

Spindle Speed Optimization in Caulking Process to Improve Shock Absorber Quality

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Abstract - The caulking process is one of the crucial stages in the manufacturing of shock absorbers, particularly in the front suspension of motorcycles. One of the main parameters in this process is the spindle speed of the Inner Tube Caulking (ITC) machine, which plays a vital role in forming and locking the components to prevent oil leakage and component displacement during operation. This study aims to analyze the effect of spindle speed variation on the quality of the caulking results, including visual appearance, bonding strength, and oil leakage performance. The methodology employed includes direct observation on the production line, data collection of process parameters, and product quality testing using leakage and strength tests. The analysis results indicate a significant relationship between spindle speed and caulking quality, where excessively high or low speeds may lead to defects such as imprecise surfaces, excessive deformation, or insufficient joint tightness. The recommended optimal spindle speed range achieves a balance between productivity and product quality. Proper parameter control can enhance suspension quality and reduce the number of defective products on the production line.

Keywords: Spindle speed, inner tube caulking, shock absorber, suspension quality.

I. INTRODUCTION

The shock absorber is one of the main components in a vehicle's suspension system, functioning to dampen vibrations and maintain vehicle stability during operation. The performance of a shock absorber highly depends on the quality of each production stage, particularly the inner tube, which serves as a key element in the damping system. In its manufacturing process, the inner tube must undergo several critical stages, including inner tube cleaning, cylinder complete assembly, inner tube caulking, oil seal greasing, nut runner/bolt damper tightening, oil seal pressing, dust seal pressing, leakage testing, oil filling, C-pin inserting, function testing, marking, and finishing. All of these stages are intended to ensure fluid tightness, joint strength, and durability under dynamic loads [1].

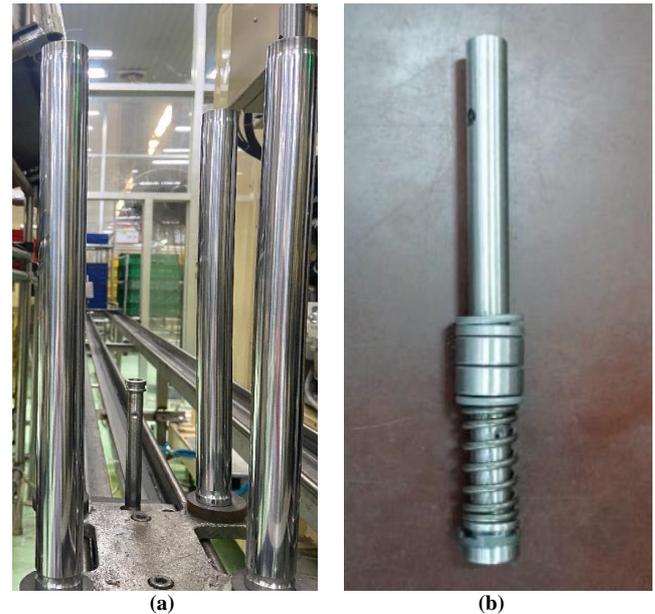


Figure 1: (a) Inner tube K1AA, (b) Cylinder Complete Assy

One of the stages that has a significant influence on the final product quality is the caulking process. Caulking is a plastic deformation process carried out by pressing or folding a portion of the material surface to create a mechanical interlocking between two components. In the manufacturing of shock absorbers, caulking serves to join and lock the inner tube with the cylinder complete assembly to achieve a strong and oil-tight connection. This process requires precise control of parameters, as even slight deviations can lead to joint defects or functional failure. Previous studies have emphasized that the caulking process design and parameter optimization, such as spindle speed, pressing force, and tool motion, are crucial to ensure mechanical reliability and prevent leakage [1-10]

The general shapes of the inner tube and cylinder complete assembly components are shown in Figure 1a and Figure 1b, while the standard-compliant joint after the caulking process is shown in Figure 2. The standard specifications of the caulking results are presented in Table 1.

The spindle speed of the inner tube caulking machine is one of the critical parameters that determines the quality of the joint. Excessive spindle speed may cause excessive

deformation, while too low a speed may result in insufficient pressure to produce a tight and leak-proof joint. Optimal speed adjustment ensures uniform and strong pressure distribution across the joint area, thereby improving caulking quality and minimizing the risk of defects [2-10]. The spindle functions to rotate and transmit the pressing force through rollers onto the joint area during the process.

Not Good (NG), meaning they do not meet the required quality standards. The common defects observed can be grouped into three main categories: loose caulking, pinched valve, and uneven (mayung) caulking. The loose caulking defect occurs when the joint between the inner tube and the cylinder complete assembly is not tight, allowing the washer to rotate even after the caulking process. The pinched valve defect is generally caused by assembly errors prior to the caulking stage. Meanwhile, the uneven caulking defect occurs due to misalignment of the rollers in the machine, resulting in non-uniform deformation along the circumference of the joint. Examples of each defect type are shown in Figures 4, 5, and 6.



Figure 2: The combination of the inner tube and cylinder complete assembly that meets the quality standards

Table1: Standard caulking result

The inspected section	Standard
Total Length (mm)	348.50 mm
Caulking Diameter (mm)	Min 15
Caulking Strength	Min 29500 N (3000kgf)
Piston / Valve Condition	The piston must not be stuck and should not move up or down.
Caulking Thickness (mm)	1.5 +0.2
Apperance	The caulking result must be free from cracks, gaps, and scratches
Ideal Surface Roughness (Ra) Value at the Seal Contact Area	0.1 – 0.6 μ m
Ideal Surface Roughness (Ra) Value on the Surface for Mechanical Caulking (Non-Sealing Area)	0.4 – 1.6 μ m

Based on field observations, it was found that the caulking process still produces several products categorized as



Figure 3: Loose caulking result

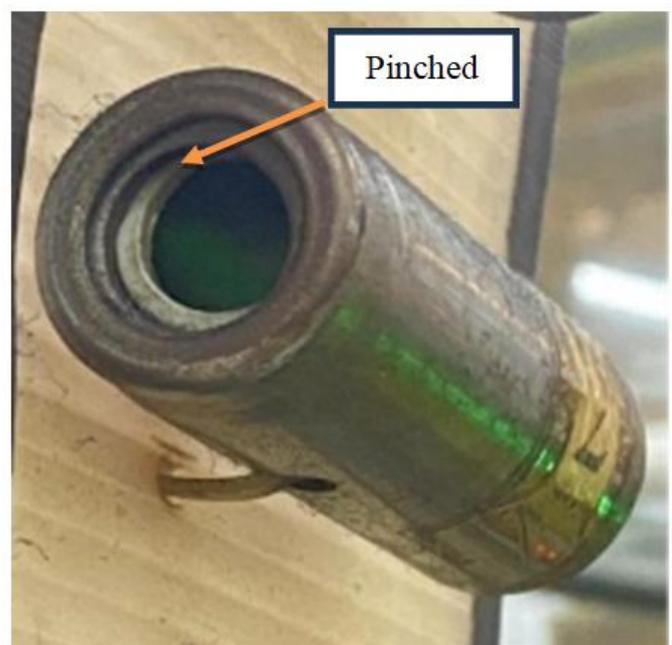


Figure 4: Pinched valve

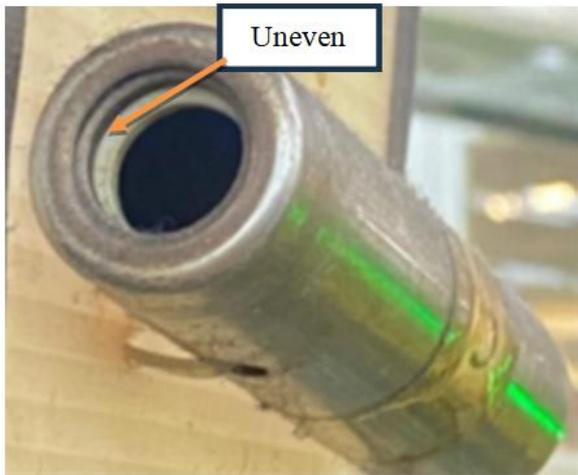


Figure 5: Uneven caulking

In terms of productivity, the defect rate in the caulking process has a direct impact on production line efficiency and operational costs. The number of NG (Not Good) products produced within a production period is presented in Table 2. The data indicate that variations in spindle speed correlate with the frequency of defects in the caulking results. Therefore, an in-depth analysis of the effect of spindle speed on joint quality is necessary to determine the optimal operating parameters.

Table 2: The number of shock absorber products produced within a production period

Day	Total Product	Good (G)	Not Good (NG)	% NG
1	3000	2680	320	10,67
2	3000	2685	315	10,50
3	3000	2690	310	10,33
4	3000	2693	307	10,23
5	3000	2695	305	10,17
6	3000	2691	309	10,30
7	3000	2689	311	10,37
8	3000	2685	315	10,50
9	3000	2675	325	10,83
10	3000	2670	330	11,00
11	3000	2673	327	10,90
12	3000	2655	345	11,50
13	3000	2660	340	11,33
14	3000	2659	341	11,37
15	3000	2657	343	11,43
16	3000	2663	337	11,23
17	3000	2655	345	11,50
18	3000	2650	350	11,67
19	3000	2648	352	11,73
20	3000	2653	347	11,57
21	3000	2656	344	11,47
22	3000	2665	335	11,17
23	3000	2670	330	11,00
24	3000	2654	346	11,53
25	3000	2650	350	11,67
26	3000	2650	350	11,67
Total	78000	69371	8629	11,06

This study evaluates the relationship between spindle speed variation and the quality of caulking in the joining process of the inner tube and cylinder complete assembly. The main objective is to determine the spindle speed condition that produces the best joint tightness and strength while

minimizing the number of defective products. The results of this study are expected to provide recommendations for more efficient process parameters and support overall improvements in shock absorber product quality.

II. METHODOLOGY

The research was conducted using an experimental method. The independent variable in this study is the spindle speed, which was varied at 700, 800, 900, and 1000 rpm. The controlled variable is the slide speed, set at 2.0 mm/s. The dependent variables are the caulking results (NG/G) and surface roughness (Ra). The data for the research variables are presented in Table 3. The testing process was repeated five times for each parameter.

Table 3: Research Variables

RPM	Load Cell	Slide Speed (m/s)
700	14.5	20
800	14.5	20
900	14.5	20
1000	14.5	20

III. RESULTS AND DISCUSSIONS

The results of the conducted tests are presented in Table 4. The test results on spindle speed variations revealed three indications of caulking outcomes categorized as Not Good (NG). This classification was determined based on tests conducted at spindle speeds of 700, 800, and 1000 rpm, where defects such as loose joints and pinched valves were still observed. These results indicate that those spindle speeds were insufficient to produce the proper deformation and sealing strength required to meet production standards. In contrast, testing at a spindle speed of 900 rpm yielded caulking results that fully met quality standards, characterized by tight joints between the cylinder complete and the inner tube, as well as smooth piston movement without signs of jamming. These findings suggest that a spindle speed of 900 rpm represents the most optimal parameter for achieving stable caulking quality in accordance with the technical specifications of the shock absorber production process.

Table 4: Test Results

RPM	Load Cell	Slide Speed (mm/s)	Caulking Result	Surface Roughness(Ra)
700	14.5	2.0	NG (Loose)	0.8
800	14.5	2.0	NG (Loose)	0.7
900	14.5	2.0	G	0.6
1000	14.5	2.0	NG (Loose)	0.4

Testing of spindle speed variations showed differences in caulking quality, which were classified as OK (meeting standards) and NG (Not Good) based on the operation manual reference. Defects such as loose joints generally occurred due to spindle speeds that were not properly matched with the required slide speed, resulting in suboptimal material deformation. Previous studies have confirmed that spindle speed directly influences caulking quality by affecting material deformation, joint tightness, and the potential for leakage [11]. The test results at various spindle speeds indicated that spindle speed has a direct influence on caulking quality [12].

At 700 rpm, the surface roughness value of 0.8 μm was still relatively coarse and unable to withstand internal pressure, potentially leading to oil leakage. At 800 rpm, with a surface roughness of 0.7 μm , the product was still classified as NG because the surface characteristics did not meet the sealing standard. The optimal condition was achieved at 900 rpm, where the surface roughness of 0.6 μm produced joints that met the required caulking quality standards. Meanwhile, at 1000 rpm, the surface roughness decreased to 0.4 μm , resulting in an excessively smooth surface that reduced the pressing contact on the seal and increased the risk of slippage or seal displacement.

IV. CONCLUSION

The test results on spindle speed variation showed that the spindle speed of the inner tube caulking machine significantly affects the quality of the joint. An increase in spindle speed within a certain limit can produce uniform deformation and optimal caulking results without compromising joint integrity. The experiments demonstrated that a spindle speed of 900 rpm provided the best results with minimal defect rates. The surface condition of the caulking area also influences the performance of the seal. An excessively smooth surface may cause the seal to slip or shift, whereas a surface that is too rough can accelerate wear and lead to potential leakage.

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