BE WHAT YOU WANT TO BE

Condition monitoring of belt conveyors on mine sites

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Presentation plan:

1. Introducing myself
2. Introduction to belt conveyors
3. Condition monitoring
4. NDTs
5. Belt repair & installation
6. Scattered energy of vibration – 3rd parameter for vibration assessment
7. Vibration based fatigue damage of bearings
8. Mechanism of belt damage

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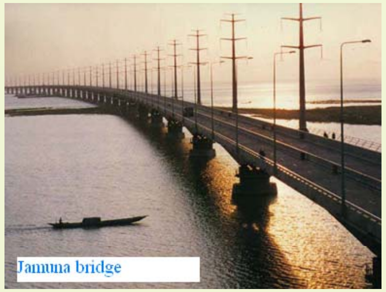
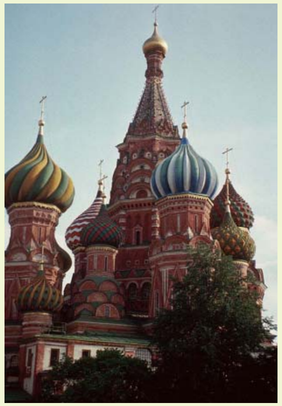
My journey:


Nepal
Bhutan
India
Bangladesh
Dhaka
India
India
Bay of Bengal
Myanmar
(Burma)


Jamuna bridge


Bangladesh home of
Roayl Bengal Tiger

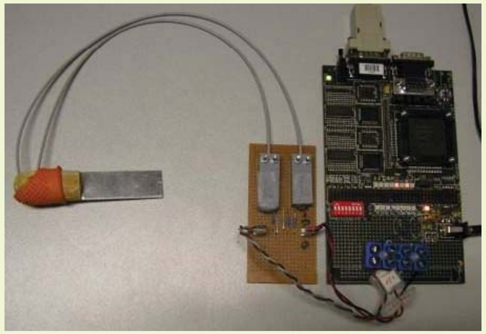


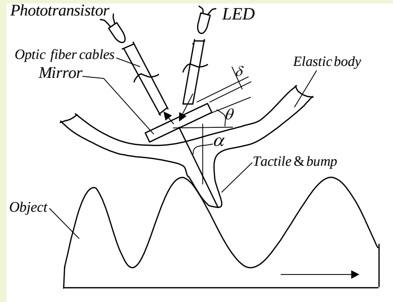

Volgograd

Areas of my specialisation:

- Machine tools design
- Manufacturing Technology

- Mechatronics





- Bulk materials handling

Belt conveyor – the backbone of mining industries:

- Prime bulk transportation means in mining & process industries;
- Capable of carrying a greater diversity of products at higher rates over longer distances;
- Belt conveyor – "A driven endless strap of flexible flat material stretched between two drums and supported at intervals on idler rollers"
- May transport - a daily average of 10,000 tonnes of coal;
- Individual sections of belts may make up an overall length of 100 km or more.
- Belt speed vary within 5-8 m/sec

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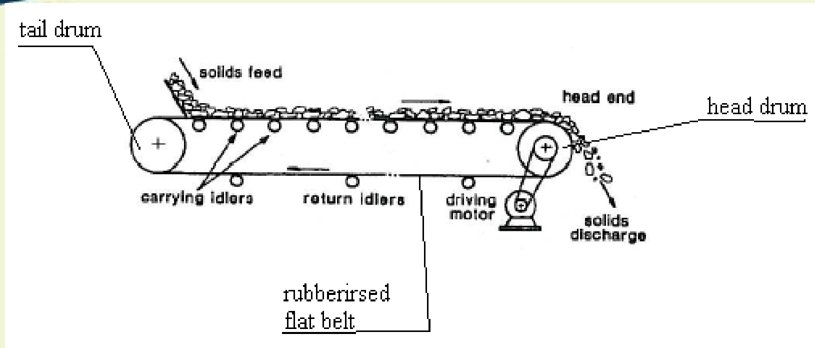
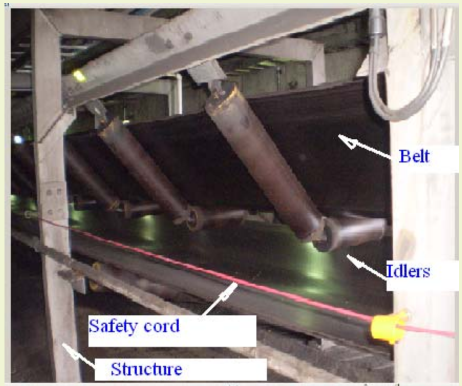
Belt conveyor – design construction





Major units of belt conveyors:

1. Endless flat rubber belt / metal mesh / fabric mesh
2. Driving & driven drums / pulleys
3. Idler rollers / Al or MS
4. Drive system / EM, coupling, gearbox, brake
5. Structural assembly
6. Pre-tension loading

1. Belt stabiliser
2. Belt cleaners / scrappers
3. Emergency stop cord

NOTE:

- The head drum is rotated by belt drive connected to the EM via a gear box (reducer)
- The friction forces created by pre-tension of the flat belt makes it moving
- Idler rollers rotates by themselves on idler bearings supporting the load on belt

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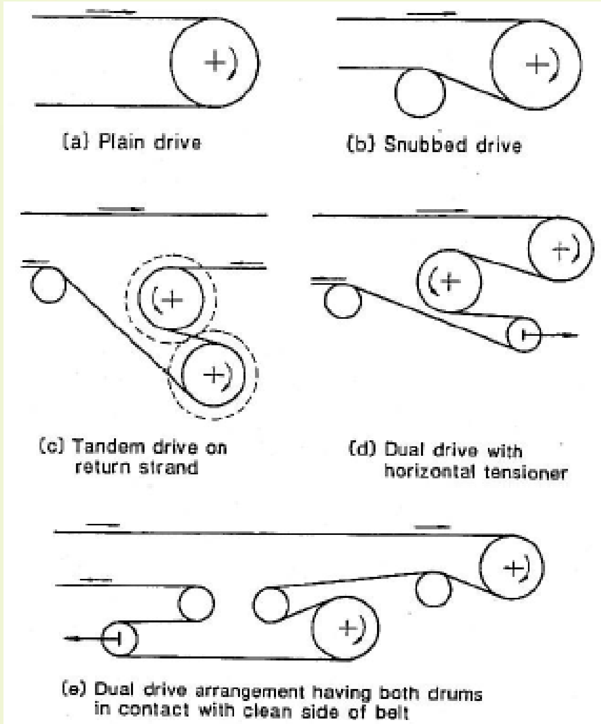
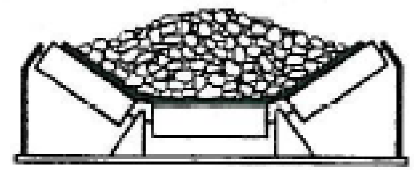
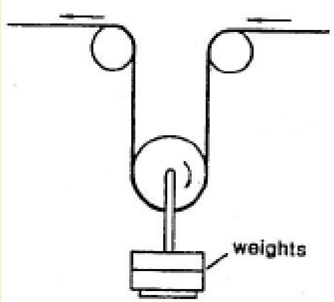
Belt conveyor - intro

Factors helping operation of belt conveyors:

- **Toughness of the belt**
- **Fitting sidewalls to increase the carrying capacity, and**
- **Fitting transverse slats or texturing the surface of the belt**

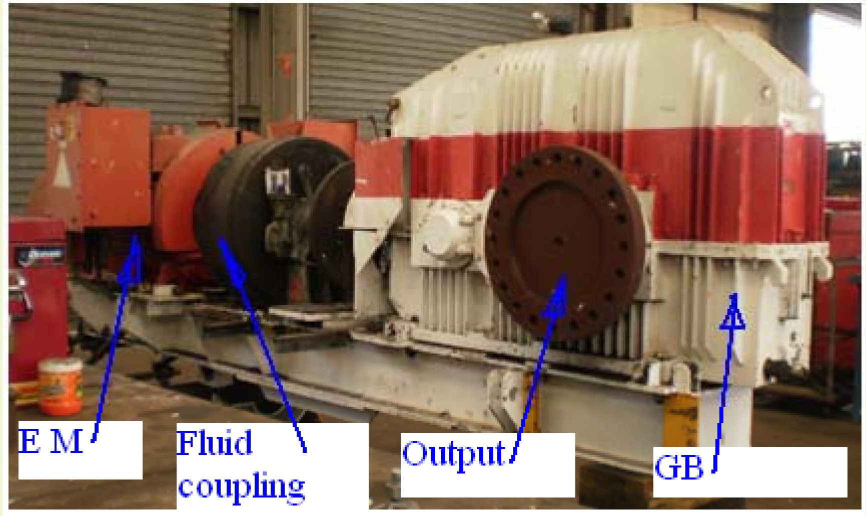



(c) Standard 3-roll idler set



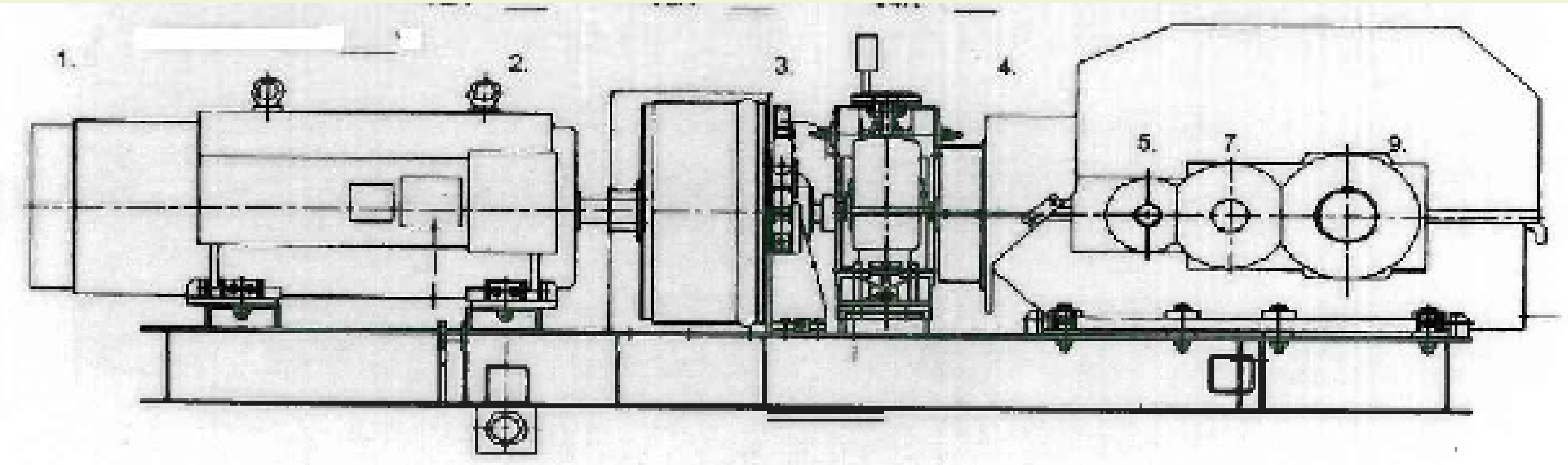
(b) Gravity take-up

Drive system of belt conveyors:



- A high power electric motor / 3-phase asynchronic
- A heavy duty gearbox / input & output shafts
- Fluid coupling / soft coupling
- Brake
- Resilient disc for flexibility

An assembly of a drive system:



Maintenance, Reliability & Condition Monitoring:

Definition of maintenance:

- **To maintain plant in time**
- **Keep your plant in existing working condition**
- **Preserve & protect your plant**
- **Keep your plant from failure & decline**

Objective of maintenance:

- ***To maintain the assets of a company so that they meet the reliability needs at an optimal cost***

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Definition of Reliability:

- *“The probability or duration of failure-free performance under stated conditions”*

Conveyor Maintenance Strategies:

- Reliability Centered Maintenance (RCM) - a process to ensure that assets continue to do what their users require in their present operating context

- Predictive Maintenance (Condition Monitoring) – e.g. Oil Analysis & Tribology, Vibration Analysis, Thermography, NDT (Non Destructive Testing), Ultrasonics, and Motor Current Analysis – All these techniques are used to monitor machine health and help determine if corrective maintenance is required;

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Conveyor Maintenance Strategies:..contd.

- Preventive maintenance & scheduled restoration – Inspection of equipment & components at fixed intervals. e.g. lubrication of pulley bearings;
- Scheduled discard – e.g. replacement of a string of idler trough rollers;
- Calibration –e.g. Instruments / often faults are discovered during calibration and are rectified;
- One-of re-design / one-time replacement;
- Run to failure –e.g. components are run to failure and replaced;

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Points to monitor for belt conveyors:

- Pulley bearings – e.g. Head/Tail/Idlers;
- Belt wear – e.g. Condition/thickness;
- Pulley Wear - Condition/thickness;
- Belt cleaners/Tail plough/Scrapper adjustments;
- Tracking frames –rollers & servo rollers condition and correctly adjusted 20mm clear each side of centred belt;
- Emergency stop cables and switches.

Belt, pulleys, rollers – condition inspection:

- **All pulley shells/lagging for damage or uneven wear;**
- **Operation of belt trackers and adjust to ensure correct alignment / servo rollers have 20mm clearance from the edge of belt, ensure all components move freely;**
- **Inspection of plough scrappers/belt cleaners / replace rubber;**
- **Inspection of skirting for wear & correct adjustment.**

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Oil analysis:

- **Oil analysis** is the sampling and laboratory analysis of a **lubricant's** properties, suspended contaminants, and wear debris

Regular analysis of oil samples from engines, transmissions, hydraulic systems, compressors provide:

- **Oil Condition & performance**
- **Wear trends**
- **Abnormal working condition to pinpoint likely causes**
- **Allows corrective actions to be planned**

Transmission & Lub-oil & cooling fluid testing:

Testings:

- Microscopic studies
- Spectrum analysis
- Sludge testing for metallic particles
- Viscosity
- Density

Regular analysis of used oil from engines, transmissions, hydraulic systems, compressors provide:

- **Establish wear trends**
- **Abnormal working condition to pinpoint likely causes**
- **Corrective can be planned**

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Condition of drive system/ 6000 hrs running

For gear boxes

- Grease labyrinth seals
- Inspect silica gel indicator
- Condition of gear cooler lines
- Visual inspection for oil leaks
- Condition of guarding

For fluid coupling:

- Inspect cooler for oil leakage
- Condition of routing of cooler lines
- Inspect silica gel indicator
- Condition of gear cooler lines

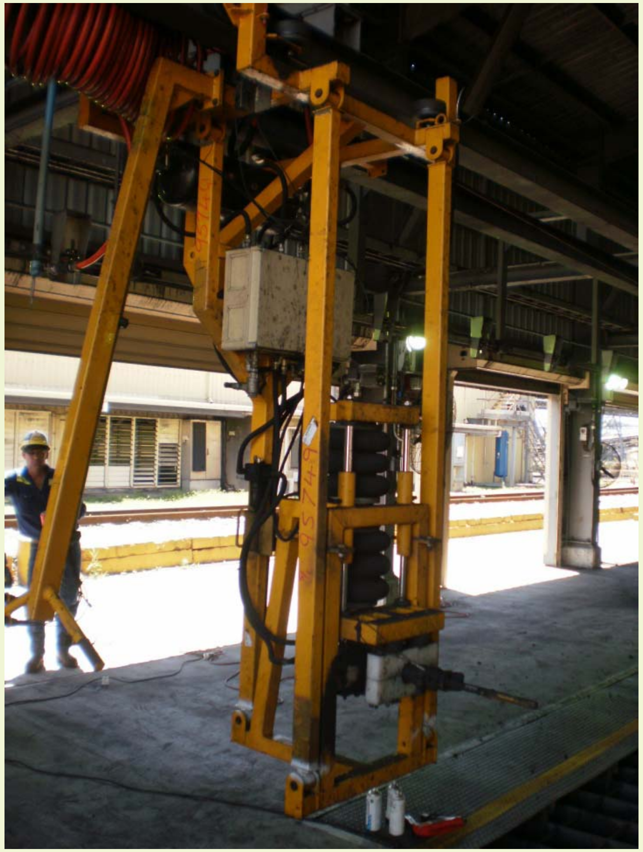
Inspection of structure:

- **Framework for corrosion**
- **Walkways & handrails for damage/corrosion**

NDT methodologies:

1. **Magnetic particle testing for crack detection**
2. **Ultrasonic flaw detection / thickness detection**
3. **Radiographic examination (X-ray / ϒ-ray)**
4. **Dye penetration testing / red & white paints**
5. **Florescent particle testing**
6. **Eddy current testing / aerospace applications**
7. **Visual inspection**

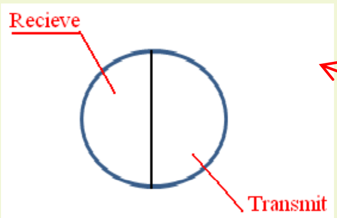
NDT - Magnetic particle testing for crack detection:



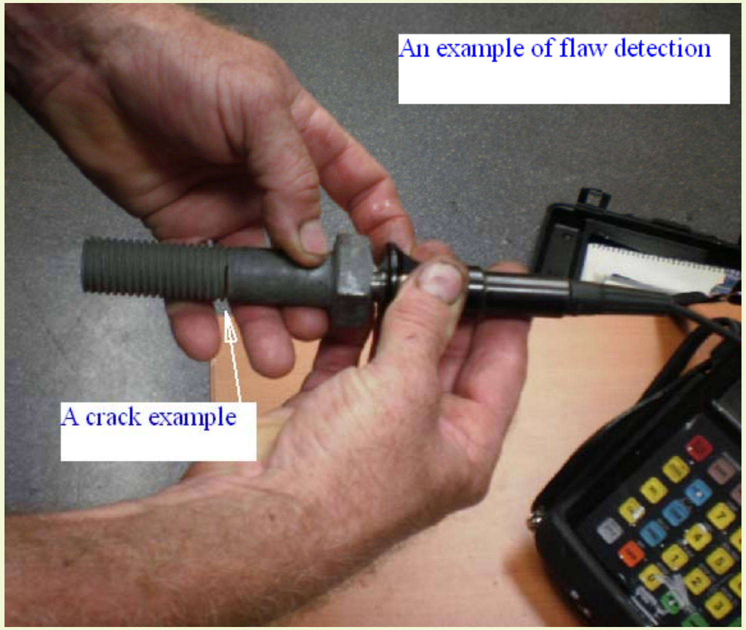
NDT- Ultrasonic flaw & thickness detection

- **Transducer D790-SM 5MHz** / piezielectric element excited by short electrical impulse to generate a burst of high frequency ultrasonic wave;
- Piezoelectric materials - **Quartz crystals, Rochelle salts, barium titanate**
- Sound energy consists of a pattern of organised mechanical vibration travelling through a medium such as air or steel;
- Air is a bad medium for vibration transmission;

37DL PLUS Ultrasonic thickness gauge / GE Panametics



NDT- Ultrasonic flaw & thickness detection – demo:



- Soundwaves in the Megahertz range do not travel efficiently through air
- A drop of coupling liquid is used between the transducer & the test piece;
- Good couplants are glycerin, propelyne glycol, water;

NDT- Ultrasonic flaw & thickness detection..a demo:

Thickness, **T = V x t/2**

V = the velocity of sound in the test material;
.t = the measured round-trip cyclic transit time

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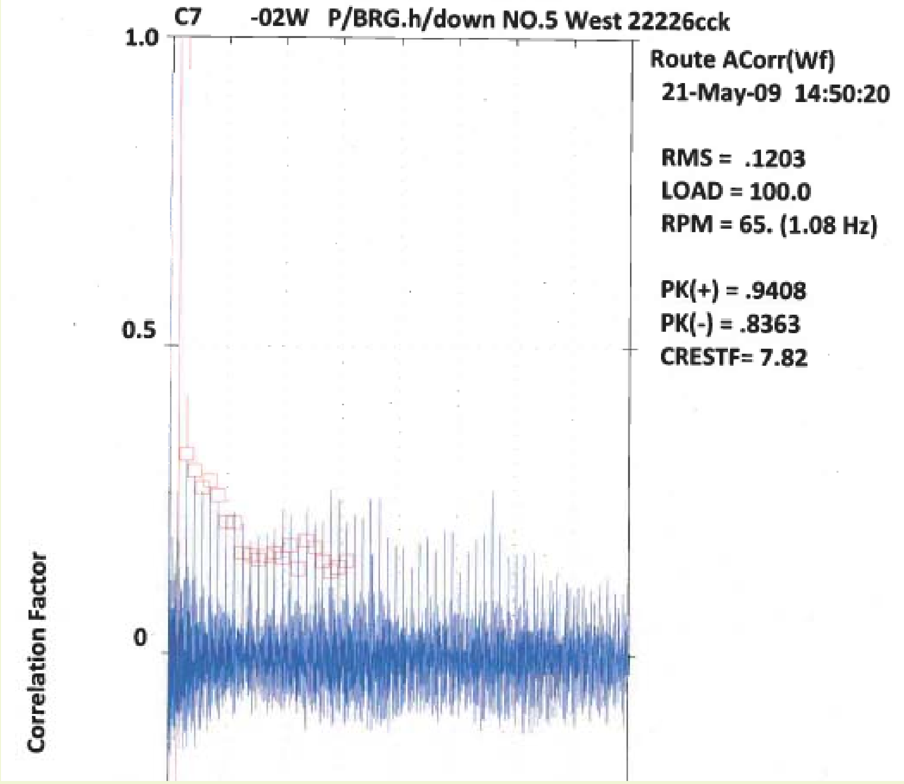
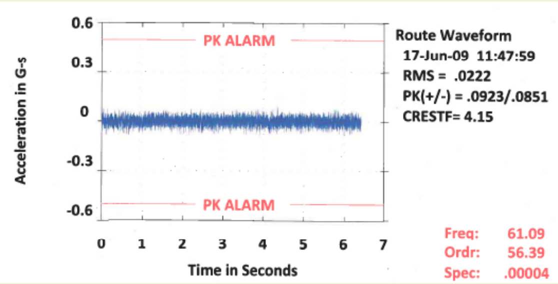
Vibration:

- Bearing defects
- Gear mesh defects
- Misalignment - shaft/coupling
- Shaft axial inaccuracy
- Unbalance
- Resonance

Vibration monitoring

CSI2130 m/c health analyser





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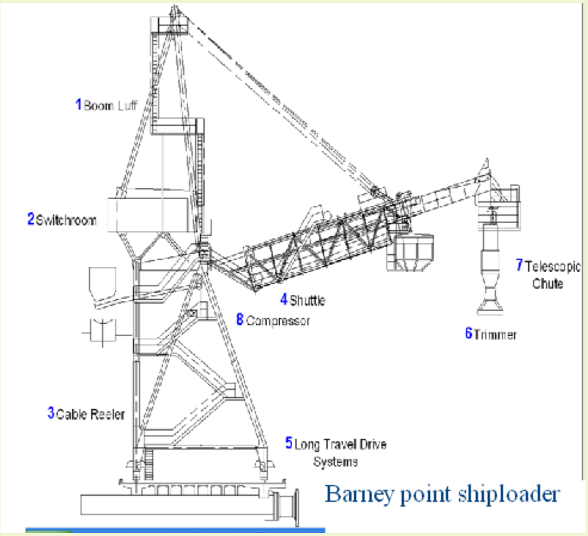
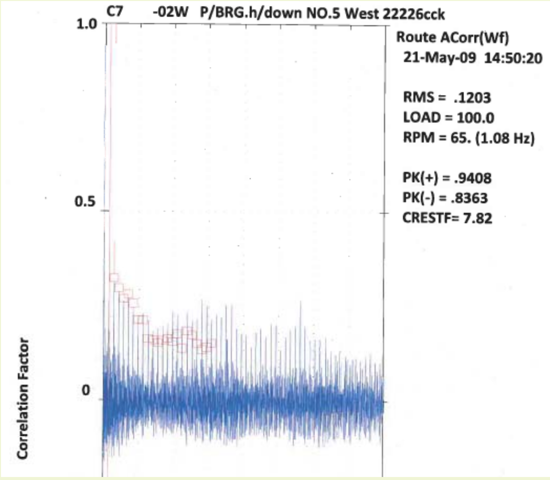
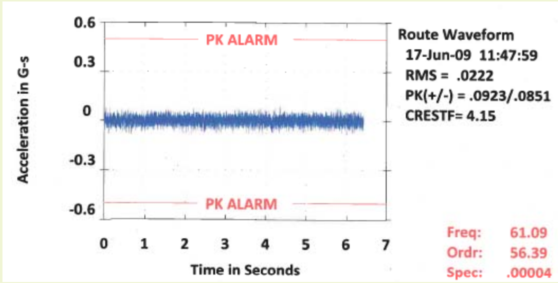
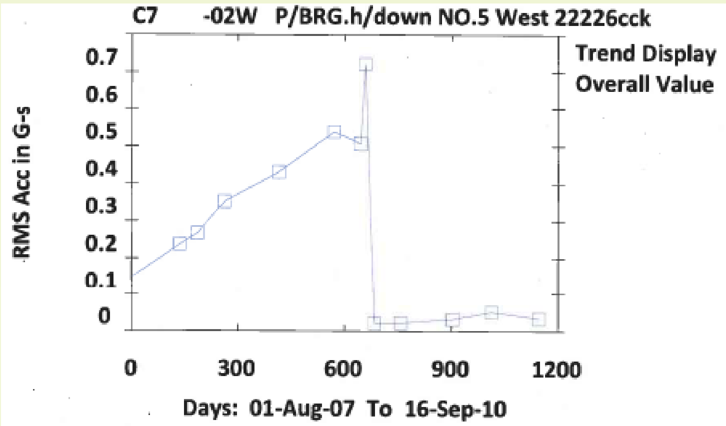
Vibration monitoring – a case study:









Ultrasonic noise detection:

- **Ultrasonic devices** can also be used to detect both high speed and slow speed bearing noise;

- **AE acoustic emission** meters can be used to identify idler bearing distress

Test bearing condition

Temperature recording / Thermography

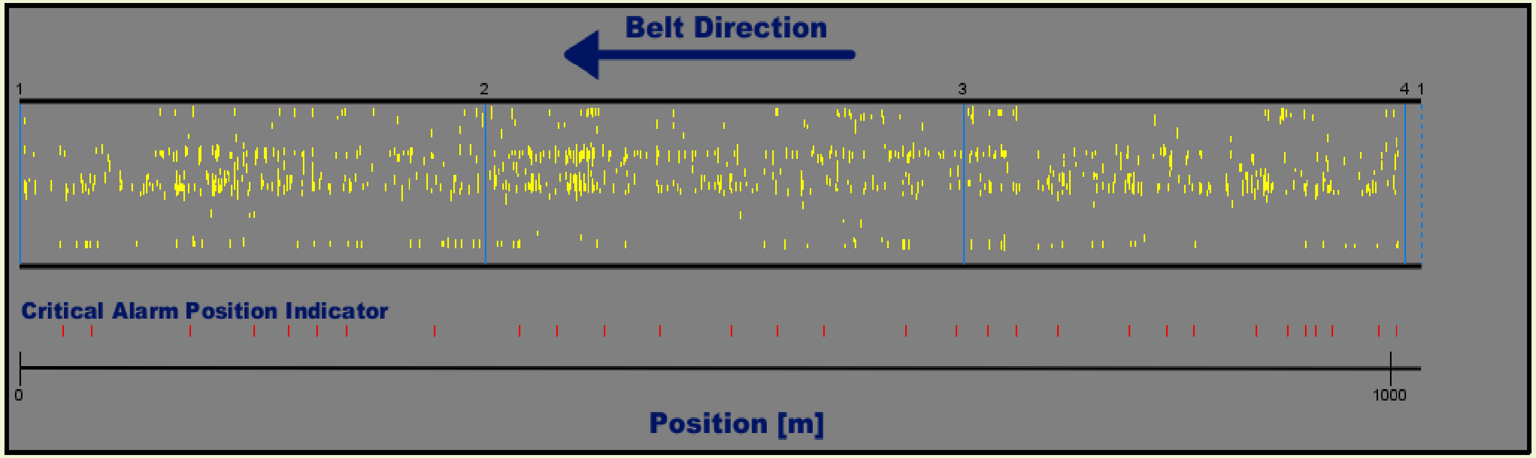
Use of a infrared temperature gun to monitor trough rollers bearing temperatures

Symptoms of broken bearings:

- **Excessive vibrations**
- **Raised temperature**
- **Unusual acoustic emission**

NDT for belts:

- Laser scanning of belts for thickness & metal mesh damage



- Belt shows significant damage by the yellow indicators, the red indicators show critical events, these critical events may be repairs that have been carried out previously

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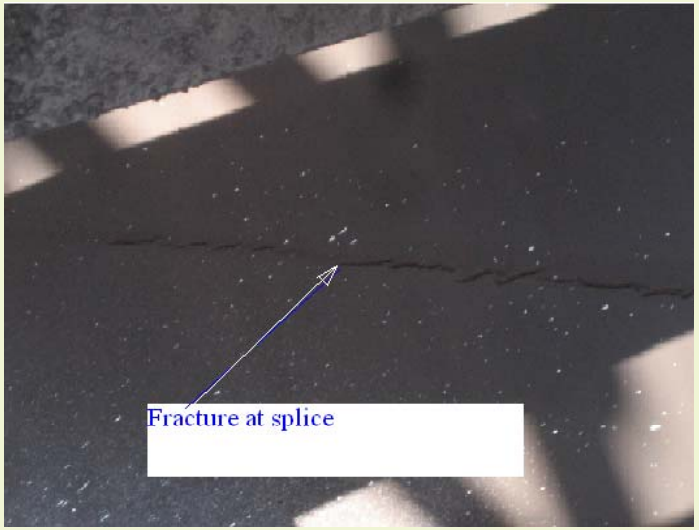
Typical belt damages:



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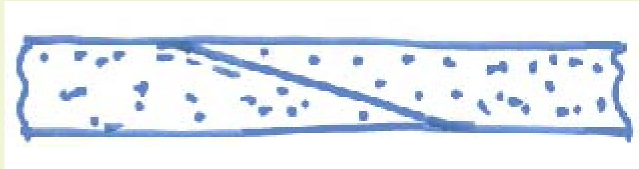
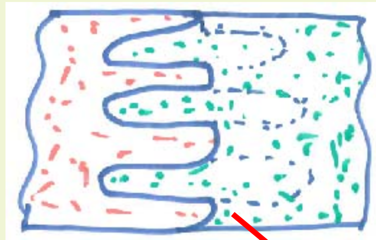
Belt replacement & repair:

Belt splice types:

- **Overlap splice**

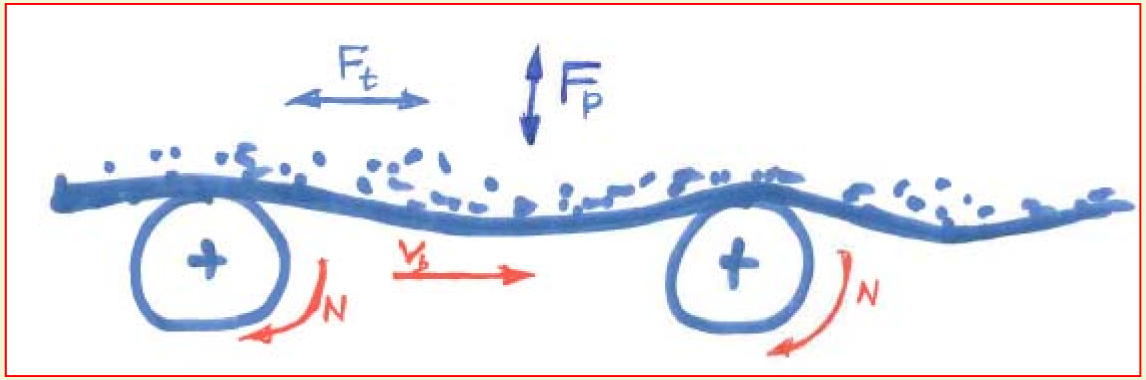


- **Finger splice / high integrity splice**



More joint strength

Mechanism of belt fatigue damage:



- **Actions of Ft & Fp create expansion & compression stresses on the belt causing pulsating fatigue stresses**
- **Rubber portion is flexible but metal wires have a limited expansion capability**

Typical drum damage, repair & replacement:

Shaft restoration:

- metal cladding / laser
- Machining to size

A damaged shaft

Shaft restored

Idler roller bearing damage:

- Hundreds of unexpected idler failure due to bearing damage;
- Failed idlers damage belt, create skives;
- Unexpected shutdown;
- Huge loss of production;

Vibration based fatigue damage of bearings !!!

Reason: Scattered energy of vibration

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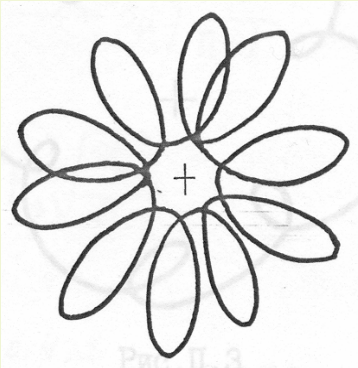
Interpretation of vibration of a mechanical body:

- Faster translation of mass of a body / shaft / spindle / particles in chaotic manner, in unaccountably multiple directions

- Mechanical vibration of a shaft/spindle mounted on bearings - chaotic oscillation of the shaft axis during its rotation in unaccountable multiple directions

- Any motion that repeats itself after an interval of time is called “vibration” or “oscillation”

Piotrashke P. found the following phenomena studying machine tool spindle rotation: oscillographic models of spindle-nose vibration

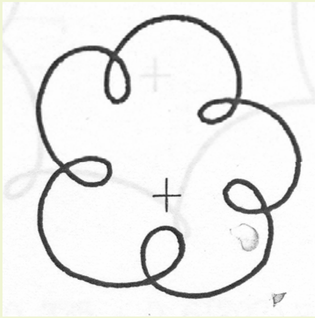


Z=6

K=5

ω=(p-1)

P=0.56z

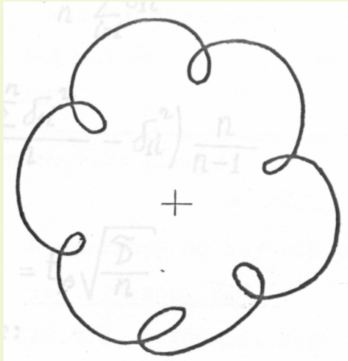


Z=9

K=5

ω=(p+1)

P=0.56z

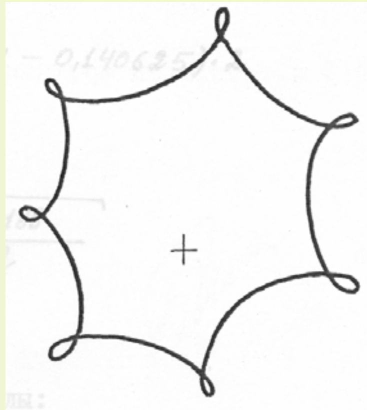


Z=10

K=11

ω=(p+1)

P=0.56z



Z=12

K=11

ω=(p-1)

P=0.56z

Z=No. of rolling elements; K=face-centricity; ω=angular velocity in rad

P=number of peaks

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How do we assess vibrations conventionally?

By evaluating the following parameters:

Galileo Galilei

1) Frequency of vibration
2) Amplitude of vibration

Proposed a 3rd parameter:

- Scattered energy of vibrations

So, what is "Scattered Energy of Vibration" ?

- Scattered Energy of Vibration -"the energy emanated during vibration by the force generating motion / translation of a mass to a particular displacement"
- Scattered Energy of Vibration – it creates impact forces

Therefore, the conclusion: what we need for modelling of energy?

- Determine the micro-translations of mass-load / mass-moment – (displacement)
- Velocity of translation of the mass-load to get the force
- Determine the acting portion of forces

(NOTE: during calculation "work" to be converted into "energy")

…………………………………………………………………….

"the energy emanated during vibration by the force generating motion of a mass to a particular displacement"

…………………………………………………………………….

NOTE:

- Micro-translations viz shaft vibrations are emanated from individual cause

Particular example and objectives:

- Application of scattered energy of vibrations of a high-speed spindle for its life prediction

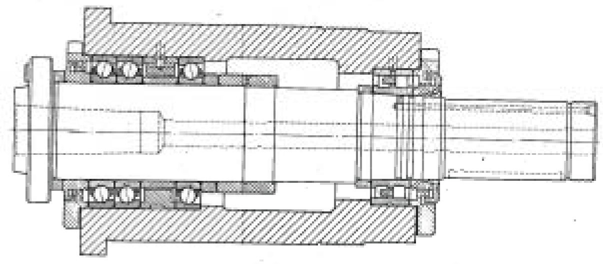


Fig.. A high speed spindle (Europe)

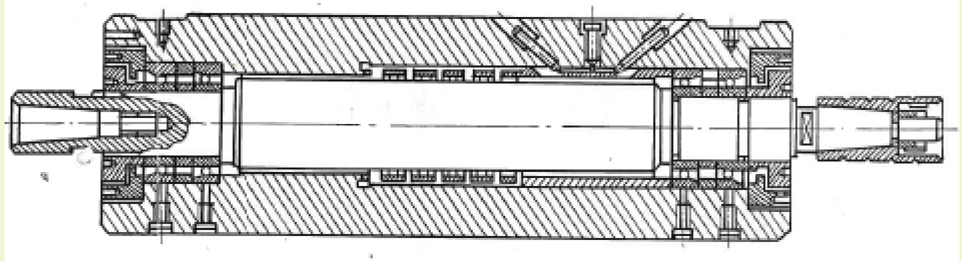
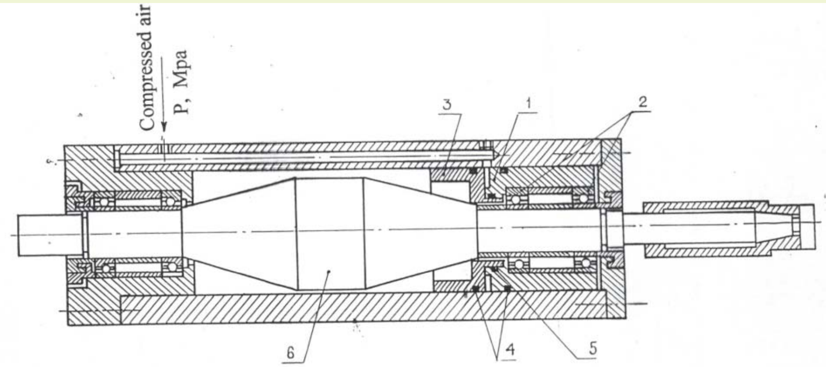


Fig...... A standard high speed spindle (Russia)



Causes of spindle vibrations:

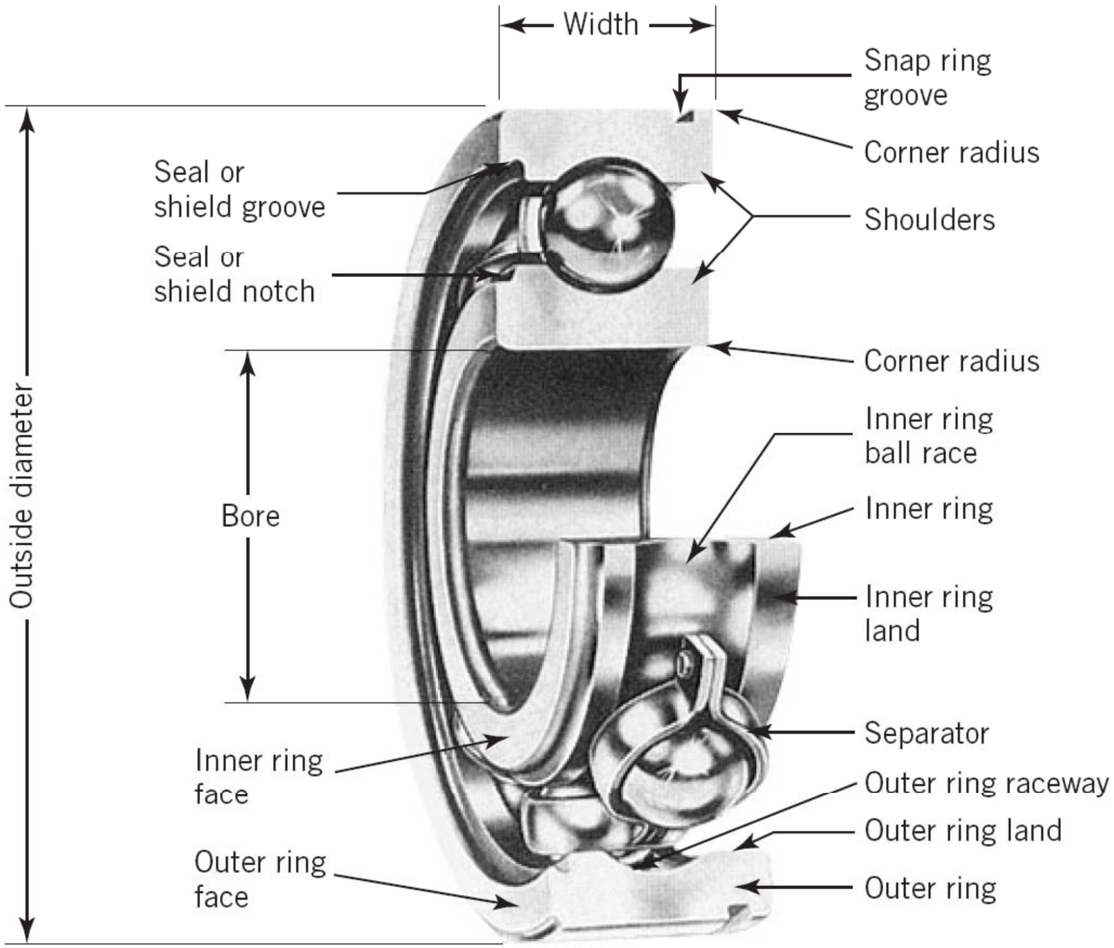
1) Deviation of ideal geometric shape i.e. profile irregularities of working surfaces and surface texture of outer and inner races of spindle bearing;

2) Deviation of ideal geometric shape of rolling elements (balls, rollers and needles) or scattered location of the latter having different tolerances during bearing assembly;

3) Technological fit-gap between rolling element and the nest of the separator (cage) of bearings;

4) Ovalness of races of rings of the spindle bearing;

Nomenclature:



(*a*)
Construction and nomenclature

Causes of spindle / shaft vibrations: ..(contd…)

5) Presence of fluidic and other hard dust particles on the working surfaces;

6) Elastic contact deformation of rolling elements and rings during high loading of spindles;

7) Manufacturing quality of separator and other elements of bearings; and

8) So many to enlist.

Hence the novel parameter:

- Scattered energy of vibrations *(En)* emanated from individual causes of vibrations

NOTE:

- Scattered energy of vibration – is the energy emanated during vibration by the motion of a body to a particular displacement and this energy is instantly disbursed around in its environment as it is emanated.

The Total Scattered Energy of Vibrations for a high-speed spindle:

$$\sum En = \xi \,(En.pi + En.fg + En.be + En.ov + \quad --) \quad (9)$$

Where,

- ξ - Coefficient of occurrence probability of a spindle/shaft vibrations or simply the factor of vibration probability. It considers all other probable vibrations emanated from known and / or unknown causes except those identified and taken into account.

What's happening with this Total Scattered Energy of vibrations?

It instantly is disbursed in the following four ways, and that's why its called scattered energy:

- *En.dest* (portion-energy accumulated in the crystal lattice of bearing material)
- *En.cond* (portion-energy conducted into surrounding components of the spindle head)
- *En.rad* (portion-energy radiated in the surrounding environment)
- *En.ac* (portion energy converted into acoustic energy)

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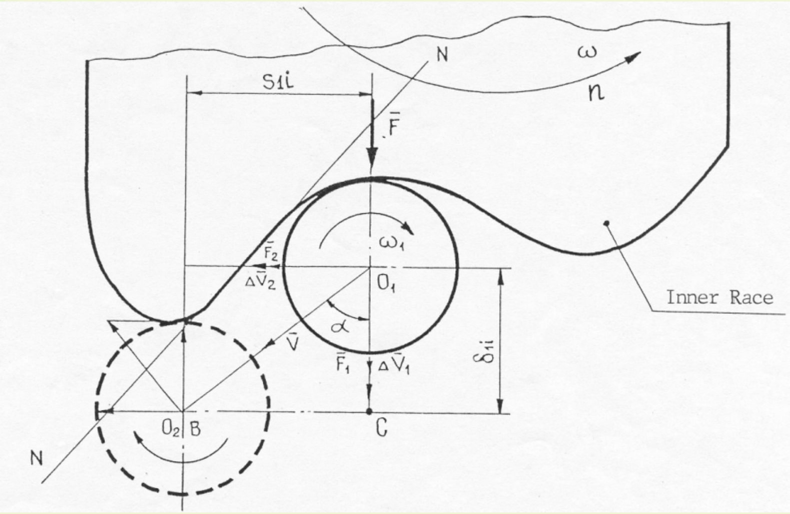
1. Scattered energy of vibration due to profile irregularities *(En.pi)*



$$En.pi = \gamma \cdot M \cdot \frac{2\,\pi z\, n^2}{60} \cdot R \cdot \sum_{i=1}^{k} \cos(arctg\,\frac{S_{1i}}{\delta_{1i}}) \cdot \delta_{1i}; \qquad (5)$$

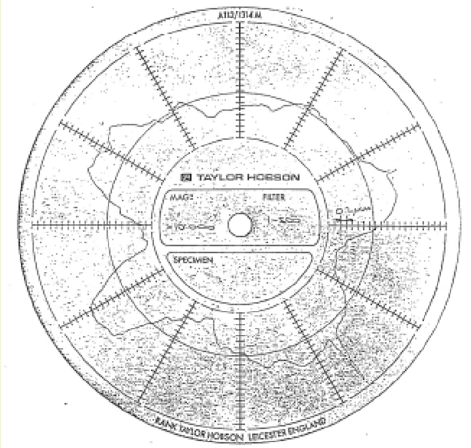


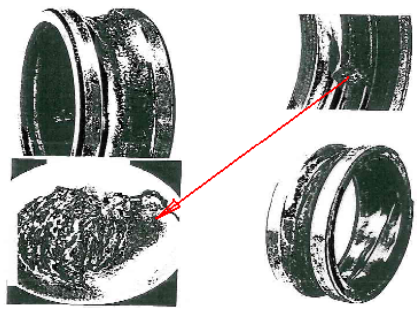
Fig. 2.3 Roundness diagramme of inner ring race of spindle bearing

M - Deduced average mass-load on the considered centre of rotation of the shaft.
z - Quantity of rolling elements in the bearing considered;
n - Speed of spindle rotation (rpm);
R - Deduced average radius of rotation of the system;
γ - Coefficient of relative slip of rolling element;
S_{1i}, δ_{1i} - Geometry of i-th profile irregularity of race of inner ring of spindle bearing as in the Figure;

Bearing damage

Bearing Outer Race

Bearing Inner Race - Double row spherical



Signs of pitting

Hypothesis - Criterion of working surface destruction of bearings due to scattered energy of vibration:

"Vibration based fatigue damage of bearing parts occurs due to accumulation of scattered impact energy of shaft/spindle vibration in the crystal lattice of bearing parts, achieving the threshold energy required for damaging the crystal-bonding of material initiating fracture in working surfaces bearing parts."

The hypothesis promotes the phenomena of vibration based fatigue damage of working-surfaces discovering the real causes of fatigue damage and fatigue crack initiation in metals.

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Criterion of working surface destruction:

We have the energy balance formulated:

$$\sum E_{n.scat} = \left(E_{n.dest} + E_{n.cond} + E_{n.rad} + E_{n.ac}\right)$$

Rewriting this we get the a criterion for working surface destruction:

$$\left(\sum E_{n.sc} - E_{n.cond} - E_{n.rad} - E_{n.acc}\right) \geq E_{n.dest}$$

Application of scattered energy of vibration model for idler bearing fatigue damage:

Have done these:

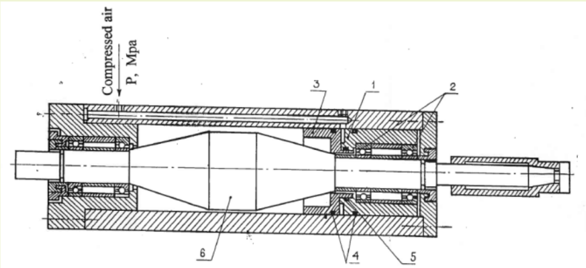


Fig. 4.1 High Speed Spindle Block VShG-33 (ENIMS)

1- bearing housing, 2 - outer ring of bearing, 3- support, 4, 5 - gaskets, 6 - spindle shaft

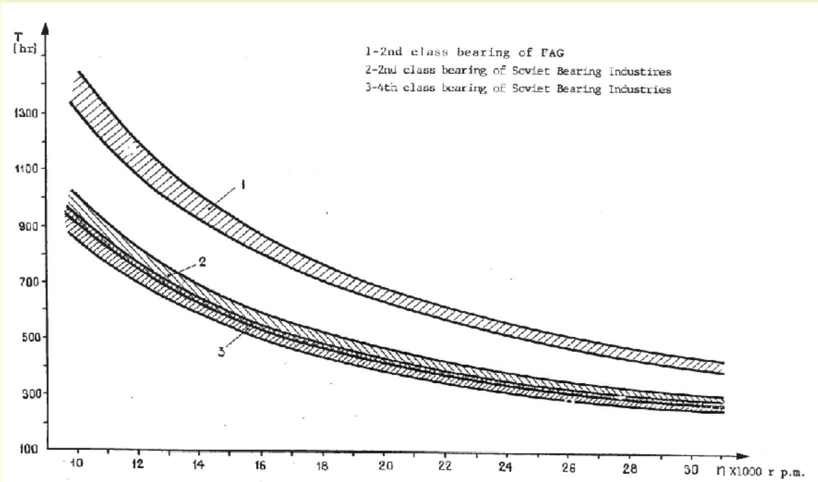
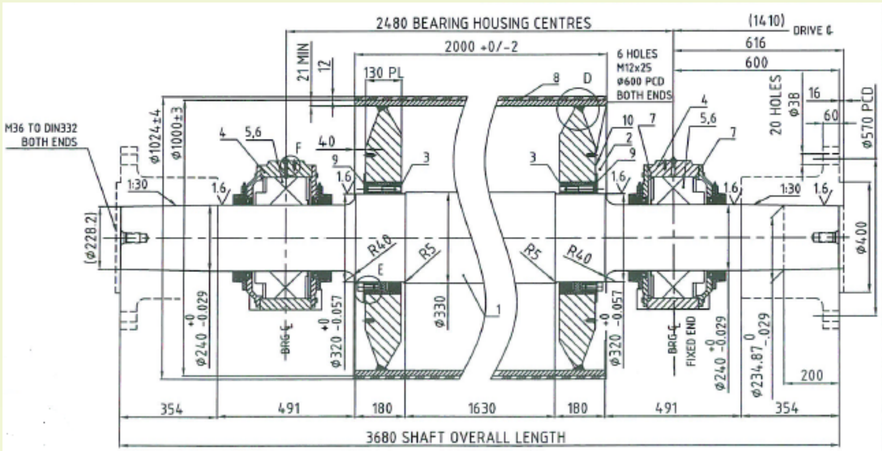


Fig 4 2. The Area of Working Ability of High Speed Spindle VSHG-33 (ENIMS)

Want to do for these:



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Question Time

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