ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ANALYSIS AND REDUCTION OF STRESS IN A CIRCULAR SAW BLADE

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ABSTRACT

Circular saw blade is a valuable multipoint cutting tool used in the manufacturing industry. During the machining process the circular saw undergoes various stresses because of the cutting forces generated, which affect the tool life. So, the current project work helps to select an optimized circular saw blade and provides a method to reduce the stresses developed during the machining process with the help of Hypermesh software and its modules. This project involves the selection of an optimized saw out of three different saw blade (differ in design of type of slots cut) and calculating the stresses developed in the saw during cutting of four different specimens (differ in material). After comparing the results of stresses developed while cutting the four different specimens, maximum stress is calculated. Then the maximum stress is been reduced by using three different coated material. The result of stresses developed after coating the circular saw blade is compared. With the help of this result we can determine the coating material which reduces the maximum stress.

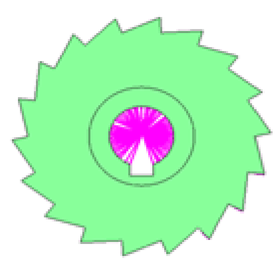
KEYWORDS: Saw blade.

INTRODUCTION

Circular saw blades have variable applications in metal cutting industry. And because of variable applications the saw has to withstand variable cutting forces. Few researches have been done to calculate the stresses developed in the saw used in the industries for various operations. The stresses are generated because of the cutting forces generated during the operation. These stress leads to wear and built-up edges in the saw. The process of determining the stresses is practically a difficult process which requires an experimental setup. This thesis includes the use of finite element method on hypermesh, CAE software which reduces all the complexities of experimental setup. Also there are some methods available in surface technology like thermal treatment, thermochemical treatment, plating and coating which helps to reduce stresses. The current thesis work starts with the selection of an optimized circular saw blade and the same is analyzed for cutting four different specimens. The stresses developed are then compared and by the method of coating higher stresses are reduced. For coating titanium nitride, aluminium oxide and titanium carbide are used. Values of stresses after coating are then compared.

METHODOLOGY

An optimized circular saw blade was selected through static analysis and normal mode analysis from three different circular saw blades which differ in the design of expansion slots with the help of OPTISTRUCT module of hypermesh. The first case of saw has a circular saw blade with no slots, second case has circular slot and the third case has cut sections on the base line as shown in figure 1.



Case 1:
Circular Saw Blade
Baseline or with no cut
section or hole

ISSN: 2277-9655
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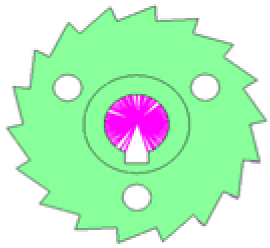
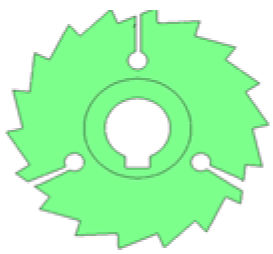


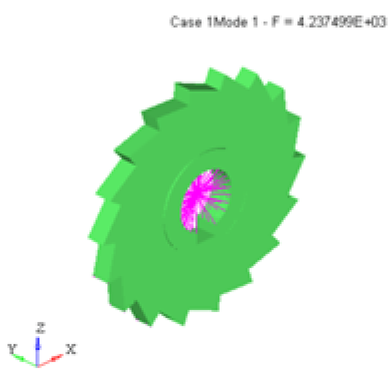
Case 2:
Circular Saw Blade
Baseline with holes



Case 3:
Circular Saw Blade
Baseline with cut sections

Figure 1: First mode analysis of 3-cases

Normal mode analysis of the entire three saw was done to determine the natural frequency. Since higher the natural frequency lower will be the residual stresses. So as to determine the residual stresses developed in the circular saw blades, three modal analyses were done as shown in figure 2. The modal analysis was done in three different planes X-Y plane, X-Z plane and Y-Z plane.



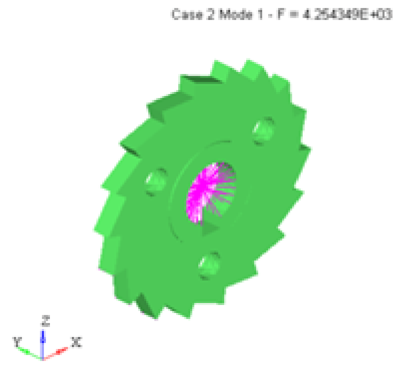
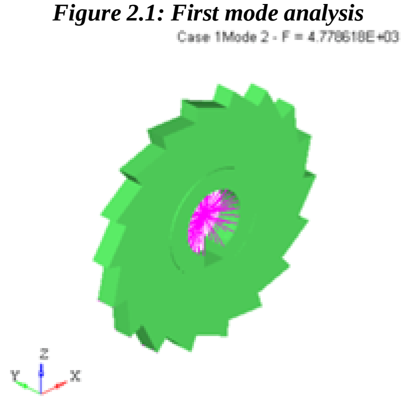


Figure 2.1: First mode analysis



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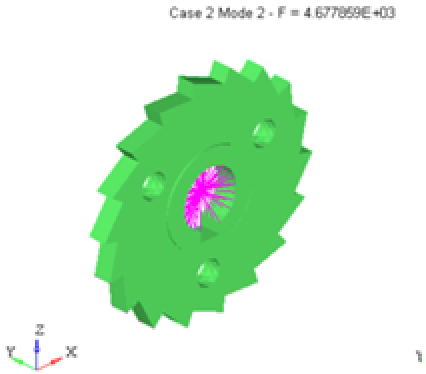


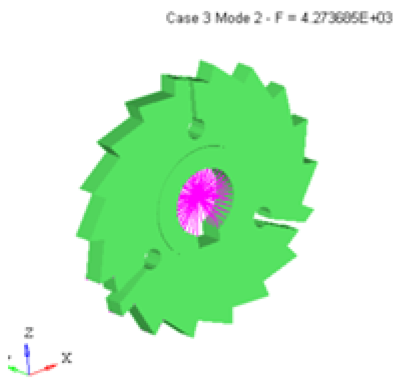
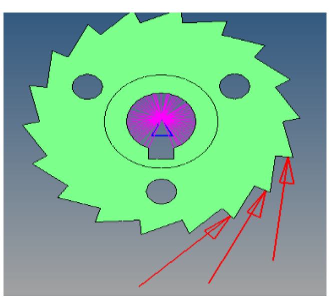
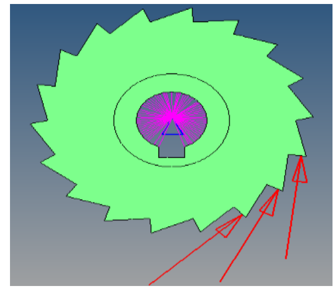


Figure 2.2: Second mode analysis

By keeping the circular saw blades stationary (fixed from centre) and applying a load of 1.2kN as shown in figure 3, the deflection (shown in figure 3.1) and stresses (shown in figure 3.2) are calculated. The natural frequency, deflection and stresses that are compared to select an optimized saw are given in table 1.





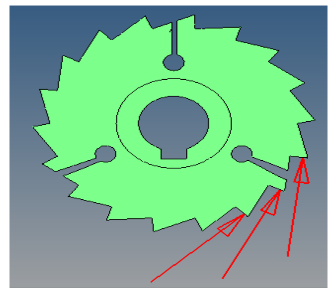
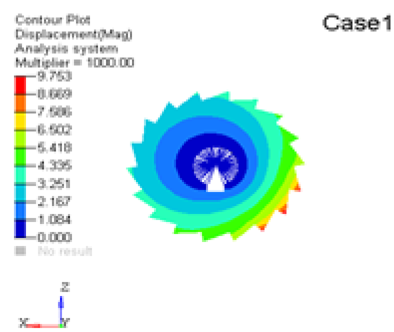
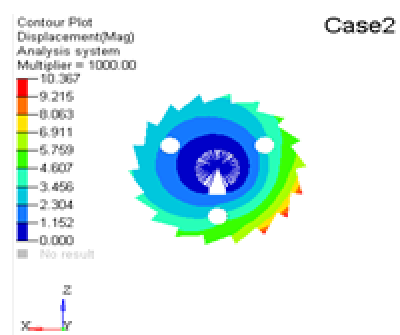


Figure 3: 1.2kN load applied on the saws





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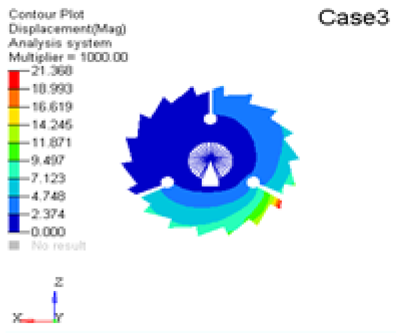

Figure 3.1: Deflection in the saws after the application of 1.2kN load.

Figure 3.2: Stresses in the saws after the application of 1.2kN load.

Table 1: Comparison of values found during natural frequency and static analysis

Circular saw blades	Case 1	Case 2	Case 3
Natural frequency	4.77	4.67	4.27
Deflection (micrometer)	9.7	10.3	21.3
Stresses (MPa)	33	35	43

After comparison it was found that Case 1 and Case 2 have almost similar natural frequencies for first, second and third mode conditions. Case 3 is showing low natural frequency as compared to other cases hence this design (circular saw with cut section) is weaker than other designs. Case 1 and Case 2 have almost similar stresses and deflection. Case 3 is showing higher stresses and deflection as compared to other two cases hence the design of circular saw witho cut section is weaker than other designs. So Case 3 can be neglected. Case 2 has lower weight due to holes. Hence with weight optimization we can select Case 2 for further analysis. After checking of stresses and deflection in Case 2 by applying forces of different magnitude not much differences found. So, Case 2 can be selected as the optimized saw.

For further analysis, four different specimens were cut by the optimized circular saw in LS-DYNA to determine the stresses generated in the saw. The four different specimens used are of steel, copper, aluminum and wood. The mechanical properties of these specimens are given in table 2.

Table 2: Mechanical properties of the specimens used

Mechanical Properties	Elastic Modulu s (GPa)	Poisson' s Ratio	Yield stress (MPa)	Ultimate stress (MPa)	Density (*1000 kg/m3)
1. Steel	190-210	0.27-0.3	280-1600	340-1900	7.85
2. Copper	110-120	0.33-0.36	55-330	230-380	8.94
3. Aluminium	70	0.33	20	70	2.71
4. wood	10-11	-	40-70	50-100	0.56-0.64

When these specimens were cut by the optimized saw on LS DYNA, the force-time history (as shown in figure 4) and stresses (as shown in figure 6) were noted and compared. The cutting forces with respect to time for the specimens were compared, the comparison is shown in figure 5 and it was found that the maximum cutting force generated in the optimized saw while cutting the steel specimens i.e. 1.2kN. Then the

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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stresses developed in the circular saw were compared. From figure 6 it was found that maximum stresses developed during the cutting of steel specimens.

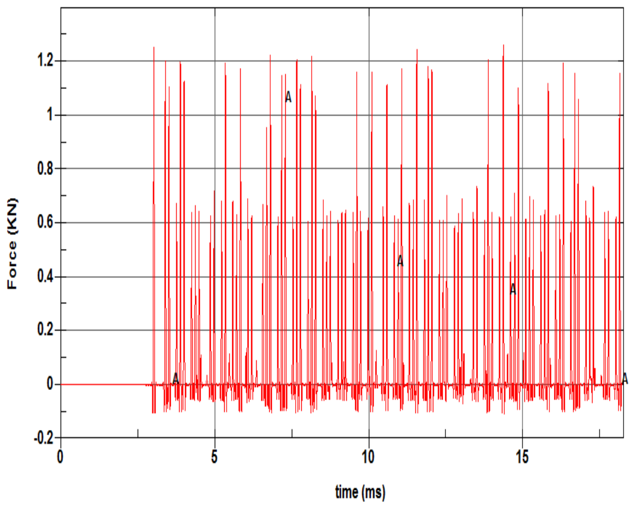


Figure 4.1: Force-Time plot for Steel specimen

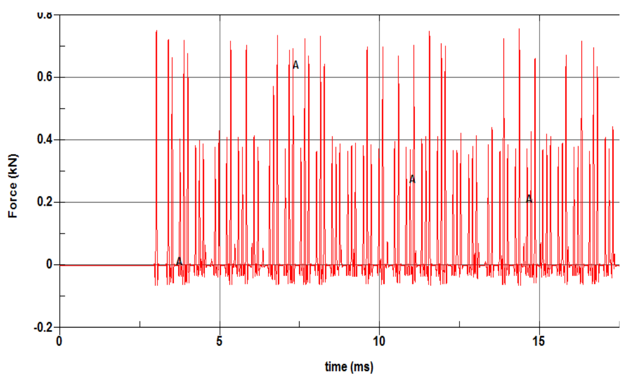


Figure 4.2 Force-Time plot for Copper specimen

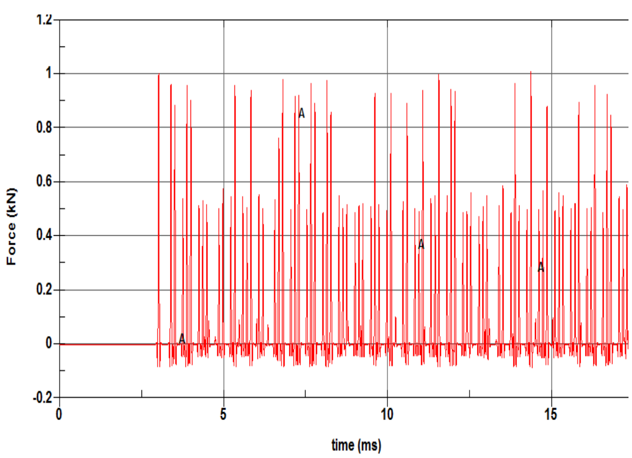


Figure 4.3: Force-Time plot for Aluminium specimen

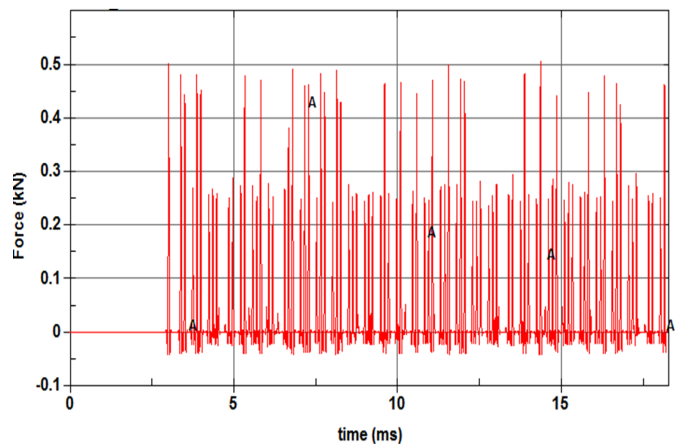


Figure 4.4 Force-Time plot for wood specimen

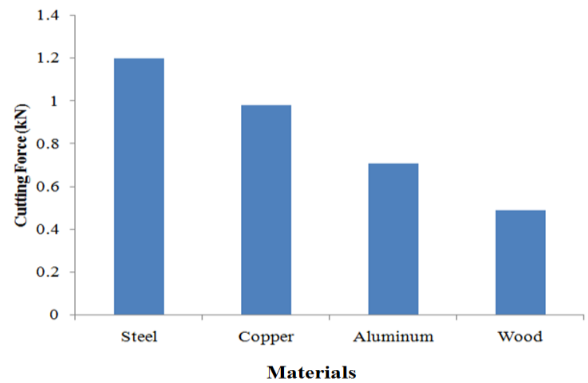
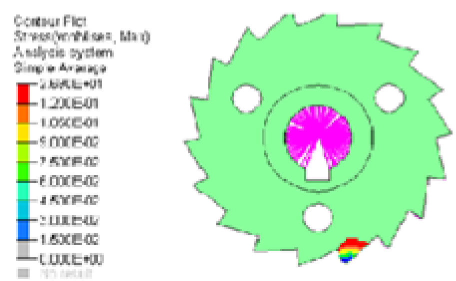


Figure 5: Comparison of cutting force generated while cutting the four different specimens.



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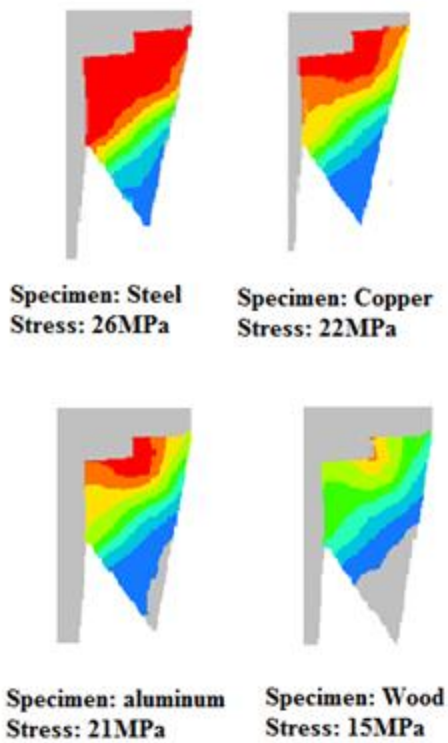


Figure 6: Comparison of stresses in the saw after cutting four different specimens.

Development of stresses in any tool affects the tool life. And to reduce the stresses of a cutting tool there are several methods available in metal cutting industry like thermal treatments, thermochemical treatment, plating, coating etc. In this project method of coating is used to reduce the stresses developed in the circular saw blade, which is a well known method of surface technology. The materials used for coating are aluminium oxide (Al2O3), Titanium Nitride (TiN) and Titanium carbide (TiC). The mechanical properties of these coating materials are given in table 3.

Table3: Mechanical properties of materials to be used for coating

Properties	Titanium Nitride (TiN)	Aluminium oxide (Al_2O_3)	Titanium Carbide (TiC)
Density (g/cc)	5.22	3.69	4.94
Poisson's ratio	0.25	0.21	0.18 – 0.19
Modulus of elasticity (GPa)	251	300	448 - 451
Shear Modulus (GPa)	240	124	186

The circular saw blade was coated with 1mm thick layer of these three coating materials as shown in figure 7. The stresses in the coated circular saw blade were calculated while cutting steel specimen. Then these stresses were compared with the previous result of uncoated saw cutting steel specimen which is shown in figure 8.

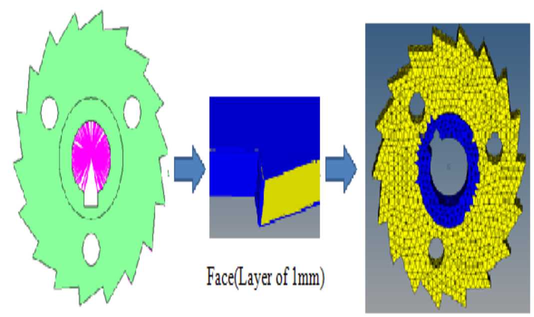
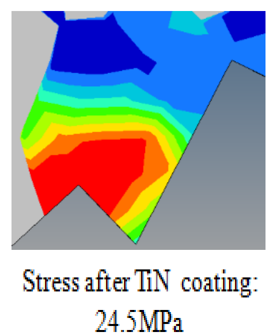
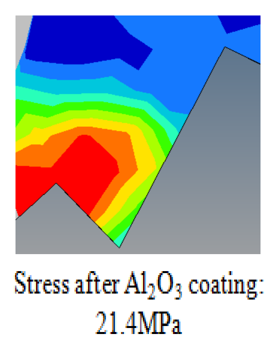
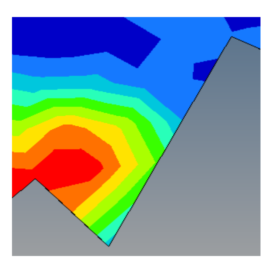


Figure 7: Coating on the circular saw blade with 1mm thickness.







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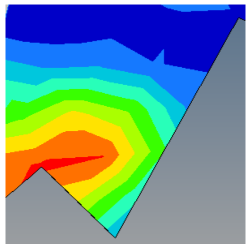

Figure 8: Comparison of stresses with and without coating.

On comparison it was found that stresses were reduced in the cirular saw after coating. And the maximum stress was reduced when the saw was coated with titanium carbide (TiC).

RESULT

The analysis was divided in to two parts. From first part an optimized circular saw blade was obtained by using normal mode and static load analysis on OPTISTRUCT and then in second part the stresses were calculated, developed in the optimized saw in LS DYNA while cutting four different specimens. The results of normal mode and static analysis of the optimized circular saw blade sre shown in table 4.

Table 4: Result of normal mobe and static analysis of the optimized saw.

Normal mode analysis	Static load anaylsis	
	Deflection (micrometer)	Stress developed (MPa)
4.67	10.3	35

The result of second part i.e. calculation of stresses in the optimized circular saw blade while cutting four different specimens is given in table 5.

Table 5: Stress developed in the optimized saw while cutting four different specimens.

Specimens	Steel	Copper	Aluminium	Wood
Stress (MPa)	26	22	21	15

When these stresses were compared it was found that maximum stresses were developed in the circular saw while cutting the steel specimen i.e. 26MPa. So as to reduce this stress coating method was employed and the results after coating is shown in the table 6.

Coating material	Stress without coating (MPa)	Stress after coating (MPa)	Percentage of stress reduction
Titanium Nitride (TiN)	26	24.5	5.70 %
Aluminium oxide (Al_2O_3)	26	21.4	17.69 %
Titanium Carbide (TiC)	26	15	42.30 %

CONCLUSION

On analyzing the saw with various parameters it was found that saw with circular hole has higher natural frequency comparatively. Also there was a nominal change of deflection in that saw when applied with 1kN, 1.2kN and 1.5kN of forces. After analyzing the saw for cutting four different specimens i.e. aluminum, steel, copper and wood, it was found that maximum stress of 26 MPa developed while cutting steel specimen. So as to reduce these stresses the saw was coated with three different materials having wear resisting properties. Out of which titanium carbide coating reduced the stresses from 26 MPa to 15 MPa. The percentage of stress reduction after titanium carbide (TiC) coating was 42 % which will affect tool life positively since TiC gives abrasion resistance and prevents the chip from dissolving the tool material, leaving craters.

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