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Wedge, A New Designed Part Integrated to a Sawmill Carriage for Oil Palm Stems Using Polygon Sawing Pattern

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ABSTRACT

The oil palm trunk (OPT) is increasingly becoming important as raw material resource for wood composite products in Malaysia to mitigate the depletion of solid wood supply. Currently the OPT represent a massive volume of agricultural waste with great potential to develop rapidly the wood composite industry in the country. An improvement in sawing technology has potential to improve the yield of the commericially important hard outer core of the OPT by about 27% whereby the present sub-optimal square sawing pattern can be changed into the more efficient and higer yielding polygon sawing pattern. To effect this a 'wedge' device was designed mounted on the sawing carriage. The integrated device can provide more accurate sawing of the OPT with improved handling of the sawing process. This paper describes the concept and design of the wedge device.

KEYWORDS

Wedge, Sawmill Carriage, Oil Palm Stems, Polygon Sawing Pattern

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INTRODUCTION

The main issue faced by most wood manufacturers all over the world is the shortage of wood. The gap between supply and demand is big where the supplies of wood material have left far behind the demand for it. This gap is becoming bigger due to the aggressive depletion of forest that leads to a reduced wood supply. On the other hand, the wood demand increases due to the fast population growth.

Wood which is a raw material is classified into solid wood and composite wood. Between these two categories, solid woods have more severe supply problem than the composites wood. As a result, many efforts have been made to increase the application of composites wood such as plywood, Laminated Veneer lumber (LVL), Parallel Strand Lumber (PSL), particleboard, Oriented Strand Board (OSB) and Medium Density Fiberboard (MDF) as this composites wood, as alternative to the use of solid wood, is becoming increasingly important (Kampman *et al*., 2008). However, certain properties of solid wood are not able to be contested by the composites wood. This is the reason why composites wood cannot be the substitution and at the same time, the demand on solid woods have never been decreased although their price becoming much more expensive.

Another reason why the solid wood is always under a strong demand is many users strongly believe that possessing a product made of solid wood is worthier, ore reliable and stronger than those from composites wood. Because the problem must be solved as soon as possible, any efforts must be done to find other alternative materials for solid wood, either from the traditional forest or lignocellulosic material such as agriculture wastes from outside of the forest.

One of the agriculture wastes that can be used as an alternative material for solid wood is oil palm trunk. In Malaysia it is estimated that about 120,000 ha oil palm were planted annually between 2006 and 2010 totaling about 4.3 million trees in 2007 (Wahid, 2008) and with about 80 million trees felled annually in both Malaysia and Indonesia (Husin, 2000) and this figure makes Malaysia the largest palm oil producing country in the world. Compare to fronds and empty fruit bunches, the oil palm trunk offers the best properties of wood. Tens of million cubic meters of oil palm trunk were yielded from the replanting of the old oil palm trees annually. The study also reported that oil palm wood from the outer parts of matured oil palm stems, which is more than 25 years old, have considerable good properties. Thus, these parts of the stem could be used as solid wood after being properly treated.

OPT has widely been used as a rich source of lignocellulose fibers in the manufacture of MDF and paper. Recently, the use of OPT as a new source for both solid wood and the bio-composite material is increasing in importance. The anatomical structure of OPT is typically that of a monocotyledon palm as illustrated in Figure 1.

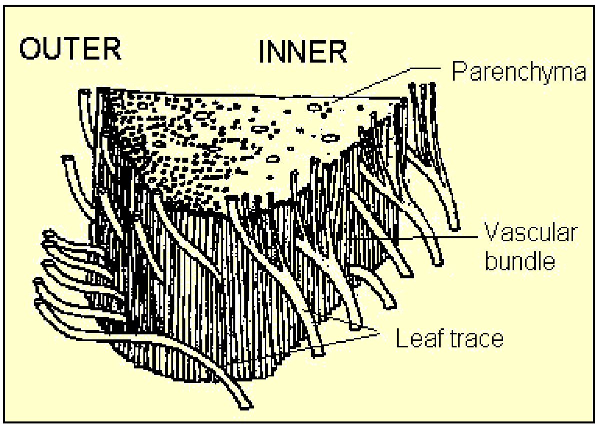

Figure 1: Oil palm trunk (Bakar et al., 1998)

OPT does not have heartwood and sapwood zoning typical of a dicotyledon anatomy. In contrast, the wood of the outer part of OPT are denser and has higher quality than that nearer the central core. The core resource for solid lignocellulose supply is the oil palm trunk (OPT) in particular the preferred hard outer layer typical of a monocotyledon trunk anatomy (Bakar *et al*., 1998).

The production of solid wood requires the conversion of logs into sawn timber through the sawing process. There are three main sawing patterns used, (i) life or plain sawing, (ii) round sawing and (iii) quartered or rift sawing. All three patterns are suitable for hardwood and softwood logs, which have central heartwood cores and peripheral sapwoods characteristic of dicotyledon species. Saw logs from heartwood core are preferred due to their higher quality. However, for OPT it is clear that the round or polygon sawing pattern would be most suitable. The polygon pattern should potentially produce the maximum volume of quality outer lumber as compared with life and quartered sawing patterns.

To maximize the yield of saw logs in polygonal sawing, and maintain size uniformity in the sawn lumber, firm and accurate handling of the OPT log is important in order to conform closely to its geometric pattern. It is thus important to improve the accuracy, hence productivity, of the polygon sawing process. The objective of this paper is to design a device that can help improve the handling and accuracy of the polygon sawing process for oil palm trunk (OPT) and conduct stress analysis on the innovated device.

MATERIALS AND METHODS

Materials

Material used to fabricate the wedge device was stainless steel. A hydraulic cylinder was a very important component to lift the movable table and the wedge device. It had a high-performance contactless sensing and linear and absolute measuring. The accuracy was 0.04% and the input power used was 12/24V. The minimum rod diameter was 25mm and minimum cylinder bore diameter was 60mm. The stroke ranges from 50mm up to 1500mm. Most importantly it able to lift, up to 350 bars.

Calculation for wedge and inner angle of the OPT

The five-angled Polygon (Pentagon) pattern was used to saw OPT. To this, the diameter range of oil palm stems between 40cm and 50cm had been taken into consideration. In the pentagon, the total angle, ω and each corner angle, α can be calculated using Equation 1 obtained from Roloff/Matek Maschinenelemente (Muhs *et al.*, 2003).

$$\omega = (n - 2) \times 180° \qquad \text{(Eq. 1)}$$

$$\alpha = \omega / n$$

$$\omega = 3 \times 180° = 570°$$

$$\alpha = 570°/5 = 108°$$

This angle was the same for all corners, regardless of stem diameter as shown in Figure 2.

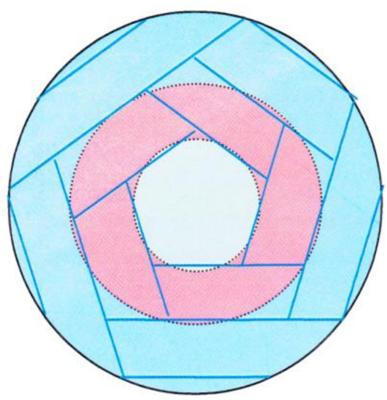

Figure 2: Polygon sawing pattern

On a band sawmill, the log was laid down in a series of the L-shaped knee on the carriage and the saw cut the log vertically. After the first cutting was made, the log was rotated clockwise to position it for the second cutting in which the angle 'α' (angle between the two lines) was 108°. At that position, the angle α could be easily set by putting a "wedge" with an angle 'β' to support the log that made it perpendicular to the first cut as shown in Figure 3. The wedge angle β can be then calculated as follow:

$\beta = \alpha - 90°$

$\beta = 108° - 90° = 18°$

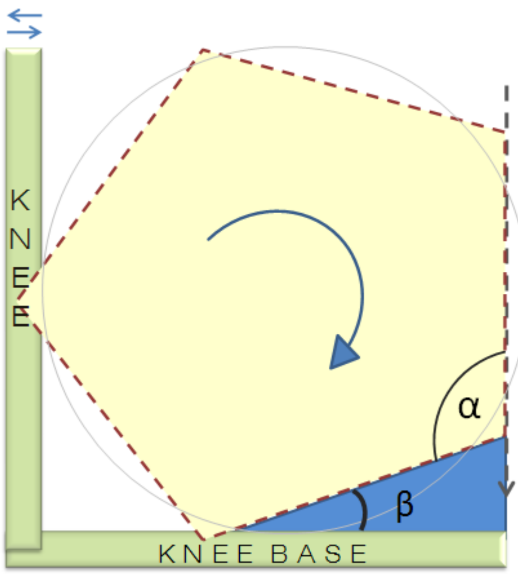

Figure 3: Polygon sawing process using innovative wedge

Since the pentagon was symmetrical, the angle of the "wedge" for all cutting must be at the same angle of β equal to 18°. The position of the knee on the base was adjustable, depending on the diameter of log or cant being sawn. And in some carriage system, the knee was also equipped with a hydraulic mechanism to rotate the log or cant above the knee base.

The innovative wedge able to be moved ´up´ and ´down´ at each set of the knee on the carriage. At the ´up´ position, the wedge will serve as a slanted base and accurately support the log/cant to allow the new cutting line form to an α angle to the previous cutting line. At ´down´ position, the knee base will be at the free horizontal condition to allow the log to be easily moved or rotated on the base.

Since the OPT was long and heavy, the attachment system must be securely and strongly positioned for each set of knees, and all moving components (log and wedge) can be moved simultaneously with one button.

Components of wedge device

The wedge was basically made of five components as shown in Figure 4. These were the rod, wedge support, movable table, hydraulic cylinder, adjustable wedge and base. The rod secured the adjustable wedge which held the log at a specific angle; 108° with the wedge supported and 120° with the adjustable wedge. The movable table supported the log which was moved in the vertical plane by the attached hydraulic cylinder. The base supported the movable table.

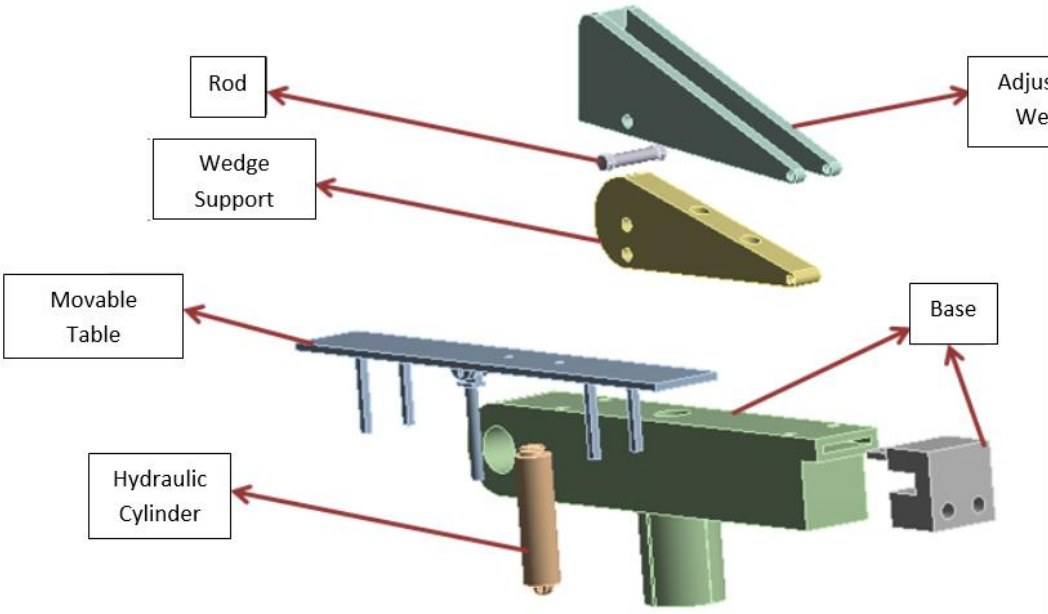

Figure 4: Components of wedge device

The top dog was a conventional device that assisted in holding securely the OPT during the sawing process. It was mounted on the vertical knee as shown in Figure 5.

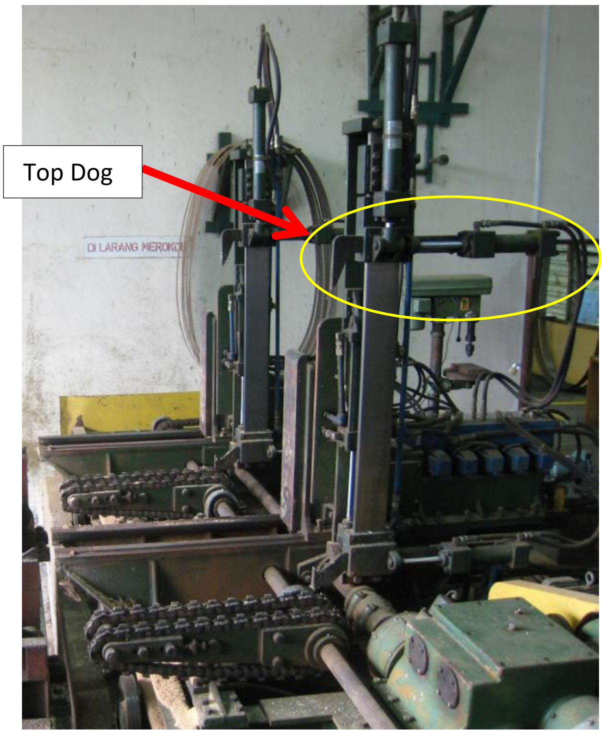

Figure 5: Top Dog of the sawing machine

Figure 6 showed the position next to the carriage base where the innovative wedge device will be assembled. Figure 7 below shows how the wedge was adjusted to change the angle β for the pentagon sawing pattern (β=18°) or the hexagon pattern (β=30

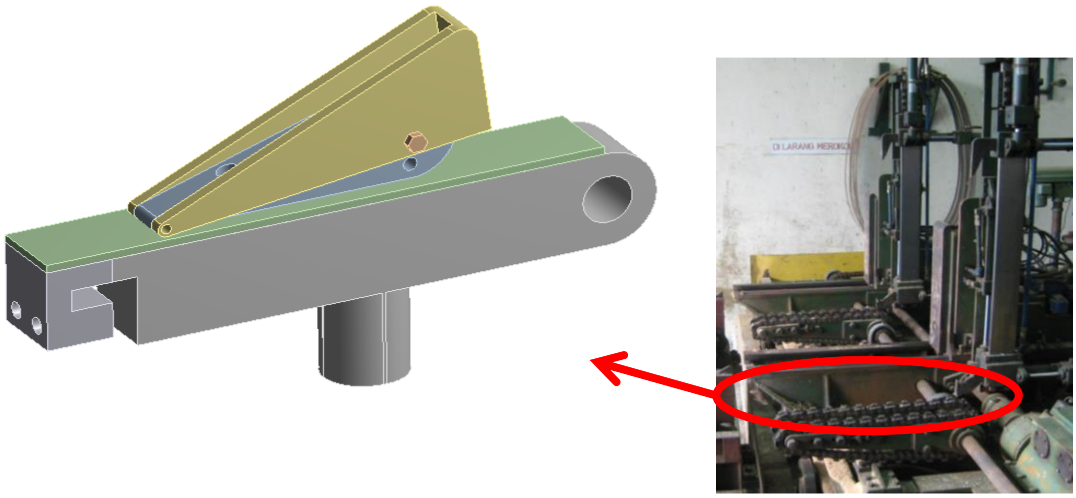

Figure 6: Wedge mounted on the sawmill carriage

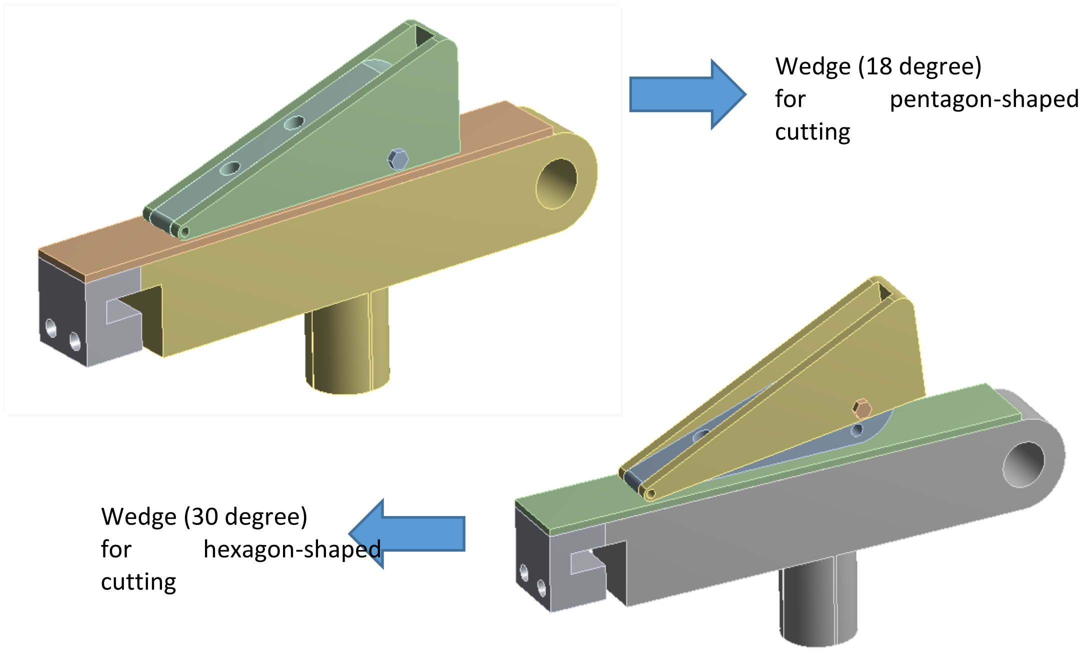

Figure 7: Adjustable wedge for pentagon- and hexagon-pentagon cutting

RESULTS AND DISCUSSIONS

Stress Analysis

Stress analysis is an engineering methodology to determine the maximum or minimum stress in structures or components subjected to static forces, dynamic forces or given loads. The analysis is usually performed to determine the safety factor or whether the elements or materials can safely withstand the specific forces. The material is safe from any failure when the calculated stress is less than the maximum allowable tensile stress, maximum compression strength, fatigue strength or maximum deformation. Thus, every material has its own safety factor before it can be used.

The safety factor depends on many aspects such as load or force that act on the component, type of material, temperature or other surrounding influences. The safety factor of any component is equal to the fraction of ultimate tensile strength and maximum allowable stress. The main part of this analysis involves determining the type of loads acting on the component including tension, compression, shear, torsion, bending or combination of such loads. The information regarding the applied load, distribution of forces between components, stress distribution and the deformation of the components can be obtained from FEM-calculation (Finite-Element-Method). The FEM-calculation program that will be used in this analysis is called ANSYS Workbench 10.0.

The base was used as a support for the wedge. It was made completely of stainless steel. It is soldered at the bottom to the hydraulic cylinder which lifted the wedge at a maximum force of 2598N. Figure 8 shows the static components which act on the base.

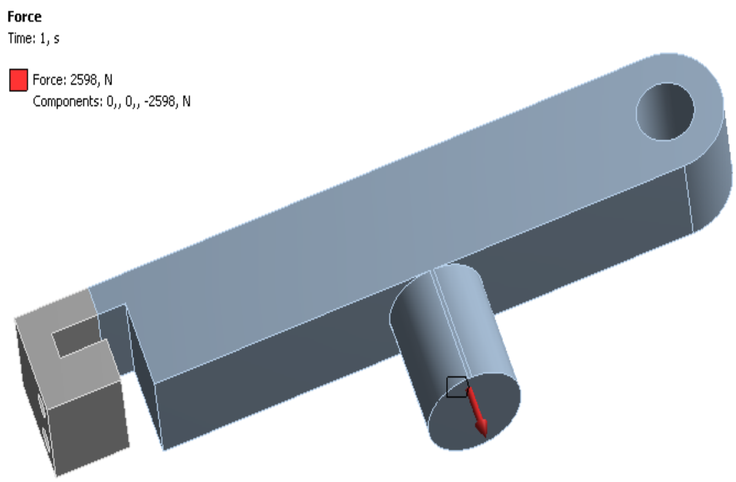

Figure 8: Force component on wedge base

Figure 9 shows the mesh generation. It is one of the most critical aspects of engineering simulation. Too many cells may result in long solver runs and too few may result in inaccurate results. ANSYS Meshing allows the user to find the balance and get the right mesh for their simulation in the most automated way possible.

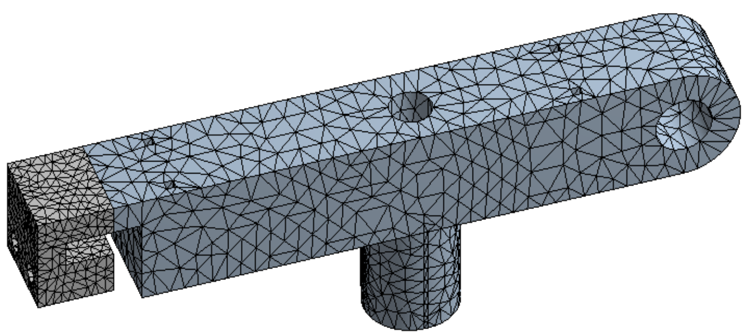

Figure 9: Mesh

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Further analysis is performed using ANSYS and the results are illustrated in Figure 10 and 11.

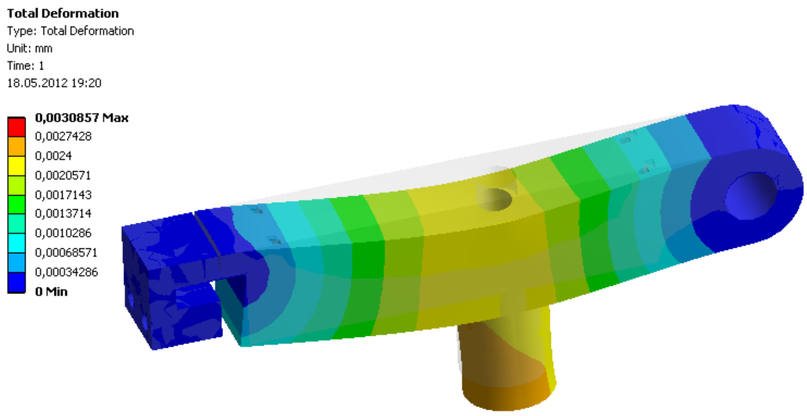

Figure 10: Total deformation

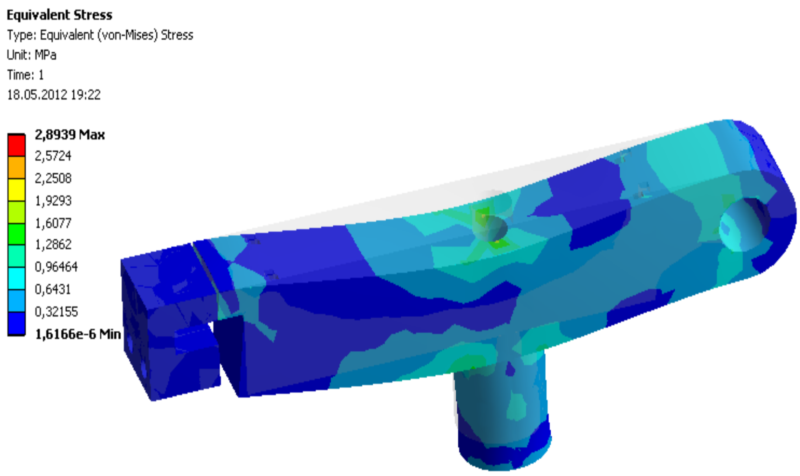

Figure 11: Equivalent stress

The analysis showed that the maximum equivalent stress exerted on the wedge base is 2.0939 MPa and the maximum total deformation is about 0.0030857 mm. It can be concluded that the base had a relatively small maximum equivalent stress under a specific load. The total deformation was also very small and will not affect the accuracy of the cutting process. The result showed that the maximum equivalent stress was around the holes and the minimum point was on the left- and right-hand sides.

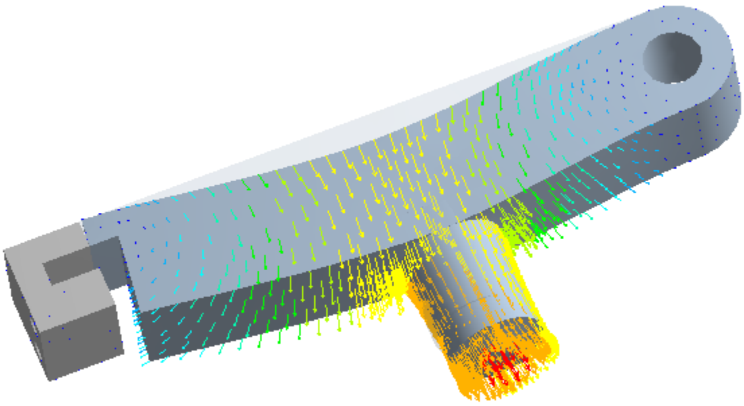

Figure 12: Vector display

Figure 12 shows the vectors that display acting forces. It clearly showed where most forces were exerted on the base. The forces moved downwards towards the bottom of the hydraulic cylinder´s housing. Thus, the bottom part will experience the greatest force. However, since the mesh was equally distributed over the solid base structure, it will experience minimum equivalent stress and minimum total deformation.

Calculation of static component strength against crack

The static component strength was calculated in order to identify whether the wedge base can withstand deformation or otherwise. The component strength will be determined and compared with the FEM-calculation (ANSYS). All equations below were available in Roloff/Matek Maschinenelemente (Muhs *et al.*, 2003).

The calculation for the static component strength against crack was as follows:

Crack, $\sigma_B = \frac{f_\sigma \cdot R_m}{K_B}$

Where,
f_σ = Factor to calculate the material strength value = 1
R_m = Tensile strength of the material
K_B = Static construction factor

Tensile strength, $R_m = K_t \cdot R_{mN}$

Where,

K_t = Technological size effect factor for tensile strength and yield strength = 1
R_{mN} = 510 N/mm^2

Static construction factor, $K_B = \frac{1}{\eta_{pl}}$

Where,
η_{pl} = notch sensitivity (factor)

Notch sensitivity, $\eta_{pl} = \sqrt{\frac{R_{pmax}}{R_p}} \leq \alpha_p$

Where,
R_{pmax} = Maximum yield strength = 1050 N/mm^2 for steel
R_p = Yield strength
α_p = Plastic stress concentration factor for component without groove

Yield strength, $R_p = K_t \cdot R_{pN}$

Where,
K_t = Technological size effect factor for tensile strength and yield strength = 1
R_{pN} = 355 N/mm^2

α_p = 1.27

Thus, notch sensitivity, $\eta_{pl} \leq 1.27$

$$K_B = \frac{1}{1.27} = 0.79$$

The maximum stress against crack for the base is:

Crack, $\sigma_B = \frac{1 \cdot 510\ N/mm^2}{0.79} = \underline{\mathbf{648\ N/mm^2}}$

In comparison with the maximum equivalent stress calculated from the FEM calculation, the maximum tensile stress at the crack for the stainless steel was higher. It can be concluded that using the stainless steel for the base was very reliable and safe against deformation and crack.

Maximum equivalent stress $= 2.0939$ MPa $\ll \sigma_B = 648$ MPa

The stainless steel base will only crack or break if the equivalent stress is higher than 648 N/mm^2 (MPa).

CONCLUSIONS

The new designed of wedge device can help improve the handling and accuracy of the polygon sawing process for oil palm trunk.

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