Analysis of the "boring instead of grinding" manufacturing optimization project for the barrel of large extrusion granulation units

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Abstract: With the rapid development of the manufacturing industry, the requirements for processing efficiency and quality are increasing day by day. Although the traditional grinding method for the barrel of large extrusion granulation units achieves high precision, the straightness and parallelism of the double holes often exceed the tolerance range, and the processing cycle is long and the cost is high. To overcome these challenges, our company has explored a new processing method in practice-using self-made tools for boring instead of grinding. The "boring instead of grinding" manufacturing optimization project has significantly improved the surface quality and dimensional accuracy of the barrel, reduced the rate of product non-conformity caused by processing errors, ensured the stability and consistency of the extrusion granulation process, and thus improved the overall quality of the product. This project has filled the gap in our company's processing technology and achieved good results and benefits.

Key words: CNC inserts; boring instead of grinding; machine barrel; optimization

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The ethylene industry is a pillar industry in China's national economy. The scale and equipment capacity of ethylene are important indicators to measure the level of national petrochemical industry. The mixing and extrusion granulation unit is a core equipment mainly used in the ethylene process. Internationally, only three companies, namely Germany, Japan, and China, have mastered the core technology of this type of unit. China has long relied on imports (with a total of more than 260 sets introduced, costing tens of billions of yuan), and technology has been blocked, the market monopolized, and prices manipulated. This has severely restricted the healthy and rapid development of China's petrochemical industry, endangering national energy and economic security. The successful development of the extrusion granulation unit has filled the domestic gap, broken the technological blockade and monopoly imposed on China by foreign countries, solved the "bottleneck" problem of large-scale petrochemical equipment, shortened the construction period of major petrochemical projects, achieved "self-control of key core technologies", and maintained national economic and energy security.

The barrel of a large extrusion granulation unit is a key core component of the equipment. The double holes of the barrel are composed of two identical circular holes intersecting (commonly known as "8-shaped holes"). The straightness requirement for the machining of the double holes is 0.03 mm, and the perpendicularity requirement to the end face is also 0.03 mm. As one set of the unit consists of 8 to 11 barrels assembled in series (see Figure 1), the quality of straightness will affect the operational performance of the unit. To ensure the straightness requirement, the machining of the double holes of the barrel is of utmost importance in the entire barrel

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machining process. The quality of barrel machining is related to the service life of the overall equipment, which in turn determines the success or failure of the unit and ultimately affects the quality of raw material mixing and plasticization. It restricts the healthy and rapid development of China's petrochemical and coal chemical industries, endangering national economic security. The quality and efficiency of barrel machining severely restrict the construction period of large extrusion granulation units. It is imperative to solve and break through this technical bottleneck.

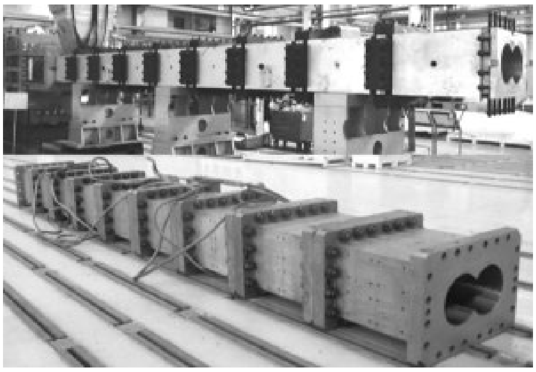

Figure 1 Assembly diagram of co-rotating granulation unit barrels in series

1 Process issues and cause analysis

In the process of machining machine barrels, double-hole machining is a crucial step, especially when these two holes need to intersect at a specific angle to form the so-called "figure-eight hole". This hole type not only requires the hole itself to meet standard dimensions and shape accuracy, but also necessitates ensuring the straightness of the hole and its perpendicularity to the barrel's end face, both of which must be controlled within 0.03 mm. For a set of machine units, typically 8 to 11 such machine barrels are assembled in series, which requires that the double-hole machining of each barrel must meet the same high-precision standards to ensure smooth coordination of the entire unit during operation, reduce friction and wear, and enhance the overall performance and lifespan of the equipment.

The material of the barrel is 38CrMoAlA, which is a kind of alloy steel that has undergone special quenching and tempering, exhibiting excellent wear resistance, corrosion resistance, and high-temperature performance. However, the high hardness and toughness of this material also make the machining process exceptionally difficult. Especially when intermittent cutting is required, tool wear intensifies, and the surface of the workpiece is prone to cold work hardening, further increasing the difficulty of machining. In addition, a layer of oxide layer will form on the surface of the barrel after quenching and tempering treatment. This oxide layer not only affects the cutting performance of the tool but may also lead to the generation of more heat and cutting force during machining, thereby affecting machining accuracy and workpiece quality.

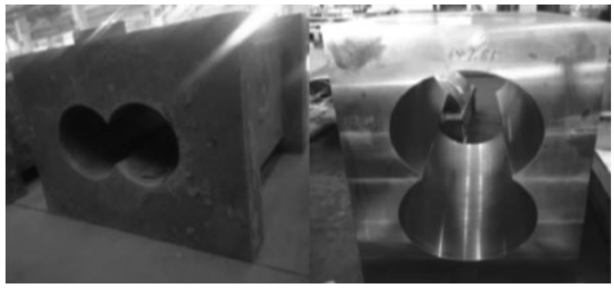

Figure2 Barrel

Currently, the double-hole machining of the barrel utilizes grinding processes. Despite employing equipment with a CNC vertical lathe for clamping and grinding heads, the analysis of post-processing data reveals that the straightness of the barrel's inner hole grinding still fails to meet the drawing requirements. This machining process indeed presents a series of significant difficulties and challenges.

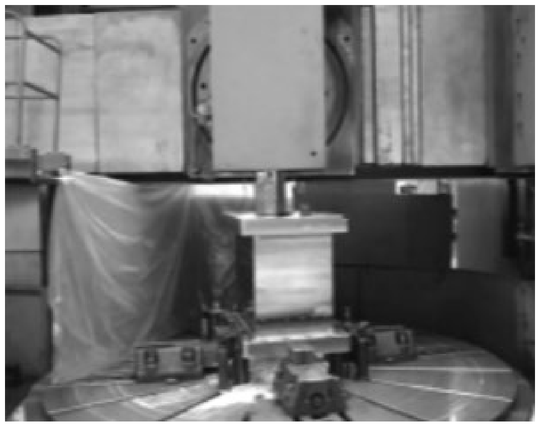

Figure3 CNC vertical lathe grinding machine cylinder bore

Firstly, the grinding method of CNC vertical lathes primarily relies on spindle feed grinding (see Figure 3). However, when machining double holes, the spindle extends a long distance, leading to a significant reduction in spindle rigidity. As a result, the straightness and parallelism of the machined double holes often exceed the tolerance range, posing a major challenge in the machining process.

Secondly, the machining of double holes requires two clamping operations, which inherently increases the risk of machining errors due to multiple clamping. Especially when the double holes are prone to forming an "eight" shape after grinding, it further increases the difficulty of machining. In addition, the perpendicularity between the double holes and the plane is required to reach 0.03 mm, which is particularly challenging under existing machining conditions.

Thirdly, the surface roughness of the double holes is also an indicator that requires special attention. In practical machining, it is not easy to achieve a surface roughness standard within Ra0.8 μm, especially in cases where the barrel length is long and the material hardness is high.

Fourthly, when the length specification of barrel-type parts exceeds 1,200 mm, the machining difficulty will further increase. Due to the limited machining range of the vertical lathe, for barrels with a large length, it is necessary to adjust the position of the vertical lathe and realign for machining, which not only increases the machining difficulty but also prolongs the machining cycle. The grinding time for each barrel may exceed 40 hours, which will undoubtedly have a significant impact on the final assembly timeline of the product.

Finally, to ensure the perpendicularity between the plane and the inner hole of the barrel, the barrel plane needs to be processed on a surface grinder. However, before processing, it is necessary to align the barrel's double holes according to their straightness and roundness on a machining center machine tool, and mill the grinding reference for the surface grinder. During this process, due to the tendency of the barrel's double holes to form an "eight" shape after grinding, there may be errors in the alignment reference, which requires multiple calibrations and corrections using a three-coordinate measuring machine in the subsequent steps. The entire processing process is cumbersome and time-consuming, seriously affecting the processing cycle and product quality.

In summary, the difficulties in the double-hole grinding process of the barrel mainly include insufficient spindle rigidity, error accumulation caused by multiple clamping, difficulty in controlling surface roughness, the difficulty in processing barrels with large length specifications, and the difficulty in ensuring the perpendicularity between the plane and the inner hole. To address these issues, a series of measures need to be taken for improvement and optimization to enhance processing accuracy and efficiency, and reduce the rate of rework.

2 Innovative solutions

(1) During the machining process of the double holes in the barrel, due to the issues of low efficiency and difficulty in ensuring quality in the original grinding process, we decided to try changing the machining process from grinding to boring (i.e., "replacing grinding with boring") (see Figure 4). The original intention of this change is to improve machining efficiency and hopefully solve some quality issues in the grinding process.

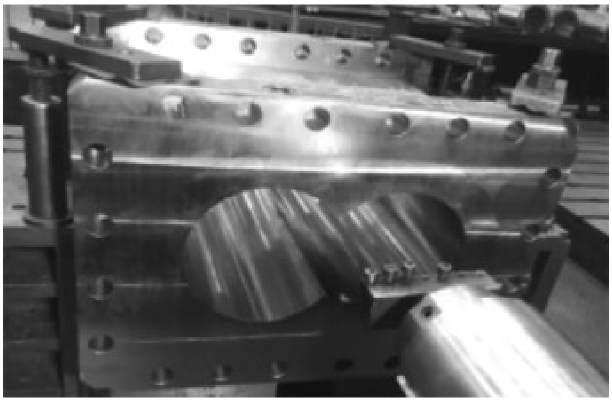

Figure 4 CNC boring machine machining

After experimentation, we found that the surface roughness of ordinary boring tools cannot reach the Ra0.8 μm required by the drawings when boring large-diameter inner holes. This is mainly due to the friction and heat accumulation between the tool and the workpiece during the boring process. To improve this situation, we tried using a light tool for inner hole machining, hoping to achieve the required surface roughness through fine cutting.

However, due to the influence of the barrel material and working conditions, the effect of light-cutting machining is also unsatisfactory. The oxide scale generated during the quenching and tempering process of the barrel and the cold work hardening phenomenon occurring during the machining of alloy barrels both increase the difficulty of machining. These phenomena not only lead to severe wear of the cutting blade during machining but also require the hardness of the cutting blade to be higher than that of the workpiece being machined when boring the inner hole (see Figure 5).

Furthermore, due to the special shape of the inner hole on the cylinder, which is shaped like an "8" and disconnected in the middle, it requires that the cutting tool not only has sufficient hardness but also good toughness. The hardness and toughness of cutting tools are often contradictory. Cutting tools with high hardness tend to be brittle, while those with good toughness have lower hardness. This contradiction poses a significant challenge when selecting cutting tools.

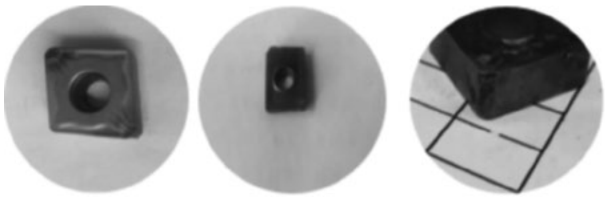

Figure 5 Various test blades

In order to find a suitable tool, we tried various types of cutting tools, including welded tools, mechanically clamped tools, and even ceramic inserts. None of these tools achieved the expected results during the machining process. Although they excelled in certain aspects, there were always some key performance indicators that failed to meet our needs.

(2) In order to enhance the efficiency and quality of double-hole machining for machine barrels, we have conducted in-depth optimization research on cutting tools. Through repeated experiments and analysis in the early stages, we have identified several key characteristics for selecting cutting inserts: wear resistance, impact resistance, and sharpness. These characteristics are crucial for improving machining efficiency and ensuring machining quality.

Firstly, we chose "round" milling inserts for the experiment. By altering their shape, these inserts enhance the toughness of the tool, thus revolutionizing the traditional boring method. We employed round inserts instead of traditional tool tips for boring and discovered that this novel approach is both wear-resistant and impact-resistant. However, round inserts perform well under conditions of low cutting volume. Once the cutting volume is increased, the contact area of the insert expands, leading to intensified tool vibration and even tool breakage, thereby reducing machining efficiency (see Figure 6).

Subsequently, during the machining process, we experimented with a 75° clamped boring tool. This tool is highly suitable for the rough machining stage of the barrel. Through comparative tests, we found that rough boring a double hole in a barrel using round inserts takes up to 12 hours and consumes 6 inserts. However, after adopting the 75° clamped boring tool, the machining time was shortened to only 3 hours, and the number of inserts consumed was also reduced to 2, significantly reducing machining time and insert costs. Nevertheless, despite the tool's excellent performance in the rough machining stage, it still fails to meet the roughness requirements of the barrel (see Figure 7).

Figure 6 Circular milling insert

Figure 7 75° Mechanically Clamped Turning Tool

To further meet the processing requirements, we ultimately chose "coated three-sided milling cutter with clamped inserts". This insert combines the wear resistance of the coating with the sharpness of the three-sided cutting edge, making the tool perform excellently during processing. We designed the corresponding tool based on the insert model and customized the boring tool body through the tool manufacturer (see Figures 8 and 9). During the customization process, we optimized the angle of the boring tool body four times to find the optimal cutting angle and stability. These optimization measures include adjusting key parameters such as the tool's rake angle, relief angle, major cutting edge angle, and minor

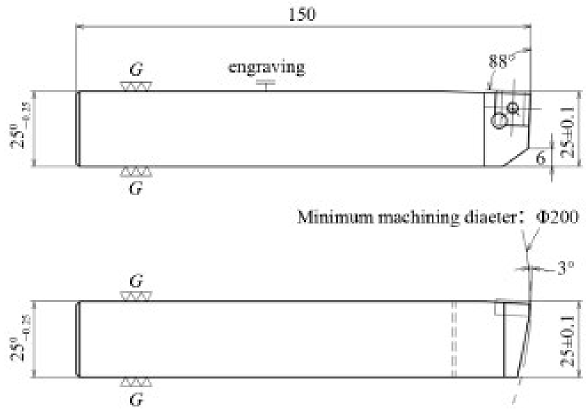

Figure 8 Self-made Tool Drawing

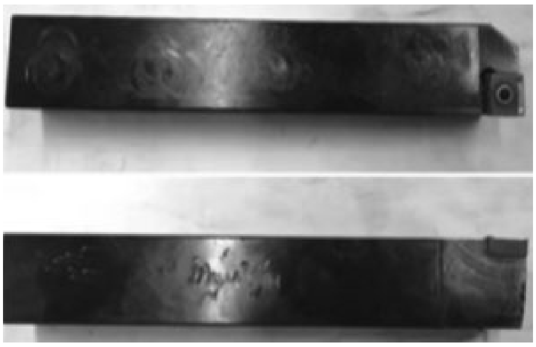

Figure 9 Self-made tool HH211011

Table 1 Record of optimization of self-made boring tool body

Optimization Count	Existing Problems	Optimize Location	Optimized Results
the first time	The side surface of the tool body is not perpendicular to the cutting edge. After clamping, the contact area between the cutting edge and the part is small, which cannot achieve the function of smoothing the tool.	Main inclination angle of the tool body	The side surface of the tool body is perpendicular to the cutting edge, facilitating tool alignment and increasing the contact area between the cutting edge and the part.
the second time	The blade height is higher than the center of the part, causing vibration during machining and affecting the surface roughness of the part.	Blade thickness	The height of the cutting edge is consistent with the center height of the part, eliminating tool vibration.
the third time	The clearance angle of the tool body is small, so during machining, the rear face of the insert contacts the part first.	Tool body clearance	Increase the clearance angle after installation, and tilt the bottom surface of the tool body by 3° when installing the insert
the fourth time	There is a slight chipping phenomenon during the machining process.	Blade installation position	Elimination of reverse tool breakage phenomenon

cutting edge angle (see Table 1) to ensure that the tool can achieve optimal cutting effects and stability during processing.

Through this series of tool optimization measures, we have successfully improved the efficiency and quality of double-hole machining for machine barrels. This not only reduces machining costs but also enhances product quality and competitiveness.

We have continuously experimented and verified various cutting tool parameters. After multiple rounds of fine adjustments and optimizations (see Table 2), we have finally achieved a breakthrough in the processing method of "boring instead of grinding". Now, the straightness, roundness, parallelism, and plane perpendicularity of the double holes in the machine barrel processed using this method can be precisely controlled within 0.02 mm, and the surface roughness of the double holes has reached a high-quality level of Ra0.8 μm or less, fully meeting the strict standards required by the drawings.

The achievement not only signifies a significant improvement in the quality of the barrel components, but more importantly, it also marks a leapfrog in processing efficiency. Previously, it took up to 40 hours to grind the inner hole of a barrel. Now, with the use of precision boring, the processing time for two holes in a single barrel section is only 4 hours, a reduction of nine times. This not only greatly shortens the production cycle but also reduces the operational costs of the enterprise.

Furthermore, it is worth mentioning that the originally separate step of machining the flat grinding reference plane can now be completed concurrently with the hole machining. This improvement not only simplifies the machining process but also saves 4 hours of time that would otherwise be required for reference milling on the machining center machine tool. This not only enhances equipment utilization but also further shortens the overall machining cycle and improves overall production efficiency.

Overall, the optimization of tool cutting parameters and the successful application of the "boring instead of grinding" processing method have not only improved the processing quality and efficiency of barrel parts, but also brought significant economic benefits to the enterprise. This achievement not only reflects our innovation ability and

Table 2 Boring Tool Cutting Parameter Test

Serial Number	Rotational Speed/min	Feed/Rotation	Cutting Depth/mm	Cutting Time/min	Surface Roughness
1	50	0.15	0.03	80	Ra3.2
2	70	0.2	0.03	60	Ra2.1
3	80	0.2	0.03	56	Ra1.6
4	100	0.25	0.03	53	Ra1.2
5	120	0.2	0.03	50	Ra0.9
6	160	0.2	0.03	47	Ra0.8
7	200	0.18	0.03	45	Ra0.5
8	240	0.2	0.03	30	Ra0.6

strength in processing technology, but also provides valuable experience and confidence for us to face more challenges in the future.

3 Effects and economic benefits

Through carefully selected coated three-sided milling inserts, combined with the meticulous design and manufacturing of specialized tools, we have successfully implemented a machining method that replaces grinding with boring. The introduction of this method has not only significantly improved machining efficiency but also achieved unprecedented machining quality, truly achieving a processing effect that combines efficiency and high precision. It is worth mentioning that this technology has also filled the technical gap in the field of machining where boring replaces grinding in the shape of an "8", which undoubtedly greatly affirms our technical strength (see Figure 10).

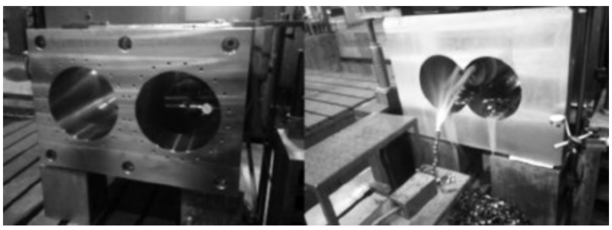

Figure 10 Barrel machining

Initially, it took up to 44 hours to process a barrel. Now, with our new method, the processing time has been dramatically reduced - by over 1,000%. Based on the cost of 270 yuan per hour for a CNC vertical lathe, each barrel can now save 40 hours of processing time, which directly translates to an economic cost savings of up to 10,800 yuan per barrel. For each granulation unit, which comprises nine barrels, the total savings can amount to over 97,000 yuan. So far, we have used this processing method to complete the processing of 10 sets of granulation units, with the cumulative cost savings climbing to over 970,000 yuan.

In addition, the novel self-made cutting tool we adopted utilizes boring instead of grinding for machining, and its application has not been limited to the processing of machine barrels. This technology has also been successfully applied to the machining of complex rotor inner holes (see Figure 11). In this application scenario, each rotor can save 40 hours of grinding time on a CNC vertical lathe. Based on the same cost calculation method, the cost reduction and efficiency improvement for a single rotor also amounts to 10,800 yuan. To date, we have used this machining method to process 74 rotors of 7 different models, resulting in a cumulative cost reduction and efficiency improvement of over 799,000 yuan. This undoubtedly proves that our new method is not only technologically advanced but also economically superior.

Figure 11 Rotor body

4 Conclusion

The "boring instead of grinding" manufacturing optimization project for the barrel of large extrusion granulation units is undoubtedly a profound innovation and breakthrough in traditional manufacturing processes. The successful implementation of this project has not only significantly improved the surface quality and dimensional accuracy of the barrel, but also substantially reduced the rate of product non-conformity caused by processing errors. This improvement in accuracy means higher stability and consistency for the extrusion granulation process, thereby ensuring that the produced products have higher overall quality.

This project fully demonstrates the innovation capability of traditional manufacturing processes, and its successful implementation is of great significance for shortening the construction period of major petrochemical projects. By improving the processing efficiency and quality of machine barrels, production tasks can be completed faster, the construction period can be shortened, time costs can be saved, and market opportunities and competitive advantages can be won. This project also contributes to improving the development level of China's "national heavy equipment" and driving the development of related enterprises, providing support for the development of the petrochemical industry. In addition, the successful implementation of the project has consolidated our company's leading position in the field of rubber and plastic machinery in Liaoning Province and across the country. Leveraging our leading position in technological innovation and process optimization, we have won market recognition and customer trust, consolidating our industry leadership. At the same time, we contribute to achieving "self-control of key core technologies" and ensuring national economic and energy security.