

THE DESIGN OF *DEBURRING AIDS* TO INCREASE THE PRODUCTION EFFICIENCY OF KN0081 *SPACERS* AT PT. XYZ

Yohanes Oscar Andrian¹ Zefanya Rangga Prangestya² Sutrisno¹
Yohanes Nugroho² Archi Kun Cahyo Utomo¹

¹Program Studi Teknik Mesin Industri, Politeknik ATMI Surakarta, Surakarta, 57145, Indonesia

²Program Studi Rekayasa Teknologi Manufaktur, Politeknik ATMI Surakarta, Surakarta, 57145, Indonesia

*Email Corresponding Author : oscar.andrian@atmi.ac.id

ABSTRAK

Deburring adalah salah satu proses produksi yang penting dari dalam pembuatan *part*. *Spacer* KN0081 adalah salah satu *part* dari *fuel bracket protactor* yang berfungsi sebagai penjaga jarak antara *bracket* dan komponen pada *engine system* mobil. Fokus dari proses *deburring* adalah kualitas *deburr* dan *cycle time* prosesnya. Kualitas dan efisiensi proses *deburr* dapat ditingkatkan dengan menggunakan alat bantu untuk proses *deburring*. Perancangan alat bantu *deburring* menggunakan mekanisme pengecaman *collet* dan sistem *interlock*. *Spacer* dicekam menggunakan *collet*, kemudian dideburr. Mekanisme *interlock* memungkinkan pengatur sudut putar alat bantu agar memudahkan proses *setting*. Metode penelitian yang digunakan adalah VDI 2221 sebagai *tools* perancangan dan *software SOLIDWORKS* sebagai perangkat untuk membuat desain rancangan. Rancangan varian terbaik dipilih berdasarkan penilaian teknis dan ekonomis menghasilkan solusi rancangan alat bantu *deburring spacer* produk KN0081. Hasil dari analisis *cycle time* proses adalah 0,55 menit untuk pengerjaan 1 *spacer*. Berdasarkan perhitungan analisis *cycle time*, alat bantu *deburring* dapat meningkatkan kualitas *spacer* dan mengurangi *cycle time* proses *deburring* menjadi 80% lebih efisien.

Kata Kunci : *deburring*; efisiensi ; perancangan ; VDI 2221

ABSTRACT

Deburring is one of the important production processes in part manufacturing. *Spacer* KN0081 is one of the parts of the *fuel bracket protractor* that functions as a distance guard between the bracket and components in the car engine system. The focus of the *deburring* process is the quality of the *deburring* and the cycle time of the process. The quality and efficiency of the *deburring* process can be improved by using tools for the *deburring* process. The design of the *deburring* tool uses a collet clamping mechanism and an interlock system. The *spacer* is clamped using a collet, then *deburred*. The interlock mechanism allows the adjustment of the tool's rotation angle to facilitate the setting process. The research method used is VDI 2221 as a design tool and *SOLIDWORKS* software as a device for creating the design. The best variant design was selected based on technical and economic assessments resulting in a design solution for the *deburring spacer* product KN0081. The result of the process cycle time analysis is 0.55 minutes for the processing of 1 *spacer*. Based on cycle time analysis calculations, *deburring* tools can improve *spacer* quality and reduce *deburring* process cycle time to 80% more efficient.

Keywords: *deburring*; efficiency; design; VDI 2221

INTRODUCTION

The sharp or burry side of the *part* is one of the product defects caused by the sequence of the machining process and/or the decrease in the quality of the cutting tool. High burry can affect the quality of the *part*, causing the *part* to not be worked on in the next process until the *part* does not pass quality control. Burry formation or sharp edges are a common problem in a wide variety of industries that require high precision such as

automotive. ^[1]High burry is a crucial problem because it can affect product quality and production activities.

PT. XYZ received an order for the KN0081 product, namely a *fuel protactor bracket*. The product is an *engine system* in a car as a buffer or cover for a car's fuel tank which functions to protect various vital parts such as fuel lines, pipes, pumps, and fuel tanks. Its main function is to prevent physical damage from impacts, vibrations, and road debris, as well as to keep these

components in a stable position. The KN0081 product can be seen in Figure 1.

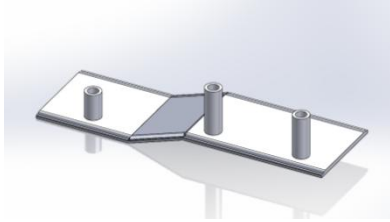


Figure 1 Product KN0081

The production of KN0081 requires 4000 pcs *spacers* with a production target of 1000 pcs for one month. The company asks that the maximum number of products that do not pass *quality control* is 2% of total production. The time requested by the company for the *deburring* process is 2 minutes for 1 *spacer*. The product processing process has problems with the *spacer* work on products that have *burries* on the outer diameter and inner diameter. The process of removing the sharp side uses the manual method with *baby grind*. The results of *inconsistent manual deburring* cause many products to not pass *quality control*. Out of the total production of 4000 pcs, 8.75% of the products did not pass *quality control*. Spacer production targets and times that are not achieved cause delays in delivery to customers. The data of the results of *manual deburring* KN0081 can be seen in Table 1.

Table 1 Manual Deburring Results Data

No.	Month	Total Production	Result Not Good
1	September	1000 pcs	102 pcs
2	Oktober	1000 pcs	95 pcs
3	November	1000 pcs	86 pcs
4	Desember	1000 pcs	67 pcs

The solution to *the problem of high burry* can be solved by the *deburring* process. *Deburring* is mostly done in the product *rework* process and the product checking process when undergoing the next process. The most common method encountered in the production process is to use cutting tools in the machining process such as lathe chisels and *countersinks*. In the implementation of the process of removing sharp edges, there are several methods that can be applied.^[2] These methods include manual *burr* removal, the use of *files* or *files*, and a brush machine. In some applications, robots are also used to carry out *the burry removal process*.

The process flow begins with the machining process, removes the sharp edges of *the machining* results, and then ends with the welding process with the product. The *deburring* process is done manually using *baby grind* and *needle file*, taking 5 – 8 minutes for one *spacer*. Out of a total

of 4000 products, 350 products did not pass *quality control*. The *spacer* of the KN0081 product can be seen in Figure 2.

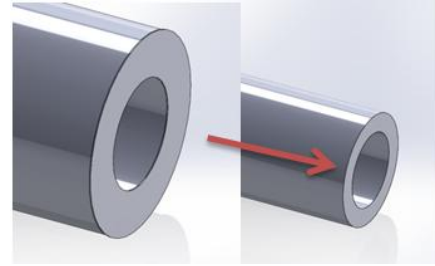


Figure 2 Product Spacer KN0081

The research focuses on designing a *deburring aid* for the process of removing the inner diameter and outer diameter sharp sides of *the spacer*. The designed tool will provide a solution to reduce *deburring* time and consistency of *the size of the burring*, so that the product *spacer* can go to the next process and the product can pass *quality control*.

RESEARCH METHODS

The research uses the VDI 2221 method.^[3] In an outline, research begins with the determination of concepts, designing tools, and completion. The research flow chart can be seen in Figure 3.

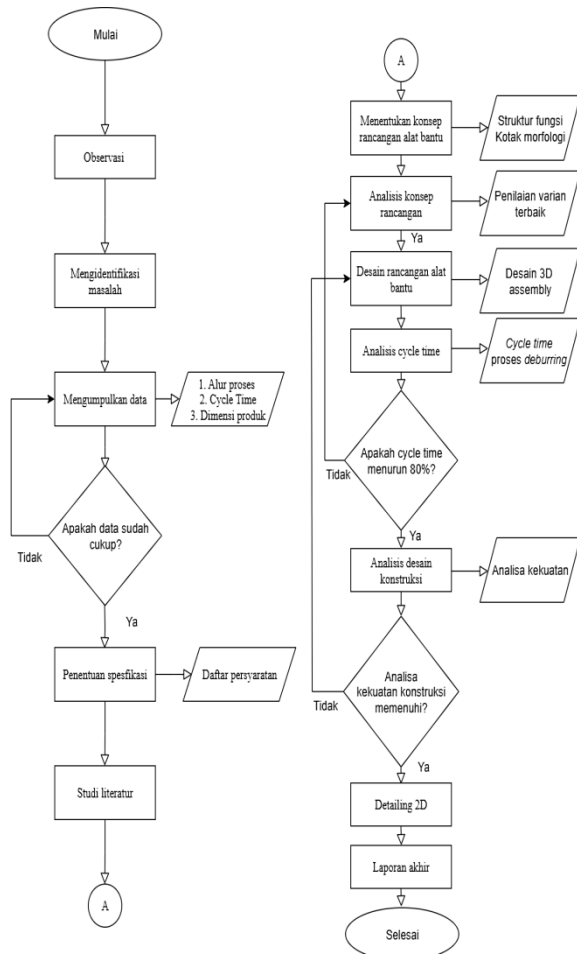


Figure 3 Research Flowchart

RESULTS AND DISCUSSION

The following are the results and discussion of the design of the *KN0081 product* deburring aid :

1. Requirements List

The specifications for the *KN0081 product deburring process* aids are described in Table 2 which is a list of requirements as design process tools. The specifications are determined through an observation process during the internship and analysis of problems discussed with supervisors and field supervisors at PT. XYZ.

Table 2 List of Requirements

Deburring Aid Requirements List		
Needs/Expectations	Requirement	PJ
K	Geometri :	Zefanya Rangga P.
K	1. Length :150-250 mm	
K	2. Width : 100-150 mm	
K	3. Height : 50-100 mm	
K	1. Kinematics :	

H	1. Easy clamping mechanism	
K	1. Easy positioning mechanism	
K	1. Energy:	
H	1. Human energy	
K	1. Energy from drilling machines	
K	1. Material :	
	1. Using S45C material	
H	1. Spacer material is Ss400	
K	1. Signal:	
	1. The tool can be rotated according to the position of the spacer so that the center with the cutting tool	
H	1. Operation:	
K	1. Setting up the tools is easy and doesn't take much time	
H	1. Produces a chamfer size of 0.1 mm x 45°	
H	1. Production:	
	1. Has a simple design and is easy to manufacture	
	1. Assembly:	
	1. Easy in the assembly	

	process of aids 1. Application: 1. Production cycle time of less than 1 minute for one spacer 1. Therapy: 1. Lubrication using grease regularly 1. Easy to maintain	
--	--	--

2. Function Structure

The function structure describes the overall function of the *deburring aid* which will be divided into several subfunctions to explain the mechanism by which the aid converts *inputs* into outputs. The functional structure of the auxiliary can be seen in Figure 4. The main function of the tool is to remove the sharp side of the *KN0081 product spacer* with *input* in the form of a *KN0081 product spacer* that has *burry*, energy used, and a signal to get the *output* in the form of a *KN0081 product spacer with a sharp side that has been debited*.

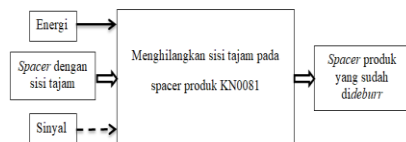


Figure 4 Functional Structure of Assistive Devices

The sub-functional structure of the *deburring aid* in Figure 5 illustrates a series of steps to transform the "*Spacer with sharp edges*" into the "*Spacer of the KN0081 product that has been deburred*". The process begins with *inputs* in the form of human energy as a resource, as well as "signals" that trigger "angle adjustments". The *spacer* will go through a compression stage. The *spacer* is then "rotated", a process that changes its position or orientation to match the center of the cutting tool. The next crucial stage is "*deburring*" to remove the sharp part. The end result of the entire process series is the "*Smelted KN0081 product spacer*", a finished product that has passed all stages of processing. For the process series of the sub functions do not produce the *output* of the finished part. The *output* of the finished part is by manually turning the workpiece over and repeating the same process, resulting in the *output of the spacer* whose four sides have been debunked.

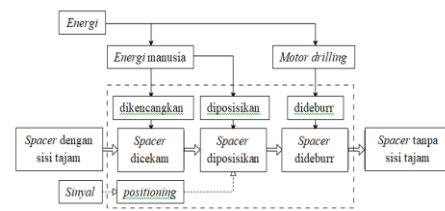


Figure 5 Sub-Function Structure

3. Morphology Box

The development of concept variants is carried out through the application of design morphology in Table 3. The morphology of the design consists of four sub-functions, which contribute to the creation of three variants of the concept along with the explanatory description of each variant.

Table 3 Morphology Boxes

No.	Sub Fungsi	Sub Sub Fungsi	Varian		
			I	II	III
1.	Material		Cast Iron	St 60	S 45 C
2.	Pencekam	Pencekam Spacer			
		Geometri			
3.	Pemutar	Mekanisme Pengatur Sudut			
4.	Tools	Alat Potong			
			Countersink	Pahat 2 sisi	

4. Variant Assessment

The technical assessment criteria consist of 7 assessment aspects. The range of values of each criterion is from 0 to 5, where a value of 0 is the worst value and a value of 5 is the best value. The value of each criterion is determined by the analysis of the results of the preparation of the morphology box of each concept variant. The ranking of variants is determined from the results of the percentage of the sum of 7 aspects of the assessment of each concept variant. The assessment of technical concept variants can be seen in Table 4 below.

Table 4 Technical Assessment

No.	Assessment Criteria	V. I	V. II	V. III	Id
		N	N	N	N
1	Mekanisme sederhana	5	5	5	5
2	Konstruksi sederhana	3	4	4	5
3	<i>Machining</i> mudah	2	3	3	5
4	<i>Maintenance</i> mudah	2	4	3	5
5	Waktu produksi cepat	4	4	4	5
6	Kemudahan perakitan	2	5	5	5
7	Ketepatan <i>center</i> benda	4	4	2	5
Nilai Teknis		22	29	26	35
Persentase		63	83	74	100
Peringkat		3	1	2	

The economic assessment criteria consist of 5 assessment aspects. The economic criteria of the variant have the same scoring format as the technical criteria. The value range of each criterion is from 0 to 5, where the value of 0 is the worst value and the value of 5 is the best value. Variant ratings are sorted by the final score obtained. The economic assessment of the variants of each concept variant can be seen in Table 5.

No.	Assessment Criteria	V. I	V. II	V. III	Id
		N	N	N	N
1	Biaya material	4	4	4	5
2	Biaya <i>standard part</i>	2	4	4	5
3	Biaya <i>machining</i>	2	4	3	5
4	Biaya <i>maintenance</i>	3	5	5	5
5	Biaya perakitan	3	5	5	5
Nilai Teknis		14	22	21	35
Persentase		56	88	84	100
Peringkat		3	1	2	

Based on the technical assessment and economic assessment that has been carried out, the selection of the best concept variant can be determined using the diagram in Figure 6. The selection of the best concept variant is determined based on the variant with a value that is close to the diagonal line of the ideal concept value as a comparison of each concept variant. Figure 6 diagram shows that variant II is the best concept variant because it has the value closest to the diagonal line of the ideal concept variant. Variant II is determined as the selected concept for the reference process of the design process of the deburring aid.

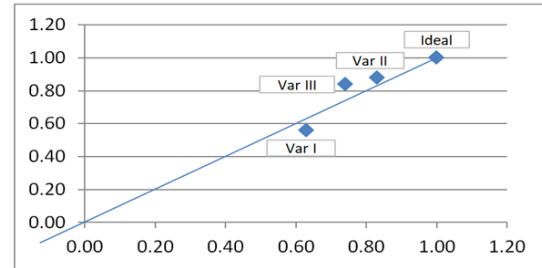


Figure 6 Best Variant Rating Diagram

5. Design Results

The design of the deburring aid is determined based on the brainstorming process and through the stages of the research methodology. The result of the design is in 3D form in Figure 7 with dimensions of 200 x 147.5 x 92 mm. The design of the deburring aid has 3 main parts, namely the base, the workpiece clamping system, and the mechanism of locking the center angle of the workpiece with a cutting tool. Base is a part of the tool as a geometric reference and fits with the list of requirements. The workpiece clamping system is a crucial part of the workpiece center against the cutting tool. The angle locking mechanism is the part that is the main focus in determining the locking system and the center angle regulator of the cutting tool.

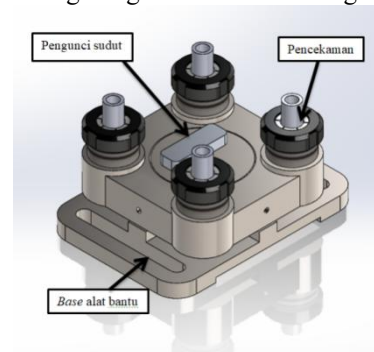


Figure 7 3D Design of Deburring Aids

The base of the auxiliary tool is the main focus when installed on the machine bed. The function of the base, in addition to being the main concentrator, is as a connecting path between the corner locking pin and the part on the workpiece clamping mechanism. The base part of the tool consists of only 1 part with S45C material and is made by the machining process. The dimensions of the base of the tool are determined by considering ergonomics and ease of operation, which is 205 x 147.5 x 55 mm. The base of the deburring aid can be seen in the following Figure 8.

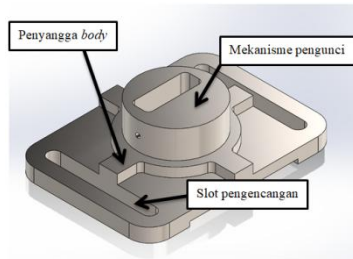
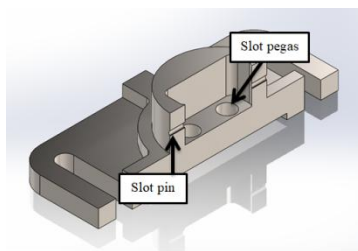


Figure 8 Base Deburring Aid

In Figure 4.6, the fastening part of the *deburring aid* with the machine bed is determined by taking measurements that are in accordance with the drilling machine table that is common in the industry. The design of the fastening slot is made so that the tool can be used on various types of *drilling machines* with different types of machine tables. The bottom of the *base* is designed to facilitate the process of *cleaning* the iron gram from the production process. The center locking mechanism part is designed to refer to the *interlock mechanism* with 2 holes of 5mm diameter as the connecting path of the locking pin from the *base* to the clamping body. At the bottom of the circle, *slots* are created for the placement of the reversing spring and the *interlock* pressing block.



Gambar 9 Section View Base

The clamping system used in *deburring aids* is to use *collet* clamping. The *collet* clamping method has a high degree of *center* precision between the workpiece and the cutting tool. In Figure 10, the geometry of the clamping part is designed in a square shape to facilitate the *machining process*. The dimensions of the clamping section are 145 x 145 x 60 mm. On the side of the *body*, there is a *slot* hole for each face of the *body* as a pin locking path to the *cutting tool* center.

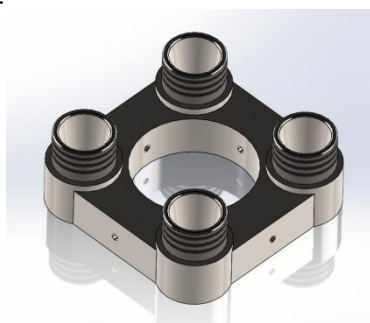


Figure 10 Body Compression

The angle locking mechanism uses a two-way locking mechanism with a press block as the pin strip to lock and open the pin lock against the clamping body. The press block uses aluminum material taking into account the pressure required to open the locking pin. The press block is designed with pin strips to lock and open the lock. At the bottom of the block, there is a slot for the placement of 2 reversing springs to make it easier in the assembly process. The placement of the press block will be concentrated by 2 springs. The dimensions of the press block are 60 x 20 x 30 mm. A picture of the press block can be seen in Figure 11.



Figure 11 Press Block

The locking pin design is made taking into account the twisting moment and the curved tension that occurs in the *deburring aid*. The specified dimensions are 5 mm in diameter by 30 mm in length. As in Figure 12, on the side of the pin there is a connection to the press block.

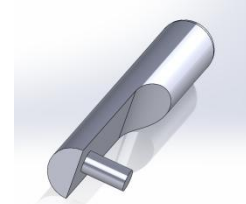


Figure 12 Locking Pins

6. Rpm Calculation

The calculation of the rotation rpm of the cutting tool is used in the next calculation to produce the twisting moment of the locking pin.

$$N_{\text{motor drilling}} = 1 \text{ Hp} = 0,745 \text{ Kw} = 0,75 \text{ Kw}$$

$$Cs = 76 \text{ m/menit}$$

$$d_{\text{Cutting tools}} = 32 \text{ mm}$$

$$n = \frac{1000 \times Cs}{\pi \times d}$$

$$n = \frac{1000 \times 76 \text{ m/menit}}{\pi \times 32 \text{ mm}}$$

$$n = 756,37 \text{ Rpm}$$

So then, the rpm used for the *deburring* process is 756 Rpm.

7. Locking Pin Calculation

a. Twisty Moment

$$N = 0,75 \text{ Kw}$$

$$n = 756 \text{ Rpm}$$

$$Mt = 9,55 \times 10^3 \times \frac{N}{n}$$

$$M_t = 9,55 \times 10^3 \times \frac{0,75 \text{ Kw}}{756 \text{ Rpm}}$$

$$M_t = 9,474 \text{ N/m} = 9474 \text{ N/mm}$$

N or the power that is passed is taken from the driving motor on the *drilling machine* and the value is obtained 0,75 Kwatt. The rpm used is 756 Rpm. The value obtained from the calculation of the torque moment is 9474 N/mm.

b. Traveling Style

$$M_t = 9474 \text{ N/mm}$$

$$R \text{ Workpiece} = 8,6 \text{ mm}$$

$$M_t = F \times R \text{ benda kerja}$$

$$F = \frac{M_t}{R}$$

$$F = \frac{9474 \text{ N/mm}}{8,6 \text{ mm}}$$

$$F = 1101,62 \text{ N}$$

$$F \text{ masing - masing pin} = \frac{F}{2} = \frac{1101,62 \text{ N}}{2}$$

$$F \text{ masing - masing pin} = 550,81 \text{ N}$$

The circumferential force is determined using the formula of torsional moment divided by the radius of the workpiece to be worked. The torsional moment is taken from the previous calculation, which is 9474 N/mm. The diameter of the spacer workpiece is 17.9 mm so the radius of the spacer is 8.6 mm. The total F is 1101.62 N, so the F for each spacer is $F/2 = 550,81 \text{ N}$.

c. Pure torsional stress

$$F = 550,81 \text{ N}$$

$$A = \text{Pin cross-section area} = \text{Circle Width}$$

$$\tau_s = \frac{F}{A}$$

$$\tau_s = \frac{550,81 \text{ N}}{\pi \times 2,5^2 \text{ mm}}$$

$$\tau_s = 28,052 \text{ N/mm}^2$$

$$\tau_s \leq \text{Tensile strength material}$$

$$28,052 \text{ N/mm}^2 \leq 569 \text{ N/mm}^2$$

The value of F is obtained from the calculation of the previous circumferential force, which is 550.81 N. The value of A is obtained from the cross-sectional area of the circle pin. The shear stress obtained from the calculation is 28.052 N/mm². The shear stress obtained is then checked whether it meets the safe criteria or exceeds the tensile strength. The comparison shows that τ_s is less than equal to the tensile strength of the material, so the diameter of 5 for the pin is safe to use.

d. Momen Lengkung

$$F = 550,81 \text{ N}$$

$$L = \text{panjang pin yang mengunci rotary} = 5 \text{ mm}$$

$$M_b = F \times L$$

$$M_b = 550,81 \text{ N} \times 5 \text{ mm}$$

$$M_b = 2754,05 \text{ Nmm}$$

The calculation of the curved moment is obtained from the multiplication between the circumferential force and the length of the pin that enters the clamping body during the locking

process. From the calculation, a value of 2754.05 Nmm was obtained.

e. Curved Housing Moment

$$d \text{ pin} = 5 \text{ mm}$$

$$W_b = \frac{\pi \times d^3}{16}$$

$$W_b = \frac{\pi \times 5^3 \text{ mm}}{16}$$

$$W_b = 24,54 \text{ mm}^3$$

The calculation of the curved resistance moment is determined by the diameter of the pin in the previous calculation. From the calculation, the value of $W_b = 24.54 \text{ mm}^3$ was obtained.

f. Curved Tension

$$M_b = 2754,05 \text{ Nmm}$$

$$W_b = 24,54 \text{ mm}^3$$

$$\sigma_b = \frac{M_b}{W_b}$$

$$\sigma_b = \frac{2754,05 \text{ Nmm}}{24,54 \text{ mm}^3}$$

$$\sigma_b = 112,22 \text{ N/mm}^2$$

$$\sigma_b \leq \text{Yield Strength}$$

$$112,22 \text{ N/mm}^2 \leq 343 \text{ N/mm}^2$$

The calculation of the curved voltage is obtained from the curved moment divided by the curved resistance moment so that a value of 112.22 N/mm² is obtained. The curved tension obtained is then checked whether it meets the safe criteria or exceeds the yield strength. Comparison shows that σ less than equal to the yield strength material, so the length of 5 mm for the pin is safe to use.

8. Analisis Cycle Time

$$T_h = \frac{L \times i}{v_f}$$

$$l_a = 2 \text{ mm}$$

$$l_s = 0 \text{ mm}$$

$$l_w = 0,5 \text{ mm}$$

$$l_u = 0 \text{ mm (lubang tidak tembus)}$$

$$L = l_a + l_s + l_w + l_u$$

$$L = 2 + 0 + 0,5 + 0$$

$$L = 2,5 \text{ mm}$$

$$\text{Panjang langkah total adalah } 2,5 \text{ mm.}$$

$$s = \text{feeding}$$

$$s = 0,15 \text{ mm/putaran (dari ketentuan diameter dan material alat potong)}$$

$$v_f = s \times n$$

$$v_f = 0,15 \text{ mm/putaran} \times 756 \text{ Rpm}$$

$$v_f = 113,4 \text{ mm/menit}$$

$$\text{Feeding speed is } 113.4 \text{ mm/min.}$$

$$L = 2,5 \text{ mm}$$

$$i = \text{jumlah pengulangan} = 4 \text{ (4 benda kerja)}$$

$$v_f = 113,4 \text{ mm/menit}$$

$$T_h 1 \text{ siklus} = \frac{L \times i}{v_f}$$

$$T_h 1 \text{ siklus} = \frac{2,5 \text{ mm} \times 4}{113,4 \text{ mm/menit}}$$

$$T_h 1 \text{ siklus} = 0,088 \text{ menit}$$

So, based on the calculation of the effective Th cycle time of drilling, the cycle time required to work on the deburring spacer is 0.088 minutes. For each 1 finished product, 2 process cycles are needed, so that the calculation of the Th time is multiplied by 2 and then added to the next cycle time.

$$\begin{aligned}\text{Th produk jadi} &= (\text{Th} \times 2) + \text{waktu setting} \\ \text{Th produk jadi} &= (0,088 \text{ menit} \times 2) + 2 \text{ menit} \\ &= 2,176 \text{ menit}\end{aligned}$$

So the calculation of the cycle time for 1 finished spacer product is Th total / 4, because in 1 cycle there are 4 products. The final result of the cycle time of one product is 0.544 minutes.

9. Deburring Aid Construction Analysis

Analysis of construction strength using the static solidworks simulation feature shows that the maximum stress in the construction occurs on the lower side of the outer diameter of the clamping of the centered workpiece with a cutting tool. The clamping part of the workpiece is most likely to be stressed with a value of 1.50 N/mm². The rotational movement of the cutting tool occurs in the clamping part, so it becomes a critical point in the construction. The results of the construction analysis can be seen in Figure 13.

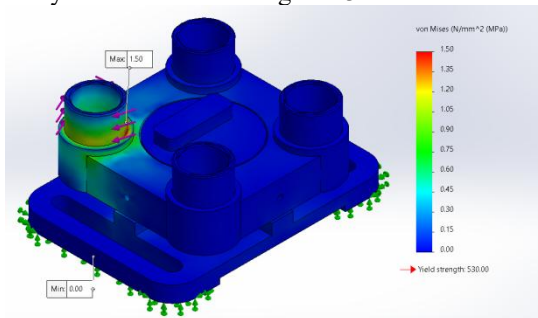


Figure 13 Construction Stress Analysis

Deformasi yang terjadi pada konstruksi alat bantu *deburring* adalah sebesar 0,000284mm pada bagian pengecaman sisi atas. Sisi bagian atas pengecaman menjadi titik kritis deformasi karena terjadi torsi dari putaran alat potong. Analisa deformasi dapat dilihat pada Gambar 14.

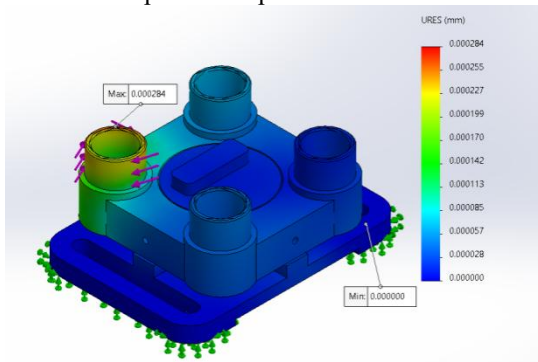


Figure 14 Construction Deformation Analysis

CONCLUSION

Conclusion of the Design of Deburring Aids to Improve the Production Efficiency of KN0081 Spacer at PT. XYZ is :

1. The design of the deburring aid for the KN0081 spacer is able to work on 4 objects at once per cycle, reducing the production cycle time from 5 minutes to 0.54 minutes (down 89%). The design uses the VDI 2221 method, increasing production efficiency and quantity, so that it has the potential to increase business profits by reducing delays and defective products.

2. The results of the FEA analysis show that the deburring aid is sturdy and safe. The maximum Von Mises stress is only 1.5 N/mm², well below the yield strength of the material (530 N/mm²). The minimal deformation (0.000284 mm) also ensures precision, proving the robust design and precise material selection.

BIBLIOGRAPHY

- [1] Niknam S. A., Songmene V., Milling burr formation, modeling and control : A review. J Engineering Manufacture; 229(6) 893–909.
- [2] Kodácsy J., Szabó A., Burr Formation in Metal Cutting Operations and Some Deburring Methods. Key Engineering Materials Vol 581 (2014) pp 235-240.
- [3] Jänsch, J. & Birkhofer, H. (2006). The development of the guideline VDI 2221-the change of direction. In DS 36: Proceedings DESIGN 2006, the 9th International Design Conference, Dubrovnik, Croatia.