**Cable Grips with Plastic Padding**
Ernst Corazza

To reduce wear and tear on both carrying-hauling ropes and haul ropes, sheaves and rollers have, for a long time, been padded with relatively soft materials in the contact areas. The padding may consist of various rubber mixtures or synthetic materials like Viskolit or Bekorit. The padding of sheaves and rollers has been state of the art for quite some time. Padded cable grips, however are new. One of the main reasons why this has not been tried before is the space needed for the padding. Usually, both the body and the brackets of cable grips are made of heat-treated steel with a relatively high strength. Because of the relatively low friction between the grip and the rope, the pressure needed is rather high, which means that the rope is subject to high lateral forces, which in turn reduce its service life. Whereas cable grips in monocable aerial ropeways should be as small as possible to ensure smooth running, this is not necessary in bicable aerial ropeways, because their cable grips will not touch the rollers when passing a line support structure. The following report refers to a reversible aerial ropeway in Austria that was opened in 1995. In this system, the cabins are connected to the haul rope loop via cable grips.

After about 67 years, one of the oldest reversible aerial ropeways in Austria, the Pfänderbahn, was rebuilt, again as a reversible aerial ropeway. The new cabins can carry 80 passengers. The haul rope consists of a closed loop, and not of more than one part, as is usual. It is gripped to the carrier truck. In each carrier truck, two grips are used. In these grips, the gripping force is transmitted directly to the nearside bracket via a group of cup springs. Each gripping mechanism consists of two brackets, the grooves of which are padded with plastic material to reduce the wear and tear of the haul rope, and at the same time increase the resulting friction. The farside brackets are bow-shaped, enclose the rope and are attached with screwbolts to the spring mechanism. The nearside brackets are connected to the guide bolts of the cup spring assembly, which exerts its pressure on them (Picture 1, attachment 1: engineer drawing of one of the two grips). To support the rope at the entry points of the grips, ropeguides are positioned there, to ensure that rope always enters the grip in a straight line, and to decouple the grip from rope oscillations. For the use of the plastic grip paddings, the authorities mandated a number of tests to be met. When determining the admissible friction coefficient, not only influences on the ropeway, as temperature, humidity,

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lubrication, and the physical and chemical properties of the padding material had to be taken into account. Moreover, the ageing characteristic of

the plastic material, possible chemical reactions with the lubricant used in and on the rope, its absorption of moisture, and its electric conductivity in relation to its moisture content had to be documented. As to slip, the usual conditions for cable grips had to be met. Note that in the determination of the permissible friction coefficient, any influence of the deformation of the padding must not be considered.

The project managers submitted four different padding materials to be tested for this purpose. These included two different versions of Bekorit, a plastic material known as Uniplast 1050, a fiberglass reinforced polyamide, and a plastic material produced by the Rydahl company, known as "Bremskerl BK 5773-asbestfrei".

Based on preliminary tests, BK 5773, a resin-based elastomer, was selected as padding material. BK 5773 is compression molded, free of asbestous, and does not include any metallic components.

To determine the suitability of the material as a padding in cable grips, the following tests were performed:

1. Determination of the friction coefficient along a smooth rod, lightly lubricated with the lubricant used on the haul rope.
2. Determination of the friction coefficient by pulling tests on a rope with round strands to simulate the haul rope.
3. Effect on the padding material of a pulling test over a longer distance.
4. Influence of ageing.
   Artificial ageing was performed as per DIN 53508.
5. Determination of the ball-pressure hardness before and after the ageing process.
6. Testing of reaction with the lubricant used for the rope, also with respect to volume changes per DIN 53521.
7. Determination of hygroscope properties after storage in cold water (DIN 53472).
8. Determination of electric resistance according to DIN 53482.
9. Properties of the padding material when in contact with the haul rope, which was subjected to tensile stress of varying magnitude between one quarter and one tenth of its breaking load.

ad 1.:

To determine the friction coefficient, a smooth rod of hardened steel, 600 mm in length and with a diameter of 32 mm, equivalent to the width of the mouth of the grip, was used. The rod was lubricated with the lubricant used for ropes, gripped by the grip with the gripping forces envisaged, and pulled in a servo-mechanical test machine at a speed of 7mm/s. Both the pulling distance and the pulling force were recorded and stored on a computer. Using Coulomb's Law on Friction, the value of the pulling force over the pulling distance under constant gripping force was used to determine the value of the friction coefficient. The friction coefficient along a smooth and lightly lubricated rod is between $\mu$=0.27 (static friction) and $\mu$=0.23 (sliding friction).

ad 2.:

To determine the pulling force along the haul rope to be used, a short piece of this rope was inserted into a universal testing machine, and pulled at 160 kN, equivalent to one fifth of the breaking load. Prior to the tests, the rope was freshly lubricated with the same lubricant as used in practical operations. Before the beginning of the tests, the lubricant was allowed to dry for about 15 hours. The pulling force was applied to the grip with a hydraulic piston. The pulling distance was recorded with a potentiometer. The average value of the friction coefficients thus recorded was $\mu$=0.44 ($\pm$0.02).

ad 3.:

The authorities also wanted a pull test over a longer distance, but due to limitations of the test equipment, this distance was limited to 90 mm. Therefore, the test was performed in five instalments, providing a total pull distance of 380 mm. The friction coefficients measured were between 0.40 and 0.48. Because of the resulting wear, the gap between the nearside and the farside pad was reduced from 4.2 to 2.6 mm. Despite this wear, the pulling force was not significantly reduced in this test, and never dropped below the required minimum.

ad 4. and 5.:

To determine the influence of ageing on the padding material, heat curing was selected similar to DIN 53508. In this method, ageing is performed by air at standard pressure and elevated temperature. To test the ageing, the producer of the plastic material provided a test disc of 130 mm in diameter and with a thickness of 6 mm. Ageing was performed in an oven with natural ventilation. For seven days, the temperature was constantly kept at 100$^{o}$C$\pm$1 degree. After that time, the loss of mass was quite low with 0.4%. The influence of ageing on absolute values $Z_a$ was also determined by measuring the ball-pressure hardness before and after ageing in the oven. The difference in

hardness was determined according to DIN 53508 and expressed as a difference in the respective unit of measurement. The average ball-pressure hardness was H=50 $N/mm^2$ before and H=66 $N/mm^2$ after the ageing process. Together with the values of ball-pressure hardness indicated, this results in an absolute change in properties of $Z_a$ = 16 $N/mm^2$. Ball-pressure hardness was determined according to DIN ISO 2039, part 1.
A visual check of the samples after ageing did not yield any detectable changes.

ad 6.:
To test the padding material with respect to its reaction with the lubricant used, the change in volume after storage in that lubricant was compared to the change after storage in standard Cetane, using the methods prescribed in DIN 53521. Storage was at a temperature of 50$^{o}$C±2 degree for 14 days. Neither the lubricant used, nor the standard Cetane caused any changes in volume of the samples. The average Shore D hardness was 82 Shore D before depositing the padding in the lubricant, and 78 Shore D after. The standard Cetane did not change Shore D hardness.

Ad 7.:
Hygroscopic properties were determined according to the methods prescribed in DIN 53472. Test discs of 6 mm in thickness and 130 mm in diameter were used. According to item 5.2 of DIN 53472, the test discs were submerged in aqua destillata of 22$^{o}$C ±2 degrees for four days. After that, the weight of the test discs had increased by about 1 %. No other changes, be it in the dimensions or other properties, were detected.

Ad 8.:
Since the monitoring of the haul rope required the electrical isolation of the haul rope from the track rope, and the carrier truck respectively, electrical resistance was measured with special care. Electrical resistance was determined according to the procedures described in DIN 53482, and both the resistance of the material and the resistance of its surface were determined. We could prove that samples of Bremskerl BK 5773 did have sufficiently high resistance, even after four days in water. The surface resistance is in the order of GΩ, and material resistance in the order of MΩ, considering voltages of 500 V.

Ad 9.:
As the preliminary investigations had yielded quite satisfactory results, the properties of the padding had to be tested under conditions similar to the practical application. To do this, the grip was attached to an 8 m part of the haul rope, and loaded with tensile stress

of varying magnitude between one quarter and one tenth of its breaking load. In this test, the grip was weight-loaded along the axis of the rope with a downward pull along the rope of 36.5 kN, equivalent to half of the maximum pull. In this test, the gap of the grip and possible sliding of the grip on the rope were measured. The first test covered 200,000 load changes. As you can see from the picture (Picture 2, attachment 2), the gap between the nearside and the farside bracket closed fairly rapidly and stabilized at about 0.2 mm below the maximum. After this test, three more tests were conducted, whereby each test was aborted after 2,000 load cycles to attach the grip at a different point of the rope. When doing so, we tried to position the grip in such a way that the rope would be able to insert itself in an unused area of the padding. Individual results show that varying tension on the rope and thus a change in the spin of rope do not strongly influence the wear of the padding. As you can see in the picture of the long-term test, the gap between the brackets shrunk more on one side. This is caused by the fact that the free part of the rope that was attached to the test cylinder was much longer than the fixed one.

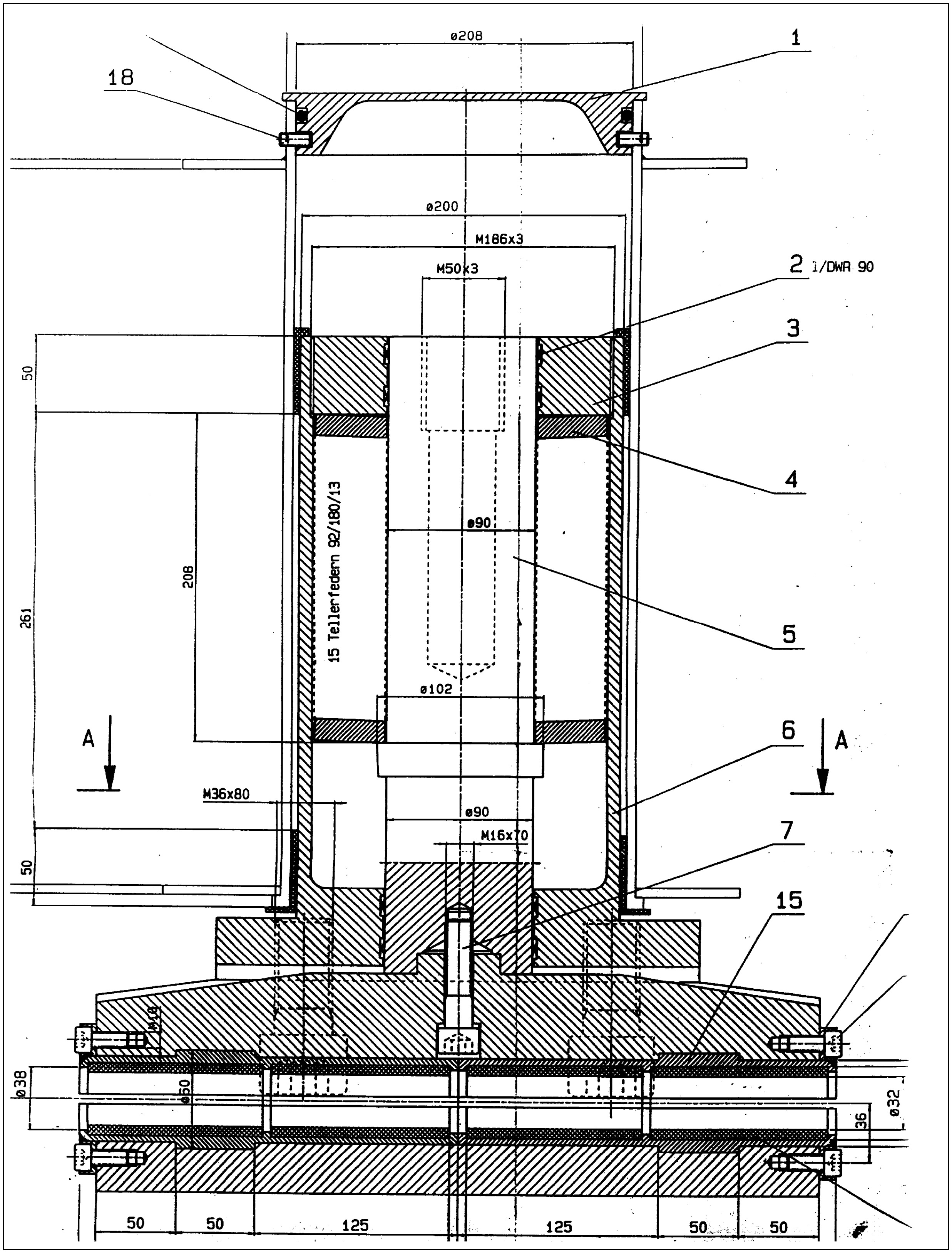
The test results led us to believe that the padding material selected would work well. A check after 1,100 operating hours showed that the areas of the haul rope subject to gripping forces did not show any visible signs of wear. The actual diameter of the rope there was not different from other areas that had not been subject to gripping forces. Eddy current tests also did not reveal any signs of rope damage. The test diagrams in the gripped areas of the haul rope show even basic curves which are comparable to those of other parts of the rope. According to the operating regulations, the position of the grips on the haul rope must be moved after 50 hours for the first time, then after 100 hours, and subsequently every 200 hours. Since neither the eddy current tests, nor visual checks of the gripped areas of the haul rope have revealed any damage, the interval of repositioning has been extended to 500 hours by the authorities.

In the meantime, this reversible aerial ropeway has been operating for more than 5,000 hours without a change of the grip paddings. In November 1998, the lower of the two grips of cabin 1 was removed for a visual check of the padding. As had been found in earlier checks, the haul rope had imprinted its pattern in the padding. In the area of the valley-side rope feed, the plastic padding was deformed strongest. However, the remaining cross section of the plastic padding was sufficient for further safe operation.

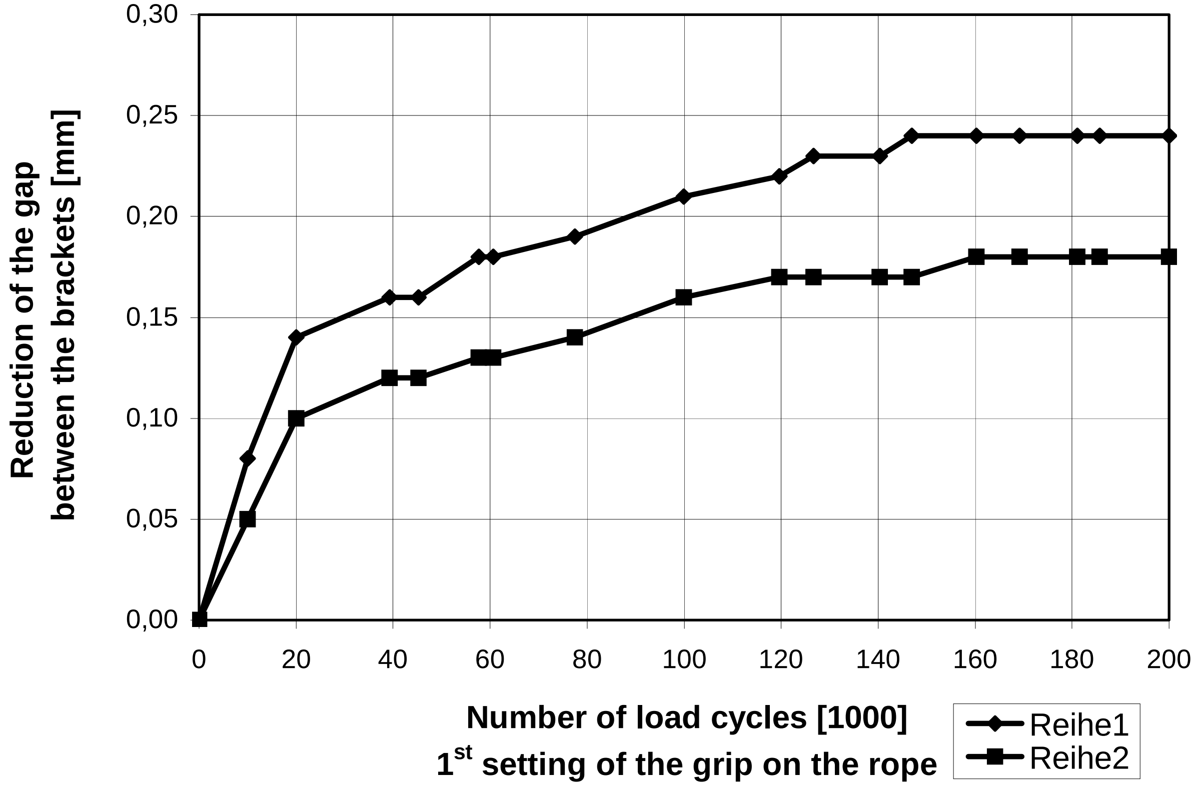
Documents provided by the operator show that the gap between the brackets (the nearside and the farside bracket) between the moving of the grips after 200 hours has shrunk by 0.2 to 0.3 mm, and that a reduction of the gap by 0.3 to 0.6 mm has occurred at 500 hours intervals. The last measurement taken after a total of 5,500 operating hours revealed a minimum gap of 7.7 mm, which is still above the legal minimum of 6 mm. The diagram in attachment 3 shows all the values for gaps measured before and after a shift of the gripping point and the respective interval. As has been the case in earlier checks, the gripped areas of the haul rope were again checked visually and with the eddy current method. The test diagrams in the gripped areas of the haul rope showed even basic curves without any sign of damage to the rope. Visual checks of the gripped areas did not reveal any visible damage of the rope.

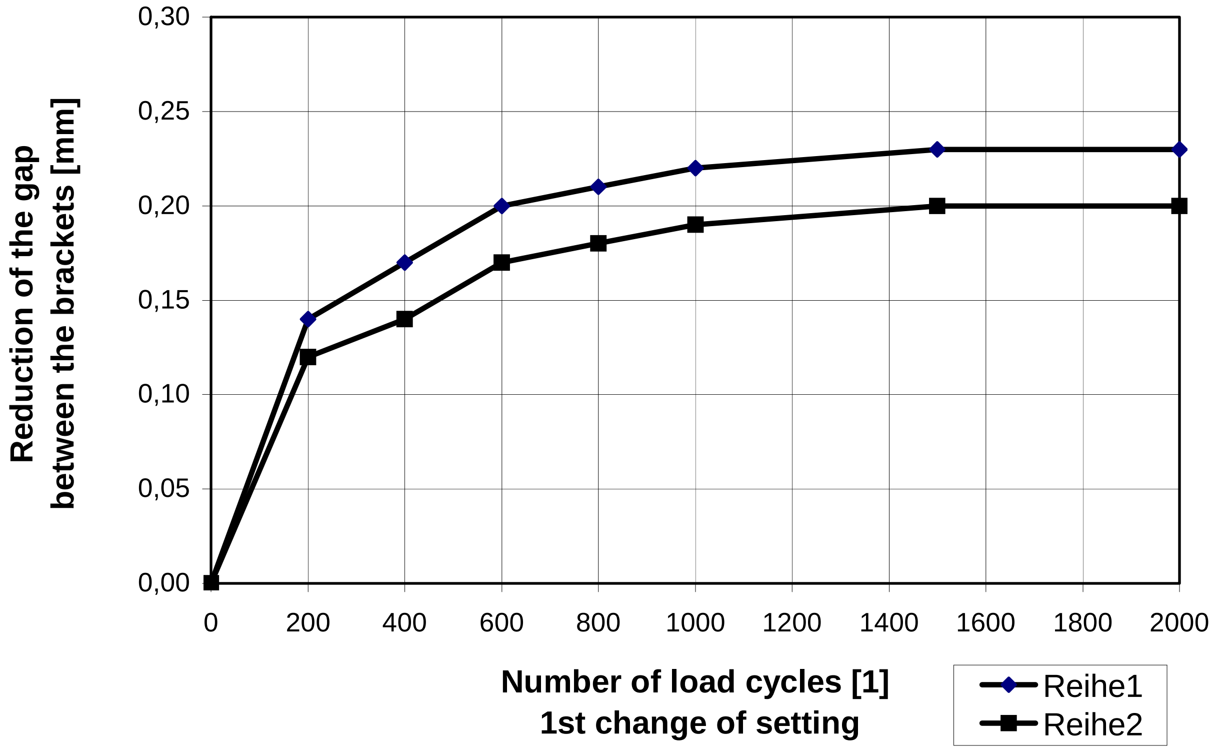
Without this plastic padding, the gripping forces would have to be about 60% higher to yield the same friction. Therefore, the goal of protecting the haul rope with a plastic padding of the grips has been met.

[3 attachments]

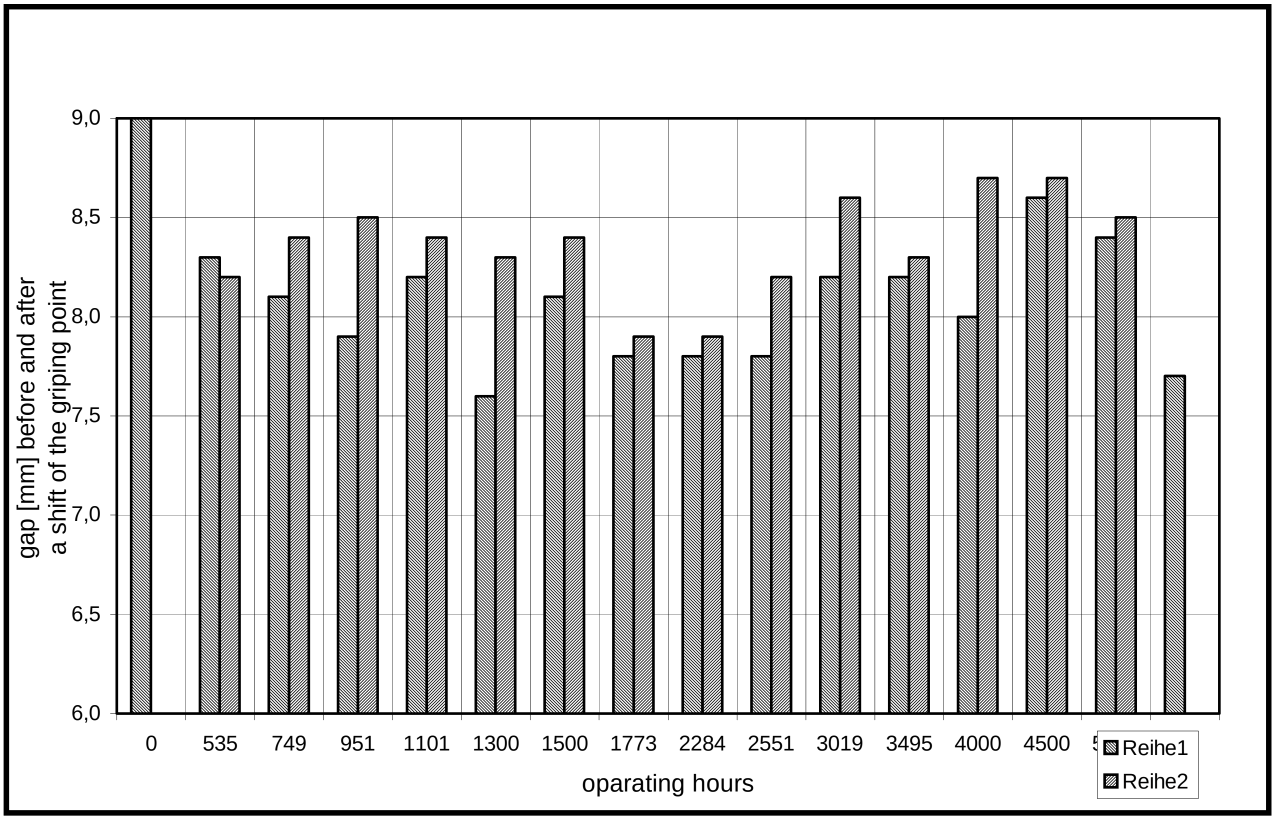



**Picture 1:** engineer drawing of one of the two grips (HÖLZL-Seilbahnbau / Lana)




**Picture 2 and 3:** Wear on the padding according to the number of load cycles
Reihe1: test cylinder side; Reihe 2: fixed side.




**Picture 5:** Readings of gaps at the grip, measured before (Reihe 1) and after (Reihe 2) a shift of the gripping point