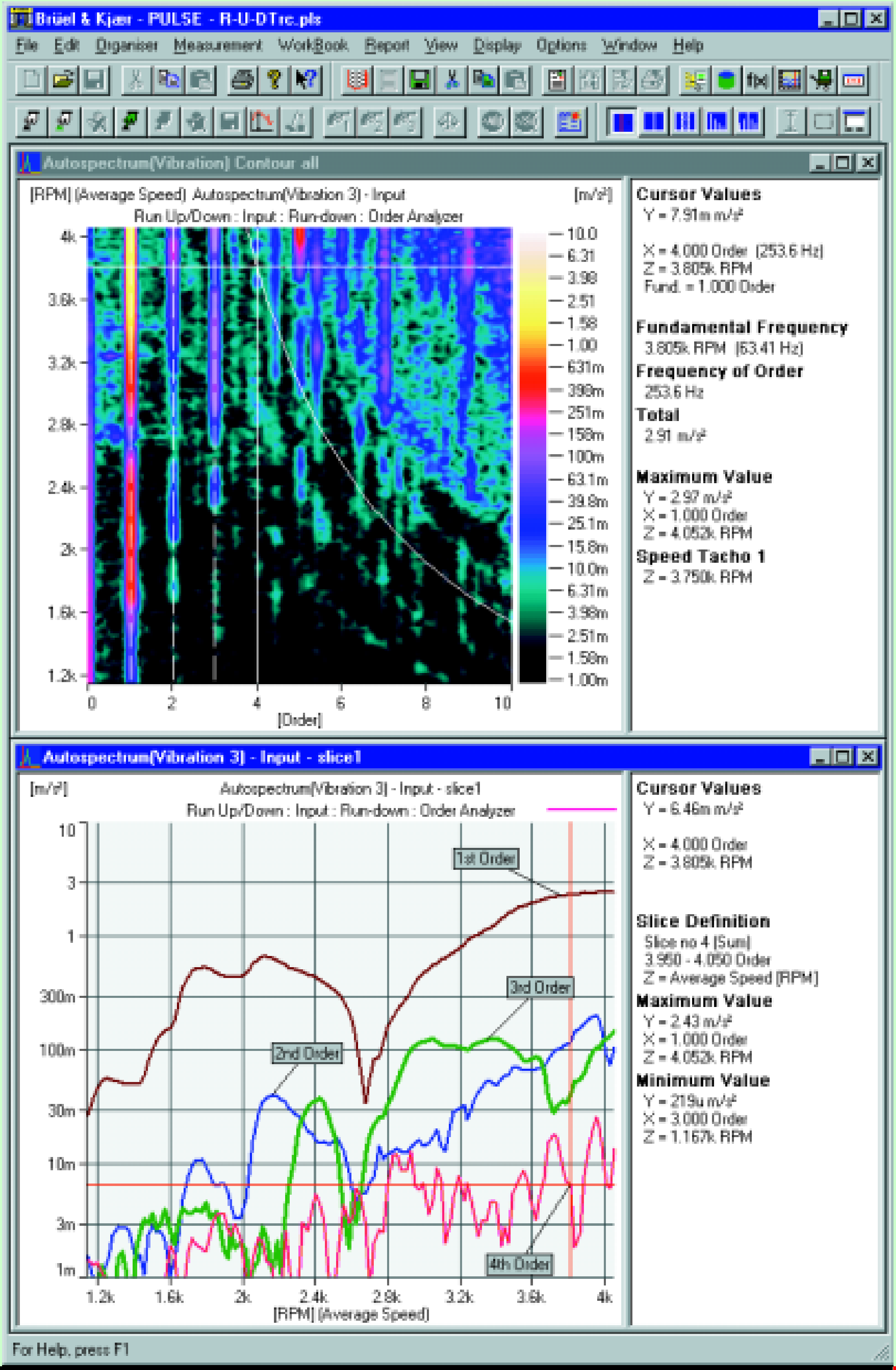
PRODUCT DATA

Order Analysis — Type 7702
for PULSE, the Multi-analyzer System



Order Analysis Type 7702 provides PULSE™, the Multi-analyzer System Type 3560 with tachometers and order analyzers, and related post-processing functions, as well as additional trigger types.

The software includes PULSE Application Projects that cover the main uses of Type 7702. The system can be easily customised to suit other measurement tasks.

7702

Brüel & Kjær

Introduction

USES

- ❍ Separation of rotational and structural noise and vibration phenomena
- ❍ Identification of noise generated by rotational vibrations
- ❍ Determination of critical speeds and resonances
- ❍ Investigation of instabilities in rotating machinery

FEATURES

- ❍ Order analysis with high-speed tracking
- ❍ Run-up/down testing with or without tracking
- ❍ Multiple tachometers with extensive range of setup parameters
- ❍ Tacho, speed and speed interval triggers
- ❍ Order analyzers with individual tracking references
- ❍ Run-up and coast-down in a single test session
- ❍ Synchronous averaging through tacho gearing
- ❍ Simultaneous noise and vibration analysis
- ❍ Slice mode for data reduction, rapid processing and fast display of slices during measurement
- ❍ Real-time calculation of average RPM
- ❍ Interpolation of slices to “round” values allowing averaging of slices
- ❍ RPM scaling to velocity

Introduction

Order analysis is a technique for analysing imperfections in the moving parts of rotating and reciprocating machinery that cause unwanted noise and vibration. The engineer’s or scientist’s knowledge about machinery such as aircraft and automotive engines, power trains, pumps, compressors and electric motors is greatly improved by performing order analysis. This is because it allows measurements to be related to the revolutions of a rotating part.

Order Analysis Type 7702 provides two instruments, namely, an Order Analyzer and a Tachometer, plus related post-processing functions and a wide range of display facilities. There are also three additional trigger types: tacho, speed and speed interval. These supplement the tools available in Noise and Vibration Analysis Type 7700 to provide a complete diagnostic toolbox for both order tracking and general noise and vibration measurements.

A number of PULSE Application Projects can be found in the PULSE Knowledge Library. These cover the main uses of Order Analysis Type 7702 and allow you to perform order analyses quickly and easily. You can also easily customise projects for other measurement tasks. The predefined PULSE Projects supplied can be used for the following applications:

- ❍ **Run-up/down Acoustic Performance Test** – projects for performing, for example, cabin noise or exhaust noise tests using octave analysis and orders versus engine RPM
- ❍ **Run-up/down Vibration Diagnostics** – a number of projects for the determination of critical speeds, resonances and instabilities from measurements performed with and without tracking

Measurement

Order Analysis Type 7702 is for analysing data acquired during a change in the rotational speed of a shaft. Noise and vibration can be measured simultaneously and any instrument available in Type 7700 can be used in parallel with order analyzers and tachometers.

Type 7702 features frequency spectra or order spectra, frequency band profiles and order profiles as functions of RPM. The spectra can be displayed as waterfalls or colour contours. The frequency bands and order profiles can be “cut out” from the colour contour spectra and are therefore referred to as “slices”. Because they are defined upon inspection of the spectra as a function of RPM, these slices are called post-slices.

If the frequency bands or orders of interest are known prior to the measurement, the analyzer can extract these slices during the measurement (pre-slices). Omitting the spectrum calculations reduces the demand for processing power and dramatically reduces the storage space required for the results.

Recording data for later analysis by using Data Recorder Type 7701 can overcome excessive real-time demands.

Order analysis can be made with or without tracking:

- without tracking, good for analysis of lower orders and moderate RPM slew rates
- with tracking, for the analysis of higher orders or higher RPM slew rates

Order Analysis with Tracking

An order analyzer and a tachometer are used to measure order spectra. The tachometer provides a tracking reference and the order analyzer, which consists of a tracking mechanism followed by an FFT analyzer, tracks the data and then performs an FFT on it to provide an order spectrum.

The amplitude and/or phase of the various orders as a function of (average) RPM/Hz is obtained by extracting slices parallel to the RPM/Hz axis from contour plots showing order spectra (see Fig. 1 and Fig. 2). Alternatively, you can reduce the amount of data acquired and obtain faster processing by selecting calculation of slices in the analyzer. This allows you to extract data at a number of orders and discard the data that does not interest you. In this way you can obtain the order slice data illustrated in Fig. 2 without all the data included in Fig. 1.

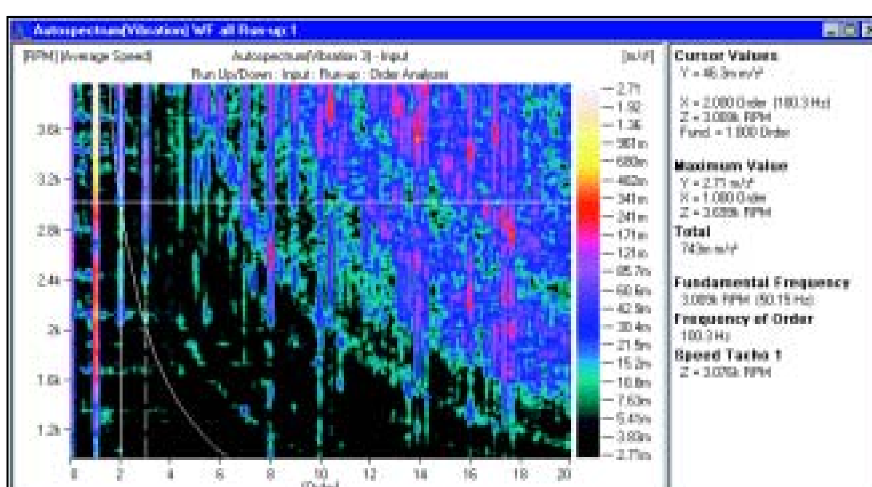
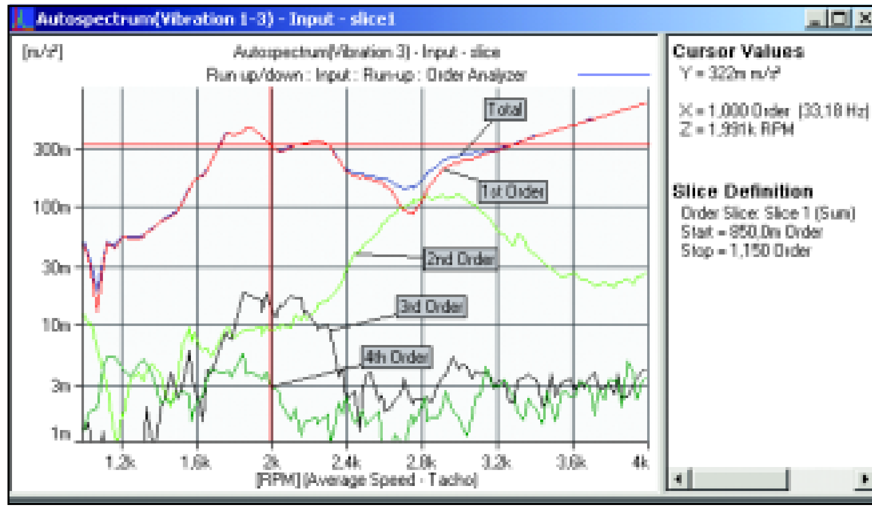


Fig. 1
A contour plot showing order spectra as a function of RPM. The X cursor is marking the 2nd order, which has a frequency of 100.3 Hz at 3009 RPM, marked by the Z cursor. The curved line that passes through the intersection of the X and Z cursors indicates all the components in the plot at the same frequency (100.3 Hz). The first three orders are selected by the harmonic cursor

__Fig. 2__
A curve graph showing the 1st, 2nd, 3rd and 4th order slices extracted from the contour plot in Fig. 1 using the harmonic cursor. The total level is also shown allowing comparison of the power in each slice with the total power. The annotation feature has been used for easy identification of slices



The **Tracking Mode** can be selected to optimise performance according to assumptions made about the change in the fundamental frequency:

- **Auto** – the fundamental frequency increases and decreases significantly within a record or the direction of change is uncertain. The fundamental frequency can change by a factor of up to 5.92 within the record.
- **Steady State** – the fundamental frequency fluctuates around a mean value. It can change up and down by a factor of up to 1.62 around the mean value within the record, i.e., by a total factor of up to 2.64. Signal processing is optimised with respect to the processing power and memory required.
- **Run-up** – the fundamental frequency is increasing. For each record it is allowed to increase by a factor of up to 5.92.
- **Run-down** – the fundamental frequency is decreasing. For each record it is allowed to decrease by a factor of up to 5.92.
- **Fixed Span** – the analysis remains within a fixed frequency range for all records. The fundamental frequency can change by a factor of up to 2.64 within each record.
- **Fixed Span Wide** – as Fixed Span but the fundamental frequency can change by a factor of up to 5.92 within each record.

Select **Fixed Span** or **Fixed Span Wide** for the highest possible optimisation of signal processing with respect to processing power and memory required. Fixed Span has the highest signal processing optimisation compared to Fixed Span Wide, but at the expense of allowable fundamental frequency variation. These modes can be used in run-up/down analysis over limited RPM ranges.

Order analysis using tracking is beneficial if frequency smearing is significant due to, for example, fast run-up or run-down or when analysing higher order components. The order components remain in the same analysis line independent of the machine speed and orders are easily identified for diagnostic purposes.

Run-up/down Tests without Tracking

To perform a run-up/down test without tracking, use a tachometer and an FFT analyzer. The tachometer supplies triggers that allow FFT measurements to be made and stored in a multi-buffer when specified conditions relative to the change in speed of a shaft occur.

Displaying these stored FFT spectra allows the identification and extraction of orders and/or frequency bands (structural resonances). The amplitude and/or phase of the various orders as a function of RPM are obtained by cutting and extracting oblique slices from contour plots showing frequency spectra versus RPM (see Fig. 3 and Fig. 4).

Fig. 3
A colour contour plot of a run-up test performed without tracking. The line passing through the intersection of the X and Z cursors identifies the 6th order. The harmonic cursor marks the first ten orders for the extraction of order slices by making oblique cuts in the contour plot of frequency spectra versus RPM

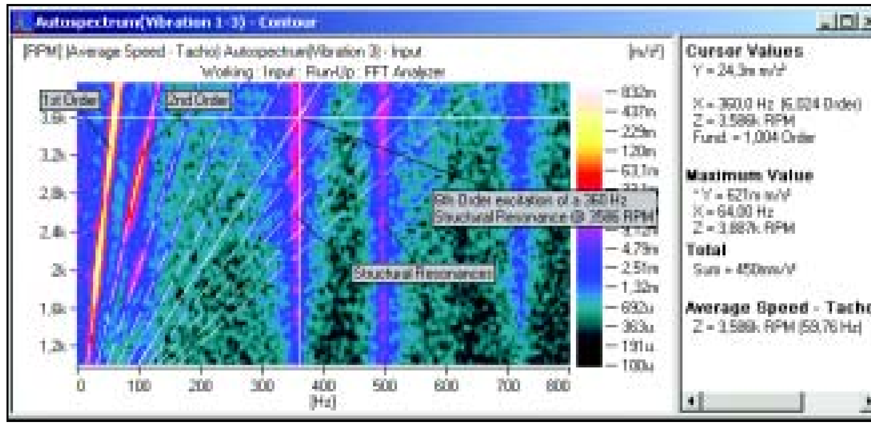
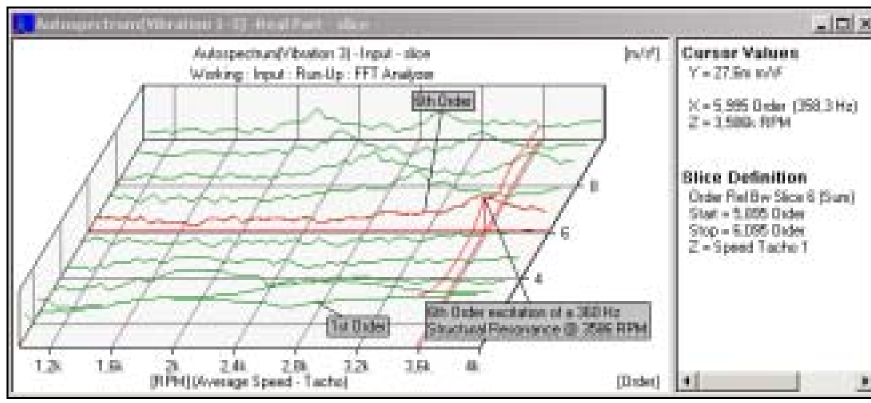


Fig. 4
A waterfall showing the harmonic order slices extracted from the contour plot in Fig. 3. The 1st and the 6th orders are annotated. The slice definition indicates the method and bandwidth used to extract the selected (order) slice



Alternatively, you can reduce the amount of data acquired and obtain faster processing by selecting calculation of slices in the analyzer. This allows you to extract data at a number of specified order and/or frequency bands and discard the data that does not interest you. In this way you can obtain the slice data illustrated in Fig. 4 without all the data included in Fig. 3.

Run-up/down tests without tracking are useful where frequency smearing is insignificant. This can, for example, be the case when analysing lower order components. One of the main benefits of this method is the real-time enhancement. A further advantage is that it shows structural resonances at fixed frequencies parallel to the RPM axis.

Inputs

Input signals can be preprocessed by applying, for example, an acoustic weighting or integration/differentiation for conversion between acceleration, velocity and displacement. The same input signal can be connected to a number of different types of instrument, e.g., Order and CPB analyzers. Each tacho signal connected to a tachometer can be individually processed, conditioned and used as a tracking reference. This allows order tracking using multiple tracking references.

Slope, level, hysteresis and hold-off can be set to ensure correct identification of tacho pulses in a contaminated tacho signal and a divider parameter allows the removal of unevenly spaced tacho pulses.

For removal of jitter from a low-quality tacho signal, you can apply an averager. This provides a running average for the distance between tacho pulses.

If the shaft under analysis in a machine is not the one supplying the tacho pulses, a tacho gearing can be defined as either a single factor, a ratio containing up to 4 fractions, or the product of these two methods.

Monitoring of the tacho signals before measuring allows you to adjust the tacho parameters to suit the measurement. During measurements, the program gives assistance in the form of warning messages, for example, "Acceleration too high" indicating when the measured data are not reliable.

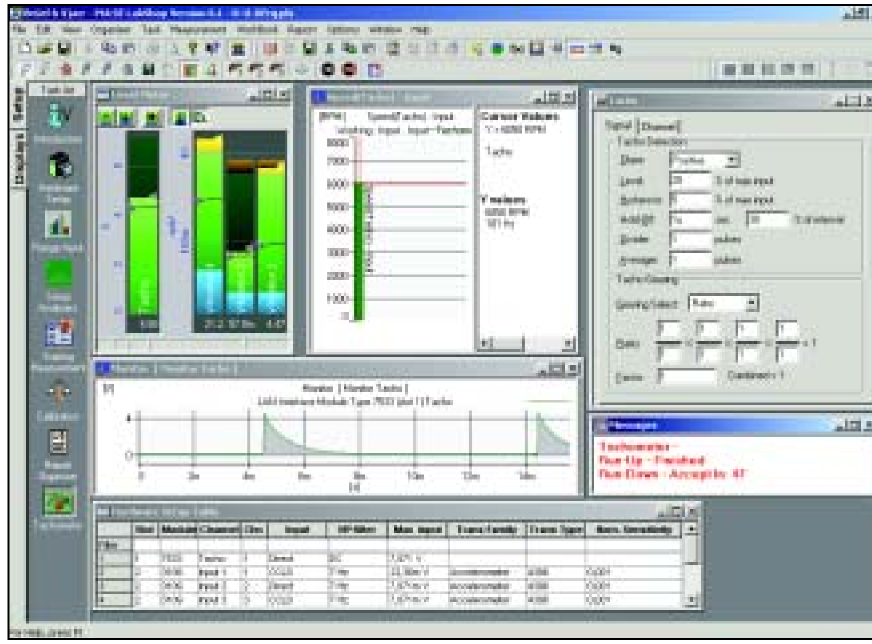


Fig. 5
Hardware setup, input level meter, tacho signal monitor and the settings for the tacho signal processing

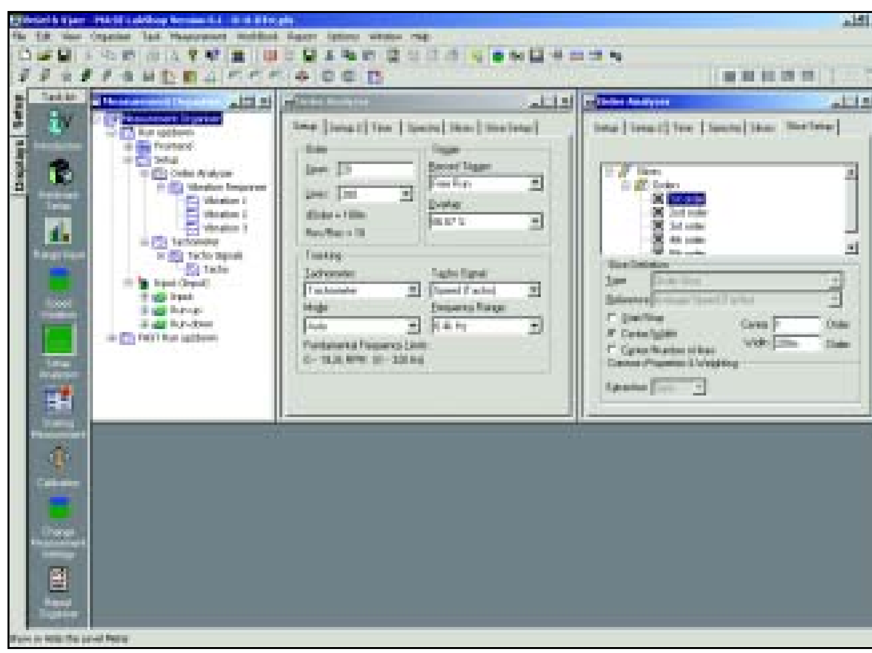


Fig. 6
A measurement template in the Measurement Organiser and the setup for an Order analyzer. The Slice Setup tab shows how to define "pre-slices"

Measurement Control

Tachometer outputs can be used for measurement control. The three types of trigger that a Tachometer output can supply are:

- Tacho Trigger
- Speed Trigger
- Speed Interval Trigger

A tacho trigger event occurs each time a tacho pulse that conforms to the specified conditions is detected at the Tachometer output for the chosen trigger signal.

A speed trigger operates by using the calculated RPM of the shaft supplying the tacho pulse or the RPM of the shaft addressed through a gearing setting. A trigger event occurs when the calculated RPM passes through a specified RPM, going up, down or in both directions.

A speed interval trigger measures the change in RPM of a shaft and generates a trigger event when the speed changes by a predefined value in the specified direction. The direction can be set as up, down or both.

These three trigger types can, for example, each be used for triggering measurements or starting, updating or stopping storage to multi-buffers. The start, update and stop conditions for the multi-buffers can be set up individually, as can the number of time signals, spectra and slices to store, meaning that a run-up and coast down measurement can be performed in a single test session.

Post-processing

A wide range of functions are available for post-processing tracked and non-tracked data. All functions that are available for the FFT analyzer, supplied as part of Noise and Vibration Analysis Type 7700, are also available for the order analyzer. A function for calculating rotational speed of a shaft can be applied to tachometer outputs.

Display

Data can be viewed in a variety of 2 D graphs and a sequence of measured time signals or spectra can be shown in a waterfall or contour plot.

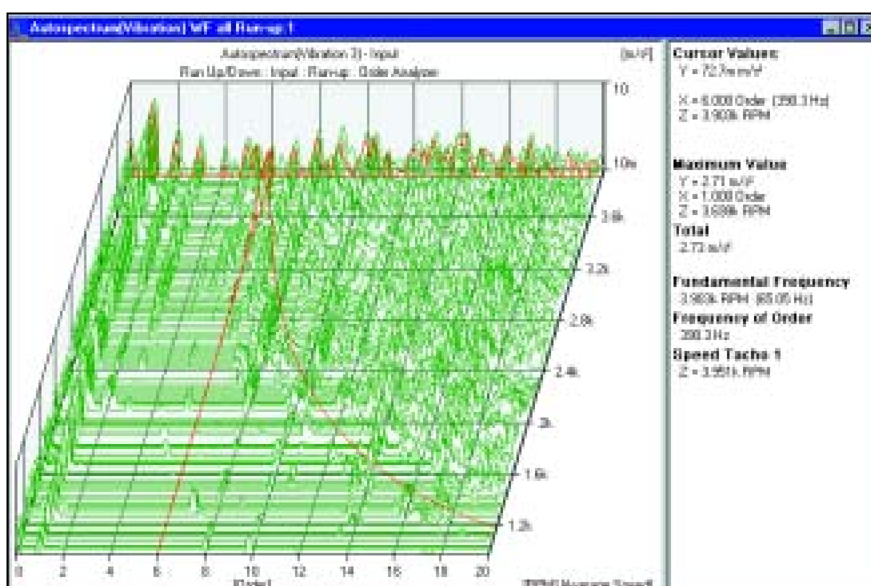


Fig. 7
A waterfall showing the results of a run-up test using tracking. It can be seen that order and non-order components are present. The cursor readings indicate that the maximum measured value is 2.71 m/s^2 for the 1st order at 3699 RPM. The speed tag reading gives the speed at the moment the spectrum was stored. The fundamental frequency and the average speed values give the average speed (and frequency) during measurement of the selected spectrum

If speed values are stored in the multi-buffer, the RPM/Hz values or averaged RPM/Hz values can be used as the Z-axis annotation for displays showing noise and vibration data. RPM/Hz values are taken at the time the data are stored in the multi-buffer. Averaged values are averaged over the duration of measurement of each spectrum, giving better RPM and order alignment for run-up/down measurements.

The RPM/Hz values can also be shown as RPM/Hz versus time profiles or RPM/Hz values for different tacho signals can be compared using a multi-value display.

If the measurement setup also includes an Overall Level Analyzer for which slice data have been saved in a multi-buffer, these values can also be used as the Z-axis annotation.

Cursors

A number of different types of cursor can be used to extract information from displays, and points of interest, such as resonances, can be annotated.

In addition to the cursor types in Type 7700, a set of order cursors is available for use on non-tracked data and includes harmonic and sideband cursor types. For tracked data, it is possible to identify fixed frequency components by using the fixed frequency indicator.

The fundamental frequency for a tracked record and the actual frequency of a selected order, as well as any of the values available for Z-axis annotation, can be shown as cursor readings.

Slices

In a colour contour or waterfall plot, individual or harmonic orders can be extracted and viewed in a 2D graph. These slices show the amplitude and/or phase of the orders as a function of, for example, RPM or time.

Slices can be extracted from tracked and non-tracked data using the cursors. For non-tracked data, if the Z-axis is rotational speed and annotated in RPM or Hz, an order slice is made by cutting across the spectra at an oblique angle with a user-definable width of cut. Thus, an order analysis is obtained using post-processing, i.e., without using an order analyzer.

Slices made as analyzer calculations are specified before measurement starts and extracted during measurement. They can be used as functions in the Function Organiser (slices extracted from a contour or waterfall plot are sub-functions) and collected in groups, simplifying data import and export and comparison of results.

Specifications – Order Analysis Type 7702

Type 7702 is software for use with PULSE, the Multi-analyzer System Type 3560

Requirements

- The PC requirements for Multi-analyzer System Type 3560 must be fulfilled
- Noise and Vibration Analysis Type 7700 must be installed

Application Projects

Type 7702 includes a number of application projects for:
- Run-up/down Acoustic Performance Test
- Run-up/down Vibration Diagnostics

The projects can be found in the PULSE Knowledge Library

Measurement

Type 7702 includes:
- Order Analyzer
- Tachometer

Tachometer and order analyzer specifications are given below

Measurement Control

The following additional trigger types are available with Type 7702 installed:
- Tacho Trigger
- Speed Trigger
- Speed Interval Trigger

Display

Specifications are the same as for Noise and Vibration Analysis Type 7700 (see System Data BU 0229) with the following additions:

CURSORS
- Order indicator for non-tracked data
- Fixed frequency indicator for tracked data

CURSOR READINGS
- Fundamental frequency for a record
- Actual frequency of a selected order
- Speed
- Average speed

SLICES
Order slices from non-tracked data

Specifications – Tachometer

A number of variants of the tachometer output can be used simultaneously
The outputs of a tachometer are used:
- As tracking references
- As tacho triggers
- As speed triggers
- As speed interval triggers
- For the display of rotational speed
- For the update of the multi-buffers

Performance

The precision of determination of the time period between tacho events is governed by the rise/fall time of the tacho signal. For pulses (short rise/fall time), the precision is better than 5 ppm. For a sine wave tacho signal, the precision ranges from 50 ppm for low frequencies to 5 ppm for high frequencies

Measurement

Any input signal can be used as a tachometer input

PARAMETERS
The following parameters can be set for each tachometer signal:
- **Level:** can be set with 1% resolution
- **Hysteresis:** can be set with 1% resolution
- **Slope:** positive or negative
- **Hold-off:** set as the higher of the relative distance between two successive tacho pulses and the absolute value
  Relative: can be set from 1 to 90%
  Absolute: 0 to 10 s
- **Divider:** can be set from 1 to 8192 in integer steps
- **Averager**: running average of distance between a number of pulses. Can be set from 1 to 999 in integer steps
- **Gearing:** tacho gearing can be defined as a single factor, a ratio containing 4 fractions or the product of these

Post-processing Functions

- Rotational speed

Specifications – Order Analyzer

A number of variants of the order analyzer can be used simultaneously. The order analyzer resamples time signals, then performs an FFT transform on the result. One tachometer output is used as a tracking reference and it determines the digital low-pass filtering, decimation, interpolation and resampling in the order analyzer

Measurement

Any input signal can be measured using an order analyzer

TIME DOMAIN OPERATIONS
- Single or double integration
- Single or double differentiation

FREQUENCY WEIGHTING
- A, B, C, D
- $j\omega^2$, $j\omega$, 1, $1/j\omega$, $1/j\omega^2$

ORDER SPECTRUM ANALYSIS
Order Span: 1–10000 orders
Spectral Lines: 50 – 6400
Tracking Mode: Auto, Steady State, Run-up, Run-down, Fixed Span or Fixed Span Wide

The **Tracking Mode** is used to optimise signal processing according to assumptions made about the change in the fundamental frequency (tacho trend). The tracking modes that can be selected are characterised in the table below

Tacho Trend	Allowed Fundamental Frequency Range Variation Within a Record	
	Wide (≤ 5.92)	Narrow (≤ 2.64)
Increasing	Run-up	–
Decreasing	Run-down	–
Within fixed range	Fixed Span Wide	Fixed Span
Unknown	Auto	Steady State

Post-processing Functions

- Rotational speed

Performance

The processing power required of the PC is measured in terms of "beats". The more analyzers and the more demanding the individual analyses, the greater the number of beats required. Type 7700 offers 25 beats. Further processing power can be obtained by adding a number of Analysis Engines Type 7707. Each Analysis Engine contributes an added 25 beats. The maximum number of Analysis Engines is limited by the specification of the PC. The PULSE Help topic "Scalable Analysis Performance" gives access to a "performance calculator" spreadsheet where the number of beats required can be calculated. See also the System Data for software for Types 3560 C, D, E (BU 0229) for details of minimum PC (PII, PIII, PIV) for specified numbers of Analysis Engines

The following examples show how the order analyzer performs and how many beats are required for various settings. The examples are made from a basic setup for acquisition of 3 signals at 25.6 kHz span, with 1 signal for tacho reference and 2 signals for order analysis
- Acquisition and tachometer cost 8 beats
- Max. overlap itself does not require as many beats as 0% overlap, as max. overlap has a range down to –1000%. But when max. overlap is chosen, the system will use every available resource to get an overlap as high as possible

Beat costs for 67% overlap at various analysis spans (Tracking Mode: Auto*)

Span [kHz]	Overlap [%]	Beats Required Order Analyzer	Beats Required in Total	Number of Additional Analysis Engines Required
25.6	67	59	67	2
12.8		36	44	1
6.4		24	32	1
3.2		18	26	1
1.6		15	23	0

Beat costs for 0% overlap at various analysis spans (Tracking Mode: Auto*)

Span [kHz]	Overlap [%]	Beats Required Order Analyzer	Beats Required in Total	Number of Additional Analysis Engines Required
25.6	0	48	56	2
12.8		30	38	1
6.4		21	29	1
3.2		17	25	0
1.6		15	23	0

Possible max. overlap on a system with 50 beats available at various analysis spans (Tracking Mode: Auto*)

Span [kHz]	Overlap [%]	Beats Required Order Analyzer	Beats Available in Total	Number of Additional Analysis Engines Required
12.8	82	28	50	1
6.4	94	20		
3.2	97	16		
1.6	98	14		

- Any 25.6 kHz Order Analyzer configuration with 2 signals and Auto Tracking mode requires more then 50 beats in total

*** On Changing the Tracking Mode**
- Tracking modes Run-up, Run-down and Fixed Span Wide have the same beats requirement as Auto
- Tracking modes Steady State and Fixed Span require *approximately* 2/3 of the beats required by Auto (for the Order Analyzer)

On Changing the Number of Signals
- Doubling the number of signals for the Order Analyzer doubles the number of beats it requires

Beats Required by the Tachometer
- The Tachometer is analysing the signal at the acquired span
- When using half the acquisition span, the Tachometer uses half the number of beats
- Doubling the number of signals for the Tachometer doubles the number of beats required by the Tachometer

Note:
The specifications given here are based on PULSE version 6.1.5

The other specifications for the order analyzer are the same as for the FFT analyzer, see the System Data for Types 3560 C, D, E (BU 0229)

Ordering Information

Type 7702 G Order Analysis, 1 – 2 channels
Type 7702 A Order Analysis, 3 – 4 channels
Type 7702 B Order Analysis, 5 – 8 channels
Type 7702 E Order Analysis, 9 – 12 channels
Type 7702 C Order Analysis, 13 – 16 channels
Type 7702 F Order Analysis, 17 – 24 channels
Type 7702 D Order Analysis, 25 – 32 channels
Type 7702 H Order Analysis, 33 – 48 channels
Type 7702 I Order Analysis, 49 – 64 channels
Type 7702 J Order Analysis, 65 – 128 channels

The licenses allow measurements on the specified number of channels with order analyzers. The license does not restrict the number of tacho channels

SERVICES
7700 X – MS1 Software Maintenance and Upgrade Agreement
X = A – J corresponding to the same numbers of channels as above
See the Software Maintenance and Upgrade Product Data (BP 1800) for further details of MS1 Agreements

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BP 1634–14 02/06 Rosendahls Bogtrykkeri

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