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ANALYSIS OF RESONANCE OF A SURFACE GRINDER

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ABSTRACT

The structure of a surface grinder comprises of a base, all the other machine members like column, the reciprocating table, the grinding wheel, spindle and spindle motor are all supported on the base. In the design of one such surface grinder waviness was observed on the ground surface. It has become necessary to investigate into the behavior of the machine under working conditions. Investigation showed that some machine components are getting into excessive vibrations. This waviness could arise due to vibrations of the machine structure while working. It is observed that the cause of such waviness is due to resonance which leads to abrupt vibrations that intern affect the surface finish and the structure itself. The present project focuses on redesigning of the surface grinder model which has maximum working speed of 3000 rpm. In order to avoid resonance the dimensions are changed in such a way that the natural frequency of the model is either reduced or increased. One method of investigation is through the experimental approach. However this approach is expensive and requires good amount of lead time. The present project employs Finite element method for investigating into the vibration characteristic of the machine. Using the FEM, surface grinder is modeled and analyzed to find out the weak links causing vibrations by modal analysis method. The design of the weak links is improved and the analysis is repeated to bring down the vibration to admissible level. The harmonic analysis is also carried out to find out the vibration amplitude and velocity. Analytical procedure is used to confirm the predicted FEM results.

KEY WORDS: Surface grinder, Resonance, Vibrations, Frequency, Harmonic analysis, etc

The phenomenon of mechanical vibration is encountered by everyone in course of their daily life. The effect is not always unpleasant, as every person who attempts to concentrate while road drills are being operated will agree. Vibration is not only physically pleasant but may also weaken a structure. It must therefore be regarded as a most undesirable condition, which must be eliminated for both comfort and safety. As mechanical vibration is found so frequently in everyday life, its study is believed to appeal to every one of us.

Most Engineering machines and structures experience vibration to some degree or other. A machine cannot be isolated from vibrations completely. In normal conditions the vibration levels in many systems are small, but sometimes a new machine when put into operation show violent vibrations, the reason could be faulty design resulting in excessive vibrations. This vibration level, if analyzed, could lead to conclusion in advance, regarding a possible failure of the machine in future.

NEED OF ANALYSIS

Vibration analysis assumes special significance in view of the following characteristics:

- From the design point of view, the magnitude and frequency of vibration need to be known to ensure that the stresses induced are not large for the material to withstand.
- Also if a certain piece of machinery is found to resonate at the given frequency, running that machine at a speed, which will excite that resonance, can often be avoided.
- For vibration damping or isolation, it is necessary to know the amplitudes and frequency involved in order to be able to select the correct damping material.

CAUSES OF VIBRATION

- There are two factors which control the amplitude and frequency of vibration in a structure which are the excitation applied and the response of the structure to that particular excitation. Changing either the excitation or the dynamic characteristics of the structure will change the vibration stimulated. The excitation arises from external sources such as ground, cross winds, earthquakes and sources internal to the structure such as moving loads and rotating or reciprocating engines and machinery. These excitation forces and motions can be periodic or harmonic in time or due to shock or impulse loadings or even random in nature.
- The response of the structure to the excitation

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depends on the method of applying and the location of the exciting force or motion and the dynamic characteristics of the structure such as its natural frequencies and inherent damping level.

REDUCTION OF VIBRATION

- Reducing either the excitation or the response of the structure to that excitation or both can attenuate the level of vibration in a structure. It is sometimes possible at the design stages to reduce the exciting force or motion by changing the equipment responsible, by relocating it within the structure or by isolating it from the structures so that the generated vibration is not transmitted to the supports. The structural response can be altered by changing the mass or stiffness of the structure by moving the source of the excitation to another location or by increasing the damping in the structure. Naturally, careful analysis is necessary to predict all the effects of any changes, whether at the design stage or as modification to an existing structure.

SURFACE GRINDER

- Surface grinding is used to produce a smooth finish on flat surfaces. It is a widely used abrasive machining process in which a spinning wheel covered in rough particles (grinding wheel) cuts chips of metallic or non metallic substance from a work piece, making a face of it flat or smooth. Surface grinding is the most common of the grinding operations. It is a finishing process that uses a rotating abrasive wheel to smooth the flat surface of metallic or nonmetallic materials to give them a more refined look or to attain a desired surface for a functional purpose.

- The surface grinder is composed of an abrasive wheel, a work holding device known as a chuck, and a reciprocating or rotary table. The chuck holds the material in place while it is being worked on. It can do this one of two ways: ferromagnetic pieces are held in place by a magnetic chuck, while non-ferromagnetic and nonmetallic pieces are held in place by vacuum or mechanical means. A machine vise (made from ferromagnetic steel or cast iron) placed on the magnetic chuck can be used to hold non-ferromagnetic work pieces if only a magnetic chuck is available. Factors to consider in surface grinding are the material of the grinding wheel and the material of the piece being worked on.

- Typical work piece materials include cast iron and mild steel. These two materials don't tend to clog the grinding wheel while being processed. Other materials are aluminum, stainless steel, brass and some plastics. When grinding at high temperatures, the material tends to become weakened and is more inclined to corrode. This can also result in a loss of magnetism in materials where this is applicable.

- A surface grinder is a machine tool used to provide precision ground surfaces, either to a critical size or for the surface finish. The typical precision of a surface grinder depends on the type and usage, however ±0.002 mm (± 0.0001") should be achievable on most surface grinders.

PROBLEM DEFINITION

- In the given model the surface finish is not to the manufacturing standards. The manufacturing standard is 0.0005 mm. In the design of a surface grinder waviness was observed on the ground surface. It has become necessary to investigate into the behavior of the machine under working conditions. According to balance quality grade ISO the vibration velocity should be 0.4mm/sec. Due to the resonance waviness is caused on the surface.
- Finite element method is used for investigating into the vibration characteristic of the machine. Using the FEM weak links causing the vibration is identified and redesigned to bring down the vibration to admissible level.

LITERATURE REVIEW

There are two main objectives, which involves on the development of a surface grinder. Firstly, the appropriate static and dynamic characteristics of the existing surface grinder have to be determined. Secondly, structural development process in order to achieve High quality of the product. There are many factors involve and must take into account. Today, there are many researches and development program available in the markets which are very much related to this study. Therefore, there are several technical papers and some other sources which are reviewed and Discussed in this chapter.

Y.X.Jiang, W.X.Tang, G.L.Zhang, Q.H. Song, B.B.Li and B.Du [2007],conducted an Experiment of Investigation for Dynamics Characteristics of Grinding Machine, in this article, modal experiments were used to analysis the dynamics characteristics of the grinding machine. This experiment laid a foundation to optimize the structure parameter to improve the dynamic character of the grinding machine.

Z.Y. Weng, W.D. Xie, B. Lu, Y.W. Ye, H. Yao and X.S. He [2004], experimented on Grinding Chatter and Ground Surface Waviness in Surface Grinding Process. The results show that cutting depth is the leading factor in grinding chatter and ground surface waviness in surface grinding process.

Zeyu Weng, Bo Lu, Hongwu You, Honggang Ding, Yong Cai, Guanchen Xu and Nannan Zhang[2009], experimented on the Influence of the Grinding Wheel Topography on Grinding Chatter and Grinding Surface Waviness. The experimental research results show that the grinding depth is a main factor which affects grinding chatter and grinding surface waviness on the grinding surface. Thus a further exploration has been made in the formative mechanism of grinding chatter and grinding surface waviness.

Tonshoff, H.K., and Foth, M [1988], studied surface waviness resulting from single point diamond dressing in cylindrical grinding. This paper describes an experimental investigation of workpiece surface waviness that stems from poor single point diamond wheel dressing procedures in cylindrical grinding. Test results verify that dressing induced circumferential waviness is similar to waviness resulting from one per rev type vibrations of the grinding wheel.

A.H.Koevoets [2003], conducted time effective transient analysis using ANSYS mechanical and Matlab Simulink. The performance of the Elite® advanced resonant power toothbrush is measured in terms of oral biofilm removal and improvements in oral health over time. These are strongly related to the mechanical performance of the brush head and bristles located on it.

METHODOLOGY

ANSYS is a general purpose, finite element computer program for engineering analysis. ANSYS is an integral part of the overall CAD environment. The ultimate purpose of a FEA analysis is to re-create mathematically the behavior of an actual engineering system. In other words, the analysis must be an accurate mathematical model of a physical prototype. In the broadest sense, this model comprises all the nodes, elements, material properties, real constants, boundary conditions & other features that are used to present the physical system.

The surface grinder is modeled in ANSYS. The dimension of the model is changed to avoid the resonance. The surface grinder column thickness is restricted up to 20 mm. The dimensions are changed in such a way that the natural frequency of the model is either reduced or increased above 50 Hz. The working speed of the surface grinder is 50 Hz.

Specifications of Surface Grinder Model

The material used for the surface grinder model is cast iron. The properties of the cast iron are Young's modulus is 11001 N/mm^2, Poisson's ratio is 0.28 and density is 7.8×10^{-6} kg/mm^3. The dimension of the given model is as given below:

- Bed (2000×500×700) mm, thickness-20mm.
- Column bed (400×200×700) mm, thickness-20mm.
- Wheel head column (360×200×1000) mm, thickness-14mm.
- Wheel head (280×200×180) mm,thickness-20mm
- Work table (1400×385)mm ,thickness-100mm

The specifications of the grinding wheel are as given below:

- Wheel dia – 200mm
- Thickness – 50mm
- Weight of the Wheel – 6kg
- Weight of the Spindle – 16kg
- Weight of the Motor – 15kg

The material used for the spindle is steel and the properties and the dimensions are Young's modulus is 21000 N/mm^2, Poisson's ratio is 0.28 and density is 7.8×10^{-6} kg/mm^3. The dimension of the spindle model is as given below:

- Dia – 70mm
- Front bearing – (ϕ60 × ϕ100) mm
- Rear bearing – (ϕ50 × ϕ90) mm

The surface grinder is constrained in all the direction at the base. The load of the motor, wheel and spindle is applied on the surface grinder. The loads and forces values are applied on the model as given below:

- Load at the wheel = 20 kg
- Load at the motor = 30kg
- Force at wheel = 0.44kg
- Force at motor = 0.7226kg

Surface Grinder Geometric Model

Figure 1(a) and (b) shows the geometric model and meshed model of surface grinder. The surface grinder model is meshed and the base is constrained in all the direction. The loads are applied on the grinder shell. The forces are applied on the grinder shell at the ends. The forces are applied in Y axis at the ends in opposite direction to each other.

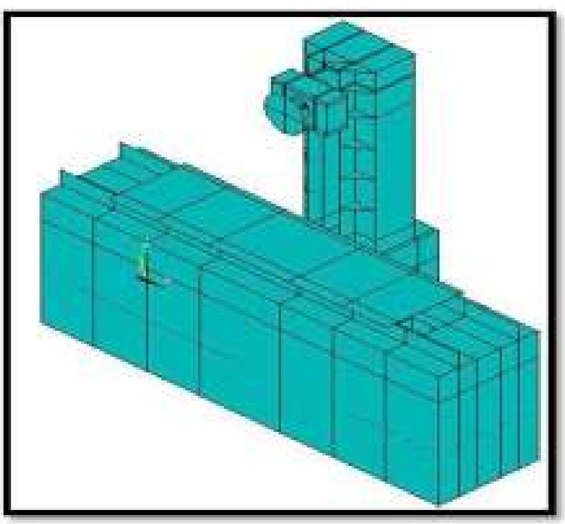

Figure 1(a): Surface Grinder Geometric Model

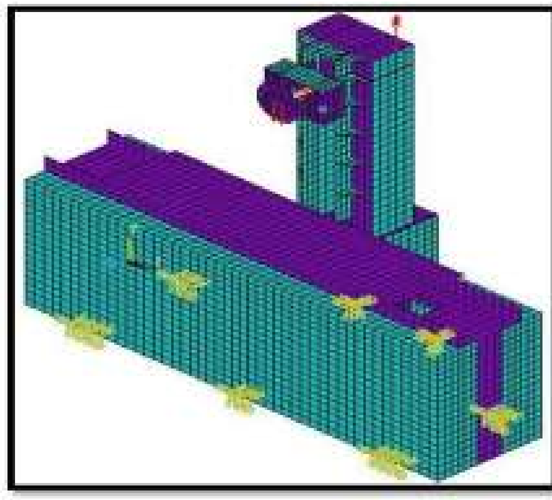

Figure 1(b): Meshed Model

The Static and harmonic analysis are carried out with change in dimensions of the weak links and the results are reviewed.

Analysis Performed on Model 1

Modal analysis is used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It also can be a starting point for another, more detailed, dynamic analysis, such as transient dynamic analysis, a harmonic response analysis, or a spectrum analysis. The table 1 shows the frequencies at which the model resonates.

Table 1: Modal Analysis for Model 1

Set	**1**	2	3	4	5
Frequency	5.317	7.604	7.906	12.27	15.34
Set	6	7	8	9	10
Frequency	17.53	48.21	48.97	71.40	91.71

The table shows that at sub- set 7 and 8 the frequency is near to working frequency i.e. 50 Hz which causes resonance. The mode shape at sub step 8 is of our interest because this causes the surface waviness.

Mode Shape for Model 1

Figure 2 shows the mode shape 8 at freq 48.977 Hz. The figure shows the mode shape of column deflecting in the YZ plane

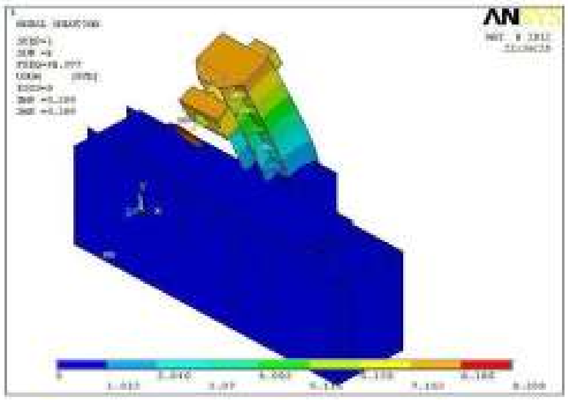

Figure 2: Mode Shape 8 for Iteration 1

The Fig 2 oscillates in the YZ plane which is of our concern. So our aim is to reduce the resonance which can be done either by reducing the frequency or increasing the frequency. This can be done by making the frequency above 50 Hz because our machine speed is 50 Hz, thus it does not affect it.

Harmonic Response Analysis for Model 1

Any sustained cyclic load will produce a sustained cyclic response (a harmonic response) in structural system. Harmonic response analysis gives the ability to predict sustained dynamic behavior of the structure, thus enabling to verify whether or not the designs will successfully overcome the resonance, fatigue and other harmful effects of force vibrations.

Harmonic response analysis is a technique used to determine the steady state response of a linear structure to the loads that vary sinusoidal with time. The idea is to calculate the structures response at several frequencies and obtain a graph of some response quantity (usually displacements) Vs frequency. The harmonic response analysis is found out with amplitude graph and vibration velocity graph.

The Fig 3(a) shows the amplitude V/s frequency graph and the Fig 3(b) shows graph between velocity vibration V/s frequency.

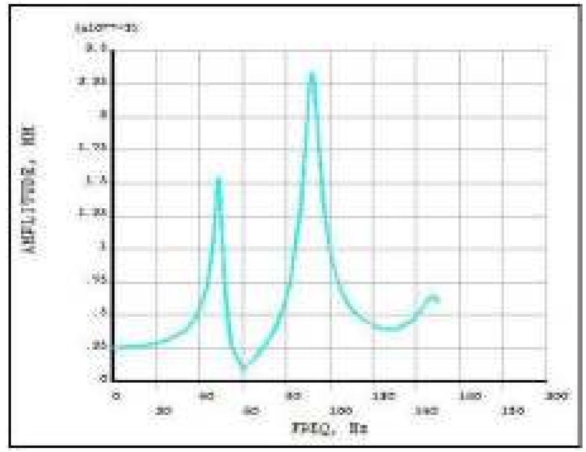

Figure 3(a): Amplitude V/s Frequency

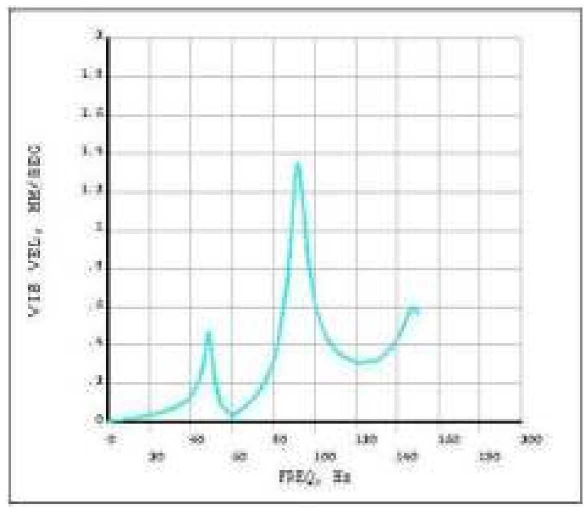

Figure 3(b): Vibration velocity V/s Frequency

The Fig 3(a) shows that the maximum amplitude is 1.5×10^{-3} mm and 2.3×10^{-3} mm and the Fig(b) shows that the maximum vibration velocity is 0.5 mm/sec and 1.3 mm/sec. We consider the first maximum amplitude because it is in the range of working frequency i.e. near to 50 Hz. Thus our aim is to reduce the first vibration velocity to the manufacturing standards.

Analysis Performed on Model 2

The surface grinder model 2 is analyzed by changing the thickness of the column from 14mm to 20 mm. At sub step 8 the frequency is above the working frequency which is safer. The amplitude is 1.25×10^{-3} mm which is not to the manufacturing standards.

Analysis Performed on Model 3

The surface grinder model 3 is analyzed by changing the dimension of the column of the surface grinder from (360×200×1000) mm to (360×300×1000) mm. At sub step 8 the frequency is 78.682 Hz. The graphs shows that the maximum amplitude is 7.2×10^{-4} mm and 0.35 mm/sec which is still not to the manufacturing standards.

Analysis Performed on Model 4

The surface grinder model 4 is analyzed by changing the thickness of the column from 14mm to 20 mm and also the dimension from (360×200×1000) mm to (360×300×1000) mm. The Table 2 shows the frequencies at which the model resonates.

Table 2: Modal Analysis for model 4

Set	**1**	2	3	4	5
Frequency	5.317	7.604	7.905	12.28	15.34
Set	6	7	8	9	10
Frequency	17.53	54.99	79.96	103.8	146.4

We can see from the table that at sub step 8 the frequency is above the working frequency which is safer. The frequency has increased from 48.97 Hz to 79.968 Hz.

Harmonic Response Analysis for Model 4

The harmonic response analysis is found out with amplitude graph and vibration velocity graph. The Fig 4(a) shows the amplitude V/s frequency graph and the Fig 4(b) shows graph between velocity vibration and frequency.

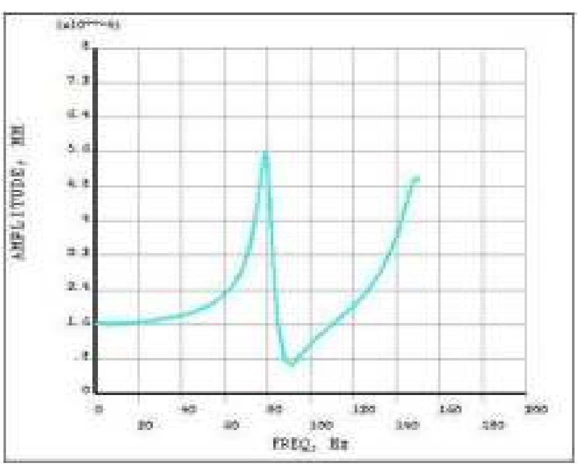

Figure 4(a): Amplitude V/s Frequency

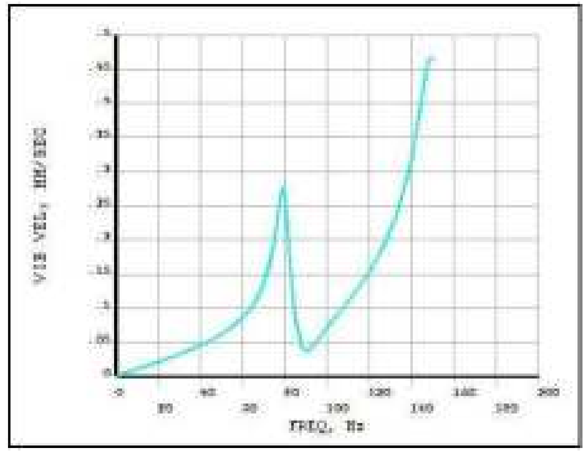

Figure 4(b): Vibration velocity V/s Frequency

Fig 4(a) shows that the maximum amplitude is 5.6×10^{-4} mm. Thus the amplitude is reduced to the manufacturing standards. According to the manufacturing standards the amplitude should be 0.0005 mm. Hence the model doesn't cause much waviness on the surface.

The Fig 4(b) shows that the maximum vibration velocity is 0.28 mm/sec. According to the balance quality grade ISO the vibration velocity should be 0.4 mm/sec. Thus the vibration velocity is reduced and the design is acceptable.

RESULTS AND DISCUSSION

The model is analyzed using ANSYS 11.0. The analysis carried out includes Modal and Harmonic analysis.

Initially the static analysis is carried out to check for the constraints. Here the spindle tip is excited from all the three directions to check whether the boundary conditions are correct. Once the boundary conditions are satisfied, then only Modal and Harmonic analysis are carried out.

The model analysis includes the calculations of mode shapes. Mode shapes are obtained for the frequency range 0 to 200 Hz. This is because the working frequency is 50 Hz the first few modes play a very important role in system stability. After which the effect of resonance is almost negligible.

Modal Analysis

The table 3 shows the modal analysis carried out for the entire iterative models.

Table 3: Modal analysis

	Model 1	Model 2	Model 3	Model 4
Set	Freq	Freq	Freq	Freq
1	5.3179	5.3179	5.3179	5.3179
2	7.6049	7.6055	7.6056	7.6064
3	7.9067	7.9087	7.9015	7.9058
4	12.274	12.276	12.278	12.280
5	15.346	15.347	15.344	15.347
6	17.537	17.537	17.537	17.538
7	48.218	50.836	51.211	54.996
8	48.977	52.410	78.692	79.968
9	71.404	81.394	86.981	103.81

The modal analysis shows that the frequency is increased at the each iteration. Our interest is on mode shape 8 which should be increased above 50 Hz. With the thickness and the dimension change the frequency has increased to 79.968 Hz. Thus the frequency is increased above the working frequency to avoid the resonance.

Harmonic Response Analysis

The table 4 shows the harmonic analysis carried out in the entire iterative models.

Table 4: Harmonic response analysis

Harmonic Response Analysis				
	Model 1	Model 2	Model 3	Model 4
Amplitude (mm)	1.5×10^{-3}	1.25×10^{-3}	7.2×10^{-4}	5.6×10^{-4}
Velocity (mm/sec)	0.5	0.38	0.35	0.28

The harmonic analysis shows that the amplitude is decreased at the each iteration. Our interest is to reduce the amplitude to the manufacturing standards. In the first iteration the maximum amplitude is 1.5×10^{-3} mm and in the fourth iteration the amplitude is decreased to 5.6×10^{-4} mm. Thus the amplitude is reduced to the manufacturing standards and the waviness is reduced.

CONCLUSION

The dynamic characteristic such as the natural frequencies and mode shapes of the surface grinder was determined. The structural modification of the surface grinder was accomplished. It is found that the structural modification carried out from model updating is quite useful reducing the surface waviness of the surface grinder.

The surface grinder model has the working speed of 3000 rpm i.e 50 Hz. The dimension of the model is changed and various iterations are carried out. The modal analysis shows that the frequency is increased at the each iteration. The frequency has increased from 48.977 Hz to 79.968 Hz.

The harmonic analysis shows that the amplitude is decreased at the each iteration. The amplitude was reduced to the manufacturing standards. The amplitude is reduced from 1.5×10^{-3} mm to 5.6×10^{-4} mm. The harmonic analysis also shows that the vibration velocity is reduced to manufacturing standards i.e from 0.5 mm/sec to 0.28 mm/sec.

As a conclusion the core objective of the project has been achieved, the waviness caused by vibration of the surface grinder is minimized to admissible levels.

REFERENCES

Y.X.Jiang, W.X.Tang, G.L.Zhang, Q.H. Song, B.B.Li and B.Du, Key Engineering Materials Vol. 329 (2007) pp 767-772, Trans Tech Publications Switzerland.

Z.Y. Weng, W.D. Xie, B. Lu, Y.W. Ye, H. Yao and X.S. He, Key Engineering materials Vol. 259-260 (2004) pp 352-356, Trans Tech Publications Switzerland.

Zeyu Weng, Bo Lu, Hongwu You, Honggang Ding, Yong Cai, Guanchen Xu and Nannan Zhang, Key Engineering Materials Vol. 416 (2009) pp 472-476, Trans Tech Publications Switzerland.

Tonshoff, H.K., and Foth, M., "In process Detection and Reduction of Workpiece Waviness Caused by Vibrations in External Plunge Grinding," Proceedings of the Third International Grinding Conference, October 4-6,1988, Fontana, WI, SME Technical Paper #MR88-620.

A.H.Koevoets : Brush head analysis, mode dynamics POHC 12NC Number: 4235 006 07241-198 Philips CFT (Centrum for manufacturing and technology) 2003-01-14 The Netherlands (CTB595-03-1074).