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ScienceDirect
Procedia Engineering 2 (2010) 2895–2900
Procedia Engineering
www.elsevier.com/locate/procedia

8th Conference of the International Sports Engineering Association (ISEA)

Active vibration damping of the alpine ski

Lutz Rothemann [a]*, Herwig Schretter [a]

[a]*Head Sport GmbH, Wuhrkopfweg 1, 6921 Kennelbach, Austria*

Received 31 January 2010; revised 7 March 2010; accepted 21 March 2010

Abstract

The Purpose of this work was to present the damping of a ski with piezoelements and to animate a ski with help of energy respectively. The idea was to eliminate the disturbing and allow non – disturbing frequencies. This should be implemented with an active damping system that consists of pizoelements. The result of this project shows that with the help of piezoelements it is possible to react to vibrations engendered by the ski-slope. But if this damping system with its very high mode of action is to be used in the normal ski collection, it has to be made smaller and more efficient.

Keywords: ski, measurements, measuring strips, acceleration sensors, active damping, piezo

1. Introduction and Goal

The goal of this project was to damp the disturbing frequencies which rise when skiing. If the ski is exposed to a vibration it could lose the edge hold and the skier loses control of the ski.

The vibration of the ski should be eliminated with a lot of piezofibers in the front part of the ski and a sensor on the ski. The sensor measures the bending vibration and sends these to a micro controller. There the information is evaluated and processed after that it goes back to the piezofibers where the information, in terms of electric energy, moves the fibers which should filter the disturbing frequencies or damps the bending vibration.

For the programming of the control unit a lot of information about the action of the ski during the drive time is needed. Previous to the project a lot of measurements on the ski-slope were made. These are going to be described in the following.

* Corresponding author.
E-mail address: l.rothemann@head.com.

doi:10.1016/j.proeng.2010.04.084

2. Preliminary investigation - measurement of vibration

2.1. Methods

The aim of this investigation was to record the vibration and acceleration when skiing and to then analyse the vibration state of the ski at any time. It was attempted to make a lot of standardized ski runs to record the array of vibration. These tests were realized with two different measurement systems. The first system was a structure of measurement strips and the other was a system to record the normal acceleration with the help of acceleration sensors. (see figure 1) In addition to these ski experiments, tests in the lab were performed to find out the natural frequency of the ski.

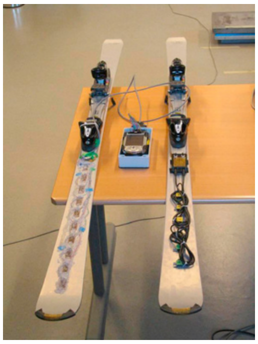

Fig. 1: Ski (left side with MFCs and PDA, right side with acceleration sensors and data logger MM3

2.2. Results

The data of the ski was analyzed with the help of the LabView Software. It turned out that the actual frequencies did not match the frequencies measured in the lab. The reason for this is that the ground animates the ski but it also prevents the swinging of the ski. In figure 2 you can see the frequency of 10 DMS-sensors in the front part of the ski.

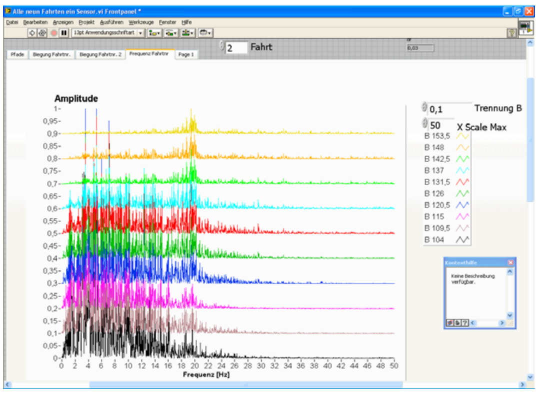

Fig. 2: frequency area of the MFCs

In front of the binding all frequencies from 1 Hz to 25 Hz were animated. The ski nose only swings in a region of 20 Hz.

In figure 3 you can see the acceleration data of the MM3 system.

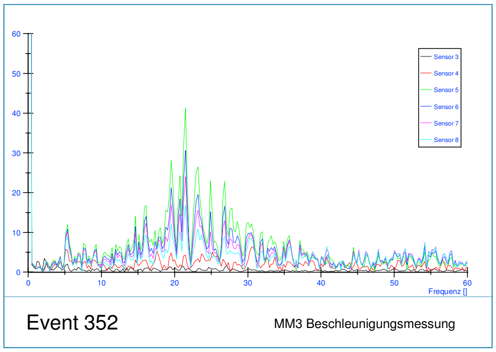

Fig. 3: frequency area of the acceleration sensors

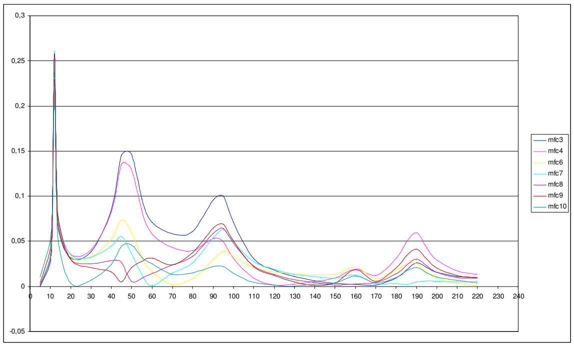

Fig. 4: natural frequencies

In Fig. 4 you can see the natural frequencies which were measured in the lab. The natural frequencies are 12 Hz, 48 Hz, 96 Hz, and 190 Hz. (see figure 4)

Comparison MFC – MM3

The 6 acceleration sensors from the MM3 were put in the same position as the MFC 4 to 9. This made a direct comparison between the two sensor types possible. Comparing the occurring frequencies showed that the acceleration sensors worked in an area from 15 Hz to 30 Hz while the MFCs near the binding additionally measured the deformation of the ski. These deformations were visual in a vibration up to 7 Hz. The MFCs at the nose of the ski showed a picture of vibration similar to the acceleration sensors. This meant that both systems could be used, whereas the MFC system could also be used to show the deformation of the ski.

The natural frequencies measured in the lab did not occur in the field test. The ski vibrations on the ski-slope went up to 20 Hz, whereas one must rather speak of a deformation due to the slope in an area up to 5 Hz. For an active damping of the ski it is better to filter out an area of frequencies instead of just one specific frequency.

3. Vibration damping with an active system

In order to impact a ski with an active system, the first idea was to damp the bending natural frequencies. If it were possible to damp these frequencies the performance of the ski would be better. The first difficulties came with the natural frequencies. These work together with many factors such as speed, snow conditions, weight of the skier and others. This means that every natural frequency must be defined for every skier individually which would be a substantial additional work necessary for an optimally working system.

But this problem is only theoretical, because the vibration on the ski-slope is completely different than the vibration in the lab. In the outdoor tests frequencies up to 20 Hz appeared. The result is that the active damping should not only filter out one natural frequency but rather a wide frequency band.

The implementation of this issue was to program a control unit with help of LabView Software and the company Smart Materials. The control unit satisfied our demands, for example with the adjustable frequency area and strength of damping. With the possibility to use a PDA this version would have been ideal for skiing, because no unnecessary weight would be produced. But the first lab test showed that this system was too slow to directly and efficiently react to the appearing vibrations.

Therefore, a faster alternative had to be searched. A hardware solution without a PDA was found. With the help of Schuler Electronic company a hardware which was added to a circuit board and took regulated signal analysis to the activation of the high voltage amplifier was developed. But as opposed to the first version it was not possible to filter specific frequencies with this version, because this system works with the 0 – 1 principle. This means if the ski gets a hit from the bottom and deforms to a certain degree the system reacts to it and counter steers.

3.1. Function Units and explanation

5 MFC actuators were applied at the front part of the ski. A sensor MFC to capture the data was applied in the middle front part of the ski. You can see the function units in figure 5. Besides the ski other equipment, such as a high voltage amplifier, battery packs, control circuit boards and cables were needed. These hardware Units were stored in a backpack which the test driver carried.

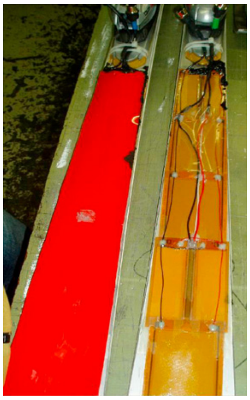

Fig. 5: ski with MFCs

For every ski there is an amplifier and a box in which the control circuit as well as an appendant cable set is located. The hardware which is inside the box (see figure 6) converts the signal of the sensor into a control signal which is transmitted from a high voltage amplifier to the MFCs. You can see the configuration of the control unit in figure 7.

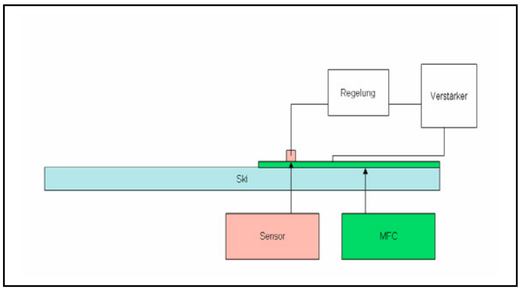

Fig.6: Hardware

Fig.7: schematic assembly of the activ control unit

The measured frequency was 500 Hz and every 2 ms a record was measured. To reach the required operating voltage of 48V 40 batteries, with 1.2V, connected in series were needed. The batteries were packed in 5 pieces. This means that there were battery packs of 6V in each vest. (see figure 8)

Fig. 8: battery pack

The connection between ski and electronic equipment was realized with a cable set. The set consisted of one sensor cable and one high voltage cable. In addition to the two cables there was a BNC – cable which transferred the signal from the control circuit box to the amplifier, and a network cable connected to the pc.

3.2. Measurement in lab

The vibration graphs of an undamped and actively damped curve can be seen in figures 9 and 10. These two graphs show that the vibration curve of a damped ski only needs half the time in comparison to the curve of undamped ski to reach low vibration amplitude. This functional test in the lab proved that the developed control unit works well under lab conditions and could now be tested on ski-slope test.

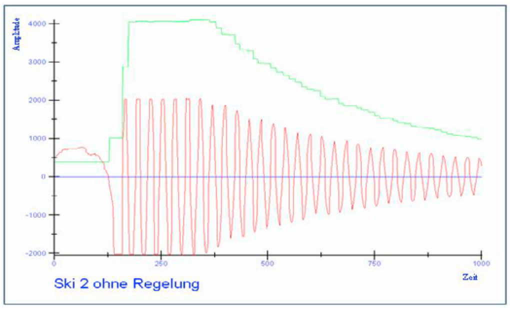

Fig. 9: ski vibration with out damping

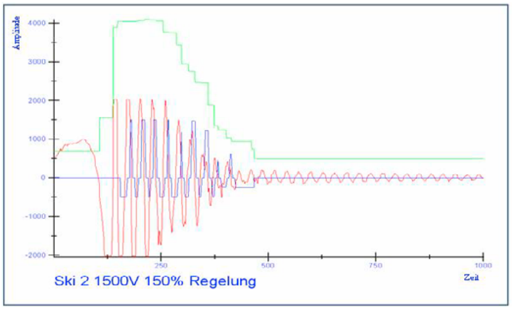

Fig. 10: ski vibration with damping

The control unit was adjusted to 150%. The time of regulation with maximum power after one hit was 300 ms. The decay time was circa 750 ms. However, when increasing the regulation a higher energy use can be reached but not a better functionality because it is possible that the ski is activated through further hits before the ski is fully damped.

To confirm the good lab test, ski-slope tests with the electric damping system were made. These tests delivered measured data and subjective impressions of the testers.

3.3. Ski-slope tests

Ski tests were performed on 4 days. The functionality of the system under real circumstances was tested on the first day. On the second and third day measurement data was recorded and on the last day a ski-slope test for the subjective impression was performed. On every testing day, 15 test runs were made. The test drivers were educated skiing instructors and test drivers from a ski test team. Therefore, it was guaranteed that the arches could be replicated in various ski runs. Various ski runs that differed in the choice of the route, driving and speed were driven.

3.4. Results of the piste tests

In order to understand what the ski does when being tested and how the measurement data is to be interpreted, you have to know that the analog input sensor signal only shows the heterodyne of the ski vibration which is a reaction to the vibration of the ski, caused by the excitation of the ground and the excitation of the piezofibers which are located in the front part of the ski. Nevertheless, it is possible to make a statement, because an additional control signal shows when the MFCs are active and with which strength. In the next figure (figure 11) you can see that the control unit works well with slow vibrations and, therefore, damps all vibrations of the ski that occur under normal slope and driving conditions. Under extreme skiing-conditions that are linked with fast vibrations the control unit reacts very slowly and is partially not effective. (see figure 12)

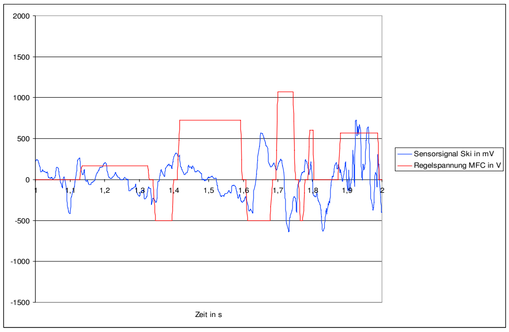

Fig. 11: slow vibration > damping is good

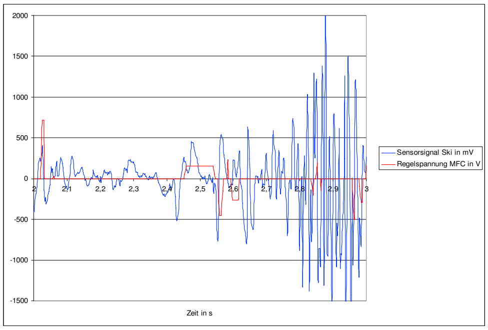

Fig. 12: fast vibration > damping to slow

4. Conclusion

The results of the ski-slope test delivered useful technical measurement statements as well as subjective impressions. Conclusion of the tests and therefore of the measured data and the subjective impressions is that the damping system actually works well, however it is too slow under extreme conditions. On the basis of these tests it cannot be said with absolute certainty that a big, perceivable, positive effect is noticeable for the skier in every situation. Maybe it would be better to apply the system to a softer and inferior quality ski construction in order to get perceivable statements about its effectiveness under extremer conditions. But it is not reasonable to apply an expensive system to a cheap ski in order to get a good ski that you can get with help of cheaper and easier construction work.

To develop this system up to series maturity and to, therefore, make it smaller, cost – efficient and to produce it in large quantities a close cooperation between ski firms and big software- and measurement firms is necessary.

Finally it must be emphasized that a lot of technical expertise which can be used for new projects was found with help of this project.