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RESEARCH ARTICLE

RESEARCH AND MANUFACTURING OF *ROTARY KNIFE CUTTER* FOR SUGAR PROCESSING FACTORY

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ABSTRACT

Rotary knife cutter is a part of cane chopper machine that mounted on the machine shaft. The number of rotary knife cutter mounted on the machine are 24 pieces that arranged to 6 lines and each line has 4 pieces. Chopper machine is driven by steam turbine, when the engine is operated shaft rotates and rotary knife cutter also rotating because it being tied to the engine shaft. Sugarcane entering through the hopper machine will cut into small parts with a size of 1 - 1.5 cm and further the pieces of cane will be processed on a hammer machine. Rotary knife cutter used in the Sei Semayang and Kualamadu sugar factories is straight shape and sharpened at one end and both sides. Rotary knife cutter materials used are aumtits that imported in the form of plate and manufactured in local workshops. This knife can be used to cut sugar cane upto 60,000 tons, and then be replaced due to wear. In this study resulted four pieces of rotary knife cutter that fabricated by metal casting techniques. Blade material is adopted from the ASSAB, XW-41 standard by modifying the elements molybdenum into three variations. To obtain the actual dimensions used milling and drilling machines. Casting that has been finished on the machine, processed again by heat treatment to a temperature of 1000^{0}C and cooled in the air blow to obtain an appropriate hardness. Rotary knife cutter has been tested in the Sei Semayang and Kualamadu sugar factories, from the test results obtained the life time of rotary knife cutter is 175000-210000 tons sugarcane.

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INTRODUCTION

Preliminary

Thrasher sugarcane using some knife mounted on a knife holder that is fixed to the engine shaft. By the time the machine is operated, the blade spins while this will cut the cane into small parts. Because the system is working rotating blades while cutting cane then this knife called a rotary knife cutter. Rotary knife cutter must be sharp in order to obtain quality and good cutting capacity. If a blunt knife, the cutting results are not perfect so the cane fiber will stick to the blade resulting in engine load becomes high and efficiency decreases thereby decreasing production capacity. During the process of cutting cane, friction between cane and a knife that causes wear and tear so that the blade becomes dull. The shape and size of the rotary knife cutter used in sugarcane processing plants vary, depending on the type and capacity of machine used.

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Type of separate blades, the blades are made of different materials with the handle and the blade can be replaced without replacing the stem, as shown in Figure 1. The sugar factory Sei Semayang and Kualamadu using a knife straight shape sharpened at the tip and both sides as shown in Figure 2. Rotary knife cutter used in sugar mills Sei Semayang made from Aumtit materials, these materials are still imported in the form of sheet plate, manufacturing is done by cutting the plate and then machined to obtain the desired shape and size. In this research, engineering and design of rotary knife cutter with the metal casting technology. The shape and size of the blade is made equal to the shape and size of the rotary knife cutter used on sugar mills Sei Semayang and Kualamadu in order to be tested at that factory.

RESEARCH METHODOLOGY

Materials and Equipment

The materials used for the manufacture of rotary knife cutter is steel scrap and alloy materials. Making a rotary knife cutter is done by casting techniques so that the necessary auxiliary materials are needed for the manufacture of the pattern and mould. The main equipment needed is an electric induction furnace, the pattern making equipment, mould manufacturing equipment, spectrometer and for the purposes of testing required tensile testing machines, hardness testing machine, impact testing machine and metalurgical microscope. In this modified rotary knife cutter was made in accordance with the shape and size of the cutter which is used in the sugar factory Sei Semayang and Kualamadu. The rotary knife cutter material adopted from the ASSAB, XW-41 standard. Raw materials and alloy materials are mixed to modify the composition of the XW-41 then do smelting in electric furnaces induction.

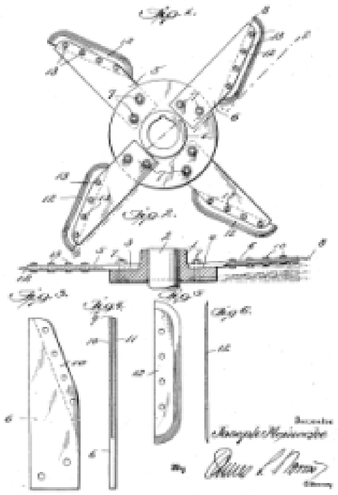


Figure 1. Type Blade Separated

Figure 2. Rotary knife cutter at Sugar Factory Sei Semayang

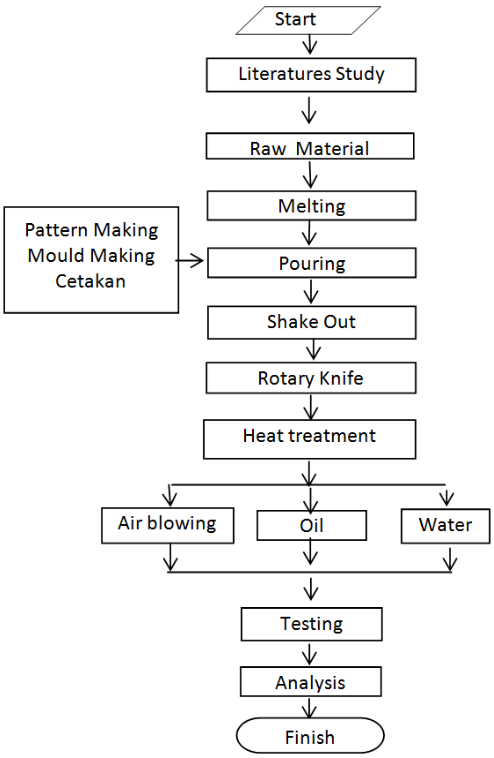


Figure 3. Reseacrh Flow Diagram

The element of molybdenum varied as many as three variations ie variations 1, Mo (0.2-0.5) %, variation 2, Mo (0.6-1.0) %, and the variation 3, Mo (1.1-1.5) %, other elements remain. Implementation of engineering is done in accordance with the engineering flow diagram as shown in Figure 3.

Making the pattern

Pattern serves to form a cavity in a sand mould, the size of pattern added to cope shrinkage and machining. Pattern was made of wood jelutung with a surface that smoothed so that the sand is not attached to a pattern where printing is performed (Figure 4).

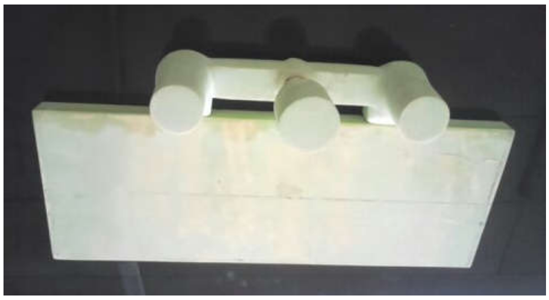


Figure 4. Pattern of Rotary knife cutter

Moulding

Moulds made of sand by adding water glass binder as much as 5 % and then mixing in a mixer for 2 minutes. Mould making is done by using the pattern and moulding box. Moulding sand is compacted and hardened by shooting CO_2 gas through the slit moulding sand, after the mould hardens pattern withdraw. Mouldig cavity coating using zircon, dried and heated by using a burner, mould assembled, made of ballast on and then do the pouring.

Figure 5. Moulding

Smelting

Materials used consist of steel scrap and alloy materials such as carburizer, silicon, manganese, chromium, vanadium. These materials are weighed according to the calculated results of alloying material.

Figure 6. Melting Furnaces

At the time of smelting made chemical test samples for each variation, by pouring molten metal into metal moulds. Chemical composition testing is done by using a spectrometer, the test results are shown in Table 1.

Table 1. Test Results Composition

Element (%)	Variation 1	Variation 2	Variation 3
C	1,593	1,550	1,643
Si	0,303	0,445	0,379
Mn	0,443	0,360	0,442
Cr	11,867	11,933	13,033
Mo	0,448	0,902	1,137
V	0,855	0,956	0,833

Pouring

Pouring performed after the mould is prepared, the preparation of the mould is needed, the mould is coating with zircon, drying mould, heating the mould, mould assembly and delivery of ballast. Molten metal that has been prepared in the ladle and taken to the mould and the pouring is done at a temperature of 1650 ºC, Figure 7.

Figure 7. Pouring of Rotary knife cutter

Shake out Moulds

After pouring is completed, the mould allowed to cool and then casting removed from the mould by shake out. Casting cleared of sand and gating system is cut using a grinding, casting product is shown in Figure 8.

Figure 8. Casting Results

Machining

Castings have a high enough hardness of about 43-47 HRC, making it difficult machined, therefore do softening with full annealing process. Castings heated to 1000 ºC in the furnace and held for 2 hours and then allowed to cool slowly in the furnace. After going through the process of annealing, castings hardness reduced to approximately 17-20 HRC

Figure 9. Casting which has annealed

Rotary knife cutter obtained by the casting process has not had the same size as the actual size, therefore it is necessary to machine the surface, manufacturing of sharp edge and bolt holes. To flatten the surface and sharpen the blade used milling machine, and to make bolt hole use drilling machine. Rotary knife cutter that has been ready machined to be processed again by heat treatment to increase the hardness. Rotary knife cutter after machined shown in Figure 10.

Figure 10. Rotary knife cutter after machined

Examination

To know the characteristics of a rotary knife cutter, conducted a series of tests. The test sample in the form of U block casted together with a rotary knife cutter for each variation. The test sample is formed to be test specimens in accordance with the testing requirement. Tests were conducted: tensile testing, hardness, impact and metalograpic.

Tensile test

Tensile test specimen taken from the test sample U block by cutting in the longitudinal direction and formed by using a lathe machine in accordance with ASTM E8M-04, Figure 11.

Figure 11. Tensile test specimens

Table 2. Tensile Testing Results

No.	Sample	Tensile Strength (kgf/mm^2)		Elongation (%)	Reduction area (%)
Air blowing hardening					
		σ_y	σ_{maks}	ε	R
1	Variation 1	30,35	31,94	0,40	0,97
2	Variation 2	38,20	39,33	0,40	0,95
3	Variation 3	40,81	41,90	0,20	6,30
Oil hardening					
No.	Sample	Tensile Strength (kgf/mm^2)		Elongation (%)	Reduction area (%)
		σ_y	σ_{maks}	ε	R
1	Variation 1	31,50	32,11	0,00	0,00
2	Variation 2	36,47	36,76	0,00	0,00
3	Variation 3	38,44	38,96	0,00	0,00
Water Hardenig					
No.	Sample	Tensile Strength (kgf/mm^2)		Elongation (%)	Reduction area (%)
		σ_y	σ_{maks}	ε	R
1	Variation 1	15,83	16,89	0,00	0,00
2	Variation 2	24,33	24,90	0,00	0,00
3	Variation 3	31,32	31,91	0,00	0,00

Hardness testing

Test of hadness is the most effective because with this testing, we can easily find a picture of the mechanical properties of a material. Although the measurement is only carried out at one point or a certain area, the hardness value valid enough to express the strength of a material. Sample for hardness test was also taken from the test sample U block, to determine the level strength of rotary knife cutter with treatment of different heating, testing the hardness using a Rockwell hardness tester with load 1471 N (150 kgf), the test results are tabulated in Table 3,

Table 3. Hardness Test Results

No.	Sampel	Hardenig Hardness at 1000 ^{0}C (HRC)			
		As Cast	Air blowiing	Oil	Water
1	Variation 1	43.5	56.7	57.9	57.2
2	Variation 2	43.9	57.9	58.0	57.9
3	Variation 3	45.8	58.7	59.2	58.2

Impact testing

Impact test is required to determine the ability of a material when under the stress of a sudden. The use of rotary knife cutter on the actual condition will experience the imposition of a sudden, because the blade rotates quickly and restrained sugarcane. Therefore rotary knife cutter needs to have enough toughness to be able to withstand the load. A material is said to be tough if have the ability to absorb large shock loads without cause cracks/deformed easily, impact test apparatus is shown in Figure 12. Sample of impact test was also made of the test sample U block and do different heat treatment process, impact testing conducted by the method charpy impact test results are shown in Table 4.

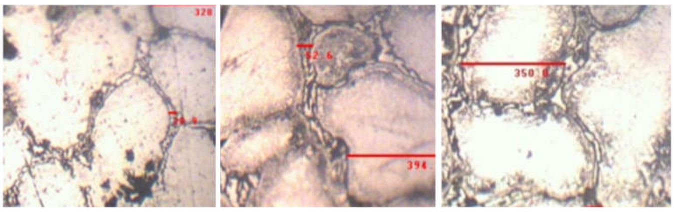
Figure 12. Impact Test Equipment

Table 4. Impact Test Results

No	Variation	Impact Value (kgm/cm2)			
		as-cast	Air blowig	oil	water
1	Variation 1	0,69	0,74	0,50	0,45
2	Variation 2	0,70	0,83	0,63	0,56
3	Variation 3	0,68	0,67	0,60	0,41

MetallographyTesting

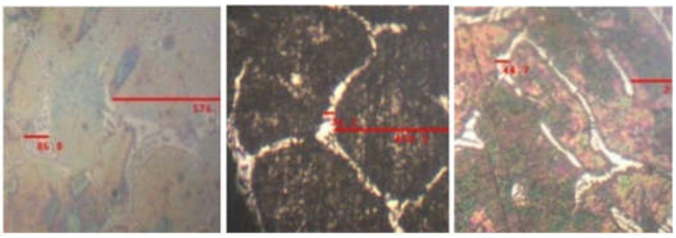
The microstructure happens to affect the mechanical properties of metal microstructure changes can occur because of the composition and rate of cooling. At different heat treatment process performed on a rotary knife cutter will affect the microstructure so that its mechanical properties will also be different. Microstructure observation done by using metalurgical microscope as shown in Figure 13.



(a) variation.1 **(b) variation.2** **(c) variation.3**

Etcha nital 3 %, Magnification 200 x

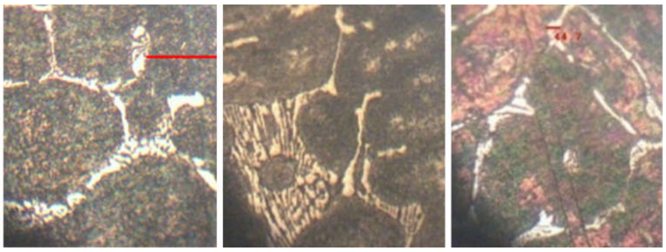
Figure 13. As-cast sample microstructure



(a) variation.1 **(b) variation.2** **(c) variation.3**

Etcha nital 3 %, Magnification 200 x

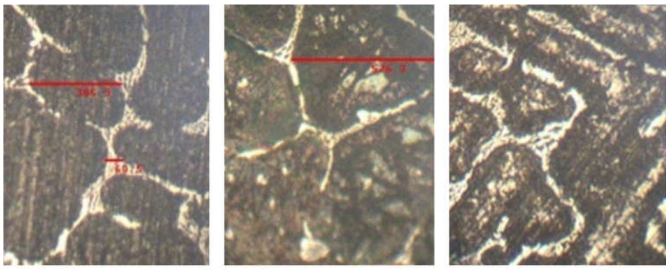
Figure 14. Air blowing sample microstructure



(a)variation1 (b) variation2 (c) variation3

Etcha nital 3 %, Magnification 200 x

Figure 15. Oil sample microstructure



(a) variation1 (b) variation2 (c) variation3

Etcha nital 3 %, Magnification 200 x

Figure 16. Water sample microstructure

RESULTS AND DISCUSSION

Judging from the content of the element carbon in Table 1, about 1.5 %, that materials are classified to the high-carbon steel because carbon content greater than 0.5%, and if the terms of the amount of alloy elements, this material can be categorized into high alloy steel because total elements of its content has been above 8%. From the tensile test results Table 2 was made a graph illustrating the relationship between heat treatment with a tensile strengh for each variation as shown in Figure 17.

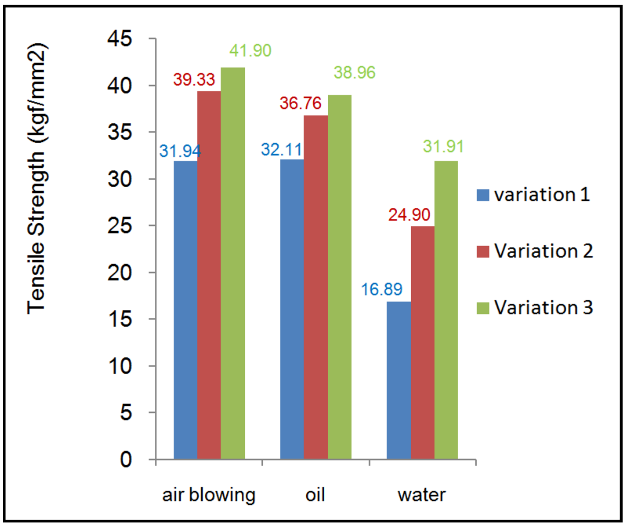


Figure 17. Graph Tensile Strength Vs Heat Treatment

From Figure 17 it can be seen that the tensile strength for each variation of molybdenum (variation 1, 2, and 3), the highest tensile strength figures obtained on hardening with air blowing and tensile strength tends to decrease at hardening with oil and water. This indicates that for the greatest tensile strength of the hardening is done with air blowing. The highest tensile strength obtained in three variations for each type of good hardening with air blowing, oil or water. Relations with the tensile strength variation molybdenum can also be made from Table 2 as shown in Figure 18.

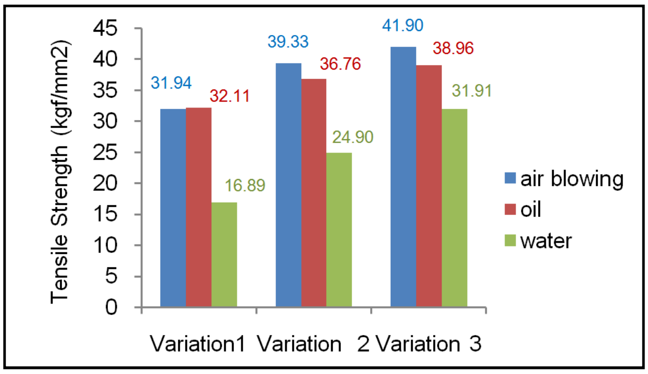


Figure 18. Graph Tensile Strengtth Vs Variations molybdenum

Columns of blue, red, and green is a graph hardening with air blowing, oil, and water. Hardening with air blowing (blue column) conducted on rotary knife cuter for each variation, showing an increase in tensile strength, tensile strength of the lowest occurred in variation 1, an increase in the variation 2 and the highest in variation 3. The same trend is also occurring on hardening with oil and water. The tensile strength for each variation of the highest among the hardening performed with air blowing, thus to produce the highest tensile strength to do the heat treatment process with air blowing hardening. Judging from the shape fracture tensile testing, material rotary knife cutter includes a brittle material, there are no plastic deformation, fracture perpendicular and shiny. Since the material is brittle it is necessary to heat treatment further to increase the toughness by means of tempering heat treatment. Hardness testing performed on the test specimen before and after heat treatment are shown in Table 3. To see the effect of variations in molybdenum and the effect of heat treatment hardneess by heat treatment (Figure 20).

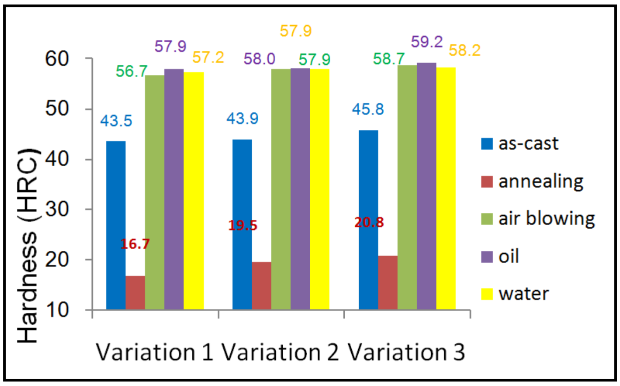


Figure 19. Graph Hardness with Variations molybdenum

Column blue, red, green, violet, and yellow is a graph of the test specimen as-cast (without heat treatment), annealing, air blowing, oil, and water, for every variation of molybdenum. The castings produced by the casting process (as-cast) has a hardness that is sufficiently high so it was difficult for the machined. As-cast castings variation 1 has a hardness of 43.5 HRC and increased at variation 2 and the highest in the variation 3. Due to difficult machined castings is carried annealing heat treatment process. After annealing, hardness testing for each variation, the condition is also a trend towards an increase in hardness from one variation 1 to variation 3, the material hardness on annealing conditions showed the lowest hardness. After machining at annealing conditions, the specimen is processed again by heat treatment with air blowing hardening, oil and water. In this condition the material hardness numbers are not much different, being approximately 56.7 up to 59.2 Rockwell scale.

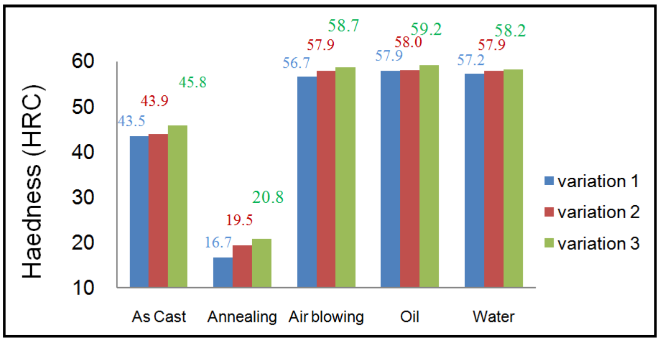


Figure 20. Graph Hardness with Heat treatment

Column chart in blue, red, and green is the test object variation 1, variation 2 and variation 3. Hardess castings as-cast (without heat treatment) have a high hardness so hard to machine, hardness test object is likely to increase from variation 1, 2 and 3, for ease of machining performed annealing heat treatment hardness decreased to 16.7 to 20.8 HRC. Once machining is completed hardening media air blowing, oil, and water. Hardness caused by hardening of the media air blowing, oil, and water is not much different around 56.7 to 59.2 HRC. Judging from the number of hardness generated through the heat treatment process, hardening is done by using air blowing hardening. Impact testing is required to determine the strength of material, the greater the force of energy absorbed to break the material, the stronger the material. From Table 4, graphed to determine the toughness of the specimen obtained from the variation 1, 2, and 3, also due to the different heat treatment, as shown in Figure 21.

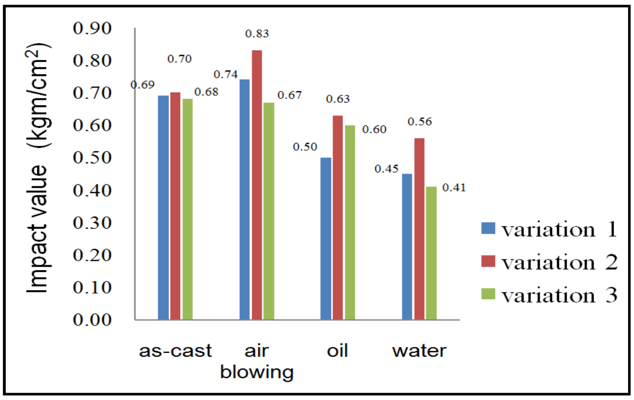


Figure 21. Graph Value Impact with Heat Treatment

In Figure 21, a column chart in blue, red, and green is a variation of the test object 1, 2, and 3. The heat treatment is performed is without heat treatment (as-cast), hardening with air blowing, hardening with oil, and hardening with water. Values greater impact than any variation which is hardened at the same cooling medium is on the variation 2 (red column). Means among variation 1, 2, and 3, the more resilient material is variation 2 because it can absorb greater energy. For hardening heat treatment with air blowing, oil, and water, the greater the energy absorbed in the air hardening heat treatment furnace. The absorbed energy is highest in material variation 2 with air blowing hardening. In other words, the material most formidable is the second variation with air blowing hardening. In the microstructure observation test object as-cast etched with nital 3 % magnification 200 X (Figure 13 a, b, and c), it appears that the grain boundaries are carbide derived from the alloying elements, structures occurring is perlitis subtle, differences granules between the third variation is not visible difference. In observation of the microstructure of specimens with hardening air blowing etched with nital 3 % magnification 200 X (Figure 14 a, b and c), it appears that the white color is the grain boundaries, grain boundaries variation 1 is greater than the grain boundary variation 2 and more small that occur variation 3, the microstructure is martensite. In observation of the microstructure of specimens with hardening oil etched with 3 % nital 200 X magnification (Figure 15 a, b and c), the color white is a grain boundary, and the dark color is a martensitic structure. Granules more subtle variations on variations 2 and 3. In observation of the microstructure of specimens with water hardening etched with nital 3 % magnification 200 X (Figure 16 a, b and c), the color white is a grain boundary, and the dark color is a martensitic structure. Granules more subtle on variations 2 and 3.

Conclusions and Recommendations

After doing research, engineering rotary knife cutter for sugar factory Sei Semayang, it can be concluded:

1. Rotary knife cutter can be manufactured with a metal casting technology.
2. Material used are high alloy steels.
3. The composition of the material is the best on variation 2 with composition: C: 1.550%, Si: 0.445%, Mn: 0.360%, Mo: 0.902%, V: 0.956%
4. Heat treatment:
   - Softening of 1000 degrees Celsius (full annealing) for machining.
   - Hardening of 1000 degrees Celsius (hardening) with air blowing Tempering 500-600 degrees Celsius for quality improvement.
5. Life time modified rotary knife cutter capable of chopping sugar cane as much as 175,000 upto 210,000 tons of sugarcane.

Suggestion

Life time of rotary knife cutter can be increased if it is used for chopping fresh sugar cane and clean from other objects such as rocks, gravel or metal.

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