Influence of the measuring grid of a foil sensor on the accuracy of pressure measurements

Klaus Hoffmann* – Klaus Decker*

Összefoglalás

A fóliaszenzor mérőrácsának hatása az érintkezési nyomás mérési pontosságára

A Tekscan rendszert *(1. ábra)* kiterjedten használják az érintkezési nyomás méréséhez. A dolgozat e rendszer használatakor fellépő mérési hiba okainak vizsgálati eredményeit tárgyalja. Az összehasonlításhoz Fuji előskálázott filmmel is elvégzett mérések eredményeit használták, illetve végeselem-módszerrel számításokat végeztek. Megállapították, hogy a Tekscan rendszer mérési hibája függ az érintkező testek rugalmas tulajdonságaitól és a kalibrálási módszertől. A lényeges eltéréseket az aktív érzékelő cellák és az inaktív területek *(6. és 7. ábra)* eltérő merevsége okozza. Minél nagyobbak az inaktív területek miatti mérési veszteségek, annál nagyobbak a számított és mért értékek összehasonlításakor tapasztalt eltérések. Ezt igazolja a kötéllel érintkező poliamiddal bevont csigakerék elempáron a Fuji filmszenzorral illetve a Tekscan rendszerrel mért érintkezési nyomások közötti jelentős különbség *(15. ábra)*.

Introduction

The measurement of contact stresses between elastic bodies is of great importance in a wide range of fields. Many methods are based on a sensor sheet which is placed between the bodies in contact. Depending on the application, the accuracy of measuring results can be considerably affected by the finite thickness and structure of the inserted sensor.

This study deals with the imprecision of the Tekscan system and attempts to explain the cause of deviations. For this purpose an imprint method and the FE method was used to compare the results with the results of the Tekscan system.

Characteristics of measuring methods

The Tekscan system [1], [2] is assigned to the electrical methods and is suitable for time-dependent measurement. The technology of the Tekscan system is based on a conductive grid network of rows and columns deposited onto thin, flexible film (see *fig. 1*).

Each conductive trace generates a change in electrical resistance when pressure is applied to its surface. The array is scanned electronically to determine the pressure at each sensing cell. A certain calibration method must be used to receive the right correlation between change of electrical resistance and pressure value.

Pressure ranges from 0 up to 170 N/mm^2 can be specified. Using TEKSCAN software the changing of contact stresses can be displayed in various formats in real time up to about 100 Hz.

The other measuring system is an imprint method using Fuji prescale film [3], [4]. It can only be used for static loads. Fuji prescale film is usually composed of two sheets, A-film and C-film, placed simultaneously between the bodies in contact. Only for a high pressure range from 10 N/mm^2 to 130 N/mm^2 a single sheet type is used (see *fig.2, 3*).

After applying a load, a red colour is obtained with a density depending on the maximum amount of local pressure for the duration of the test. A computer-aided evaluation of colour density enables a quick and accurate interpretation of pressure distribution. The GODAV system [5] used for these investigations was developed at the Institute for Engineering Design and Transport, Handling and Conveying Systems at Vienna University of Technology. This system satisfies certain requirements, e.g. low costs, application of a commercially-available PC and scanner, multicolour presentation of results, resulting forces, statistical data and others.

The characteristics of both the Tekscan system and the Fuji/GODAV method are listened in *table 1*.

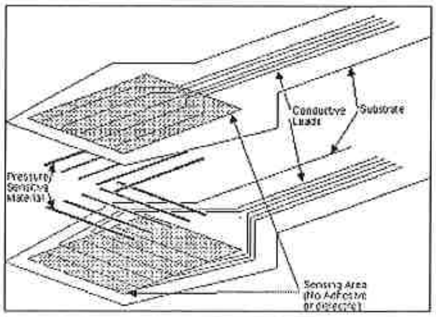

Figure 1: Configuration of a Tekscan sensor [2]
1. ábra. A Tescan szenzor felépítése [2]

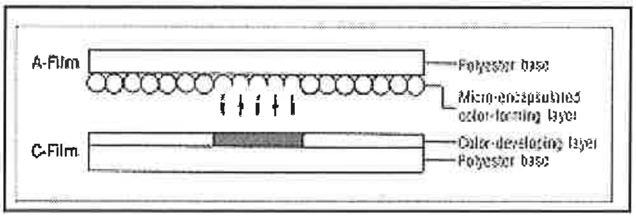

Figure 2: Two-sheet type for low pressure [4], (0,2 – 10 N/mm^2)
2. ábra. Kétrétegű film kis nyomások (0,2 – 10 N/mm^2) méréséhez [4]

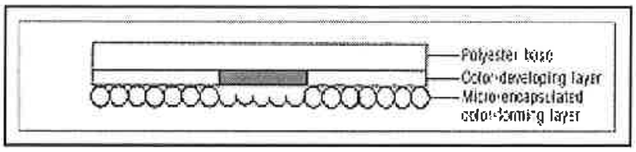

Figure 3: Mono-sheet type for high pressure [4], (10 – 130 N/mm^2)
3. ábra. Egyrétegű film nagy nyomások (10 – 130 N/mm^2) méréséhez [4]

	TEKSCAN	FUJI/GODAV
Pressure range N/mm^2	0 – 170	0 – 130
Sensor thickness mm	0,2	0,2
Young's modulus N/mm^2	~3000	~3000
Time resolution	127 Hz	static
Resolving power mm	~1,2	~0.2

Table 1: Characteristics of the measuring methods
1. táblázat. A mérési módszerek jellemzői

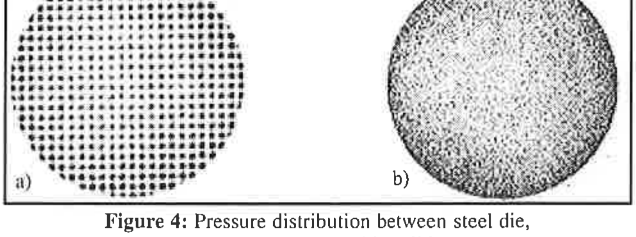

Figure 4: Pressure distribution between steel die, sensor and polyamide solid
a) Tekscan sensor b) Fuji sensor
4. ábra. Nyomáseloszlás az acélszerszám, a szenzor és a szilárd poliamid között

* Institute for Engineering Design and Transport, Handling and Conveying Systems, Vienna University of Technology, Getreidemarkt 9, A-1060 Vienna, Austria, http://www.ft.tuwien.ac.at

An idea of the local resolving power of both systems is given by *figure 4*. On the left side the imprint of the pressure distribution of a Tekscan sensor using a Fuji film is shown. *Figure 4b)* shows the imprint of a Fuji sensor. For both images the same measurement device was used (see *fig. 5*).

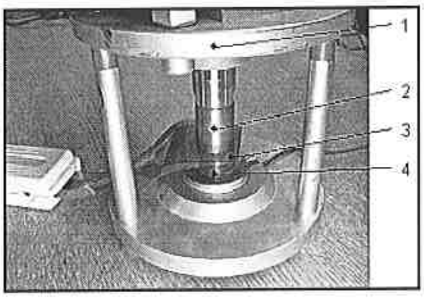

Figure 5: Measuring device
5. ábra. A mérőkészülék: 1 Pneumatic cylinder – pneumatikus henger; 2 Steel die – acélszerszám; 3 Tekscan sensor; 4 Polyamide die – poliamid-szerszám

Measuring errors

We can establish that the accuracy of measuring results can be considerably affected by the following characteristics [6]:

a) Measurement errors due to certain method characteristics, which are inherent in the system and therefore unchangeable, but they are to take in account:
  - a1) Local resolving power of the system
  - a2) Elastic properties and inhomogeneity of the sensor structure

b) Measurement errors due to certain contact characteristics like:
  - b1) Steep pressure gradient
  - b2) Load sensitive contact area
  - b3) Steep pressure gradient combined with load sensitive contact area

Inaccuracies caused by the measuring grid

The main disadvantage of the Tekscan sensor is the high rigidity in the vicinity of the sensor crossing-points compared to the areas between (see *fig. 6*). The big differences in the young's modulus are shown in *figure 7.*: areas with different elastic properties.

This fact causes very inhomogeneous pressure distributions and makes calibration of the sensor more difficult. Because the sensing array is a combination of "sensing areas" and "inactive areas", the sensor must be calibrated with a material whose stiffness is similar to that of the material to be tested.

The Tekscan sensor cannot detect the portion of the force that occurs in the "inactive areas". This can lead to high inaccuracies, depending on the elastic properties and the pressure distribution of the bodies in contact.

To explain this problem the measuring device shown in figure 5 was used. A steel die was pressed against a polyamid die, both of the same diameter. The Tekscan sensor and simultaneously a Fuji foil were inserted between both dies. You can see the results as a Fuji-imprint in *figure 8*.

Due to the stiffness inhomogeneities of the Tekscan sensor the pressure distribution is very uneven *(fig. 9)*. The peaks of the pressure are detected by the Tekscan sensor, but the sensor cannot detect the portion of the pressure that occurs in the inactive areas.

The FE-Simulation shown in *figure 10* gives an idea about the influence of the stiffness of the bodies in contact.

Steel to steel gives very good results, because the losses are low and constant (dotted line in *fig. 11*). In the case of steel die pressed against a polyamide die on the one hand high losses can be observed and on the other hand the boundary effects with high pressure values are recognizable (see *fig. 11*).

Example

An example where high inaccuracies can be caused by the measuring grid of the Tekscan sensor is with the contact area of rope and polyamide inlay of a pulley wheel. This investigations were carried out in cooperation with a cable car company. *Figure 12* shows the experimental set-up.

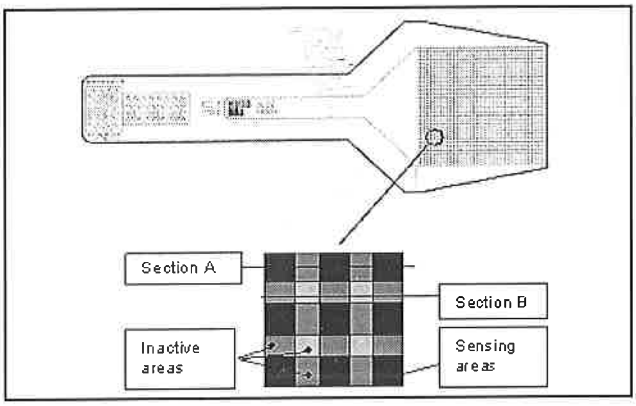

Figure 6: Structure of the Tekscan sensor
6. ábra. A Tekscan szenzor szerkezete

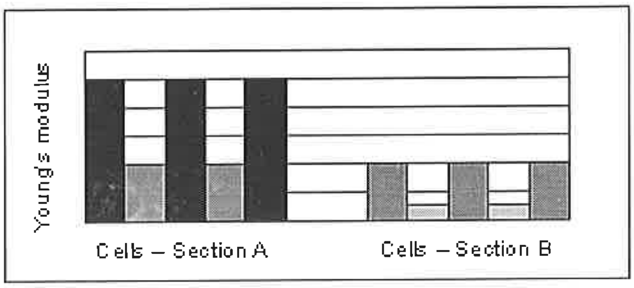

Figure 7: Young's modulus
7. ábra. A Young-modulus változása a 6. ábrán bejelölt A és B metszetek mentén

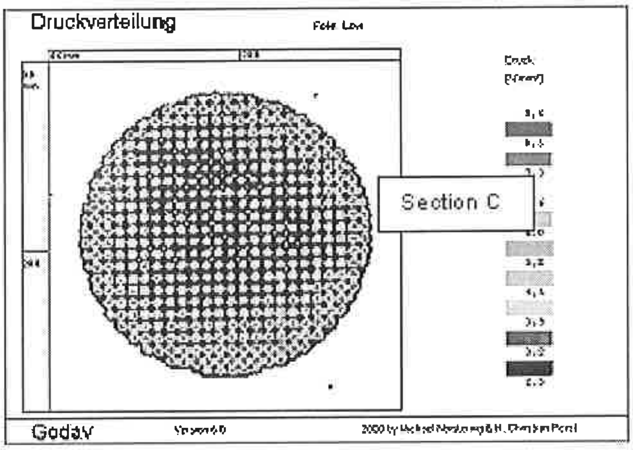

Figure 8: Pressure distribution between steel die and polyamide die
8. ábra. Nyomáseloszlás az acél- és a poliamid-szerszám között

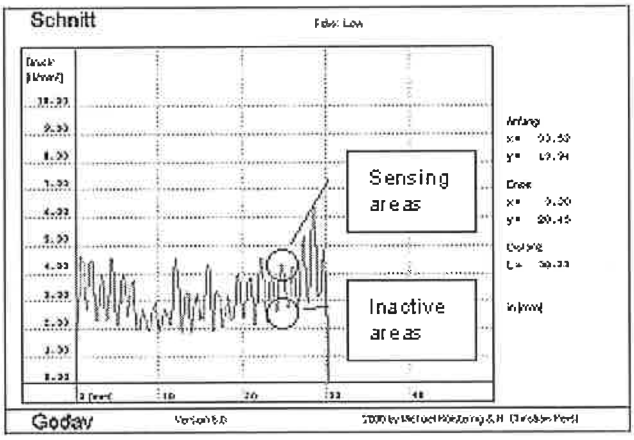

Figure 9: Pressure distribution along section C
9. ábra. Nyomáseloszlás a C metszetben

The measurement results of pressure distribution are shown in the *figures 13* and *14*. A comparison of results obtained by Tekscan and Fuji systems is given in *figure 15*.

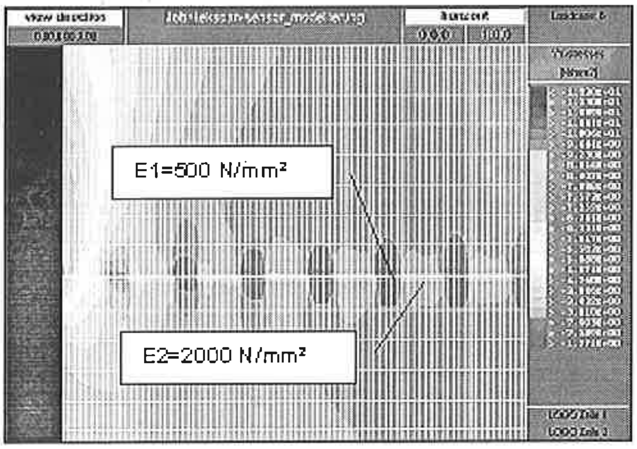

Figure 10: FE-Simulation steel die / polyamide die
10. ábra. Az acél- és a poliamid-szerszám érintkezésének végeselem-szimulációja

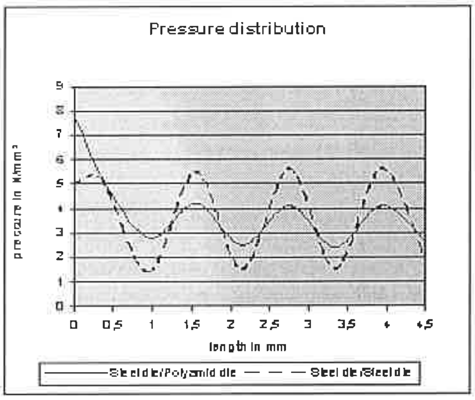

Figure 11: Results FE-Simulation
11. ábra. A végeselem-szimuláció eredménye;
----- acél acéllal,
—— acél poliamiddal érintkezik

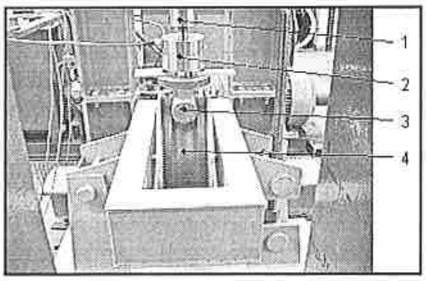

Figure 12: Experimental set-up [7]
12. ábra. Kísérleti elrendezés; 1 Hydraulic cylinder – hidraulikus henger; 2 Force sensor – erőérzékelő; 3 Rope dummy – próbakötél 4 Pulley with polyamide inlay – csiga poliamid bevonattal

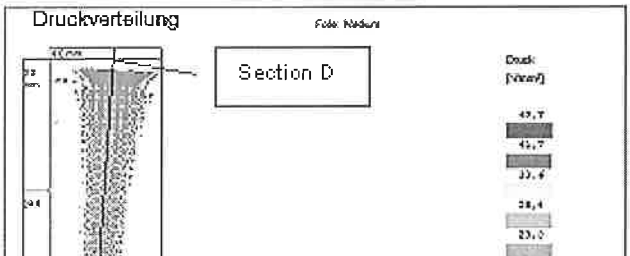

Figure 13: Pressure distribution between rope dummy and polyamide inlay
13. ábra. Nyomáseloszlás a próbakötél és a poliamid bevonat között

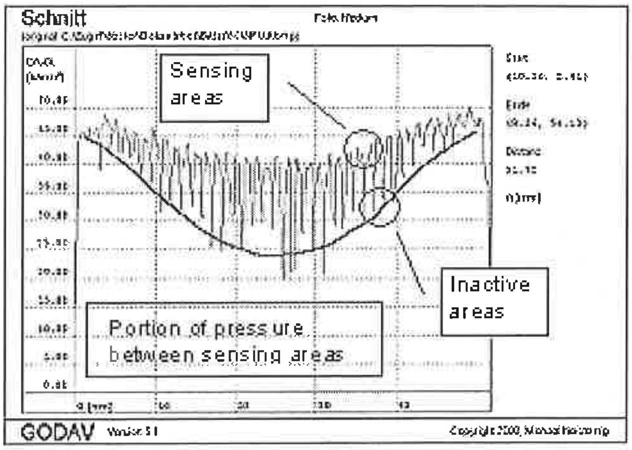

Figure 14: Pressure distribution along section D
14. ábra. Nyomáseloszlás a 13. ábrán bejelölt D metszetben

The reason for the large deviations between the results of Fuji film and Tekscan system is that a large portion of the pressure occurs between the sensing areas. This portion is not included in the measurement results. That is the reason why the Tekscan sensor provides an lower output than the Fuji film. The higher these measurement losses the higher the deviations of results.

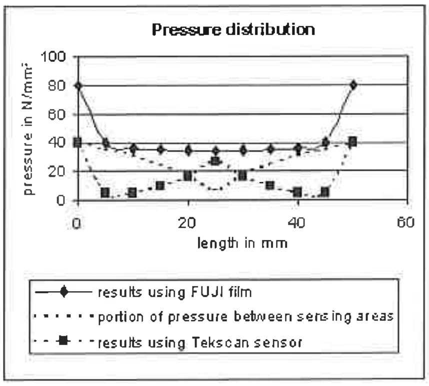

Figure 15: Explanation of deviation
15. ábra. Az eltérések értelmezése

Summary

The Tekscan system is widely used for pressure measurements. In this paper some problems of accuracy of measurement results using this system were investigated. For comparison FE-calculations and measurement results by means of Fuji prescale film were used. The measurement errors using Tekscan system depends on the elastic properties and inhomogeneity of the sensor structure, of geometric and elastic properties of the bodies in contact and of the calibration method. The main deviations are effected by the differences of stiffness of the active sensing cells to the inactive areas. The higher these measurement losses of the inactive areas the higher the deviations of results.

References

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