Essential ski characteristics for cross-country skis performance

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Abstract: Winner or trail hog? Much depends on the ski characteristics. The manufacturing of skis is a complicated process involving several materials and different process steps. This gives as a result that every ski obtains unique characteristics such as span curve and bending stiffness etc. For high performance skiers as the member of the Swedish ski team the importance of equal characteristics of each ski in a pair is vital. The process of matching skis to a pair is the process of finding two individual skis with the most similar characteristics. This is traditionally done by hand with simpler equipment. Our measurement system is developed for faster and more accurate ski characteristics assessment. The characteristics do impose the overall performance of the ski. It produces the span curve with very high accuracy and gives a good representation of the pressure distribution over the full length of the ski. The measured characteristics could, in our opinion, also be used in selecting skis for different weather and track conditions. The ski measurement system has been used by the Swedish cross-country team during the last 2,5 years which have resulted in a faster and more accurate matching of skis. In collaboration with the Swedish ski team have also an investigation concerning correlation between ski characteristics and weather and track conditions has been initiated with some preliminary results already obtained.

Key words: Cross-country skis, ski characteristics, pressure distribution, matching of skis

1- Introduction

No singular cause determines the overall performance of a race ski. First of all, we have of course the definition of performance to be established. Parameters in cross-country skiing are typically: glide, grip, weight, stability, and the performance is often rated through a combination of those parameters reflected on if the skis are for classical or skate races? (Ekström, 1981; Ekström, 1987)
However, there are some structural ski factors that are more essential than others when considering glide and grip in general (Kuzmin and Tinnsten, 2006). The manufacturing process of skis consists of many steps influencing the final ski characteristic. As a result of the manufacturing strategy, with great parts of manual labor, do the products show variances in quality? This implies that each ski is an individual with its own features. In order to achieve a pair of skis that could satisfy a number of different demands, the first task is to actually pair skis with similar attributes. The next task is to transfer these attributes to ski pair characteristics.

It is almost impossible to obtain more explicit information from the manufacturers of skis about their construction methods and design to achieve certain ski characteristics. This is treated as business secrets and is used as a sales argument for high-end race skis. Hence, many of the manufacturers do have their own equipment/method to classify their skis.

One of the main features that are constructed into a ski is the rigidity and stiffness along the length of the ski. An example of this is the result of cooperation between Salmon and Subaru Factory Team. This is a very important feature influencing the span of the ski and hence also the pressure distribution under the ski in interaction with the snow (Antti et al, 1993, Internet www1). Since the predominant factor for glide and grip depends on the pressure distribution of the skis, the means and method to measure this is of greatest importance (Erkkilä et al, 1986).

Recently private companies have also presented machines that measure span curves and to some extent rigidness of the ski (Internet www2). This can of course be of guidance to know more about some of the important parameters but principles have to be developed further.
In order to have the ability to measure the pressure distribution and the ski span curve, a completely new measuring apparatus was designed and manufactured. This was done as a result of the lack on the market of a computerized logging device with accuracy and speed to fulfill our demands for research work.

2- Experimental setup and method

A measurement device designed to perform measurements of ski characteristics has been developed. One ski at a time can be measured for ski characteristics such as span curve and the ski ground-pressure distribution when loaded. The experimental setup consists of a frame made of aluminium, a load unit and a measurement system. A simplified overview of the experimental setup is presented in Figure 1.

The aluminium frame (4) and (5) is designed to withstand the forces generated from the loading unit without any significant deformations. The load unit is mounted on the beam (6) and the applied load, measured by a load cell, can be adjusted to the desired value by a power screw in contact with the ski. The load cell is connected to a digital display and the whole load unit can be adjusted along the ski depending on where the load should be applied. A detailed view of the load unit is shown in Figure 2. Accuracy of the load cell is ±0.05 kg.

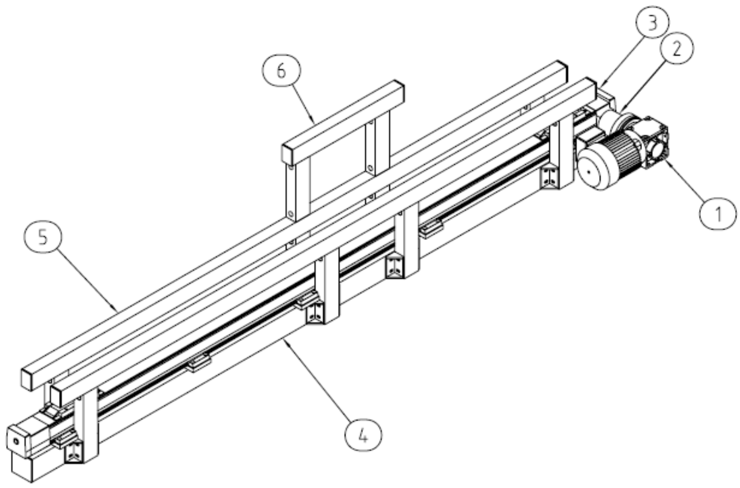

Figure 1 View of the ski test rig.

To obtain the span curve two linear position sensors are used. One sensor is used to measure the position of the ski surface above the reference surface (5) and one to calibrate for differences of straightness of the reference surface. By the load cell the distribution of the contact force of the ski surface in contact with the reference surface (5) can be measured when the ski is loaded. The longitudinal pressure distribution, hereafter denoted PPD (the proportional pressure distribution), is directly proportional to the contact force. The load cell has a capacity of 1 kN. All the sensors are transported by a linear drive unit (3) continuous during measuring over the whole measuring range of a ski length. The linear drive unit is driven by a gear motor (1) connected together by a coupling (2). Signals from the sensors are sampled continuously at a frequency of 200 Hz and stored in a computer. When the sensors reach the end of the measuring length the linear drive unit will stop automatically. The position of sensors during measuring is measured by an incremental shaft encoder connected to the rotating part in the linear drive unit. The maximum length of a ski which can be measured is 2.1m. Computer software has been developed to sample signals and show the result of measured span curve and the pressure distribution which will be presented in tables and diagrams. One measuring cycle consist of measuring a pair of skis.

The first step in the measuring process is to open a new ski test and record data of the skier into the computer software. After this the type of ski (classic or skate) is specified. To measure a pair of skis the first ski is placed and fixed in the test rig, where after the load unit is positioned where the load should be applied.

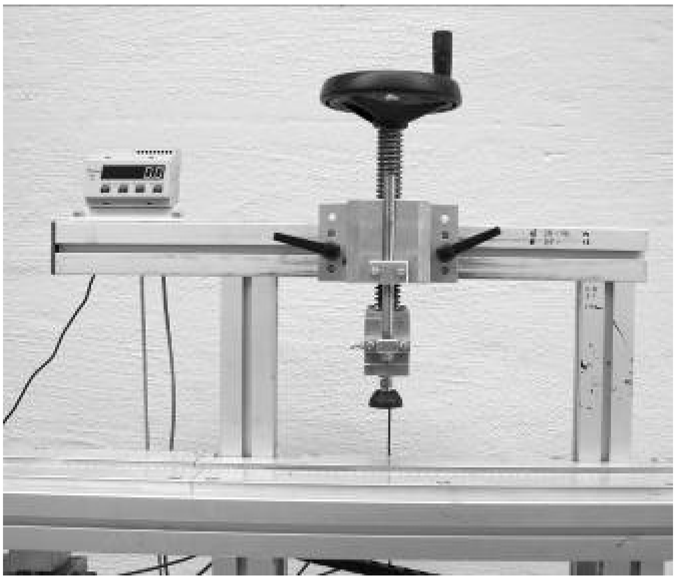

Figure 2 The load unit

The ski is loaded to the desired value with the power screw and the measuring process on the computer is initiated. The measuring process is started by activating the gear motor to the linear drive unit. First the span curve will be measured, then the pressure distribution. After this the ski is unloaded and replaced with the other ski in the pair and the measuring process is repeated. When the measuring process is ended the software produces the result of the data automatically and tables and diagrams for both skis are presented. In Figure 3 the ski is placed in the test rig and prepared to be measured.

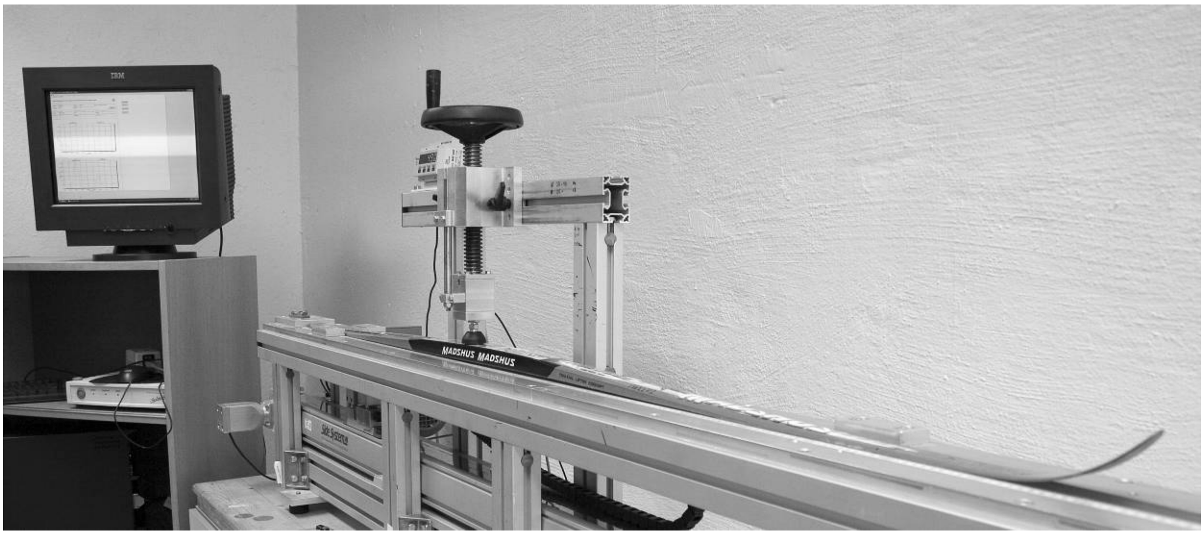

Figure 3 The ski placed in the test rig.

3- Results

Measurements have been conducted to a load of 40.0 kg for both classic and skating skis for men. For women the load has been between 25 to 30 kg for classic skis and 35 kg for skate skis. The position where the load should act is for skate skis 70 mm behind the point of balance of the ski for both men and women. For classics skis the position of load is placed 140 mm for men and 100 mm for women behind the point of balance of the ski. More than 500 pair of skis have been studied by this method by the Swedish ski team for more than 2.5 years.

In Figure 4 the results from measuring a pair of skate skis is shown. Figure 4 a) shows that the PPD curve is similar for the same for both skis and the span curve in Figure 4 b) has a span maximum of 3.30 mm at a distance of 993 mm from the rear end of the ski. The PPD curve also shows that the maximum value at the front glide zone is lower than at the rear glide zone.

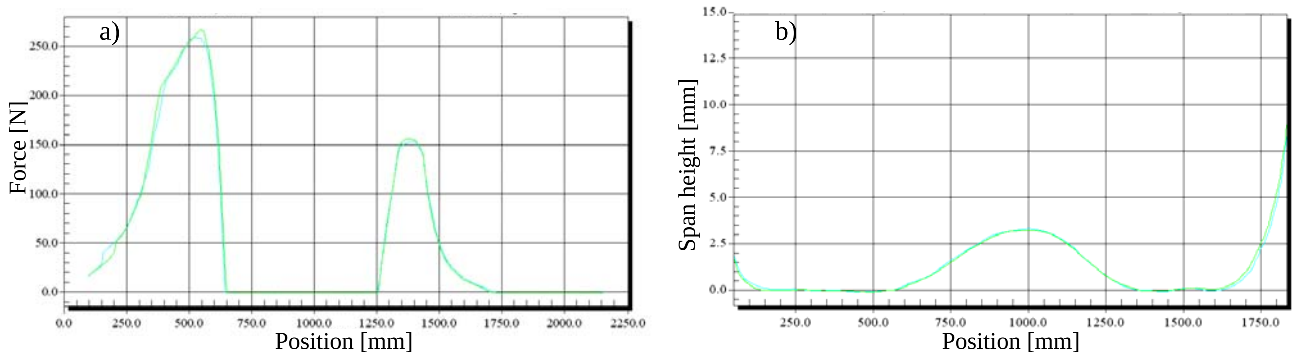

Figure 4 The PPD curve (a) and the profile of the span curve (b)

Figure 5 shows how results from measurements of classic skis in the test rig can differ when comparing skis delivered from ski manufacturers. By this test, skis that differ too much can be sorted out in an early state of the selecting process of skis for the skiers.

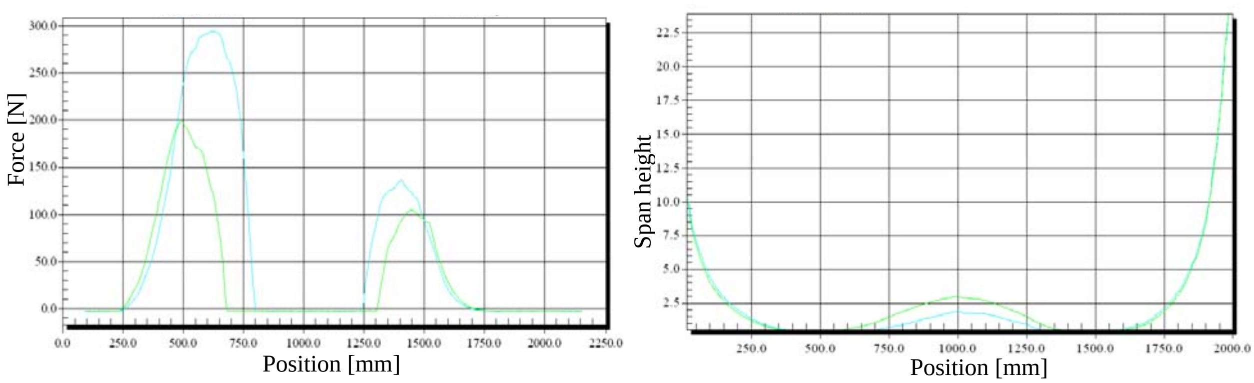

Figure 5 PPD curve and span curve of a pair of classics skis.

Figure 6 shows the measured pressure distribution profile of two different pair of classic skis for the same skier. The curves for the front glide zone pressure distribution can differ between the skis and the profile in Figure 6 a) shows a smoother profile compared to the profile in Figure 6 b). This is also the case for the rear glide zone pressure distribution profile.

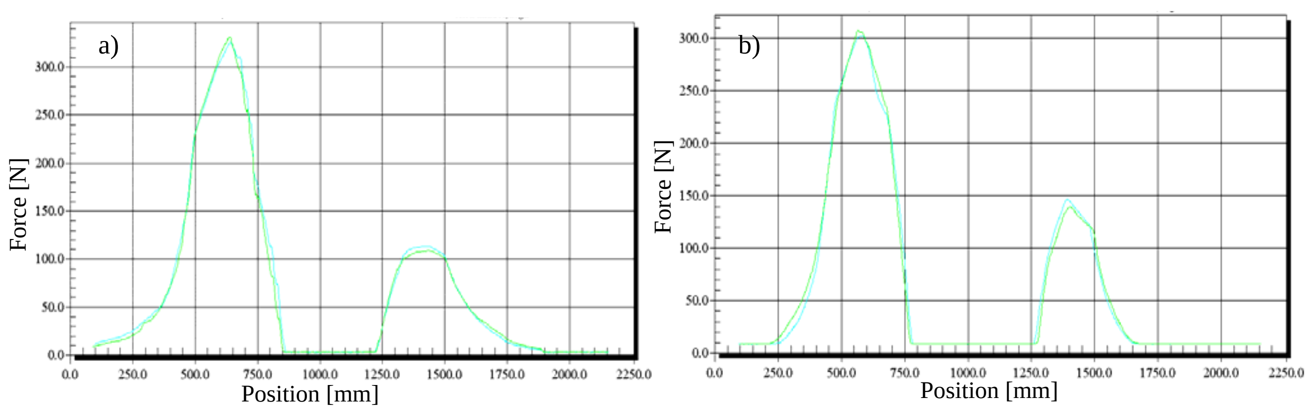

Figure 6 PPD profiles of two different pair of skis.

In Figure 7, a typical relationship between the front and rear pressure distribution curve is shown for men (a) and women (b). The ration between the rear top and the front top of the force distribution curve is much higher for men compared to women.

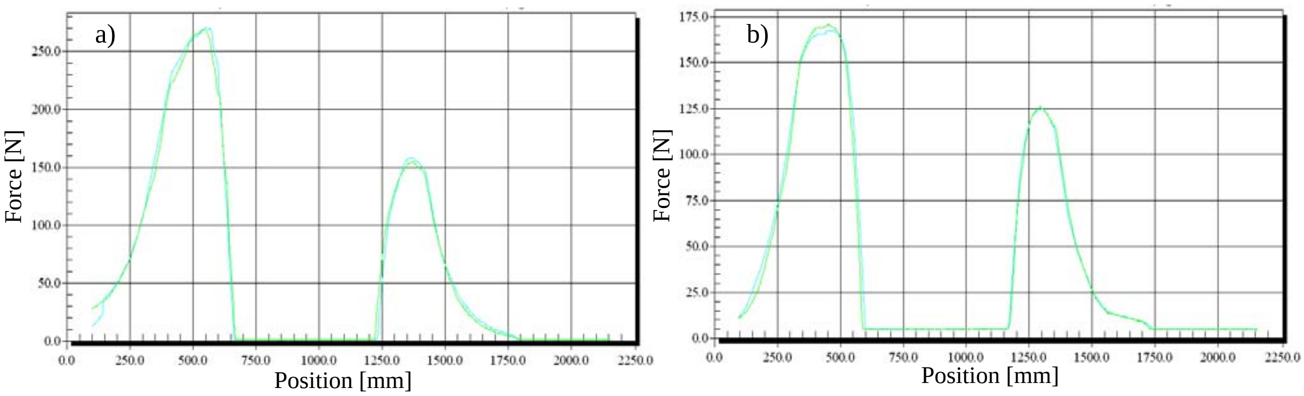

Figure 7 View of a typical profile of the PPD curve for men (a) and women (b).

4- Discussion and conclusions

Although the Swedish national team in cross country skiing have used the ski measurement system intensely for nearly three years there is no clear correlation between the ski pressure distribution or the span curve and to the weather or track conditions. Initially the team used the system to determine the skis span curve with higher accuracy and less time consumption than with earlier methods. Later they also began to routinely determine the pressure distribution for the team members` skis. At present, nearly all skis in the national team have been measured and all of the data been saved. The measurements have been performed using a predefined method, i.e. the weight on the ski, the point of applying the weight etc. has been equal from measurement to measurement. According to Mikael Book, former member of the waxing team in the national team, the measurement system has provided the team with a much faster and more accurate measurements of the span curve. The system also has provided the team with new knowledge of the skis pressure distribution curve and facilitated the process of pairing two individual skis to a pair. According to Mikael Book, he and the team has gained experience and understanding of ski performance by using the system and it has also simplified the selection of skis for a particular race occasion. Although no comprehensive explanation exists for what makes the skis glide optimally related to weather conditions, some factors have been revealed. For skating skis used in cold conditions, the maximum span height should be lower than in warm/wet conditions. Also the arching of the span and the pressure zone in front of the binding should be longer in cold conditions compared to warm/wet conditions. For skis used in the classical techniques, the grip wax and consequently the maximum span height is of the most importance regardless of weather conditions. Here also the span length, especially in front of the binding, is of great importance.

5- Future consideration

The results from this study reveal the problem of understanding in which way different characteristics of a modern cross country racing ski influence its performance in a race situation. Here the span and the mean (perpendicular to the ski) pressure distribution curve have been investigated in order to find some correlations to weather and track conditions. There are of course several other characteristics that are of great interest when trying to understand what makes a ski perform well on the track. The mechanical construction together with the material and the assembly of the ski is of course of great importance – this gives together with the chosen materials the span curve and the pressure distribution for the track. If the pressure distribution and span characteristics are known then a method for attaining this could be developed. But also other characteristics that are believed to be of great importance must be investigated; torsional stiffness, vibration characteristics, material and structure of the running surface, etc.

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