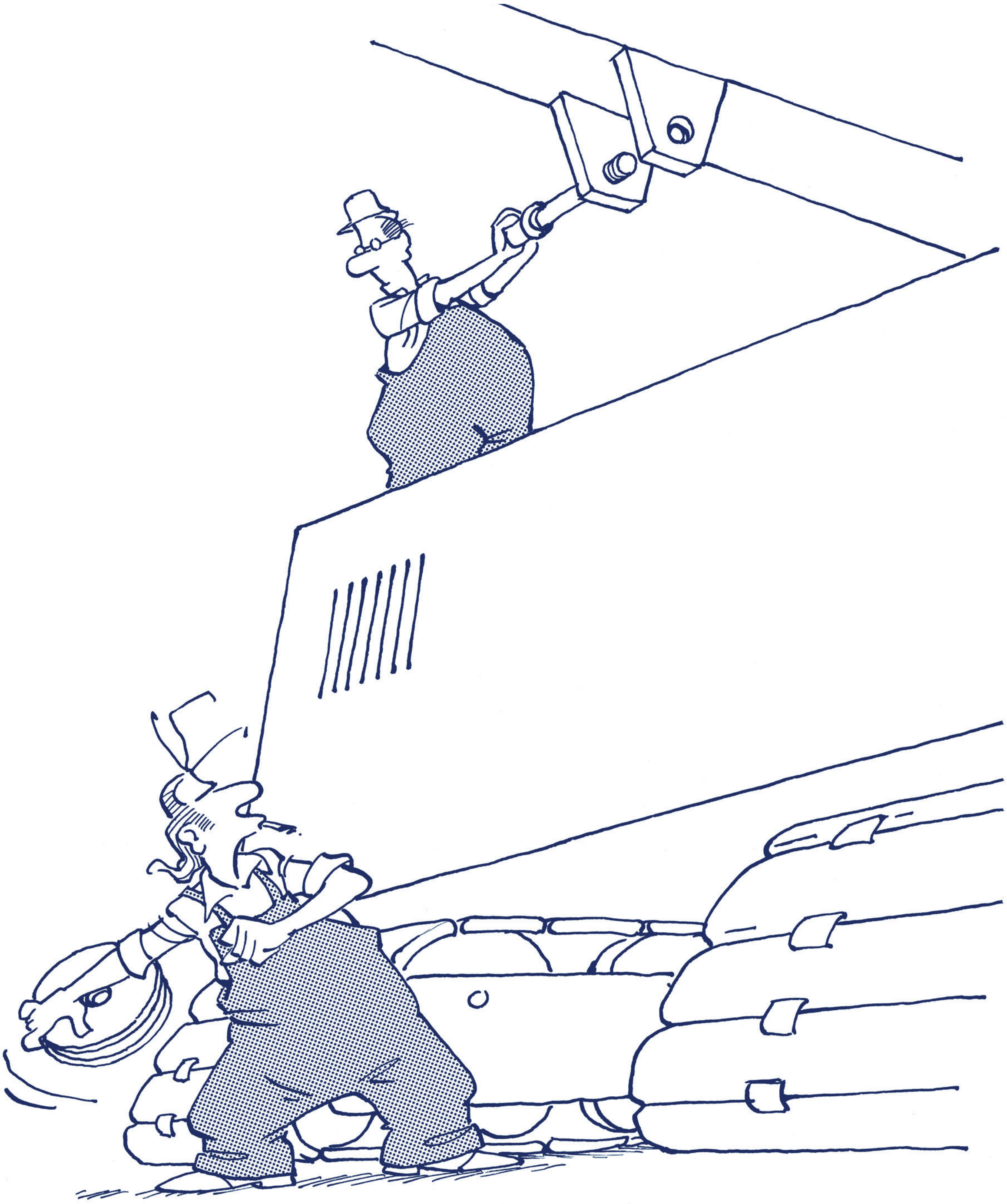
WIRE ROPE

TECHNOLOGY AACHEN



The Groove Angle Of Rope Sheaves

The Groove Angle Of Rope Sheaves

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Content

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Mark Sparrow, Bath: Thank you for proof-reading the manuscript.

1. Unsubstantiated Fears

When ropes travel onto a sheave under a fleet angle, they will be twisted when rolling down into the bottom of the groove (Fig. 1).

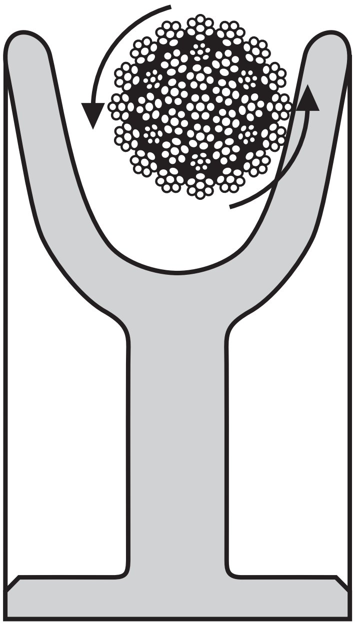

Fig. 1

This twisting can lead to a twist of the hook block of the crane or cause structural damage (e.g., a birdcage, see Fig. 2) on a rope.

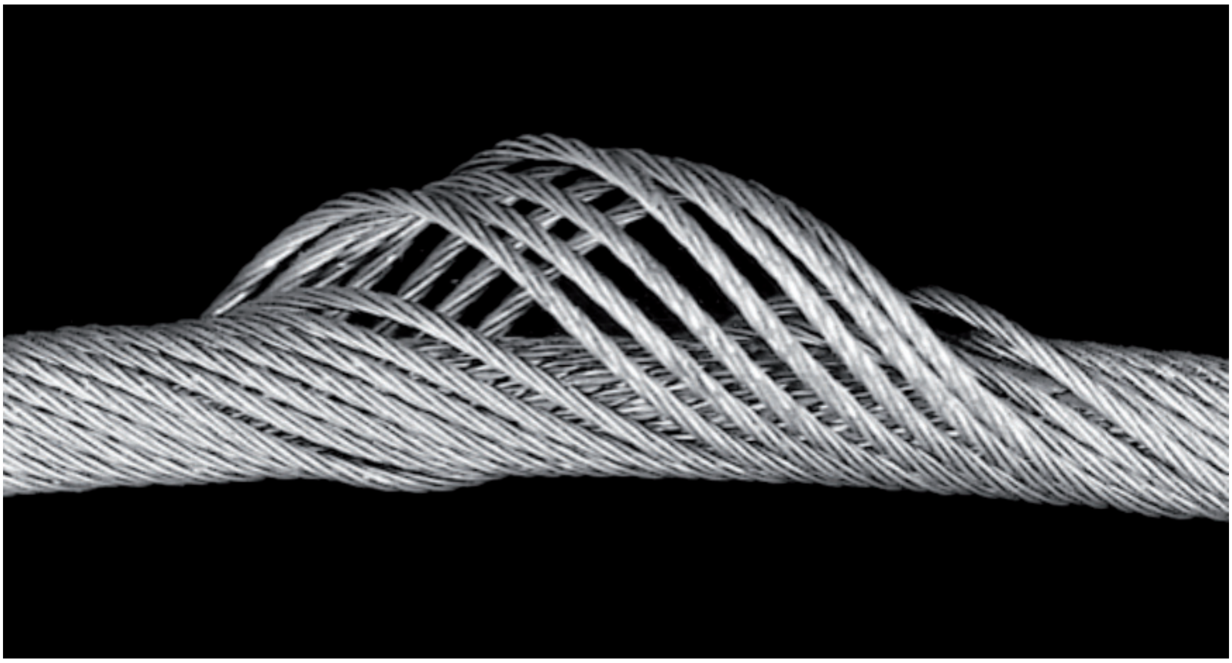

Fig. 2

The amount of twist caused by the sheave can be dramatically reduced by opening the groove angle, e.g., from 45° to 60°. Many crane and equipment manufacturers, however, are reluctant to take these measures.

Some manufacturers refer to industry standards that supposedly define the groove angle. German engineers refer to DIN 15 061 which, as they say, defines a groove angle of 45°, and deviation from this is strongly discouraged.

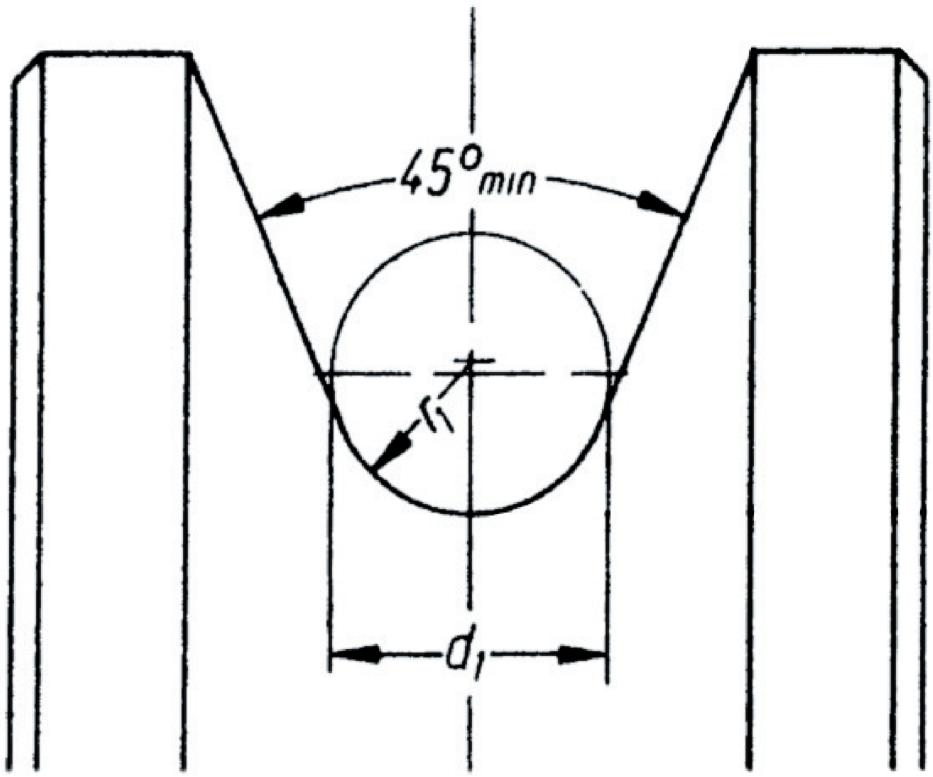

Fig. 3, from DIN 15 061

However, this is not correct: As Fig. 3 shows, DIN 15 061 says that the groove angle should be a minimum of 45°. This means that a groove angle of 60° is also permitted although this was not specifi-cally mentioned in the standard which dates to 1977.

Based on test results published in an earlier German version of this paper and based on successful practical applications, the European crane standards EN 13001-3-2 and EN 13135 now specifically permit groove angles up to a maximum of 60°.

Today, ISO 16625 (2013) specifically permits groove angles between 45° and 60° and notes: "It should be greater if the fleet angle ex¬ceeds the values given in B4" (which are 2° for rotation resistant ropes and 4° for non-rotation-resistant ropes).

Other engineers argue that the rope is held in place by the flanges of the groove and that "opening up" the groove by increasing the groove angle increases the danger of the rope falling out of the groove.

The author has found the opposite to be true: A brave engineer who wanted to make certain that the rope would stay in the sheave groove, under a fleet angle, produced a sheave with a groove angle of 0° (Fig. 4, left). The result was that even under a moderate fleet angle the rope derailed immediately.

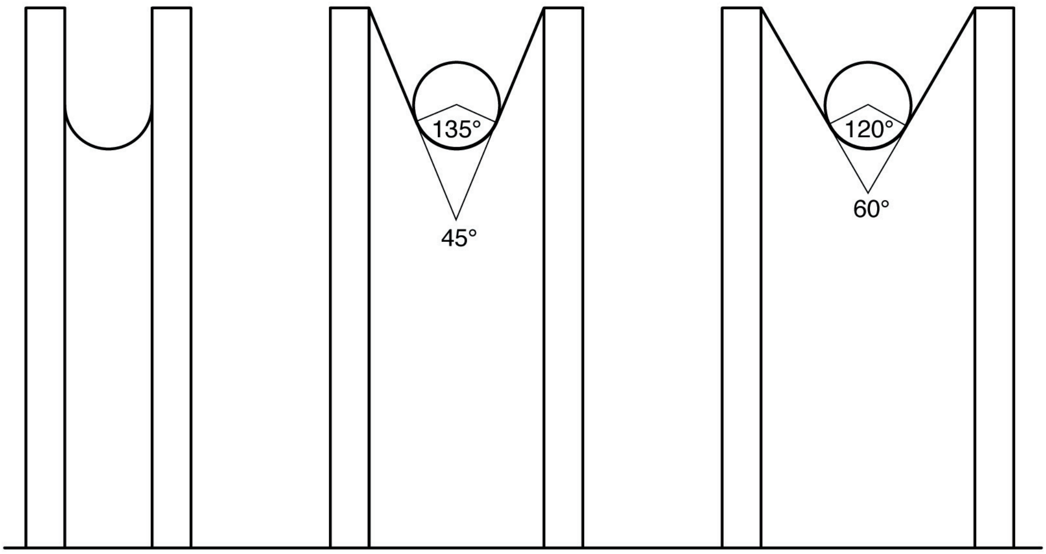

Fig. 4

On the other hand, on fishing trawlers, the ropes must sometimes be pulled in under fleet angles of more than 30°. Here the fishermen use sheaves with a groove angle of 120° to make sure the ropes stay in the groove. Despite the great groove angle, the ropes do not derail. On the contrary: it is exactly the greater groove angle that guarantees that the rope does not derail.

In other marine applications, groove angles of 80° or 90° are not uncommon (Fig. 5).

Other engineers are worried about the fatigue life of the rope: The angle of the circumference on which the rope is supported by the sheave is exactly 180° minus the groove angle. That means that a sheave with a groove angle of 45° supports the rope under 180°-45°= 135° (see Fig. 4 middle) while a sheave with a groove angle of 60° only supports the rope under 180°-60°= 120° (see Fig. 4 right).

However, the rope will only lose support on the outer 7.5° of the supporting angle where the support is minimal. Therefore, the increase in pressure in the sheave grooves is only minimal. Fig. 6 shows the pressure distribution over the arc of contact for a groove angle of 45° (black line) and a groove angle of 60° (red line). The difference is minimal.

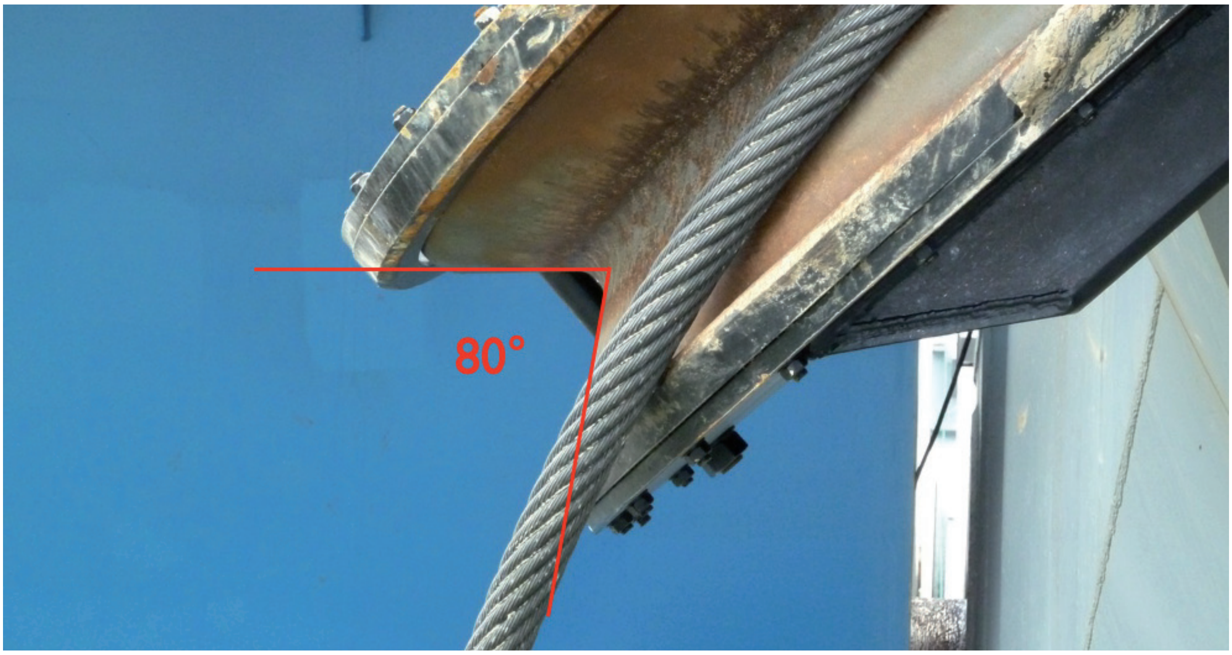

Fig. 5

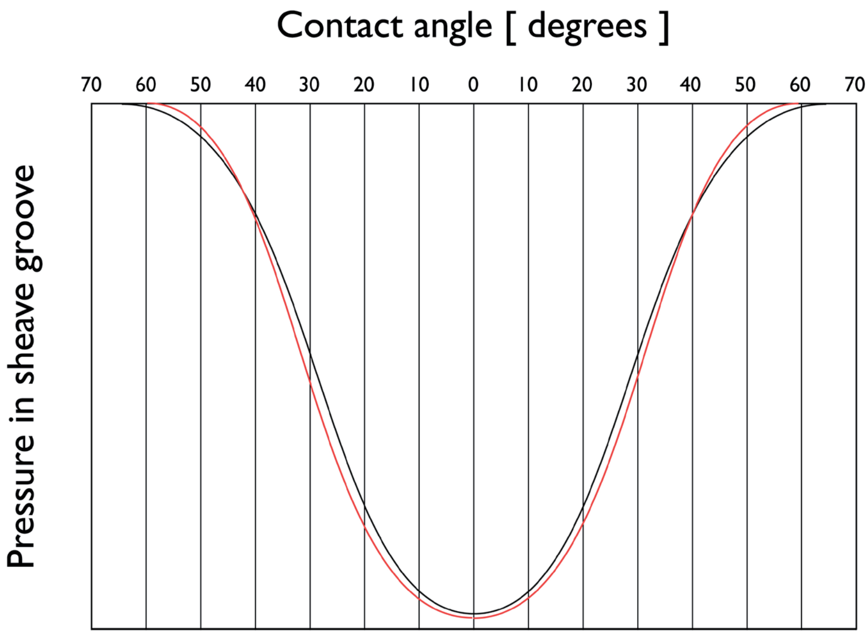

Fig. 6

Bending tests on sheaves with 45° and 60° groove angles performed at a German university confirm this statement: on both grooves, the average number of bending cycles achieved was the same. In a "real life" application, however, the ropes will be twisted less on the sheaves with a 60° groove angle and therefore achieve higher fatigue lives.

2. Derailing Tests On An Overhead Crane

The author has modified an overhead crane in a way that permitted the hoist rope to run over a sheave under a range of fleet angles and to determine under which conditions the ropes would derail and fall out of the sheave.
The following parameters have been varied:

Groove Angle

- Groove angle 30° (common in the US)
- Groove angle 45° (common in Germany)
- Groove angle 60°

Line Pull

- Line pull 4% of the minimum breaking strength of the rope
- Line pull 12% of the minimum breaking strength of the rope

Types Of Ropes

- 6-strand rope
- 8-strand rope
- 18-strand rotation resistant rope

In addition, the 8-strand rope has been tested both in a regular lay and Lang´s lay design. In addition, the ropes were deflected in the direction of their lay (Fig. 7) as well as against the direction of their lay (Fig. 8).

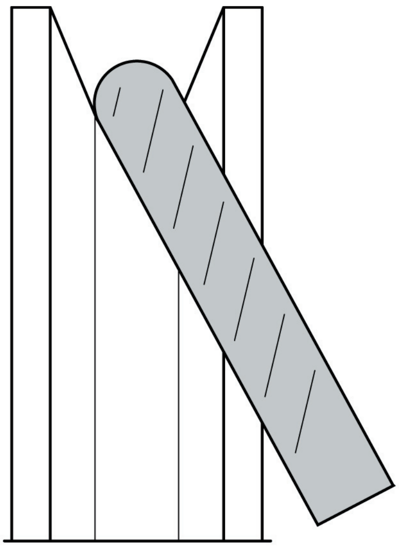

Fig. 7

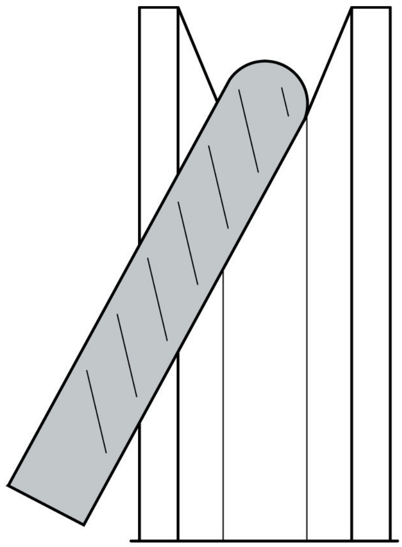

Fig. 8

During every test, a load corresponding to 4% or 12% of the rope's MBL was lifted. If no derailing occurred, the fleet angle of the rope was increased in steps of 2° by tilting the sheave around the upper rope axis (Fig. 9).

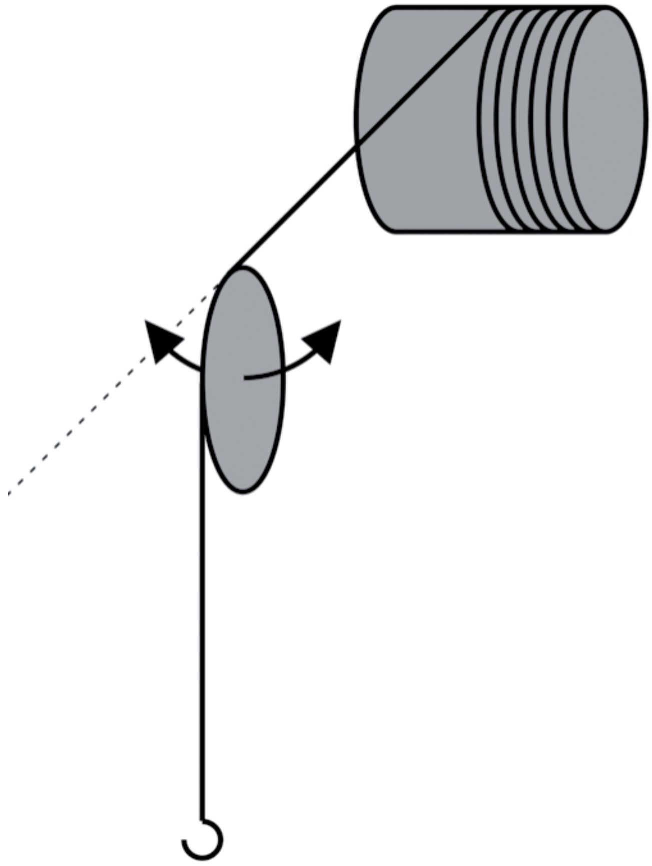

Fig. 9

Up to a fleet angle of 12°, no derailing was observed. Under fleet angles of 14°, some ropes derailed under certain test conditions. Under a fleet angle of 18°, all the ropes derailed under all test conditions.

The test results can be summarized as follows: The tendency of a rope to derail

- increases with increasing fleet angle
- increases with increasing line pull
- reduces with increasing number of outer strands
- reduces with increasing groove angle (!!!)
- is greater for regular lay ropes than for Lang's lay ropes
- is greater when the rope is deflected against the lay than with the lay.

Therefore, contrary to a widespread assumption, the use of sheaves with a groove angle of 52° (according to British Standard 6570) or 60° is not a safety risk. Sheaves with larger groove angles will even reduce the risk of a rope derailing.

A few years after the publication of the first (German) version of this paper, the technical manager of one of the largest crane manufacturers in the world told the author: “Based on your recommendation, we changed the sheaves of our large lattice boom cranes from a groove angle of 45° to a groove angle of 60°. We still get complaints of block rotation and birdcaging on the older cranes, but we have not had a single complaint on the cranes with 60° groove angles.”

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