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The use of an Edge Load Profile static bench for the qualification of alpine skis

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Abstract

The work reports the results of several tests performed on a set of commercial skis ranging from racing to recreational skis by means of a special bench designed for evaluating the Edge Load Profile produced by a ski when pressed against a bed of calibrated load cells.
The test bench is equipped with 21 uniaxial load cells of 100 mm width and with a linear actuator able to press any type of alpine ski at edging angles ranging from 0° to +/- 70°.
The Edge Load Profiles were presented along a normalized ski length and their shapes were compared within each category of skis. The bench output was clearly revealing the presence of critical spots along the ski where either the contact to the ground was missing or some non-uniform peaks were present.
The experiences here presented confirm the appropriateness of the Edge Load Profile bench as tool for the skis qualification process and its continuous design improvement.

Keywords: Ski; edge load profile; laboratory tests

1. Introduction

The knowledge of the pressure distribution at the edge of an alpine ski has always been considered as a key-point for the comprehension of skiing mechanics and the design of ski structural and geometrical properties [1-4]. Several activities were carried out in this direction by researchers and ski manufacturer and different benches were developed with the ability of measuring the static edge pressure profile with

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the ski pressed against a bench at different angles or loads. Very few data on the contrary are available about the in-field distribution of such edge pressures [5].

Recently such a bench has been widely used at the Department of Industrial Engineering, University of Padova, Italy, in order to evaluate different types of alpine skis, ranging from special slalom to giant slalom skis. The out coming curves will work as an engineering qualification “footprint” of the ski, to be correlated with the results of users subjective evaluations performed in the field.

2. Materials and Methods

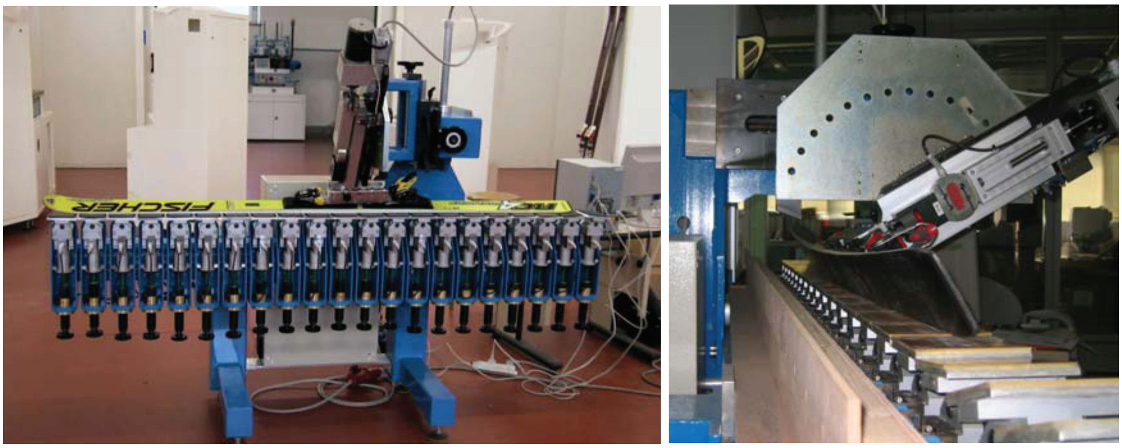
2.1. Bench description

The test bench, developed by the Italian company Slytech™, is equipped with a set of 21 uniaxial vertical load cells disposed horizontally along the ski axis, sustaining each a rocking plate of 100 mm length, with rocking axis perpendicular to the ski axis. Plates are regularly spaced of 2 mm from each other and present a rigid neoprene surface on top.

A linear actuator with axis adjustable in a vertical plane is used to load any type of alpine ski on a bed of load cells: the edging angles can be varied at steps of 10°, ranging from 0° to +/- 70°. On each cell, the contact takes place between the ski sole and the stiff neoprene surface supported by each load cell.

The ski is connected to the actuator by a dummy boot sole made of aluminum, shaped as the ISO boot sole, presenting 5 positions of application of the load spaced of 50 mm from the boot midpoint: position placed at +50 mm from the boot midpoint was used in the tests.

The bench includes a system for introducing a known compliance at each load cell by using springs of known elastic constant and adjusting the spring preload with a set of screws from underneath: in addition, the contact surface can be modified by interposition of foams of different properties simulating the snow in different conditions.



(a) (b)

Fig. 1. (a) Overall view of the Edge Pressure bench; (b) Detailed view of the bench during a test at 60° edging angle

2.2. Tested Skis

A set of 11 skis were extensively tested and are included in the present work. The skis sidecut and geometrical properties are collected in Table 1. Skis were grouped into three main groups according to their design and commercial classifications: three Special Slalom skis (S), four Giant Slalom skis (G) and four skis for Tourist use (T). The skis intentionally came from different manufacturers and had different lengths and years of production: this allowed exploring a wider sample of products that can be found in the market. No systematic field testing of the tested skis has been performed yet.

Table 1. List of the skis tested and reported in the present work

ID	Description	Length [mm]	Shovel [mm]	Waist [mm]	Tail [mm]	Radius [m]	Camber [mm]	Mass [kg]
S1	Head SL Worldcup 156 (2008)	1560	109	64	93	12.5	9.15	3.1
S2	Kneissl Red Star SL 166 (2008)	1660	111	64	96	13.5	7.6	3.55
S3	Nordica SLR 165 (2009)	1650	111	67	96	14.55	6.5	3.76
G1	Atomic Race Gs 190 (2008)	1900	102.5	68	89	27	9.25	4.13
G2	Blizzard Magnesium GS 191 (2010)	1910	102	67	87	27	8.35	3.77
G3	Nordica Doberman GSR (2009)	1860	100	67	87	27.05	10.1	3.74
G4	Head GS Worldcup 175 (2008)	1750	101	62	86	21	5.35	3.21
T1	Nordica Mach 3 Speedmachine (2010)	1700	121	74	106	15.5	5.85	2.72
T2	Nordica Hot Rod (2006)	1700	119	74	104	16	11.2	3.43
T3	Nordica Spitfire (2009)	1700	122	70	105	14	11	3.05
T4	Stöckli 188 Stormrider (2004)	1880	122	89	112	26.8	5	3.54

2.3. Test method

One ski from each pair of selected skis was submitted to the edge loading tests, from 0° to 60° edging angles: the total load was applied to the ski at the same boot position and its value increased from 500 N (0°) to 1400 N (60°) with increasing edge angles, as reported from field data acquisition [4, 5]. Loads measured at the i-th load cell $\mathbf{q_i}$ [N] were plotted along the ski length to obtain the Edge Load Profiles (ELP): the load cell position was normalized to the ski length to compare skis of different overall length and the ELP were studied for each ski at increasing edging angle. For each edging angle, the ELP were compared within each type of ski group to find the combined effect of factors like the ski sidecut, the ski construction and the binding plates properties on the ELP measured on the bench: this curves will be correlated in the future with the grip and carving behavior of the skis from field tests.

3. Results

The Load Profiles obtained on the Special Slalom ski S3 and on the Giant Slalom ski G2 after testing at increasing angles are reported in Figure 2. From a qualitative point of view, the particular shape of load profiles at 0° edge angle result evident, as well as the presence of a “double peak” shape under the binding plates for the Giant ski G2 that differs from the “single peak” shape of the Slalom skis S3. Moreover, the G2 Load Profiles show at the shovel a flat unloaded plateau, centered on the 80% of the ski length, that only tends to be recovered at 60° edging; conversely, S3 presents a smoother load profile at the shovel without unloaded area but without advanced peaks. In addition, G2 consistently presents a tip peak, increasing in magnitude with increasing edging angles, which has never been evident in S3.

The comparison of Load Profiles from different skis within the same groups is reported in Figure 3a for Slalom skis, Figure 3b for Giant skis and Figure 3c for Tourist skis. The Load Profiles are compared at 40° edging angle which resulted to be a meaningful comparative angle easily reached either in racing or in recreational skiing: at 40° edging angle, sidecut and construction effects are both involved.

From the analysis of Figure 3 several considerations may arise, regarding the differences among skis of the same group and among groups. Within Slalom skis (Figure 3a), despite a common trend at the tail and the central ski portion, S3 showed the most uniform load profile at the shovel, whereas S1 and S2 showed evident peaks towards the ski tip.

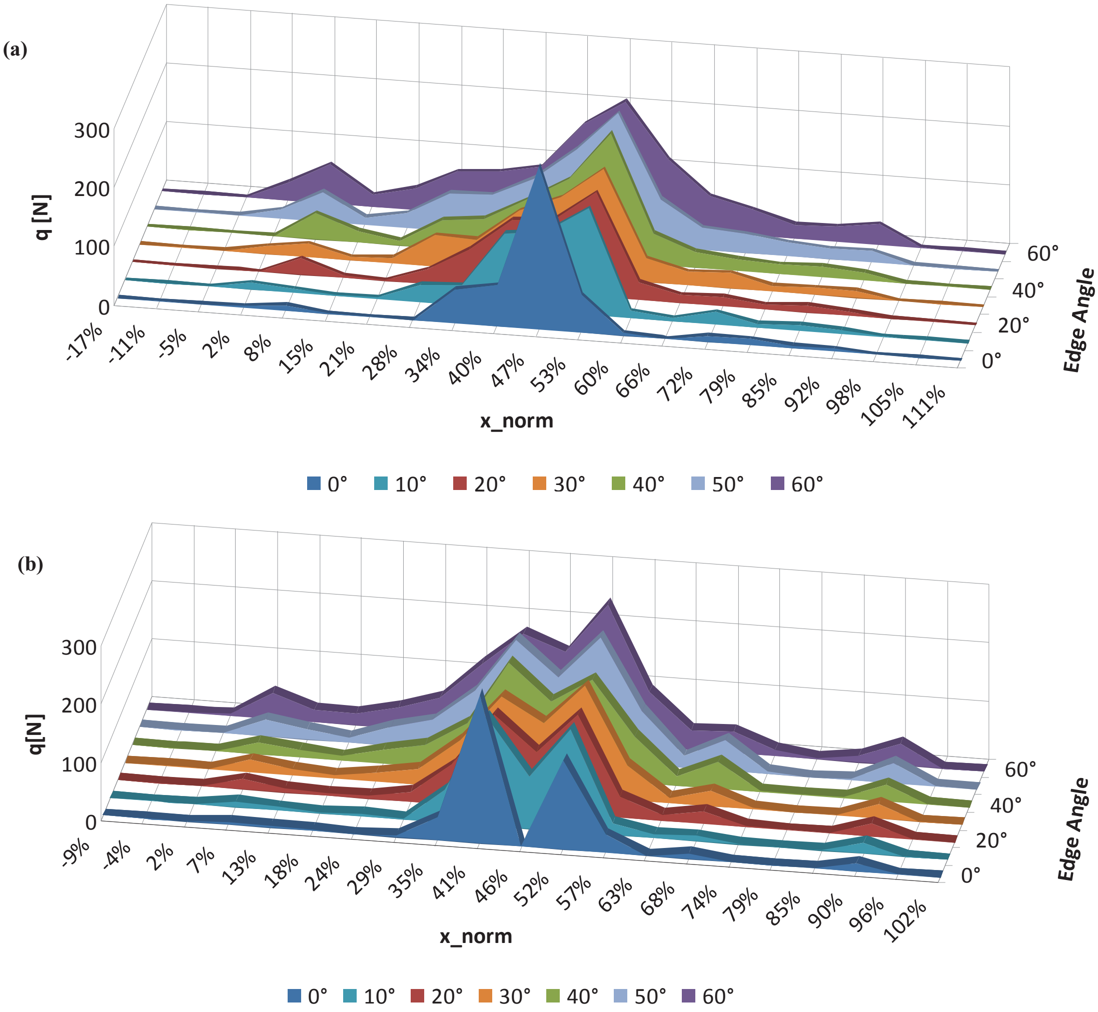


Fig. 2. (a) Edge Load Profile at increasing edging angles for the Special Slalom Ski S3; (b) Edge Load Profile at increasing edging angles for the Giant Slalom Ski G2

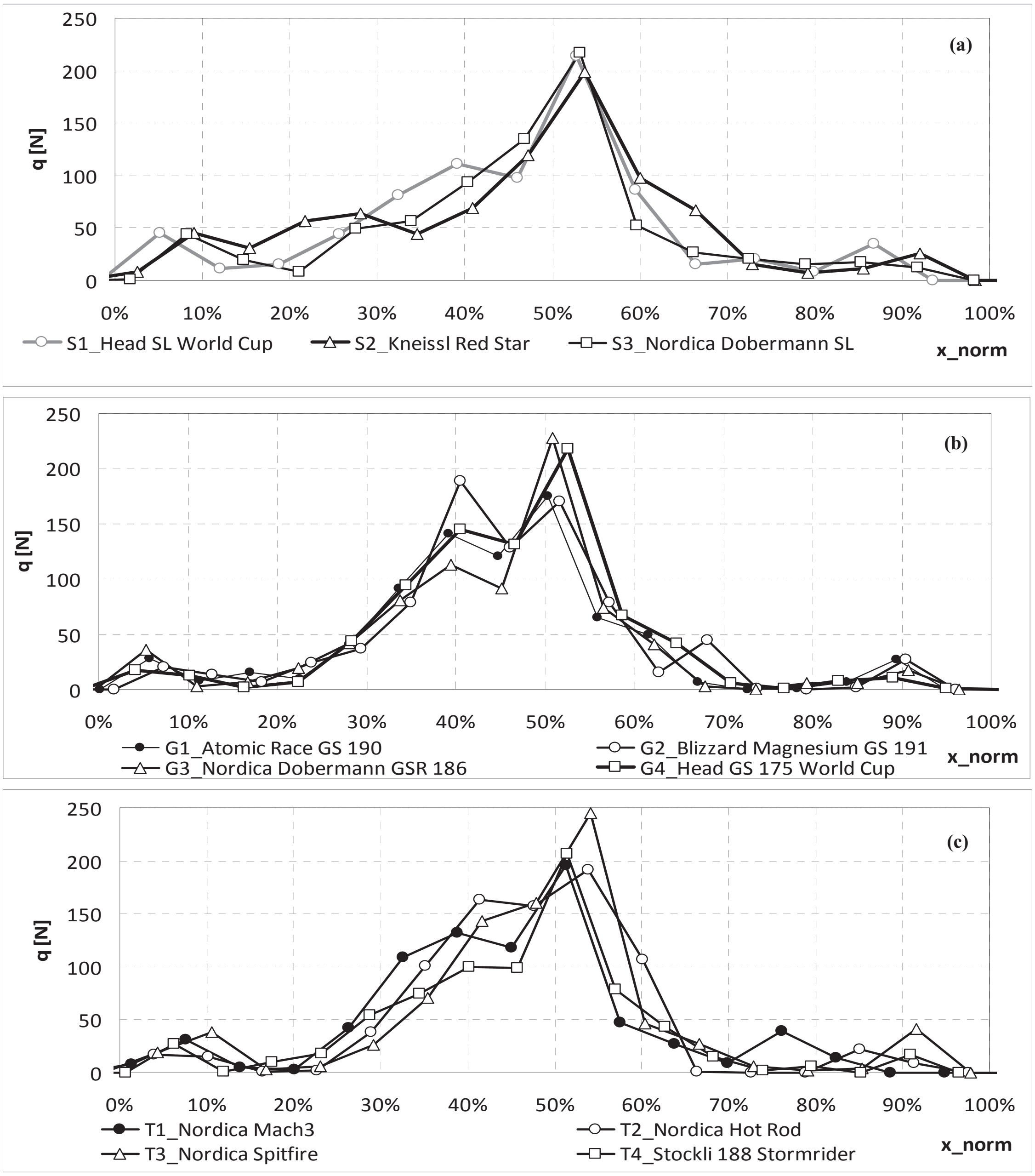


Fig. 3. Load Profiles at 40° edging angles for different groups of skis. (a) Special Slalom skis comparison; (b) Giant Slalom skis comparison; (c) Tourist skis comparison

Giant skis (Figure 3b) showed again a common trend at the tail and a twin peaked profile at the central ski portion: almost all skis presented a flat unloaded plateau at the shovel, but G1 and G2 presented the most forward and intense peaks towards the ski tip. Regarding Tourist skis, the Load profiles were much more different from each other: apart from T1, all other three presented a wide unloaded plateau at the shovel. However, T2, T4 and T3 had an intense local peak much closer to the ski tip than T1. From a general point of view, some Tourist skis (T3) presented a Load Profile very similar to some Giant slaloms (G2), despite great differences in the nominal radius and all other construction parameters.

The analysis of the Load Profile curves allowed also defining and quantifying some shape parameters such as the ski Effective Length (distance between most forward/backward peaks) that will not be discussed here for brevity.

4. Discussion and Conclusions

The bench output was clearly revealing the presence of critical spots along the ski where either the contact to the ground was missing or some non-uniform peaks were present, thus confirming the utility of the bench in the ski qualification process for their design improvement. The major limitations of the study were (i) the small number of ski tested and presented in the study, which prevented from carrying on any statistical analysis of the results, (ii) the absence of functional test evaluations in the field for the measured skis. The latter consideration is the major direction of development of the study: once completed, it will allow correlating the presence/absence of peaks/plateau/valleys in the Edge Load Profiles with the carving and racing properties of skis in the field tests. These analyses will be carried out together with other structural and dynamic properties of the skis such as the global/local Bending stiffness, the Torsional stiffness, the effective carving radius, the dynamic damping of shovel and the ski rebound properties. In addition, pilot tests showed that the use of foams of different consistency, applied to the load cells in order to simulate different types of snow, can result in a set of Edge Load Profiles that are sensibly different from those obtained on a flat rigid surface, generally reducing the peak loads and the extension of the unloaded areas.

Based on the presented work, some conclusions can be summarized: (a) the Edge Load Profile is a repeatable curve that can be measured as the peculiar "footprint" of each ski on the snow; (b) the Edge Load Profiles of different skis should be correlated with their field test ranking ("good", "average" or "bad" scoring) in order to identify the target Edge Load Profiles that have be preferred for each market segment or for various snow conditions; (c) the Edge Load Profiles have to be seen as one of the engineering parameters to be evaluated for an integrated approach to ski functional design; (d) the measured Load Profile will be helpful in the validation of numerical analysis of the ski-snow interface.

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