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WHICH MATHEMATICAL AND PHYSICAL FORMULAS ARE RELEVANT IN VOICE DIAGNOSTICS

By
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Bilal Hussain Akram stud.med.
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DATA SOURCES FOR MATHEMATICAL AND PHYSICAL FORMULAS FOCUSED UPON

1 Acustical signals

2 High speed films (HSDI) Wolf Ltd. Germany

With software: ”Glottis Analysis Tools”, Erlangen Germany

which includes the following data sources:

- Glottal Area Waveform (GAW)
- Trajectories (Traj 50%)
- Phonovibrogram (PVG)

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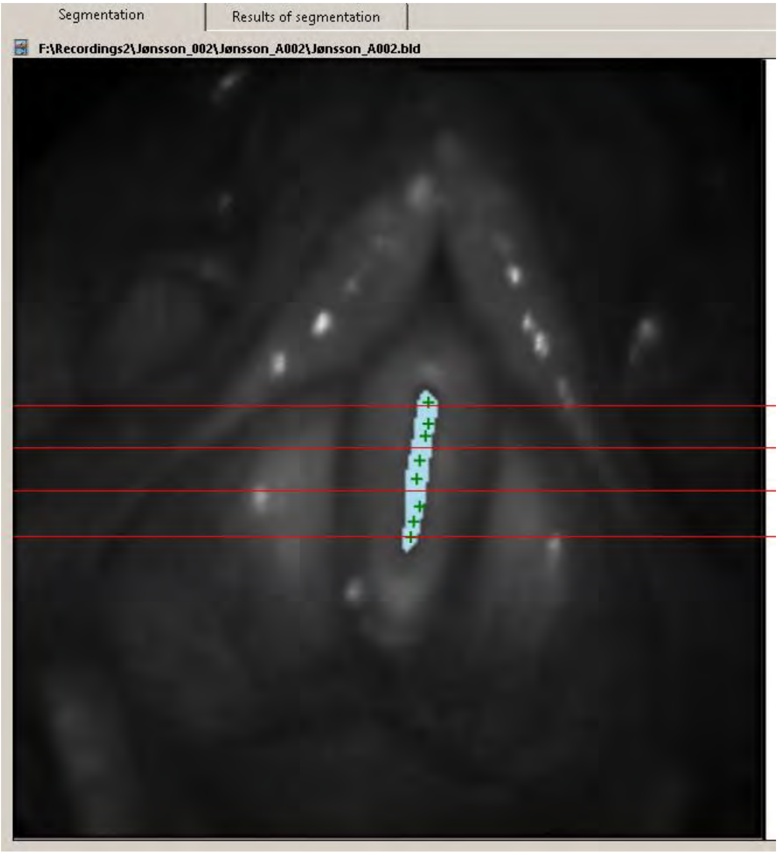
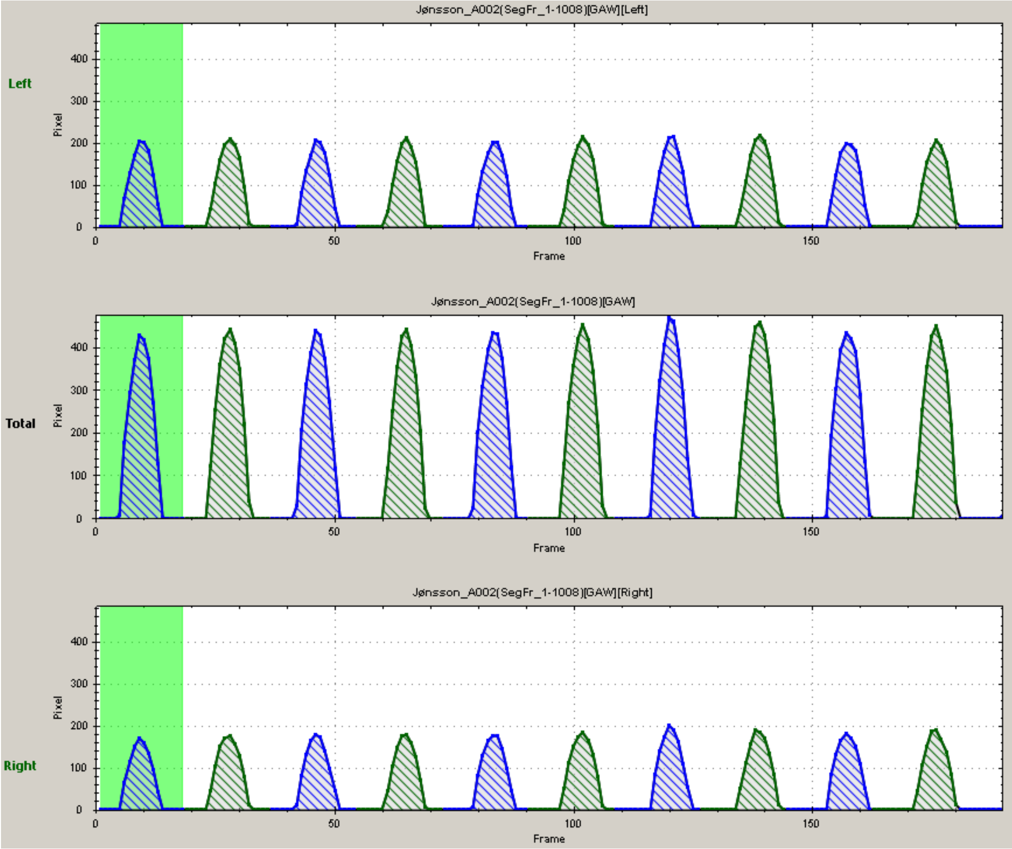
Glottal Area Waveform presentation





Glottal area waveform:

”Space curves” – the area between the vocal folds is calculated and plotted in a curve.

The curves switches between green and blue to indicate change between the different cycles in the software system from Erlangen, Germany

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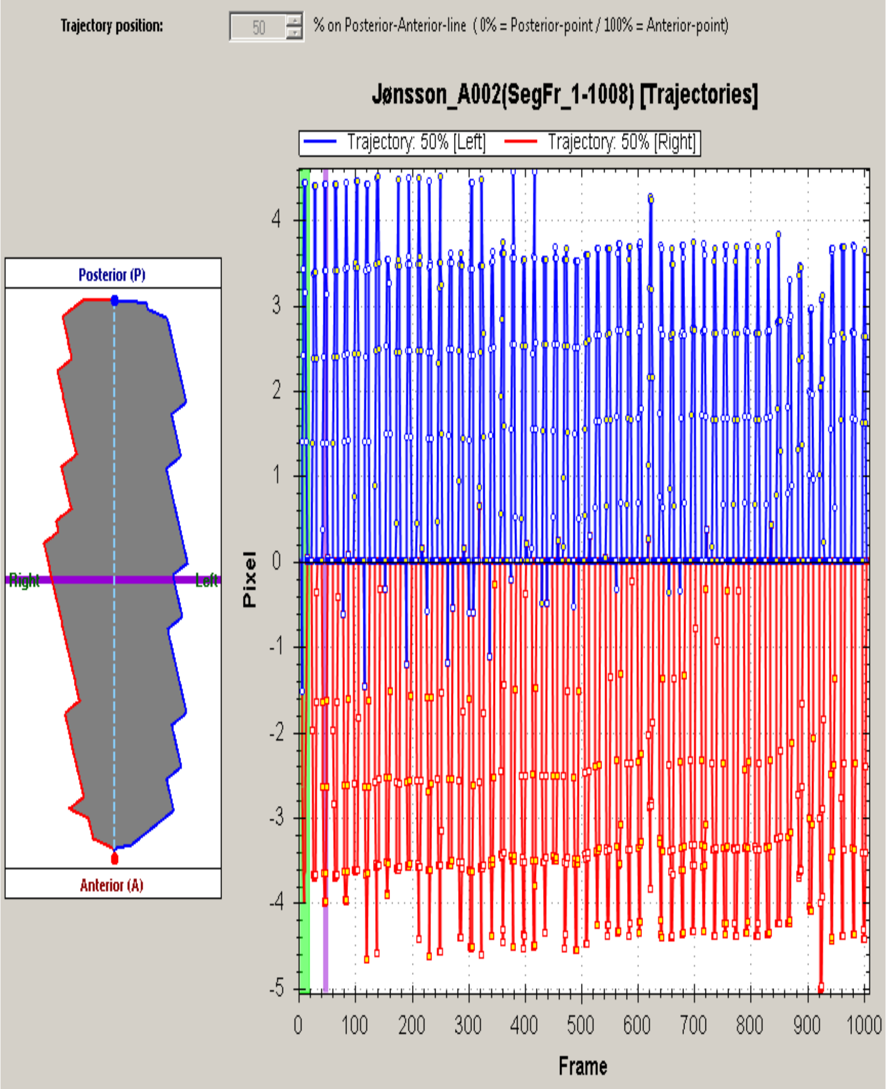
TRAJECTORIES ("QUANTITATIVE KYMOGRAPHY")



Trajectories:
The image in the middle is an electronic representation of the rima glottidis. The dark blue line defines the left vocal fold. The red line delimits the right vocal fold. The blue dotted line is the center line between the vocal folds. The vocal fold movements are calculated from this line.
The left chart illustrates a computed cycle. The dark blue curve is the left vocal fold fluctuation, and the red curve is the right vocal fold fluctuation.

50% is an indication that the chart depicts the vocal folds in 50% distance from the posterior limit (and therefore 50% distance to the anterior limit).
The purple line in the computed image indicates, where Traj-50% downloads the numbers from.

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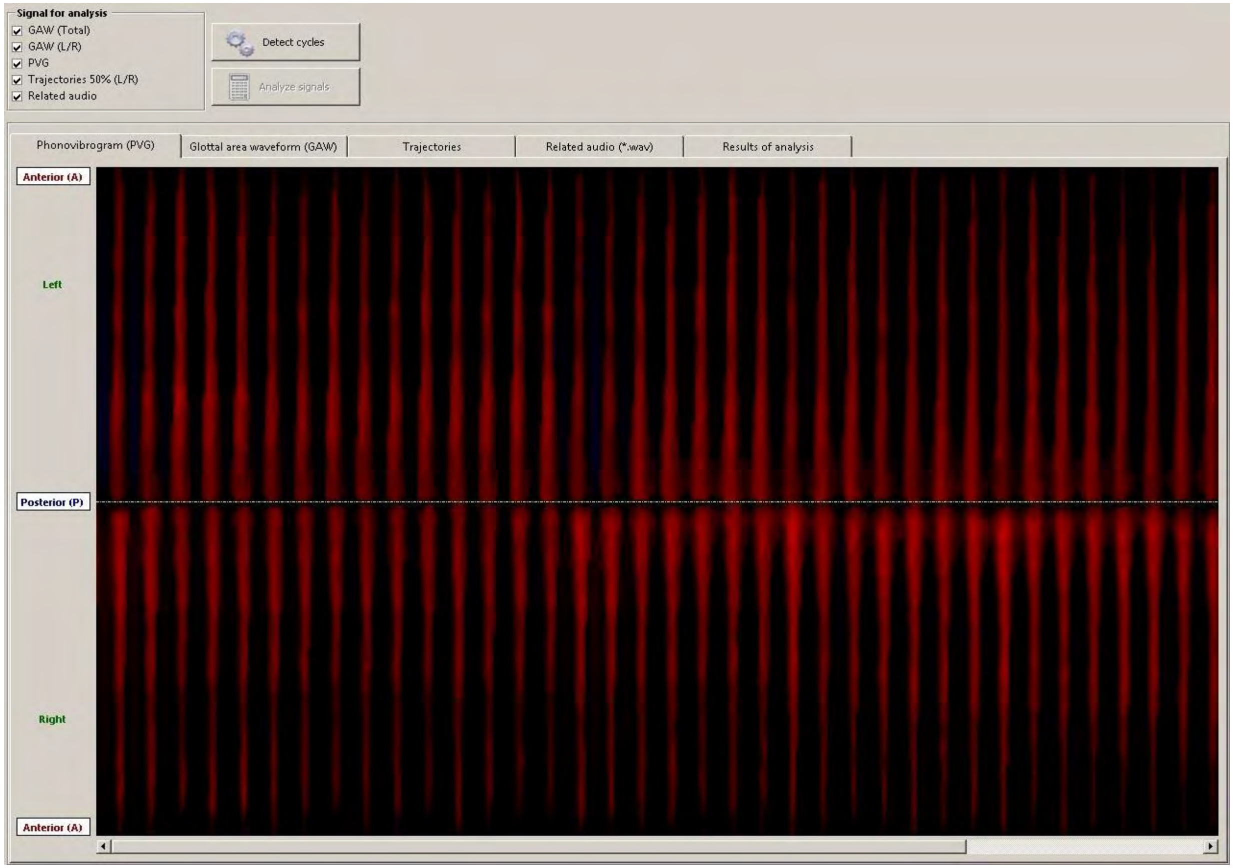
HIGH SPEED FILMS AND PHONOVIBROGRAMS

Phonovibrogram of a contest winning female, showing the regularity of single movement of the right and left vocal folds



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FORMULAS AND DATA SOURCES

Please notice that many of the following formulas can be used on different data sources (Glottal area waveform, trajectories 50% or acoustical measures) as they are all ”curve”/sinusoidal signals -that can be analysed with the formulas.

This includes jitter and shimmer.

This means that clinical evidence is made for each data source, if the formulas are to be used in the clinical pathology.

All mathematical and physical formulas in "Glottis Analysis Tools" Erlangen, Germany

Source: Audio
APF(%)
APQ-11(%)
APQ-3(%)
APQ-5(%)
AVI
CHNR-v1(dB)
CHNR-v2(dB)
CPP(dB)
Cycle-duration(ms)
EPF(%)
EPQ-11(%)
EPQ-3(%)
EPQ-5(%)
Fundamental-Freq(Hz)
GNE
Harmonics-Intensity(%)
HNR(dB)
Jitt(%)
Jitt-Factor
Jitt-Ratio
max-Harmonic(Hz)
max-WMC
mean-Jitt(ms)
mean-Shim(dB)
mean-WMC
min-Subharmonic(Hz)
NNE(dB)
PPF(%)
PPQ-11(%)
PPQ-3(%)
PPQ-5(%)
PVI
RAP-v1
RAP-v2
Shim(%)
SNR-v1(dB)
SNR-v2(dB)
Spectral-Flatness(SFM)

Source: GAW
Amplitude-Length-Ratio
Amplitude-Periodicity
Amplitude-Quotient
Amplitude-Symmetry*
Amplitude-Symmetry-Index
APF(%)
APQ-11(%)
APQ-3(%)
APQ-5(%)
Asymmetrie-Quotient
AVI
CHNR-v1(dB)
CHNR-v2(dB)
Closing-Quotient(ClQ)
CPP(dB)
Cycle-duration(ms)
DynamicRange-Symmetry*
DynamicRange-Symmetry-Index
EPF(%)
EPQ-11(%)
EPQ-3(%)
EPQ-5(%)
Fundamental-Freq(Hz)
Glottal-Area-Index(AC/OQ)
Glottis-Gap-Index(GGI)
GNE
Harmonics-Intensity(%)
HNR(dB)
Jitt(%)
Jitt-Factor
Jitt-Ratio
max-Harmonic(Hz)
Maximum-Area-Declination-Rate
max-WMC
mean-Jitt(ms)
mean-Shim(dB)
mean-WMC
min-Subharmonic(Hz)
NNE(dB)
Open-Quotient(OQ)
Peak-Acceleration
Peak-Closing-Velocity
Phase-Asymmetry*
Phase-Asymmetry-Index
Plateau-Quotient(PQ)
PPF(%)
PPQ-11(%)
PPQ-3(%)
PPQ-5(%)
PVI
RAP-v1
RAP-v2
Rate-Quotient(RQ)
Shim(%)
SNR-v1(dB)
SNR-v2(dB)
Spatial-Symmetry*
Spatial-Symmetry-Index
Spectral-Flatness(SFM)
Speed-Index(SI)
Speed-Quotient(SQ)
Stiffness
Time-Periodicity
Waveform-Symmetry-Index

Souce: Phonovibrogram (PVG)
ContourAngles-Symmetry*
ContourAngles-Symmetry-Index
Contour-Angle(DEG)

Source: Trajectories 50%
Amplitude-Symmetry*
Amplitude-Symmetry-Index
DynamicRange-Symmetry*
DynamicRange-Symmetry-Index
Phase-Asymmetry*
Phase-Asymmetry-Index
Waveform-Symmetry-Index
Amplitude-Length-Ratio
Amplitude-Periodicity
Amplitude-Quotient
APF(%)
APQ-11(%)
APQ-3(%)
APQ-5(%)
Asymmetrie-Quotient
AVI
CHNR-v1(dB)
CHNR-v2(dB)
Closing-Quotient(ClQ)
CPP(dB)
Cycle-duration(ms)
EPF(%)
EPQ-11(%)
EPQ-3(%)
EPQ-5(%)
Fundamental-Freq(Hz)
Glottal-Area-Index(AC/OQ)
Glottis-Gap-Index(GGI)
GNE
Harmonics-Intensity(%)
HNR(dB)
Jitt(%)
Jitt-Factor
Jitt-Ratio
max-Harmonic(Hz)
Maximum-Area-Declination-Rate
max-WMC
mean-Jitt(ms)
mean-Shim(dB)
mean-WMC
min-Subharmonic(Hz)
NNE(dB)
Open-Quotient(OQ)
Peak-Acceleration
Peak-Closing-Velocity
Plateau-Quotient(PQ)
PPF(%)
PPQ-11(%)
PPQ-3(%)
PPQ-5(%)
PVI
RAP-v1
RAP-v2
Rate-Quotient(RQ)
Shim(%)
SNR-v1(dB)
SNR-v2(dB)
Spectral-Flatness(SFM)
Speed-Index(SI)
Speed-Quotient(SQ)
Stiffness
Time-Periodicity

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Surgical versus non-surgical interventions for vocal cord nodules

Background: This is an update of a Cochrane review first published in *The Cochrane Library* in Issue 2, 2001 and previously updated in 2007 and 2009.

Vocal cord nodules are bilateral, benign, callous-like growths of the midt-portion of the membranous vocal folds. They are of variable size and are characterized histologically by thickening of the epithelium with a variable degree of inflammation in the underlying superficial lamina propria. They characteristically produce **hoarseness**, discomfort and an unstable voice when speaking or singing.

Objectives: To assess the effectiveness of surgery versus non-surgical interventions for vocal cord nodules also **with acoustical measures**.

Search methods: We searched the Cochrane Ear, Nose and Throat Disorders Group Trials Register; the Cochrane Central Register of Controlled Trials (CENTRAL); PubMed; EMBASE; CINAHL; Web of Science; BIOSIS Previews; Cambridge Scientific Abstracts; ISRCTN and additional sources for published and unpublished trials. The date of the most recent search was 9 April 2012.

Selection criteria: Randomised and quasi-randomised trials comparing any surgical intervention for vocal cord nodules with non-surgical treatment or no treatment.

Data collection and analysis: No suitable trials were identified.

Main results: No studies fulfilled the inclusion criteria.

Authors' conclusions: There is a need for high-quality **randomised controlled trials** to evaluate the effectiveness of surgical and non-surgical treatment of vocal cord nodules.

Pedersen M, McGlashan J (2012) Surgical versus non-surgical interventions for vocal cord nodules (Review) *The Cochrane Library. pp. 1-13*

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Reliability of Objective Voice Measures of Normal Speaking Voices

Objective: to determine the reliability of objective voice measures used commonly in clinical practice.

18 healthy volunteers (nine males and nine females)

Measures of laryngeal efficiency, and pertubation measures of fundamental frequency (Fo) for both genders.

For female **cepstral peak prominence(CPP)** had moderate reliability, wheres for males, the smooth CPP was reliable.

Noise-to-harmonic ratios (NHRs) has the lowest consistency of all measures over the course.

<u>Additional research is needed to investigate which factors within the testing protocol and/or changes to the measurement instruments may lead to more consistent test results</u>.

Leong K1, Hawkshaw MJ, Dentchev D, Gupta R, Lurie D, Sataloff RT (2012) Reliability of objective voice measures of normal speaking voices, J Voice. 2013 Mar;27(2):170-6

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Evidence-based Clinical Voice Assessment: A Systematic Review

Objective: determine what research evidence exsists, to support the **use of voice measures in the clinical assessment of patients with voice disorders.**

Litterature studies provides evidence for selected **acoustic, laryngeal imaging-based, auditory-perceptual, functional, and aerodynamic measures** to be used as effective components in a clinical voice evaluation.

<u>**There is clearly a pressing need for high-quality research that is specially designed to expand the evidence base for clinical voice assessment.**</u>

Roy N1, Barkmeier-Kraemer J, Eadie T, Sivasankar MP, Mehta D, Paul D, Hillman R (2013) Evidence-based clinical voice assessment: a systematic review, Am J Speech Lang Pathol. 2013 May;22(2):212-26

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"GLOTTAL ANALYSIS TOOLS"

Parameters with statistical significant difference between 12 healthy voices and 12 patients with complaints of hoarse voices in a prospective case/control study are shown below. Notice that only variables related to the high speed films and no acoustic measurements made at the same time are significant out of 345 measured (SAS program 9,4 Spearman Rank correlation coefficient test). THESE MEASURES MIGHT BE USED IN A CLINICAL SITUATION

	Parameter	Source	Type	Estimate	Standard Error	DF	T Value	Pr >|T|
1	Cepstral Harmonics-to-Noise Ratio-v2(dB)	[GAW]		10,63	4,41	22	2,41	**0,02**
2	Cepstral Harmonics-to-Noise Ratio-v2(dB)	[GAW]	[Left]	11,89	4,81	20	2,47	**0,02**
3	Cepstral Harmonics-to-Noise Ratio-v2(dB)	[GAW]	[Right]	8,56	4,21	22	2,03	**0,05**
4	Cepstral Harmonics-to-Noise Ratio-v2(dB)	[Traj-50%]	[Left]	10,00	4,33	21	2,31	**0,03**
5	Cepstral Peak Prominence(dB)	[GAW]	[Left]	0,58	0,26	20	2,20	**0,04**
6	Cepstral Peak Prominence(dB)	[Traj-50%]	[Right]	0,33	0,17	22	2,00	**0,06**
7	Contour-Angle(DEG)	[PVG]	[Left]	10,23	4,30	20	2,38	**0,03**
8	Energy Perturbation Quotient-5(%)	[Traj-50%]	[Left]	-9,06	3,53	21	-2,56	**0,02**
9	Harmonics-Intensity(%)	[GAW]		4,10	1,45	22	2,83	**0,01**
10	Harmonics-Intensity(%)	[GAW]	[Left]	3,17	1,25	20	2,53	**0,02**
11	Harmonics-Intensity(%)	[GAW]	[Right]	3,41	1,41	22	2,42	**0,02**
12	Harmonics-Intensity(%)	[Traj-50%]	[Left]	2,80	1,30	21	2,16	**0,04**
13	Normalized Noise Energy(dB)	[GAW]	[Left]	-3,38	1,39	20	-2,42	**0,03**
14	Period Perturbation Quotient-11(%)	[GAW]	[Left]	-1,89	0,84	19	-2,25	**0,04**
15	Period Perturbation Quotient-11(%)	[GAW]	[Right]	-2,17	0,93	21	-2,33	**0,03**
16	Signal-to-Noise Ratio-v1(dB)	[GAW]		1,15	0,56	22	2,06	**0,05**
17	Signal-to-Noise Ratio-v1(dB)	[GAW]	[Left]	1,32	0,60	20	2,19	**0,04**
18	Signal-to-Noise Ratio-v1(dB)	[GAW]	[Right]	1,03	0,51	22	2,01	**0,06**
19	Spectral-Flatness(SFM)	[GAW]		-2,74	1,20	22	-2,28	**0,03**
20	minimum-Subharmonic(Hz)	[GAW]		-81,06	40,25	22	-2,01	**0,06**
21	minimum-Subharmonic(Hz)	[GAW]	[Right]	-83,42	39,61	22	-2,11	**0,05**
22	minimum-Subharmonic(Hz)	[Traj-50%]	[Left]	-153,85	23,88	21	-6,44	**<,0001**

All formulas above are presented on the following slides

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CEPSTRAL HARMONICS-TO-NOISE RATIO (CHNR)

$$\text{CHNR-v2}\ (dB) = 10 \cdot \log_{10} \left[\frac{\sum_{n=1}^{H_{max}} |F(n \cdot \omega_0)|^2}{\sum_{n=1}^{H_{max}} 10^{\left(2 \cdot B_L(n \cdot \omega_0) - \log_{10} |F(n \cdot \omega_0)|^2\right)}} \right].$$

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CEPSTRAL PEAK PROMINENCE

CPP (dB) is defined as the difference in amplitude between the cepstral peak and the corresponding value on the regression line computed between 1 ms and the maximum quefrency. (i.e., the predicted cepstral magnitude for the quefrency at the cepstral peak).

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CONTOUR ANGLES OF PHONOVIBROGRAMS

Contour-Angles (deg) was calculated in both anterior and posterior parts during opening as well as closing of vocal folds for the left and right side of PVG, respectively.
Hence, $CA_i^{side,Item}$ denotes the Contour-Angles for i^{th} cycle,
where $side$ represents the corresponding side of PVG:

- L - Left side,
- R - Right side,

and $Item$ signifies the position of related Contour-Angle:

- $Item = OA$: Opening - Anterior,
- $Item = OP$: Opening - Posterior,
- $Item = CA$: Closing - Anterior,
- $Item = CP$: Closing - Posterior.

ENERGY PERTURBATION QUOTIENT 5% & 11%

$$\text{EPQ (\%)} = \frac{1}{N-k} \sum_{i=\frac{k-1}{2}}^{N-\frac{k-1}{2}-1} \left| 1 - \frac{k \cdot E(i)}{\sum_{j=-\frac{k-1}{2}}^{\frac{k-1}{2}} E(i+j)} \right| \cdot 100,$$

where k represents the number of cycles considered for computation of quotients:

- $k = 3$: EPQ 3 (%)
- $k = 5$: EPQ-5 (%)
- $k = 11$: EPQ-11 (%)

EPQ5% and 11% are the only statistically significant parameters of the three

Furthermore:

- $E(i)$ - signal energy within a i^{th} cycle, *i* is therefore the number of the cycle.
- N - the number of analyzed cycles (equivalent to the number of elements E).

In *Glottis Analysis Tools* the following energy-related parameters are calculated:

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HARMONICS INTENSITY

$$\text{Harmonics-Intensity (\%)} = 100 \cdot \frac{\sum_{n=2}^{H_{max}} |F(n \cdot \omega_0)|}{\sum_{\omega \geq 1} |F(\omega)|}.$$

These measures can be calculated for the following signals:

- Glottal area waveform (GAW)
- Acoustics
- Glottal trajectories

Furthermore:

- $F(k)$ - k^{th} coefficient of Fourier transform of the signal ($k = 0$ - the DC component),
- $C(k)$ - k^{th} Cepstrum coefficient

$$C(\omega) = \mathcal{F}^{-1}\{10 \cdot \log_{10}(|F(\omega)|^2)\},$$

- ω_0 - index of Fourier coefficient represents fundamental frequency (f_0),
- H_{max} - maximum order of harmonics for f_0,
- ω_{min} - index of Fourier coefficient represents minimum occurring subharmonic for f_0.

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NORMALIZED NOISE ENERGY

$$\text{NNE } (dB) = 10 \cdot \log_{10} \left(\frac{\sum_{\omega=\omega_{min}}^{\omega_{max}} \left| \hat{W}(\omega) \right|^2}{\sum^{\omega_{max}} |F(\omega)|^2} \right), \qquad \omega_{max} = H_{max} \cdot \omega_0$$

With

$$\left| \hat{W}(\omega) \right|^2 = \begin{cases} |F(\omega)|^2, & \omega \in D_i \\ \frac{1}{2} \left(\sum_{\tau \in D_i} \frac{|F(\tau)|^2}{N_i} + \sum_{\tau \in D_{i+1}} \frac{|F(\tau)|^2}{N_{i+1}} \right), & \omega \in P_i \end{cases}$$

Let $s(\tau)$ - periodic component, and $w(\tau)$ - noise component of the discretized signal $f(\tau)$, respectively.

$$\Downarrow$$

$$f(\tau) = s(\tau) + w(\tau), \qquad \tau = 1, \dots, M.$$

Discrete Fourier transform $\Downarrow$

$$F(\omega) = S(\omega) + W(\omega), \qquad \omega = 0, \dots, N-1.$$

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Normalized noise energy continued

where

- $\left|\hat{W}(\omega)\right|^2 \approx |W(\omega)|^2$ (Fourier transform of noise component $w(\tau)$),
- $D_i = \left\{ r : (i-1)\cdot\omega_0 + \frac{2N}{M} \le r \le i\cdot\omega_0 - \frac{2N}{M} \right\},$
- $P_i = \left\{ r : i\cdot\omega_0 - \frac{2N}{M} \le r \le i\cdot\omega_0 + \frac{2N}{M} \right\},$
- $N_i = |D_i|$ (Cardinality), $\quad 1 \le i \le H_{max}.$

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Signal-to-noise ratio

i) Upscale $F(\omega)$: $\mathrm{Length}\left(\hat{F}\right) = 4 \cdot \mathrm{Length}\left(F\right)$,

ii) Fundamental frequency index $\hat{\omega_0} = 4 \cdot \omega_0$; harmonics bandwidth $B_h \approx 30$ Hz,

iii) Harmonic short-time energy $E_h = \sum_{n=1}^{H_{max}} B_h \cdot \left| \frac{1}{B_h} \cdot \sum_{\omega = n \cdot \hat{\omega_0} - \frac{B_h}{2}}^{n \cdot \hat{\omega_0} + \frac{B_h}{2}} \hat{F}(\omega) \right|^2$,

iv) Total short-time energy $E_t = \sum_{\omega=0}^{\mathrm{Length}(\hat{F})} \left| \hat{F}(\omega) \right|^2$

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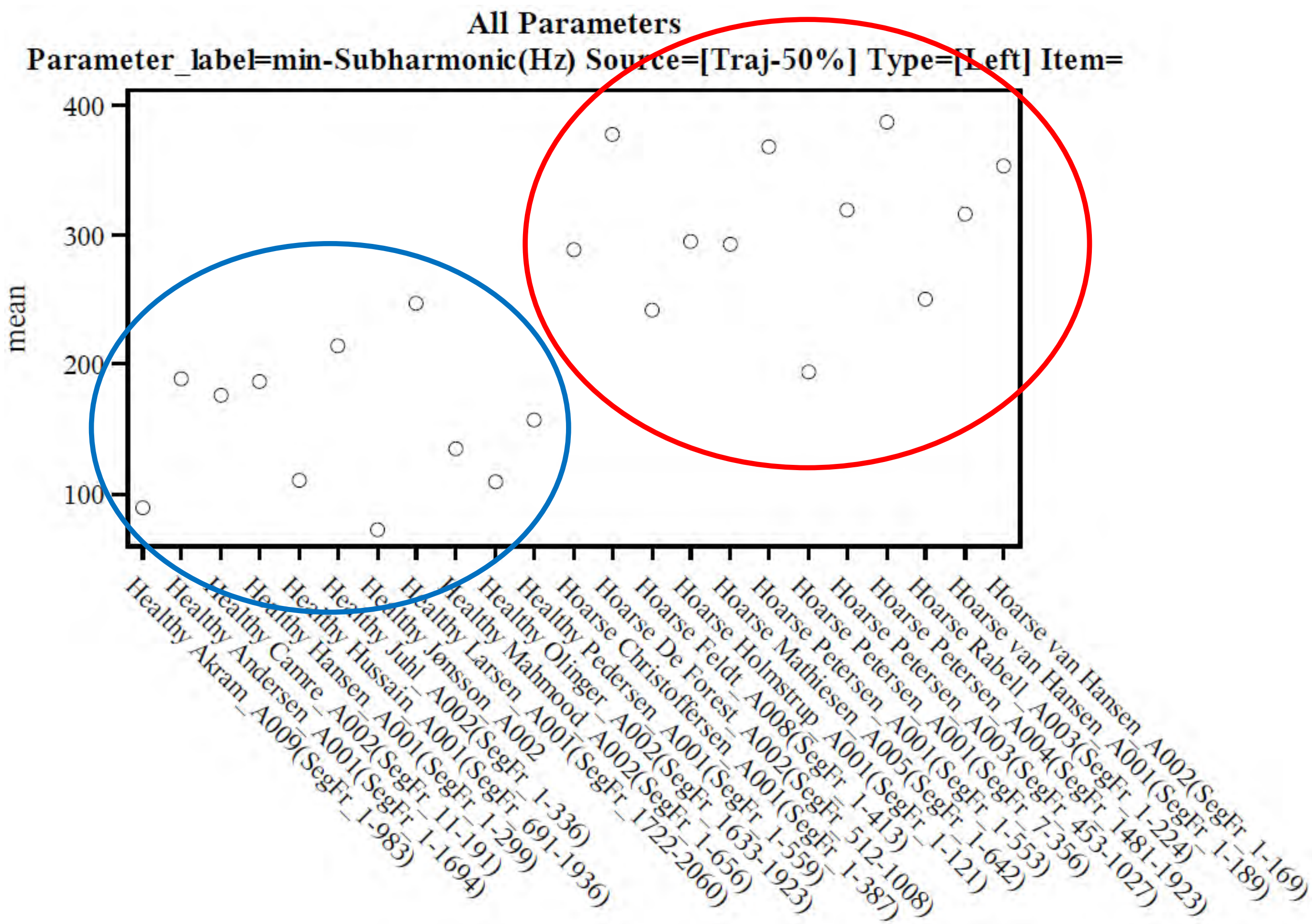
SPECTRAL FLATNESS

$$\text{Spectral-Flatness } (SFM) = \frac{20}{N} \cdot \left(\sum_{i=1}^{N/2} \log_{10} |F(\omega)|^2 \right) - 10 \cdot \log_{10} \left(\frac{2}{N} \cdot \sum_{i=1}^{N/2} |F(\omega)|^2 \right)$$

Minimum subharmonics

min-Subharmonic (Hz) - minimum occurring subharmonic frequency (fundamental frequency is the multiple of this frequency) in Hz.

Minimum Subharmonics for left vocal fold comparing 12 normal persons with 12 persons complaining of hoarseness even if P value <0,0001 the difference is visually small.



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Further formulas are presented because:

- Jitter % - is commonly used
- Shimmer % - is commonly used
- Stiffness – might be interesting in singers
- Amplitude symmetry index – earlier analyses showed signs of significance

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FREQUENTLY USED FORMULAS – MEAN JITTER

Jitter and shimmer are basically probability formulas

MEAN JITTER explanation

Jitter is a measure of the duration of the voice sound cycle.

A cycle is a vocal swingning from opening to opening.

The duration of each cycle is p(i) in mili seconds (ms).

Σ (sigma) means that you put an amount of numbers together (sum).

I=1 means that the interval between the numbers to be added together are 1. It means that all the numbers must be added together. There is also an opportunity to put every third number together (or others).

I stands for interval.

N is the total quantity of observations, that must be added. *N* - the number of analyzed cycles (equivalent to the number of elements in *p*, *p* is the duration of each cycle).

Mean Jitter (ms) = $\frac{\sum_{i=1}^{N}|p(i)-p(i-1)|}{N-1}$

p(*i*) - duration of *i*^th cycle in ms.

P(i)-P(i-1) is an indication that we put duration of the different cycles together.

The division line is an indication that we divide the total number to get an average value.

-1 is an indication that there is no cycle 0. The first cycle is called 1, therefore we substract 1 from the amount of cycles.

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FREQUENTLY USED FORMULAS – JITTER%

$$\text{Jitter (\%)} = \frac{Mean\ Jitter\ (ms)}{\frac{1}{N}\sum_{i=0}^{N-1} p(i)} \cdot 100$$

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FREQUENTLY USED FORMULAS – SHIMMER, MEAN & SHIMMER%

Shimmer is strength variation and it is measured at the maximum amplitude of all measuring points.

The explanation of how the formula are written is the same as for jitter.

$$\text{Mean-shimmer (dB)} = \frac{20}{N-1}\sum_{i=0}^{N-2}\left|\frac{A(i)}{A(i+1)}\right|$$

$$\text{Shimmer (\%)} = \frac{Mean-Shim(dB)}{\frac{20}{N}\sum_{i=0}^{N-1}|log_{10}A(i)|}\cdot 100$$

A(*i*) - dynamic range (max-min) of *i*^th cycle

N - the number of analyzed cycles (equivalent to the number of elements in *A*).

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Stiffness (from data sources Glottal Area waveform (GAW) and traj-50%)

$$Stiffness = \frac{max_{t \subset T_i}(s(t))}{A_i}$$

Where T_i is the duration of the i^{th} cycle in milliseconds (ms)

A^i is the dynamic range (max – min) of i^{th} cycle

s(t) is the magnitude of the 1^{st} derivative of considered signal for i^{th} cycle ($t \subset T_i$).

Further explanation:

s (t): The speed of vocal fold movements (compared to vocal fold resting point/starting point) - maximum value written inside the brackets.

A_i: Maximum distance/fluctuation from one extreme position to another (+ normalisation of fluctuaion to the same scale),

where ⊂ means that t ”belongs to” the duration Ti.

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AMPLITUDE SYMMETRY INDEX (GAW AND TRAJ 50%)

$$\textit{Amplitude Symmetry Index} = \frac{\min(max[GA_i^L], max[GA_i^{Rt}])}{\max(max[GA_i^L], max[GA_i^R])}$$

GA_i = Glottal area waveform for the i[th] cycle

L = Left side

R = Right side

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VARIOUS SOFTWARE SYSTEMS

Several softwares have various formulas for jitter and shimmer.

In MDVP it was rather difficult to find the formulas, it seemed to be the same as in PRAAT.

The ones used in our presentation are the same as used in PRAAT.

Formulas that are used in Erlangen for ”Glottal area tools” for high speed films were tested clinically in normal persons in our study.

Our statistician suggested to make a setup based on 12 normal persons.
The reason for this was that when it comes to pathology practically none of the acoustical parametres were significant.

Except may be the standard deviation for stiffness, as shown in an earlier publications.

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A MATERIAL BASED ON 12 NORMAL PERSONS IN OUR CLINIC. JITTER VALUES, BASED ON THREE DIFFERENT DATA SOURCES (GLOTTAL AREA WAVEFORM, TRAJECTORIES 50% AND AUDIO)

			n	mean	std	min	max
Parameter	Source	Type					
Jitt(%)	[Audio]		12	8,17	8,1	0,65	27,8
	[GAW]		12	5,63	3,36	0	9,86
		[Left]	10	6,04	3,09	1,92	10,8
		[Right]	12	5,42	3,18	0	10,4
	[Traj-50%]	[Left]	11	9,17	5,11	3,84	20,1
		[Right]	12	8,75	3,82	3,82	16
Jitt-Factor	[Audio]		12	8,34	8,26	0,65	28,2
	[GAW]		12	5,52	3,32	0	9,61
		[Left]	10	5,98	3,12	1,78	10,8
		[Right]	12	5,37	3,16	0	10,3
	[Traj-50%]	[Left]	11	9,31	5,07	3,82	19,9
		[Right]	12	8,69	3,85	3,75	15,9
Jitt-Ratio	[Audio]		12	81,7	81	6,46	278
	[GAW]		12	56,3	33,6	0	98,6
		[Left]	10	60,4	30,9	19,2	108
		[Right]	12	54,2	31,8	0	104
	[Traj-50%]	[Left]	11	91,7	51,1	38,4	201
		[Right]	12	87,5	38,2	38,2	160

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A CLINICAL MATERIAL BASED ON 12 NORMAL PERSONS. SHIMMER AND STIFFNESS VALUES, BASED ON THREE DIFFERENT DATA SOURCES (GLOTTAL AREA WAVEFORM, TRAJECTORIES 50%) AND AUDIO ALSO

Paramete	Source	Type	n	mean	std	min	max
Shim(%)	[Audio]		12	0,63	0,54	0,03	13,9
	[GAW]		12	0,68	0,6	0,28	2,28
		[Left]	10	1,71	0,93	0,7	3,45
		[Right]	12	2,39	1,62	0,82	5,51
	[Traj-50%]	[Left]	11	11,2	8,38	2,57	29,5
		[Right]	12	13,5	11,6	4,52	38,3
Stiffness	[GAW]		10	0,36	0,07	0,21	0,42
		[Left]	8	0,37	0,08	0,2	0,43
		[Right]	10	0,37	0,08	0,19	0,45
	[Traj-50%]	[Left]	9	0,41	0,06	0,32	0,5
		[Right]	10	0,39	0,06	0,3	0,48

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COMMONLY USED PARAMETERS

The commonly used parameters show no statistical difference between 12 normal persons and 12 persons with complaints of hoarseness in a prospective case control study (SAS program 9,4 Spearman Rank correlation coefficient test).

Parameter	Source	Type	Estimate	Standard Error	DF	t Value	Pr >|t|
Jitt(%)	[Audio]		0,31	3,56	22	0,09	0,93
Jitt(%)	[GAW]		-1,42	1,44	22	-0,99	0,33
Jitt(%)	[GAW]	[Left]	-1,84	1,51	20	-1,23	0,23
Jitt(%)	[GAW]	[Right]	-2,04	1,32	22	-1,55	0,14
Jitt(%)	[Traj-50%]	[Left]	-0,74	1,87	21	-0,39	0,70
Jitt(%)	[Traj-50%]	[Right]	-1,32	1,46	22	-0,90	0,38
Jitt-Factor	[Audio]		0,44	3,61	22	0,12	0,90
Jitt-Factor	[GAW]		-1,60	1,47	22	-1,09	0,29
Jitt-Factor	[GAW]	[Left]	-2,03	1,54	20	-1,32	0,20
Jitt-Factor	[GAW]	[Right]	-2,08	1,29	22	-1,62	0,12
Jitt-Factor	[Traj-50%]	[Left]	-0,65	1,90	21	-0,34	0,74
Jitt-Factor	[Traj-50%]	[Right]	-1,38	1,50	22	-0,92	0,37
Jitt-Ratio	[Audio]		3,10	35,61	22	0,09	0,93
Jitt-Ratio	[GAW]		-14,18	14,38	22	-0,99	0,34
Jitt-Ratio	[GAW]	[Left]	-18,45	15,06	20	-1,23	0,23
Jitt-Ratio	[GAW]	[Right]	-20,37	13,17	22	-1,55	0,14
Jitt-Ratio	[Traj-50%]	[Left]	-7,37	18,67	21	-0,39	0,70
Jitt-Ratio	[Traj-50%]	[Right]	-13,19	14,59	22	-0,90	0,38
Shim(%)	[Audio]		1,27	21,82	22	0,06	0,95
Shim(%)	[GAW]		-0,61	0,54	22	-1,13	0,27
Shim(%)	[GAW]	[Left]	-1,21	0,65	20	-1,86	0,08
Shim(%)	[GAW]	[Right]	-0,73	0,86	22	-0,84	0,41
Shim(%)	[Traj-50%]	[Left]	-6,53	6,34	21	-1,03	0,31
Shim(%)	[Traj-50%]	[Right]	1,90	4,07	22	0,47	0,64

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COMMONLY USED PARAMETERS CONTINUED

(SAS program 9,4 Spearman Rank correlation coefficient test).

Parameter	Source	Type	Estimate	Standard Error	DF	t Value	Pr >|t|
Stiffness	[GAW]		0,01	0,02	20	0,57	0,57
Stiffness	[GAW]	[Left]	0,02	0,03	18	0,58	0,57
Stiffness	[GAW]	[Right]	0,01	0,03	20	0,37	0,72
Stiffness	[Traj-50%]	[Left]	-0,01	0,03	19	-0,21	0,84
Stiffness	[Traj-50%]	[Right]	0,00	0,03	20	-0,15	0,88
Amplitude-Length-Ratio	[GAW]		-0,24	0,55	20	-0,44	0,66
Amplitude-Length-Ratio	[GAW]	[Left]	-0,05	0,32	18	-0,16	0,87
Amplitude-Length-Ratio	[GAW]	[Right]	-0,31	0,33	20	-0,93	0,36
Amplitude-Length-Ratio	[Traj-50%]	[Left]	-0,01	0,01	19	-0,92	0,37
Amplitude-Length-Ratio	[Traj-50%]	[Right]	-0,02	0,01	20	-1,60	0,12
Amplitude-Periodicity	[GAW]		0,03	0,03	20	1,16	0,26
Amplitude-Periodicity	[GAW]	[Left]	0,05	0,03	18	1,82	0,09
Amplitude-Periodicity	[GAW]	[Right]	0,03	0,03	20	0,98	0,34
Amplitude-Periodicity	[Traj-50%]	[Left]	0,03	0,03	19	1,19	0,25
Amplitude-Periodicity	[Traj-50%]	[Right]	0,02	0,03	20	0,48	0,63
Amplitude-Quotient	[GAW]		0,11	0,31	20	0,35	0,73
Amplitude-Quotient	[GAW]	[Left]	0,01	0,32	18	0,05	0,96
Amplitude-Quotient	[GAW]	[Right]	0,04	0,35	20	0,10	0,92
Amplitude-Quotient	[Traj-50%]	[Left]	0,01	0,26	19	0,05	0,96
Amplitude-Quotient	[Traj-50%]	[Right]	-0,20	0,29	20	-0,70	0,49
Amplitude-Symmetry*	[GAW]		0,10	0,13	20	0,76	0,46
Amplitude-Symmetry*	[Traj-50%]		-1316,17	1447,91	20	-0,91	0,37
Amplitude-Symmetry-Index	[GAW]		0,03	0,04	20	0,79	0,44
Amplitude-Symmetry-Index	[Traj-50%]		0,07	0,07	20	1,07	0,30

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CONCLUSION

“Glottis Analysis Tools” video analysis is an interesting supplement of voice analysis, as it operates on vocal fold level instead of voice level.

There are 2 problems:

1. The old measures of voice analysis do not show statistical difference between normal and pathological voices, complaining of hoarseness in our prospective case /control study. Still stiffness measures standard deviations are of interest.
2. Randomized studies are lacking. The new methods on the market should be focused upon: Overtones/ harmonics – Optical Coherence Tomography – Narrow Band Imaging

Find the slides on: http://www.mpedersen.org

Thank you for your attention!

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APPENDIX: STIFFNESS

HTTPS://EN.WIKIPEDIA.ORG/WIKI/STIFFNESS

Stiffness is the rigidity of an object — the extent to which it resists deformation in response to an applied force. The complementary concept is **flexibility** or pliability: the more flexible an object is, the less stiff it is

Calculations

The stiffness, *k*, of a body is a measure of the resistance offered by an elastic body to deformation. For an elastic body with a single degree of freedom (DOF) (for example, stretching or compression of a rod), the stiffness is defined as

where, $$k = \frac{F}{\delta}$$

F is the force applied on the bodyδ is the displacement produced by the force along the same degree of freedom (for instance, the change in length of a stretched spring)In the International System of Units, stiffness is typically measured in newtons per meter. In Imperial units, stiffness is typically measured in pounds(lbs) per inch.

Generally speaking, deflections (or motions) of an infinitesimal element (which is viewed as a point) in an elastic body can occur along multiple DOF (maximum of six DOF at a point). For example, a point on a horizontal beam can undergo both a vertical displacement and a rotation relative to its undeformed axis. When there are M degrees of freedom a M x M matrix must be used to describe the stiffness at the point. The diagonal terms in the matrix are the direct-related stiffnesses (or simply stiffnesses) along the same degree of freedom and the off-diagonal terms are the coupling stiffnesses between two different degrees of freedom (either at the same or different points) or the same degree of freedom at two different points. In industry, the term **influence coefficient** is sometimes used to refer to the coupling stiffness.

It is noted that for a body with multiple DOF, the equation above generally does not apply since the applied force generates not only the deflection along its own direction (or degree of freedom), but also those along other directions.

For a body with multiple DOF, in order to calculate a particular direct-related stiffness (the diagonal terms), the corresponding DOF is left free while the remaining should be constrained. Under such a condition, the above equation can be used to obtain the direct-related stiffness for the degree of freedom which is unconstrained. The ratios between the reaction forces (or moments) and the produced deflection are the coupling stiffnesses.

A description including all possible stretch and shear parameters is given by the elasticity tensor.

Compliance

The inverse of stiffness is *compliance* (or sometimes *elastic modulus*), typically measured in units of metres per newton. In rheology it may be defined as the ratio of strain to stress, and so take the units of reciprocal stress, *e.g*. 1/Pa.

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Appendix: Stiffness

https://en.wikipedia.org/wiki/Stiffness

Rotational stiffness

A body may also have a rotational stiffness, *k*, given by

Where

$$k = \frac{M}{\theta}$$

M is the applied moment θ is the rotation in the SI system, rotational stiffness is typically measured in newton-metres per radian.

In the SAE system, rotational stiffness is typically measured in inch-pounds per degree.

Further measures of stiffness are derived on a similar basis, including:

shear stiffness - ratio of applied shear force to shear deformation

torsional stiffness - ratio of applied torsion moment to angle of twist

Relationship to elasticity

In general, elastic modulus is not the same as stiffness. Elastic modulus is a property of the constituent material; stiffness is a property of a structure. That is, the modulus is an intensive property of the material; stiffness, on the other hand, is an extensiv property of the solid body dependent on the material *and* the shape and boundary conditions. For example, for an element in tension or compression, the axial stiffness is

Where

A is the cross-sectional area,*E* is the (tensile) elastic modulus (or Young's modulus),*L* is the length of the element.Similarly, the rotational stiffness of a straight section is

Where

$$k = \frac{AE}{L}$$

"J" is the torsion constant for the section,"G" is the rigidity modulus of the material

Applications

$$k = \frac{GJ}{L}$$

The stiffness of a structure is of principal importance in many engineering applications, so the modulus of elasticity is often one of the primary properties considered when selecting a material. A high modulus of elasticity is sought when deflection is undesirable, while a low modulus of elasticity is required when flexibility is needed.

In biology, the stiffness of the extracellular matrix is important for guiding the migration of cells in a phenomenon called durotaxis.

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