



*Research Paper*

# MODIFICATION AND ANALYSIS OF DETACHABLE TYPE MODULAR OIL SPILL GUARD FOR CNC VERTICAL PLANO-MILLER

Ajay Panwar<sup>1\*</sup>, Rahul Verma<sup>1</sup> and M K Chudasama<sup>1</sup>

*\*Corresponding Author: **Ajay Panwar**, ✉ [ajaypanwar092@gmail.com](mailto:ajaypanwar092@gmail.com)*

Vertical Plano Miller Machine is used in various industries for precisely shaping of metals and other solid materials and an adjustable sliding guard is manufactured to provide safety from the hazardous moving part of this machines and to eliminate the risk exposure which rails on a channel section. It is the only support to the guard. Hence it becomes imperative to give sufficient strength to the railing section and to the upper frame of the guard. Making compromises may prove to be fatal and a cause of injury. In this paper an analysis is done for the improvement of the strength capability of the guard. Practical consideration are taken into account and applied to the analytical results. The study is carried out by considering important analysis tools, thus the results are quite satisfactory and can be useful for safety in Industries operating heavy machineries.

**Keywords:** Machine guard, Computational analysis, Static load analysis, Fatigue analysis, Bending moment, Wind load analysis

## INTRODUCTION

Machine is also used for carrying out various processes like routing, slot cutting, turning and welding in metallurgy industry and the guard is located in such a way that wind load inducing bending Forces are imposed on the whole guard and transferred to the channel section due to a necessary industrial fan fixed on the roof wall. Fan blows a high velocity air on the guard-mounted machine and with repeated

loading and unloading with passage of time fatigue load is produced at the curvature of channel section which consequently weakens the guard. Machining a bulky work piece which requires long hours manufacturing processes produces many scarps that can possibly impose a continuous impact on the guard. Thus these factors and turbulent air creates a high pressure zone near the sliding mechanism of guard and hence possibility of guard derailing

<sup>1</sup> Dr. S. & S.S. Ghandhy Government Engineering College, Surat, India.

arises. The end effect of the wind blowing is the concentration of bending stress at the shaft of sliding guard. Many guards are defined according to the risk assessment. Guards with different applications are designed by considering proper metal selection and the necessity to provide safety to the operator. Other functions of a Guard include restricting the scattering of chips produced during machining process to the outside of machine zone and deflecting the sprinkling of lubricant drops towards the machining area.

## LITERATURE REVIEW

The initial focus of the industrial safety movement beginning in the early 1900's was to protect workers by providing adequate safeguarding of machinery. Widespread public opinion was aroused in 1908 when the Russell Sage Foundation published the Pittsburgh Survey documenting the deaths of 526 workers and the permanent crippling of more than 500 others in the mills and factories of Allegheny County, Pennsylvania during a one-year period. The public response to the reporting of this information was dramatic. By 1915, the Federal Government and a majority of the states had enacted some form of worker compensation law, the US Bureau of Mines was established, the Bureau of Labour statistics was created, the National Safety Council was formed, and the American Society of Safety Engineers was organized.

Regarding guard construction, this text further states that, generally speaking, a guard should:

- Provide positive protection.
- Prevent all access to the danger zone during operation.

- Cause the operator no discomfort or inconvenience.
- Not interfere with operation.
- Operate automatically or with minimum effort.
- Be designed for the job and the machine.
- Preferably is a built-in feature.
- Provide for machine oiling, inspection, adjustment and repair.
- Withstand long use with minimum maintenance.
- Resist normal wear and shock.
- Be durable, fire- and corrosion-resistant, and easily repaired.
- Not constitute a hazard itself (without splinters, sharp [or] rough edges, or other sources of injury).
- Protect against any contingency, not merely against normal operations.
- Conform to the provisions of American Standards Association codes (now ANSI).

Safeguards must be provided at three basic locations:

- At the point of operation
- At mechanical power transmission apparatus
- At other moving parts which could potentially create a hazard.

Machinery containing moving parts with rotating, transverse, or reciprocating action will be effectively guarded according to OSHA regulations. One or more methods of machine safeguarding must be provided to protect from hazards such as those created by point of

operation, nip points, rotating parts, flying chips, sparks and so on. Safeguards must conform to OSHA standards and are recommended to be designed in conformance with the American National Standards Institute (ANSI).

Neither OSHA nor ANSI standards offer guarding requirements for every possible machine configuration; therefore each machine must be evaluated by a knowledgeable, trained person and compared to the appropriate machine safeguarding standard. ensuring the safety of the operator and other employees.

## MATERIAL SELECTION

The selection of material is one of the most important tasks in hand during a product designing process as well as before an analysis being performed. The material selection is indeed a daunting task to be performed as not one but many parameters have to be simultaneously evaluated. The evaluation is being carried out on the basis of considering the most important properties required for the application of that material by having comparisons between different related materials.

There is significant number of materials used today for the manufacture of machine guards and channel section. Though not many are there that would make our needs suffice. After many considerations and rejections the material which finally fulfills our requirement is Cold Rolled Steel (CRC). Cold Rolled Steel is steel which is being cold rolled. The advantages which a cold forming process offers are that it has the effect of increasing the yield strength of steel. The effect of cold

working is thus to enhance the mean yield stress by 15%-30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15%.

Cross sectional shapes are formed to close tolerances and these can be consistently repeated for as long as required.

**Formability:** Cold rolling can be employed to produce almost any desired shape to any desired length.

Pre-galvanised or pre-coated metals can be formed, so that high resistance to corrosion, besides an attractive surface finish, can be achieved.

All conventional jointing methods (i.e., riveting, bolting, welding and adhesives) can be employed.

High strength to weight ratio is achieved in cold-rolled products.

Excellent Surface Appearance.

**Paintability:** Due to stringent surface roughness controls, CRC is readily paintable using appropriate paint system.

**Weldability:** It can be joined using accepted welding practices.

They are usually light making it easy to transport and erect.

Another characteristic which makes CRC so popular and so important for manufacturing is its Fatigue Endurance Strength. When CRC was in its development stages, several fatigue tests were performed with cold rolling process. It was observed that cyclic yield strengths increased and the ductility decreased as the degree of cold rolling increased. The notched specimen fatigue strength was only slightly

increased by cold rolling since two opposing factors, the smooth specimen fatigue strength and the notch sensitivity, were both increased by cold rolling.

The materials have been evaluated based upon design parameters like Elastic Modulus, Poisson's Ratio, Shear Modulus, Tensile

Strength, Yield Strength, Thermal Expansion Coefficient and Specific Heat. So clearly we can say that AISI 1020 CRC is a winner.

There are only a few materials which compete very close to the CRC. Below is a table depicting the comparisons between them and showing why CRC is considered the best of lot.

**Table 1: Material Properties**

	Elastic Modulus	Poissons Ratio	Shear Modulus	Density	Tensile Strength	Yield Strength	Thermal Expansion Coefficient	Specific Heat
AISI 1020 Cold Rolled Steel	2.05E+11	0.29	8.00E+10	7870	420000000	350000000	1.17E-05	486
AISI 1015 Steel, Cold Drawn (SS)	2.05E+11	0.29	8.00E+10	7870	385000000	325000000	1.20E-05	486
AISI 1010 Steel, Hot Rolled	2.00E+11	0.29	8.00E+11	7870	325000000	180000000	1.22E-05	448

## STATIC LOAD ANALYSIS

The beginning of an analysis starts with the Static Load Analysis. It is assumed those Restraints and loads all are time invariant, thus remaining constant with passage of time. Hence, dynamic loads which induce inertial and damping loads are neglected here since accelerations and velocities are so small which can be neglected. Static Load Analysis for the sake of study can be further classified into two types:

1. Linear Static Load Analysis
2. Non Linear Static Load Analysis

### LINEAR STATIC LOAD ANALYSIS

A body gets deformed when loads are applied and the effect of loads is transmitted throughout the body. These loads induce internal forces and reactions which render the body into a state of equilibrium.

Now, what Linear Static analysis do is to calculate displacements, strains, stresses, and reaction forces under the effect of applied loads.

The assumptions being made for the usage of Static Analysis is as follows:

#### Static Assumption

"Loads under consideration are applied slowly and gradually upto their full magnitudes and remain constant as they reach to a maximum value, i.e., time invariant. Thus the inertial and damping forces (time dependent) due to negligible accelerations and velocities can be neglected. There are time dependent loads which induces considerable inertial and/ damping forces that may warrant damping analysis. Dynamic loads are time variant and often induce considerable inertial and damping loads which if neglected may prove to be fatal."

#### Linear Assumption

There is a linear relationship between loads and induced reactions. Simply to say, if we

double the loads, the response of the model (displacements, strains, and stresses) will also double.

The conditions to be met for the linear assumptions are listed as below:

- In the model, all materials comply with Hooke's law, i.e., stress is directly proportional to strain.
- The induced displacements are small enough so that one can ignore the change in stiffness caused by loading.
- During the application of loads, boundary conditions aren't varied. Loads must be constant in magnitude, direction, and distribution and that they should not change while the model is deforming.

One can use static analysis to calculate the structural response of bodies spinning with constant velocities or travelling with constant accelerations since the generated loads do not change with time.

A static analysis of a combined system of a Machine Guard and a channel section (upon which the guard rails) will guide one to understand a number of forces applied on the body.

Generally following types of loads are applied on the channel section of a machine guard.

**Weight:** Weight of the guard (W) will be imposed Vertically Down and will be transmitted to the channel section through horizontal rollers supported by rail.

**Fixture Load:** The usage of fixtures on a channel to keep it fixed with guard can't spare

it stress free and that HORIZONTAL REACTION is induced opposite to the bolt load.

**Wing Load:** A shop floor has a variety of small and large machines according to the jobs required to be done. Cooling is a major aspect during a machining process which can't be ignored. Lubricant is used for the cooling of the machined work-piece while high speeds Industrial Fans are used for the comfort of workers. These fans impose Wind Load on the guard. The guard which acts as a Cantilever Beam transmit it to the channel section through its vertical rollers located on both sides of the rail.

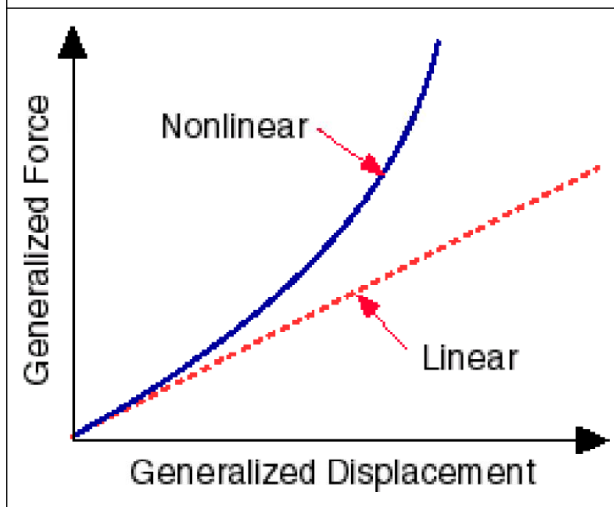
## NON-LINEAR STATIC LOAD ANALYSIS

In Linear static analysis the relationship between loads and the induced response is linear while in Non Linear static analysis it is exactly opposite, i.e., the relationship is non-linear.

All real structures behave non linearly in one way or another at some level of loading. In some cases, linear analysis may be adequate. In many other cases, the linear solution can produce erroneous results because the assumptions upon which it is based are violated. Nonlinearity can be caused by the material behaviour, large displacements, and contact conditions.

In the nonlinear static analysis, dynamic effects like inertial and damping forces are not considered.

The difference between Nonlinear and Linear static forces can be depicted from the graph given as below Figure 1.

**Figure 1: Linear and Non Linear Force Depiction 1**

## STATIC ANALYSIS RESULTS

### Weight of the Guard

Cold rolled Steel = 231.45 Kg

Toughened Glass = 19.168 Kg

Total Load = 250.618 Kg

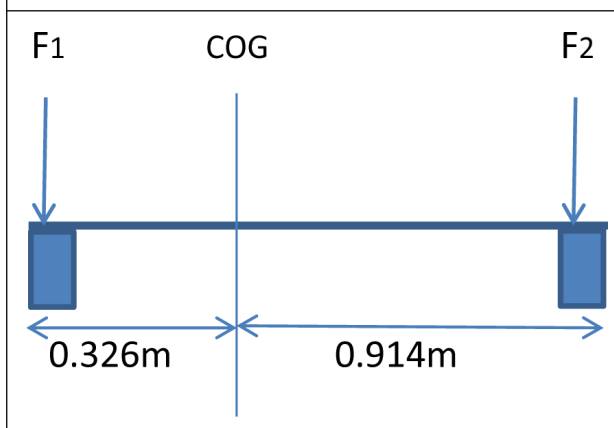
Hence,

$$250.618 \times 9.8 = 2456.0564 \text{ N}$$

### Vertical Force Calculation on the Bearings

$$F_1 \times 0.326 = F_2 \times 0.914$$

$$F_1 + F_2 = 2456.0564$$

**Figure 2: Forces Acting on Bearings**

$$\therefore (2456.0564 - F_2) \times 0.326 = F_2 \times 0.914$$

$$800.6743 = 1.24F_2$$

$$F_2 = 645.705 \text{ N}$$

$$F_1 = 1810.351 \text{ N}$$

### Horizontal Force Calculation on the Vertical Roller

$$F_1' \times 0.326 = F_2' \times 0.914$$

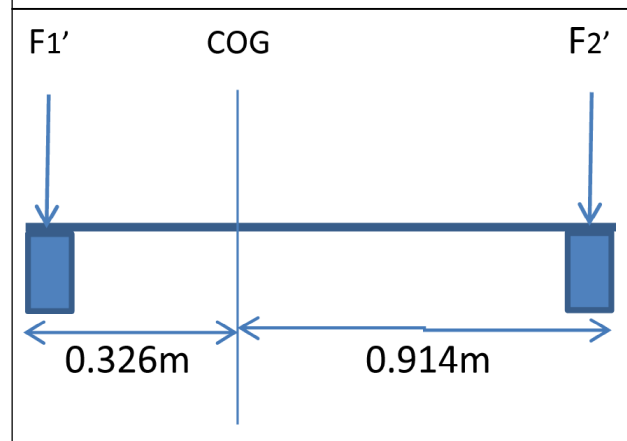
$$F_1' + F_2' = 3580.2415$$

$$\therefore (3580.2415 - F_2') \times 0.326 = F_2' \times 0.914$$

$$1167.158 = 1.24F_2'$$

$$F_2' = 941.257 \text{ N}$$

$$F_1' = 2638.98 \text{ N}$$

**Figure 3: Forces Acting on Rollers**

## WIND LOAD ANALYSIS

In a workshop, many machining processes are in operation continuously for long hours to produce a plethora of products of the same kind or of a variety. The manufacturing results into heat generation sufficient enough to raise the temperature of the ambience to the level of worker's discomfort. Generation of smoke in conjunction with heat emanation contributes in workers' fatigue and low level of enthusiasm to work. Hence Ergonomics suggests ways to

eradicate such problems in a convenient manner. Ergonomics state the use of Industrial Fans in Workshops to improve the comfort level of a worker which conclusively improves state of well-being and removes heat generated quite efficiently.

A Machine Guard is always attached with large machines. It is observed quite often that the Industrial Fans are located to the opposite of the inner face of the guard and at an elevation. Since an industrial fan of diameter more than 1 meter rotates at high rpm, hence throw the air at very high velocities towards the guard. Though it may not affect humans but indeed makes a significant impact on the life of guard in the longer run.

So it becomes necessary to do Wind Load Analysis to consider conditions in which wind load is imposed on the guard and also to calculate wind loads which will further be considered during static and fatigue analysis of the Channel Section of the guard.

### CONSIDERATION OF INDUSTRIAL FAN ELEVATION AND ITS INCLINATION ANGLE

- The recommended Standard Inclination Angle of an Industrial Fan measured from a vertical axis is  $30^\circ$ .
- Since the direction of wind is inclined to the guard by  $30^\circ$ , hence it is necessary to calculate Projected Area of the guard, which is taken as perpendicular to the direction of the wind and is shown in Figure 4.

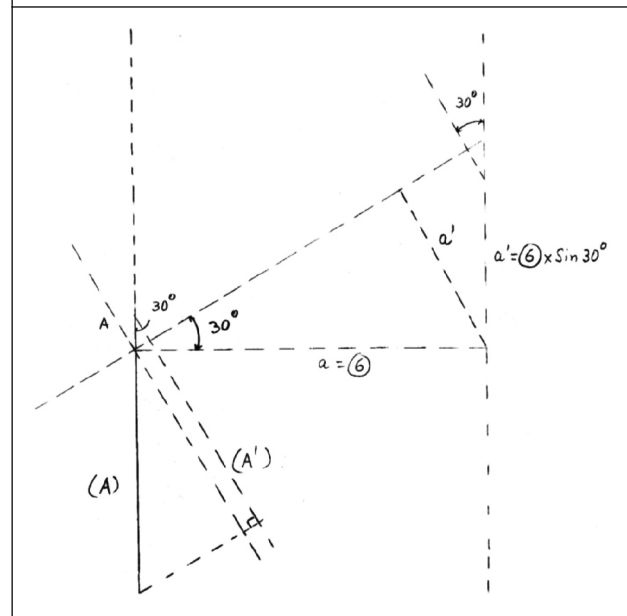
Let us assume the guard to be made up of individual sheet metal plates. And let the area of each of these plates is indicated by 'A'. Then

the projected area is assumed to be indicated by  $A'$ .

The formula derived from the above figure is given by:

$$\frac{A'}{A} = \cos 30^\circ$$

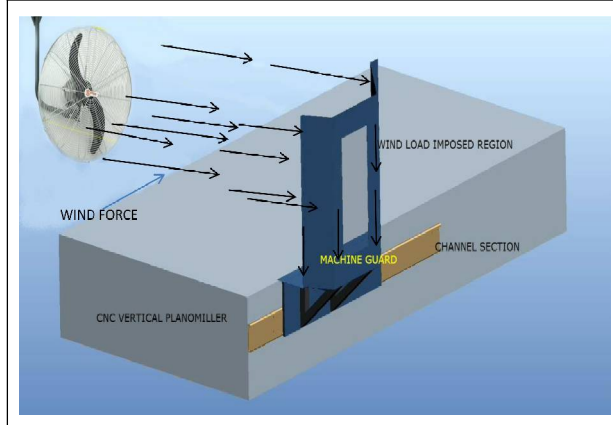
**Figure 4: Fan Inclination Angles and Wind Force Angles**



### FATIGUE LOAD ANALYSIS

When repeated loading and unloading takes place in an object, it fails over time. It will happen even when the induced stresses are considerably lesser than the allowable stress limits. This phenomenon is known as Fatigue Analysis. With every cycle of stress fluctuation, object becomes weak to some extent. As the number of cycles increase to a critical level, the object becomes so weak that it fails. There are many causes of failure for an object but the major cause is none other than Fatigue failure, especially for metals. Examples of failure due to fatigue include, rotating machinery, bolts, airplane wings, consumer

**Figure 5: Actual Depiction of Forces Acting on the Guard and their Flow to the Base and Channel Section**



products, offshore platforms, ships, vehicle axles, bridges, and bones. The Pictorial representation of fatigue Load due to wind is shown in Figure 5.

The main problem with linear and non-linear static analysis is that they are unable to predict the failure due to fatigue. In linear and non-linear static analysis, calculation is done for the response of a design subjected to a specified environment of restraints and loads. If the calculated stresses are within allowable limits, it is concluded affirmatively that the design is safe in this environment regardless of how many times the load is applied.

For defining a fatigue study static, non-linear, or time history linear dynamic studies can be used as a Wind Force prime basis. The most important term in the entire fatigue study is SN Curve. It gives value of the number of cycles required for fatigue failure to occur at a location. The calculated value is dependent on the material and the stress fluctuations.

### Endurance Limit

There is a term in the fatigue study which when gets smaller; the material can take more stress

cycles before it fails due to fatigue. The endurance limit is defined as the highest alternating stress that does not result in fatigue failure. Simply put, if the alternating stress is equal to or lower than the endurance limit, the number of stress cycles to cause failure becomes very large (practically infinite) The endurance limit is also called the fatigue limit. This behaviour is only found in steel. In aluminium alloys, fatigue strength at  $10^7$  cycles is usually used in place of the fatigue limit. This is a stress which will produce failures in  $10^7$  cycles.

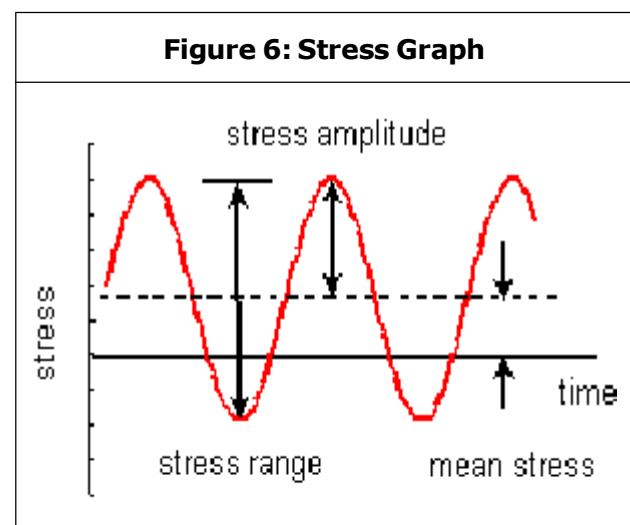
### Alternating Stress

The alternating stress is defined as  $(\sigma_{\max} - \sigma_{\min})/2$  where  $\sigma_{\max}$  and  $\sigma_{\min}$  are the maximum and minimum stresses respectively. It is denoted by  $S_a$ . It is the amount the stress deviates from the mean. It is sometimes called the stress amplitude. Below Figure 6 represents all the Stress in graphical form.

### Stress Range

$$\text{Stress} = (\sigma_{\max} - \sigma_{\min})$$

It is defined as the difference between the maximum and minimum stress in a cycle.





## Mean Stress

$$\text{Mean stress} = S_m = (\sigma_{\max} + \sigma_{\min})/2.$$

It is taken as an average of the maximum and the minimum stress in a cycle.

## Stress Ratio

$$\text{Stress ratio} = \sigma_{\min}/\sigma_{\max}$$

It is defined as the ratio of the minimum and the maximum stress obtained in a cycle.

## Fatigue Life

Fatigue life, at a given alternating stress level and mean is the number of cycles required to cause failure due to fatigue.

## Fatigue Strength

The stress at which fatigue failure occurs after a given number of loading cycles.

Or in other words, the stress required producing failures in a specified number of cycles.

In steel this is usually  $10^6$  cycles and is  $10^7$  cycles for welds and aluminium alloys. It is directly related to the strength of the material.

## STAGES OF FAILURE DUE TO FATIGUE

Failure due to fatigue occurs in three stages:

**Stage 1:** Initially one or more cracks develop in the material. What makes crack so brutal is that they can develop anywhere in the material. But they usually occur on boundary faces due to higher stress fluctuations. Some of the reasons for the occurrence of cracks are imperfections in the microscopic structure of the materials and surface scratches caused by tooling or handling.

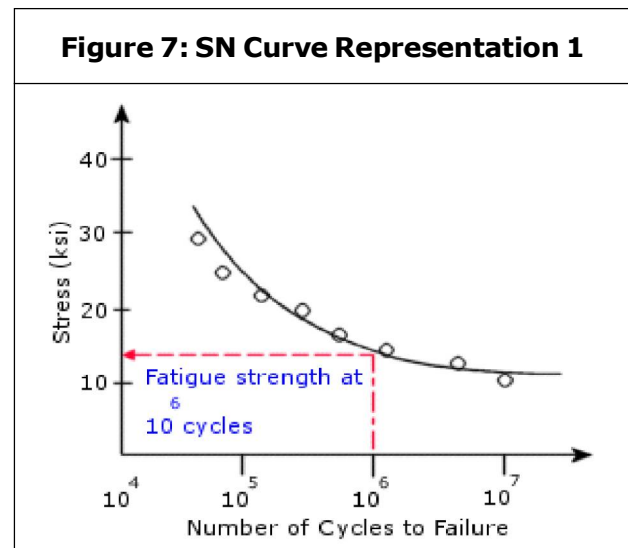
**Stage 2:** With repeated loading or unloading some or all cracks grow gradually and speedily.

**Stage 3:** More the material resists the impact of applied loads, more it continues to deteriorate until failure occurs.

Fatigue cracks start on the surface of a material. Strengthening the surfaces increases the life of the model under fatigue events.

The fatigue strength can be graphically computed using the values of number of cycles (N) for failure to take place.

This is depicted in the Figure 7 as given below.



## FATIGUE LOAD ANALYSIS RESULTS

The Number of Cycles as per the fatigue constant amplitude result is 60,000, i.e., the Guard can endure these many stress cycles throughout its life span as shown in Figure 8.

The Damage percentage is also very minor of the amount 0.00248%. Thus the section is safe for this result also and the guard can function without failure as shown in Figure 9.

Figure 8: Total Life Cycle of Guard

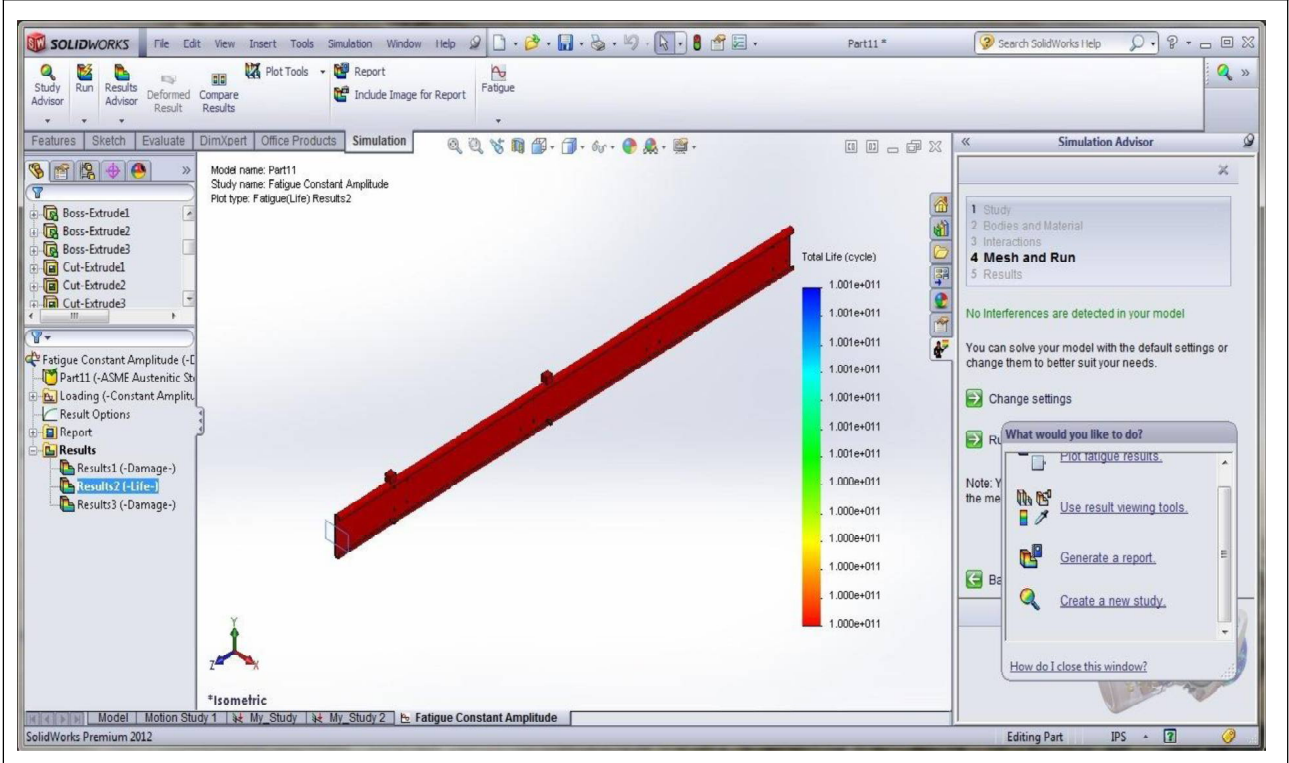
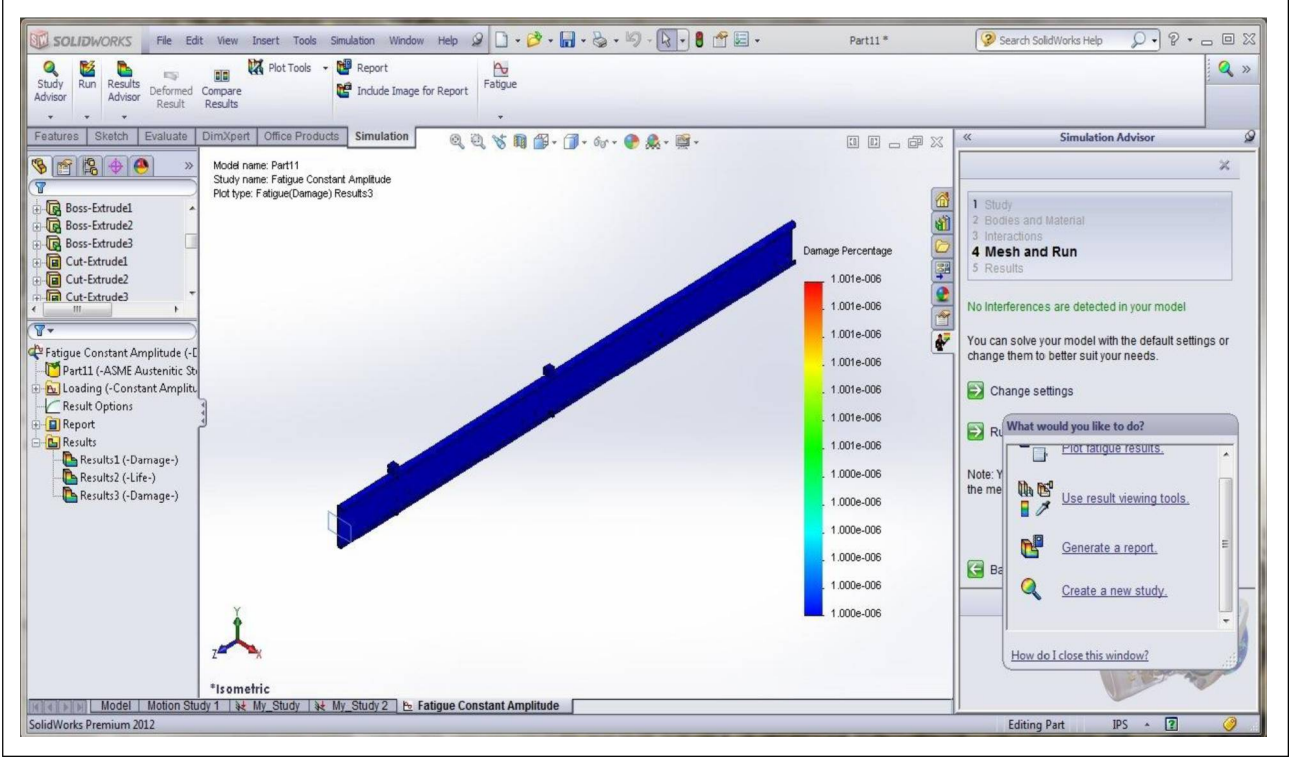


Figure 9: Damage Percentage to the Guard



## CONCLUSION

After having done a comprehensive and extensive work, the results found are pretty much satisfactory and came out to be close to our estimations and expectations. During the on-going process, the core issue and after having done many rounds of brainstorming sessions we were successful in clicking on a few innovative ideas which indeed has improved the fatigue strength and life cycle of the guard significantly. The following points discussed below are our key solutions to our problem defined:

**Provision of Braces:** To prevent the failure and to improve the supportive system for the guard the braces are approved. This has significantly reduced chances of fatigue failure and provided a supportive base to the guard. This will reduce chances of derailing in the future.

**Provision of Dents on Face of Guard:** Dents are very handy in making the air pass through them. With the use of dents high velocity air will not have enough strength to create oscillation cycles of guards which are the main ingredients to building up of fatigue. So life of the guard will be more than before.

**Oil Spillage Minimized by Improvising the Shape of the Base:** An inclination of 45° is given to a lower part of the base metal sheet to return the oil through the passage. This is

significantly reduced wastage of oil and made the surrounding floor clean and comfortable to walk and work.

### Rollers Replaced by Cylindrical Bearings:

The Bearing is selected instead of rollers. The disadvantage of roller is that it doesn't contribute in bearing vertical and horizontal loads. The best pick from the lot considering the current scenario is Cylindrical Bearing which can take radial loads effectively. The fatigue failure which can happen due to continuous wind load imposing can be reduced to minimum using the same. 🌀

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