THERMAL ANALYSIS OF GRINDING WHEEL OF WHEAT FLOUR MILL

[1] Prof. Gunwant A. Ghatole, [2] Dr.S.C.Kongre
[1]Assistant Professor, [2]Assistant Professor
[1]Department of Mechanical Engineering,
[1]ISB&M, School of Technology, Pune, India

***Abstract:** In grinding, high specific heat is generated and hence appropriate control of temperature throughout the surface of grinding wheel is necessary to obtain quality flour. This work deals with thermal analysis through finite element analysis of grinding wheel of wheat flour mill. Generally grinding wheel is made with abrasive material, so Cubic Boron Nitrides (CBN) abrasive material is used for analysis. The objective of this work is to calculate thermal stress generation on grinding wheel.PRO-E OR CRE-O and ANSYS Software is used for modeling & analysis of grinding wheel.*

***Index Terms** - Grinding wheel, Thermal Analysis and ANSYS Software.*

I. INTRODUCTION

Grinding of cereal seeds is due to the mechanical action of several forces: compression, shearing, crushing, cutting, friction and collision, to which seeds are subjected, depending on the design if the mill used for grinding (roller mill, hammer mill, stones mill or ball mill). By applying these forces, when the mechanical resistance of the particles is exceeded, their division happens in a number of smaller particles of different sizes, geometric shapes, masses and volumes .An industrial wheat mill has several technological phases, starting with coarse grinding of seeds to fine grinding of the resulted milling products, after their sorting in fractions of different sizes. The first technological phase of grinding process, in wheat mills, is gritting or coarse grinding phase, which also consists of several technological passages. A technological passage consists of a grinding machine (roller mill), a machine for sifting and sorting of the resulted milling fractions (plan sifter compartment) and, eventually, a machine for the conditioning of semi-final product (semolina machine or bran finisher). In a technological passage, intermediate fractions are obtained, which, by a new grinding, lead to the obtaining of high-quality flour at milling passages (fine grinding).

A. Traditional methods of grinding grain

The milling is one of the oldest cultural techniques of humanity. All civilizations that feed more or less exclusively from cereals were forced to develop technologies for grinding the grains of grain crops. In all traditional civilizations, grinding is the domain of women.

There are two different techniques:

- The grinding done by beating the grain.
- The grinding done by rubbing the grains between two stones.

B.Principle of operation

The principles of operation of these mills are the grinding of the grain by crushing it between two abrasive surfaces: the wheels. They consist of a fixed wheel and a mobile wheel turning upon the first in a horizontal or vertical plain. The two wheels of the machine are identical regarding material and dimensions. The grain is poured into a conical or pyramidal hopper. A supply valve located at the base of the hopper is used to regulate the flow of grain. It flows into the grinding chamber through the center of one of the wheels of which the axial portion is hollow. The grinding of the grain is done in the trajectory that is does between the two wheels, from the center to the periphery. The horizontal and vertical wheel mills give different results. Indeed, in the case of horizontal wheel mills, the grain is gradually led to the periphery during the milling, guided by the splines of the wheel under the effect of the centrifugal force alone. In the case of the vertical wheel mills, the grain undergoes the effect of its weight more, which pulls it down, i.e. towards the periphery of the wheel. It has a shorter passage time, which results in a less regular flour with the horizontal millstones.

C. Wheel materials

The principal parts of these mills are crushing wheels. The materials used for manufacturing these are of different nature. There are two main types of wheels, their choice is based on our purpose and the price can be paid on them:

[1] METAL WHEELS

These mills are also known by the name "disk mill" or "plate mill"; plates are cast iron. They are very strong, inexpensive and can grind a wide variety of dry or slightly damp products like cereals, peanuts. However, there is a risk of heating of the flour and it takes the wheel two passes if we want fine flour.

[2] STONE WHEELS

Among these we distinguish:

I] Natural stone wheel mills, these are generally made from a blend of siliceous rocks close to quartz, and are found in a quarry (sometimes called flint stone wheels). There is also granite or volcanic basalt wheels cut on of a rock formation.

II] Abrasive particles wheels (natural or artificial) agglomerated with oxy-chloride magnesium cement. The abrasive is generally synthetic corundum, very hard material. Other wheels are made from natural corundum, the Naxos, stone originating from Greece or Turkey.

The wear of the wheel does not deprive them of their abrasive properties, since new edges always appear at the surface. Because of the weight and difficulty to place them in a vertical position, the large diameter wheels (from 60 cm diameter) are often arranged horizontally.

II. LITERATURE REVIEW

[1]. R. Deivanathan and L.Vijayaraghavan, “Theoretical analysis of thermal profile and heat transfer in grinding”, International journal of mechanical and materials engineering, vol. 8 (2013), no. 1, Pages: 21-31. This article presents the theoretical modeling and analysis of the temperature distribution in a surface grinding process. Temperature in grinding is one of the major factors, affecting the quality of the ground surface. The factors influencing the temperature for burn were identified by thermal modeling. The rate of change of temperature was calculated at discrete intervals along the temperature profile over time. The grain zone model gives a meaningful estimate of heat partition. Analysis of partition ratio revealed that proper choice of wheels (with high kg), fine grain abrasives. Effect of grinding parameters on the peak temperature had been studied. The grinding energy, work speed and wheel-work contact length were the key parameter influencing the heat affected zone. Among other factors, the work speed, the length of contact and the work material properties, significantly influence the heating rate in grinding. All of the thermal damages reduced and possibly avoided by careful choice of grinding conditions and a grinding wheel having favorable properties. Compared to other metal removal processes, grinding is a high specific energy process in which almost all the grinding energy is converted into heat and is concentrated within a narrow grinding zone and this leads to several types of thermal damages to the work piece.

[2]. Fang, Campbell et al. (2002) showed that if the distance between rollers increases from 0.3 mm to 0.7 mm, wheat seeds breakage in the gritting phase has a lower intensity, resulting in more particles of large sizes and less particles of smaller sizes. Distance between rollers indirectly influences the specific surface and energy consumption per mass unit and directly influences the specific energy. Different flutes arrangements on the rollers lead to the obtaining of different size distributions. If the roller flutes are arranged in blade, blade position results in a relatively uniform size distribution and back to back arrangement lead to a deep parabolic distribution.

[3]. A. Aguiar Vieira, A. Monteiro Baptista, R. Natal Jorge And M. P. Lages Parente, experimental and fem study of the influence of the grinding stone on the temperature field during superficial grinding, viii international conference on computational plasticity complas viii E. Oñate and d. R. J. Owen (ends) © cimne, barcelona, 2005, Grinding is a mechanical process that involves a great amount of energy per unit volume of removed material. This energy is almost all converted into heat, causing a significant rise of the temperature, mainly on the surface of the work piece. The grinding Cubic Boron Nitride [CBN (B-60- N-50-M)] wheel of diameter 350 mm -metallic bond. A thermocouple is placed in a hole with 0.5 mm of diameter, at a distance of 1 mm below the surface. Results indicate that CBN wheels introduce less heat in the sample than other wheels. The CBN grinding wheel introduces on the work piece a smaller percentage of the spent energy on the grinding operation and as a consequence, the maximum temperatures obtained are lower. The maximum temperature depends of the depth of cut, the work piece material and the grinding wheel. In all the situations the CBN grinding wheel produced lower temperatures.

[4]. G.Hanumantharao, S.Vijay and Dr.M.Venkateswara Rao "Transient heat transfer analysis for optimum temperature distribution to reduce thermal stresses" International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 6, August - 2012 ISSN: 2278-0181. In this, investigated the thermal stresses of aluminum plate welded by gas tungsten arc (GTA) in boilers and pressure vessels. The variation of the temperature gradient with time, and thermal stress are obtained. The variations of these are reported and discussed present analysis is used to calculate thermal gradients thereby reduce thermal stresses for the optimum temperature distribution in aluminum welded joints. Couple analysis using structural load of pressure 4 N/mm2 on areas and thermal loads was carried out by giving heat flux as the time varying input to estimate the thermal stresses, thermal strain, displacement and temperature gradient variations

[5]. Sachin Kaushik, K.S. Mehra and Dr. S. Singh "Thermal analysis for various materials and alloys.” International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 11, November - 2013. In this work, comparative study of thermal analysis of a rectangular block ($1x1x1unit^3$) is done by taking different material (i.e. Copper, Steel, Brass) for the conduction and convective boundary condition. The result is based on temperature, thermal heat flux variation in the material, contour of temperature distributions and heat flux. A numerical and computationally study of different material elements are discussed i.e. copper, steel and Brass are used as working material. And finally compare the temperature distribution and thermal heat flux at the same point (along the length) for all three materials. Then concluded the best material. For larger the value of thermal conductivity and heat transfer coefficient at low temperature with respect to time, the more heat convection on lateral surface and the more thermal energy is efficiently transferred into environment through the surface, also result in heat transfer rate reaches time invariant early.

[6]. Subhasis Sarkar and Prof. (Dr.) Pravin P. Rathod "Review paper on Thermal analysis of ventilated disc brake by varying design parameters" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 12, December - 2013. Brakes convert friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. In this study FEA approach has been conducted in order to identify the temperature distributions and behavior of disc brake rotor in transient state. This paper reviews work of previous investigators on transient thermal analysis on the vented disk rotor and rotor designs to evaluate and compare their performance. The main aim is to improve heat transfer rate of disc brake (ventilated) by changing vane geometry and material. Disc brake design plays as an important role in heat transfer as other variable like plate & vane thickness, fin material and flow pattern. There is a scope of improvement in heat transfer in grinding wheel also.

[7]. Chithajalu Kiran Sagar and Bhaskar Pal "Modeling and estimation of grinding forces for mono layer CBN grinding wheel" International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 - 5161 ©2014 INPRESSCO®, Special Issue-2, (February 2014). This paper shows a new grinding force model which was developed by incorporating the effects of tangential, normal and variable coefficient of friction force. All the coefficients were determined by considering experimental data of previous work which has been conducted on single layer brazed CBN wheel. In this paper forces were calculated from the total force values the contributions of each component of force were obtained. Grinding is a complex material removal process with a large number of parameters influencing each other. In the process, the grinding wheel surface contacts the work piece at high speed and under high pressure. It has been observed that the contribution of frictional force is much higher than the cutting force.

In this research work model, the total grinding forces have been evaluated by incorporating the combined effects of frictional forces and cutting or chip formation forces. All the coefficients were determined by available experimental data, which had captured during grinding bearing steel by single layer brazed CBN wheel.

III. STATEMENT OF PROBLEM

[1] From various types of literature review, it is found that some research have been done on the feasibility of grind-hardening and the metallographic structure of the hardened layer, the influence parameters of the grind-hardening effect, the temperature field and heat source model by the simulation method and the performance of surface hardening.

[2] Some above research done on different types of analysis of grinding wheel & Required analysis to check thermal effect on grinding wheel of wheat flour mill & how to reduce unnecessary heat content which generated during the grinding process.

[3] During the formation of whole wheat grain into wheat flour increases the heat contents due to grinding of grains into different sizes and at different speed of prime mover. A broad range of rotation speed of grinding wheel, the speeds influence the quality of the grinding, we can reduce them slightly to improve the quality of the flour, by decreasing the throughput, or else, the flour is less homogeneous and warmer.

[4] This variation may reach 25%.Uncontrollable thermal stress generation on grinding wheels is difficulties in calculation of life time of grinding wheel. Due to increases the friction between grinding wheels during the grinding process, there is problem of resharpening of grinding wheel again in very less duration.

IV. OBJECTIVE

This work is to analyze the thermal behavior of grinding wheel of wheat flour mill.

V. METHODOLOGY

A. Cad modeling of grinding wheel

CRE-O Software is used for creating model of grinding wheel**.**

Part module is most important for modeling of 3D part and it must be user-friendly so that new users can also able to work with software. Here for modeling PART i.e. grinding wheel above specification and its commands are used. Bellow figure shows the grinding wheel modeled in Pro-E software.

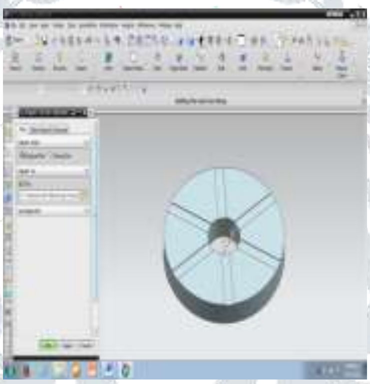

Fig.1: 3D model of grinding wheel in CRE-O software.

Below figure shows 2D view of solid modeling of grinding wheel by using drafting module in CRE-O software.

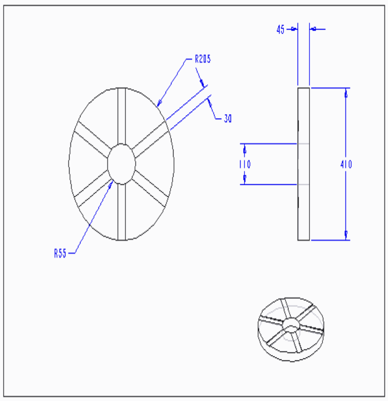

Fig. 2: 2-D View of grinding wheel.

B. Thermal analysis of grinding wheel by using Ansys

[1] Thermo-mechanical analysis

Thermal analysis results are employed to compute displacement, stress, and strain fields due to differential thermal expansion.

The objective of this paper is to investigate optimum process parameters in grinding to determine the induced stresses and the fatigue life of wheel. More specifically , the choice of wheel rotational speed have been sought with a steady two dimensional sequentially coupled thermo mechanical model implemented in ANSYS. The thermal model is based on a heat source description which in essence is governed by the rotational speed and the temperature dependent yield stress of the wheat grain material. This model in turn delivers the temperature field, in order to compute thermal strain field which is the main driver for mechanical model predicting both transient and finally residual stresses in the grinding wheel.

[2] Mesh model generated on grinding wheel:
By importing the IGES file into the ANSYS and by following the ANSYS procedure, the meshing of the grinding wheel is done where several nodes and elements are generated as shown in the following figure.

Fig.3: Meshing model of grinding wheel.

VI. EXPERIMENTATION

[A] Traditional grinding process

1] Wheel Material = Cubic Boron Nitride (CBN)
2] Temperature measurement instrument used = Thermocouple
3] Temperature measured value = 42.5 ^{0}C
4] Tachometer is used for speed measurement (N)
5] Speed (N) = 60 r.p.m.

[B] Motor operated grinding process

1] Operating Parameters for Motor Operated Grinding Process
2] Power Supply = 3 Phase AC
3] Current (I) =30 Amps
4] Voltage (V) =650V
5] Power Rating (P_r) = 6.7 KVA
6] Power Factor (Pf) = 0.8 at full load.
7] $P = I^2R$ = VI =650×30 = 19500Watts =19.5 KW
8] Wheel Material = Cubic Boron Nitride (CBN)
9] Temperature measurement instrument used = Thermocouple
10] Tachometer is used for speed measurement (N)
11] Speed (N) = 755 r.p.m.

Table 1: Temperature obtained with different sizes of wheat grains

Sr. No.	Size of Wheat Grains	Surface Maximum Temperature Obtained (^{o}C)
01	L= 5.0 mm, B=2.0 mm	70.1
02	L = 4.5 mm, B=2.5 mm	65.8
03	L= 4.5 mm, B=1.8 mm	74.0

Surface Average Temperature of all sizes of wheat grains
= [70.1+65.8+74.0] / 3
= 69.96 ^{0}C
Assumed +5 ^{0}C for more temperature occur during the grinding operations at different unusual conditions.
Hence, $T_{max.}$ = 69.96 + 5
= 74.96
= 75 ^{0}C (Approx.)

VII. RESULT & DISCUSSION

[A] Heat flux generated on grinding wheel at different nodes

[1] Heat flux generation on grinding wheel for 60 RPM as shown in below figure. As seen from figure for CBN material, the temperature of wheel surface changes from 20 ºC to 45 ºC. For above maximum temperature, the maximum heat flux generated at the centre area of the wheel and it is 455149 W/mm^2.

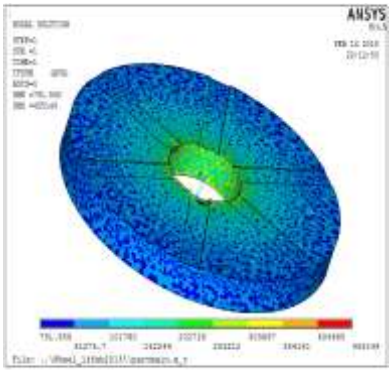

Fig.4: Heat Flux Generation on Grinding Wheel at 60 RPM.

[2] Heat flux generation on grinding wheel for 755 RPM as shown in below figure. As seen from figure for CBN material, the temperature of wheel surface changes from 25 ºC to 75 ºC. For above maximum temperature, the maximum heat flux generated at the centre area of the wheel and it is 1040000 W/mm^2.

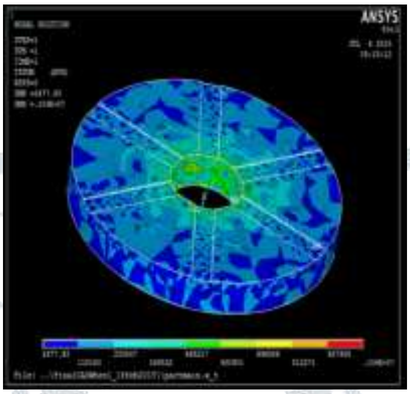

Fig.5: Heat Flux Generation on Grinding Wheel at 755 RPM.

[B] Temperature generation on grinding wheel

[1] Temperature distribution on grinding wheel as shown in below figure. As seen from figure for CBN material when wheels spacing from 0.3 mm to 1.8 mm, the temperature of wheel surface changes from 20 ºC to 45 ºC. It is because for small spacing between two grinding wheels large specific energy is required for grinding. Because as we decreases the spacing adhesive effect between wheel material and wheat grain material increases and thus lead to an increase in the frictional area. From the figure it is cleared that the maximum temperature is obtained at the centre of the grinding wheel.

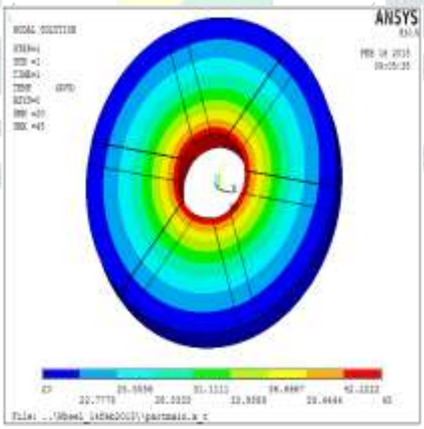

Fig. 6: Temperature distribution on Grinding Wheel at 60 RPM.

[2] Temperature distribution on grinding wheel as shown in below figure. As seen from figure for CBN material when wheels spacing from 0.3 mm to 1.8 mm, the temperature of wheel surface changes from 25 ºC to 75 ºC. It is because for small spacing between two grinding wheels large specific energy is required for grinding. Because as we decreases the spacing adhesive effect between wheel material and wheat grain material increases and thus lead to an increase in the frictional area. From the figure it is cleared that the maximum temperature is at the centre of the grinding wheel.

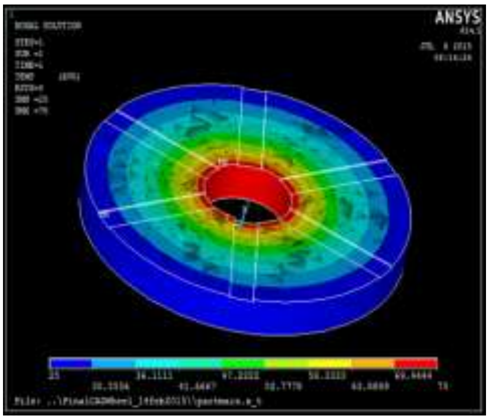

Fig.7: Temperature distribution on Grinding Wheel at 755 RPM.

[C] Von misses stress generated on grinding wheel

[1] The von misses stresses are obtained as shown in the figure; it is observed that the maximum von misses stress is 103.844 N/mm^2 and minimum stress is 0.466294 N/mm^2 for speed of 60 r.p.m.

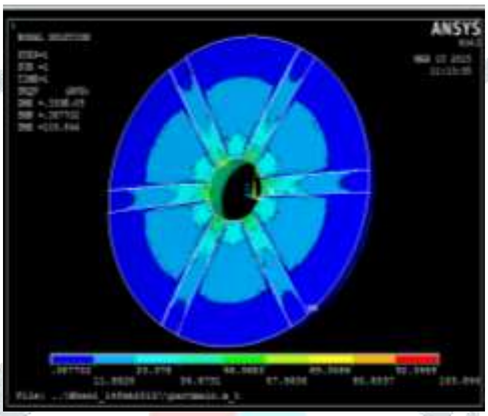

Fig.8: Von-misses Stress on Grinding Wheel at 60 RPM.

[2] The von misses stresses are obtained as shown in the figure; it is observed that the maximum von misses stress is 136.706N/mm^2 and minimum stress is 0.466294 N/mm^2 for speed of 755 r.p.m.

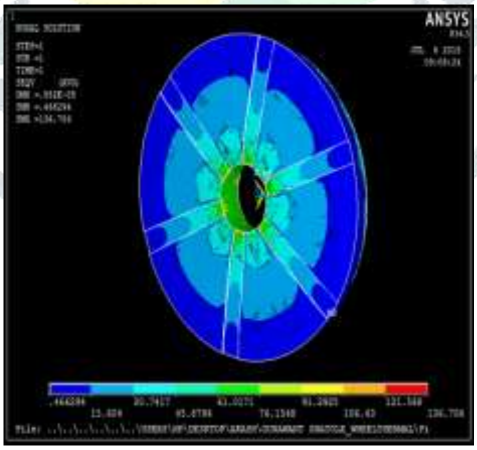

Fig. 9: Von-misses Stress on Grinding Wheel at 755 RPM.

Table 2: Comparison between Traditional Grinding and Motor Operated Grinding

Sr. No.	Various parameters	Traditional Grinding Wheel	Motor Operated Grinding Wheels
1	Heat Flux	455149 W/mm^2	1040000 W/mm^2
2	Temperature	20 ºC to 45 ºC	25 ºC to 75 ºC
4	Von-Misses Stress	103.844 N/mm^2	136.706N/mm^2

VIII. CONCLUSION & FUTURE SCOPE

[1].The finite element analysis for structural and thermal analysis of grinding wheel is carried out using solid95 element. The temperature has a significant effect on the overall grinding wheel. Maximum elongations and temperatures are observed at the centre section of wheel and minimum elongation and temperature variations at the outer periphery of grinding wheel. Maximum stresses are observed at the centre section of wheel construction i.e. cubic boron nitrides materials. It is found that the temperature has a significant effect on the overall stresses induced

on the surface of grinding wheel. The wheel temperatures attained and thermal stresses induced are lesser for speed of 60 RPM rather than 755 RPM.

[2].From the above analysis result it is conclude that the Cubic Boron Nitrides (CBN) material of grinding wheel is convenient in traditional milling process at 60 RPM as well as motorized grinding at 755 RPM.

IX.REFERENCES

[1]. R. Deivanathan and L.Vijayaraghavan, Theoretical analysis of thermal profile and heat transfer in Grinding, international journal of mechanical and materials engineering , vol. 8 (2013), no. 1, Pages: 21-31

[2]. A. Aguiar Vieira, A. Monteiro Baptista, R. Natal Jorge And M. P. Lages Parente, experimental and fem study of the influence of the Grinding stone on the temperature field during Superficial grinding, viii international conference on computational plasticity complas viii E. Oñate and d. R. J. Owen (eds) © cimne, barcelona, 2005,

[3].G.Hanumantharao, S.Vijay and Dr.M.Venkateswara Rao "Transient heat transfer analysis for optimum temperature distribution to reduce thermal stresses" International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 6, August - 2012 ISSN: 2278-0181.

[4]. Sachin Kaushik, K.S. Mehra and Dr. S. Singh "Thermal Analysis For Various Materials And Alloys International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 11, November - 2013.

[5]. Subhasis Sarkar and Prof. (Dr.) Pravin P. Rathod "Review Paper on Thermal Analysis of Ventilated Disc Brake by Varying Design Parameters" International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 2 Issue 12, December - 2013.

[6]. Chithajalu Kiran Sagar and Bhaskar Pal "Modeling and Estimation of Grinding Forces for Mono Layer CBN Grinding Wheel" International Journal of Current Engineering and Technology E-ISSN 2277 – 4106, P-ISSN 2347 - 5161 ©2014 INPRESSCO®, Special Issue-2, (February 2014).

[7]. S.Y. Sonaye and Dr. R. N. Baxi "Particle Size Measurement and Analysis of Flour "International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 3, May-Jun 2012, pp.1839-1842.