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Hose Clamp: Process Improvement and Optimization Based on Technical Innovation

Dr. Masoud Lajevardi
Corresponding author, PhD in marketing management, Commercial manager of KKS company, iran,Semnan,
E-mail: Lajevardi_masoud@yahoo.com , co_kks@yahoo.com
tell: 098-9370448301
Abolfazl albooyeh
CEO of KKS company
Mehran shahi
Factory manager and head of technical department of KKS company
Mohammah Mohammadi
Laboratory manager of KKS company
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Abstract
The present paper has been prepared with the aim of examining the hose clamp screw production process in Koobesh Kavir Semnan Company (KKS). In this scenario, in the first step, literature on this product has been written with the aim of forming a clear mental framework, which introduces it in general. Then, its production process in KKS Company has been discussed, examined, and analyzed in detail. In the next step, the pathology of this process has been carried out with the support of more than 30 years of production experience and using the valuable technical and engineering knowledge embedded in the coherent research and development cores of this company. Finally, the continuous improvement process with the application of technical-engineering corrective measures based on complex, innovative, and unique knowledge, along with the results obtained from it, has been documented on an ongoing basis over time.
Key words: hose clamp screw, KKS, production process improvement (PPI),

Introduction

Hose clamps are essential components widely used across various industries, particularly in automotive, industrial, and agricultural applications[1]. These components are designed to secure hoses and pipes to ensure leak-proof, stable connections under varying pressures and environmental conditions[2,3,4]. Over the years, hose clamps have evolved from simple mechanical devices to highly engineered products with enhanced performance, durability, and resistance to corrosion[5,6]. The production of hose clamps involves a range of engineering processes, including material selection, manufacturing techniques, and quality control measures, all aimed at improving the efficiency and reliability of the product[7,8].

The automotive industry, in particular, demands hose clamps that meet stringent requirements for durability, performance, and safety[9,10]. As a result, manufacturers have continuously sought to optimize the production processes and incorporate innovative designs that can improve the overall performance of the product[11]. Research in this field has focused on the development of new materials, the implementation of advanced manufacturing technologies, and the analysis of production processes through modern management techniques[12]. Innovations such as the use of corrosion-resistant materials, precision manufacturing methods, and process automation have become key factors in enhancing the quality and cost-effectiveness of hose clamps.

Despite these advancements, there remains a significant opportunity for further improvements in the manufacturing processes of hose clamps, particularly in relation to process efficiency, sustainability, and customization for specific applications. This research aims to address these challenges by analyzing the existing production processes and proposing optimizations based on innovative models and methodologies.

The production of hose clamps based on the market needs of the automotive industry and the internal capabilities of KKS Company has been a key focus since 2012. One of the most important tools for continuous improvement is process analysis through a systems thinking approach. As leading the market requires superior quality in a company's processes, improvement is an ongoing performance over time. Therefore, the starting point for any improvement is the design and analysis of the company's current processes. In this regard, and at this stage of the research, the hose clamp production process (OPC) at KKS was identified and documented by the Research and Development team.

Analysis, Optimization, and Improvement of the Hose Clamp Production Process Based on Technical Innovation

In the first step, the goal is to identify the production process, followed by analysis and diagnosis of issues, and finally, improvement. 1.Transport of raw materials to the raw materials warehouse. 2.Inspection and control of incoming raw materials. 3. Transport to the pressing station. 4.Pressing and inspection. 5. Transport to the threading station. 6. Threading and inspection. 7.Transport to the finished goods warehouse. 8.Final inspection. 9.Transport to the packaging station. 10.Weighing, counting, and packaging. 11.Transport to the product warehouse. 12.Transport to the customer warehouse. The goal of the production process analysis in the first step is to identify areas for improvement, and in the next step, to formulate and implement strategies for correction and enhancement.

Identification, analysis, and improvement of areas for enhancement

Pressing Stage

In the hose clamp production process, after the wires are fed into the production line, in the first stage, which is the pressing stage, they are placed onto the rotating coil. In this process, the wires are fed into the KP5/02 (SAKAMURA) machine. This machine is a 5-cavity single-stroke press. The mechanism of the machine is such that initially, if the wire is bent, it is straightened using a straightening roller. Then, the feed roller directs the material into the machine. Afterward, the material undergoes a cutting mechanism, which includes the cutting mold, support, and cutting blade. In the next stage, with the help of a finger and the first hammer, the material enters the first mold and is extruded. In the subsequent stage, the second finger guides the material into the second mold, where a pear-shaped hammer shapes it. Then, the third finger holds the material in place in front of the third mold, where the third hammer, which has a double-square shape, shapes the piece and trims it at the same time (fig 1).

A rotating coil is a key component in the wire feeding mechanism used in many industrial machines, particularly in wire-based manufacturing processes like hose clamp production. It is a spool or drum that holds the wire in a coiled form and rotates to feed the material into the production line. The wire is unwound from the rotating coil and guided into the machine, ensuring a continuous, smooth supply of material for the next stages of production. The coil's rotation is carefully controlled to prevent tangling or damage to the wire, making it essential for maintaining an efficient and uninterrupted manufacturing process.

Fig 1) KP5/02 (SAKAMURA) machine

Based on the aforementioned details, the blank and the schematic diagram of each stage of the pressing process are reviewed below (fig2, fig3, fig 4 and fig 5)

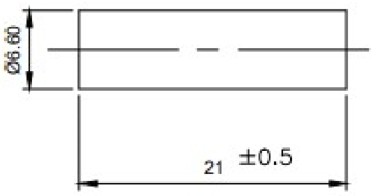
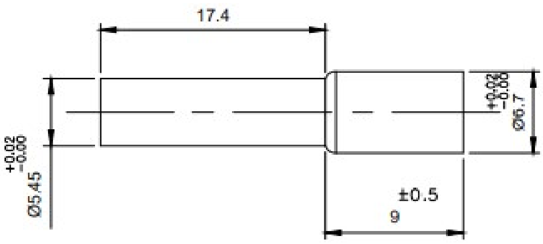


Fig 2) Cutting

Fig 3extrusion



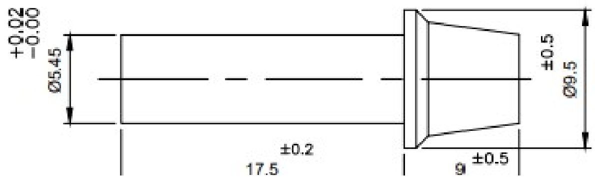


Fig 4) pre-forming

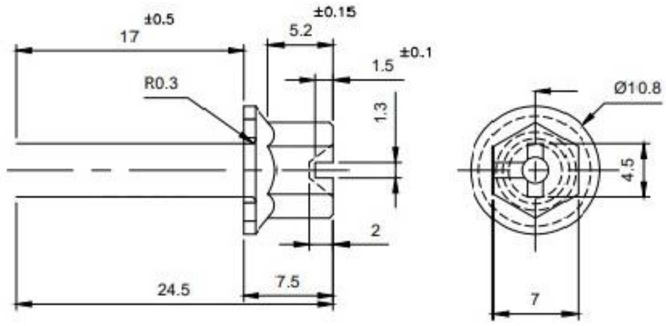


Fig 5) forming and heading

Over the course of several years of manufacturing experience, the overall mechanism for producing hose clamp screws has undergone systematic modifications aimed at enhancing product quality, reducing production costs, and minimizing material waste. These improvements were achieved primarily by extending the operational lifespan of key production components, including forming dies, hammers, and cutting blades.

All changes have been implemented in alignment with the principle of continuous improvement, grounded in a precise engineering perspective on both the production process and the defects observed in the final product.

Among the most significant modifications to the production tools are the redesign of the second hammer, structural optimization of the pear-shaped preform, and the replacement of the third hammer with a segmented configuration.

Optimization of the Second Punch and Pear-Shaped Preform Geometry

The pear-shaped preforming stage serves as a critical step in preparing the metal workpiece for subsequent full deformation into relatively complex head geometries. Omitting this stage in the cold heading process can lead to cracking during forming or incomplete head formation, primarily due to the high degree of plastic deformation required in the heading stage compared to previous operations.

To address this, the pre-heading zone is initially formed into a pear-shaped profile, allowing the material to better accommodate the metal flow and stress distribution during the final blow, thereby ensuring proper head formation with acceptable dimensional and surface quality.

In earlier processes, the pear preform had a predominantly cylindrical shape, which resulted in an uneven or non-flat screw head face (top surface), negatively affecting the final product quality. To resolve this issue, the engineering and R&D team at KKS conducted extensive research on metal flow behavior and deformation mechanisms under high strain rate conditions typical in cold forming. These studies led to the development of optimized dimensions and angles for the pear-shaped blank.

Following the implementation of the revised preform geometry and the design of a new second punch tailored to the updated profile, the head face is now formed completely flat. Additionally, due to improved metal flow and reduced localized stress during forming, the process achieved a more uniform deformation. As a result, die life has increased by approximately 20%, contributing significantly to production efficiency and cost reduction.

Considering the use of low-carbon steel wires (approximately SAE 1010), with a flow stress coefficient K of 550 MPa and strain hardening exponent n of 0.16, the effective strain rate during pear-shaped preforming was estimated at 30 s^{-1}.

The logarithmic strain prior to optimization was 0.262, corresponding to a flow stress of 434.5 MPa. After optimizing the pear-shaped blank geometry, the effective strain reduced to 0.22, resulting in a decreased flow stress of approximately 407 MPa, representing a 6.3% reduction in forming stress (fig6).

This stress reduction contributes to less tool wear and is consistent with the observed 20% increase in die life, improving production efficiency and reducing downtime.

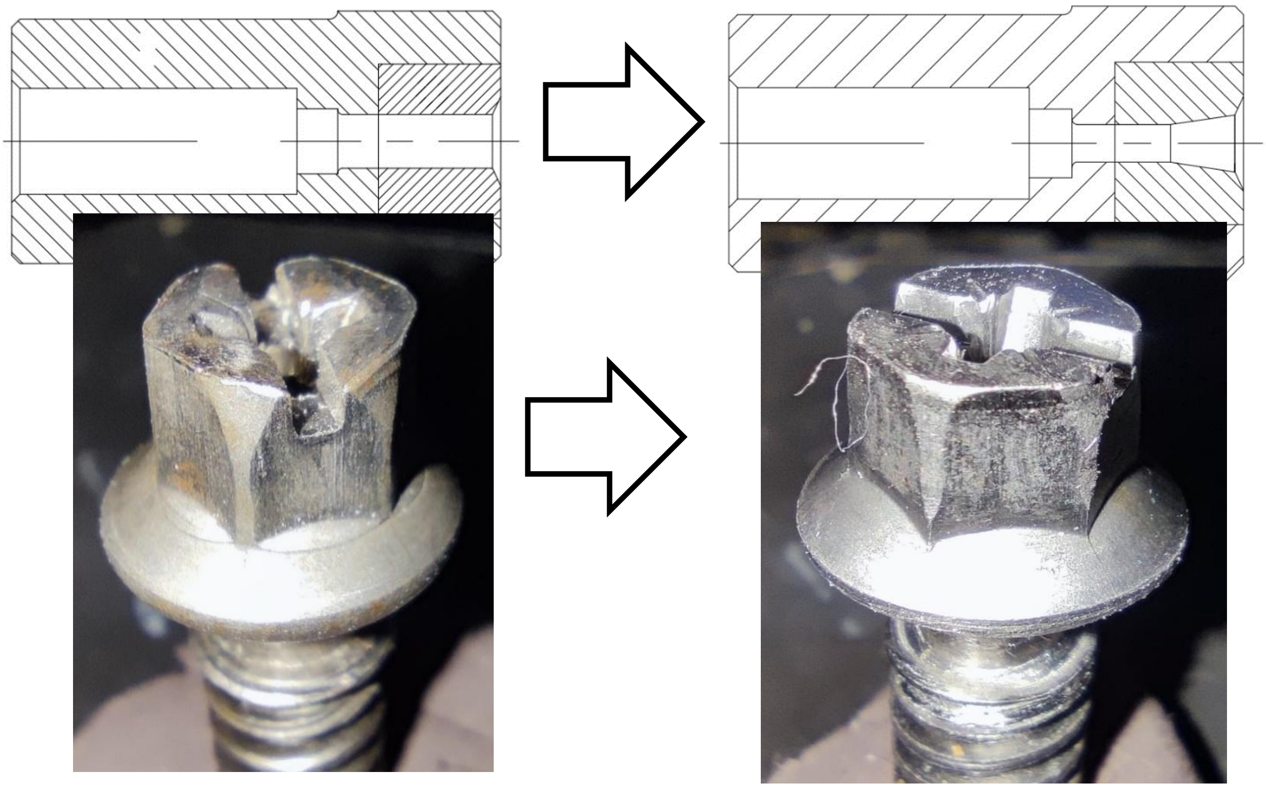


Fig 6) Optimization of the Second Punch and Pear-Shaped Preform Geometry

Modification of the Third Punch and Transition to a Segmented Mechanism

In the third stage of hose clamp screw production, following the pear-shaped preforming, the blank is positioned by a finger mechanism in front of the third die cavity. At this stage, the third punch delivers an impact to form the hexagonal shape of the screw head, along with the slotted drive (Phillips) on its top surface. In the previous design, the hexagonal impression was integrated directly into the punch body and manufactured as a monolithic piece using tungsten carbide. However, this one-piece configuration led to incomplete and non-uniform formation of the hexagonal head during the cold heading process. Due to the critical dimensional and visual quality requirements of this section of the screw, the engineering and R&D teams at KKS. initiated extensive investigations. The outcome of this research was the development of a segmented punch design, incorporating modular inserts and segments instead of a one-piece tungsten carbide structure.

Following implementation, the newly formed screw heads were subjected to several rounds of precision dimensional inspection. The results confirmed the complete and defect-free formation of the head geometry. Furthermore, replacing the monolithic punch with a segmented system significantly reduced tooling waste. In the event of wear or damage, only the affected insert or segment requires replacement rather than the entire punch, resulting in a 45% reduction in punch material waste during production (fig7).

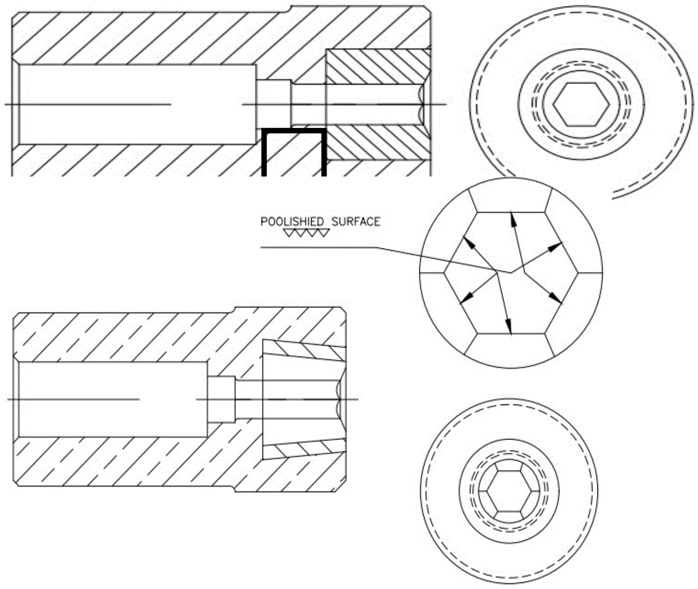


Fig 7) Modification of the Third Punch and Transition to a Segmented Mechanism

Due to persistent issues in the second punch—particularly in forming the hexagonal profile—which resulted in increased scrap rates and frequent production stoppages, the engineering team decided to redesign the punch using a six-piece segmented configuration. This decision was supported by prior research and experience with two-piece dies, and was aimed at improving air evacuation between the part and the die cavity.

The implementation of the six-segment punch significantly improved the dimensional accuracy and corner definition of the hexagonal shape, thereby reducing defects and improving overall line stability. This modification contributed directly to a reduction in production waste and an increase in manufacturing efficiency.

In parallel, several other improvements were implemented, including changes to the carbide grade and grinding method used for the die face. Specifically, the front face of the die was upgraded from a lathe-machined profile to a finely ground and polished surface, and the notch (relief) geometry was optimized. These adjustments resulted in improved surface finish and dimensional consistency of the screw head, reducing defect rates in the final product. Overall, the combined effect of the segmented punch design, enhanced die face treatment, and optimized carbide material led to more reliable screw head formation, reduced process variability, and enhanced visual and dimensional quality of the product (fig8).

In addition to the improvements described above, modifications were also applied to the pear-shaped preforming mechanism in the first punch. These changes successfully resolved the previous issues related to the geometry of the preform, which had caused inconsistencies in the downstream forming stages.

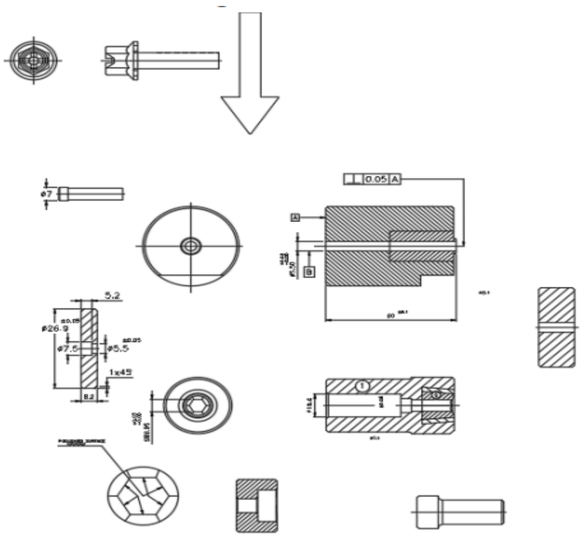


Fig 8) Modification of the Third Punch and Transition to a Segmented Mechanism

As a result, the overall performance of the forming process was enhanced, and recurring production problems associated with this stage were significantly reduced (fig9).

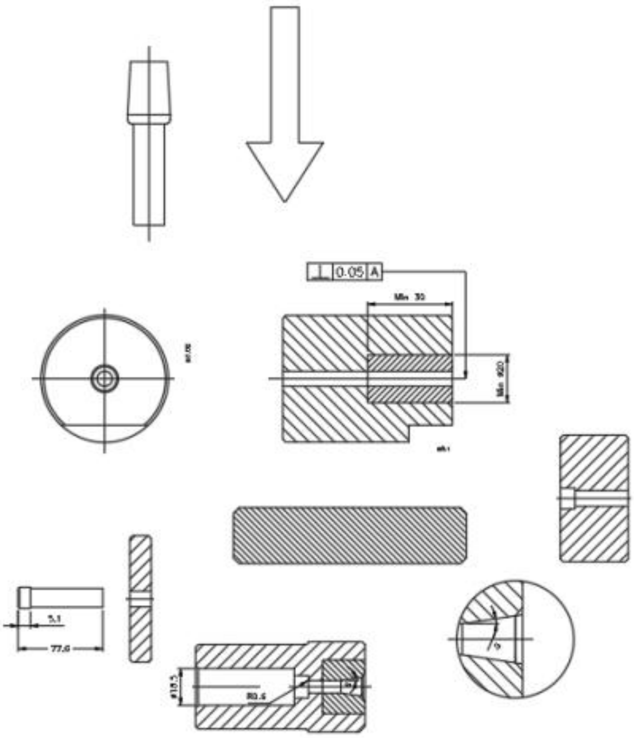


Fig 9) Modification of the Third Punch and Transition to a Segmented Mechanism

Modification of the Relief Groove Formation Mechanism under the Screw Head

The hose clamp produced at KKS Factory features a component known as the relief groove (as shown in Figure ()). This groove is designed to limit the rotational movement of the screw at the curved edge of the band clamp section (fig10).

Fig 10) Modification of the Relief Groove Formation Mechanism under the Screw Head

(a) The curved section on the hose clamp band where, after completing the manufacturing and assembly processes of the screw and the band, the relief groove is positioned.
(b) The relief groove located on the hose clamp screw.

The presence of the relief groove on the screw is of great importance, as it functions to control the rotational movement of the screw during tightening of the assembly. If this movement is not properly controlled, the screw head may become eccentrically positioned, resulting in misalignment of the clamp band, which in turn can cause operational issues such as stiff movement and jamming of the assembled product. Therefore, the complete and precise formation of this feature during the screw manufacturing process is critical.

Previously, to form this relief groove on the screw, an inverse negative pattern of the groove was placed in both the second and third dies. However, over time and with continued production, several issues arose—particularly during setup.

One of the main problems was the misalignment between the groove impressions created by the second and third dies, which led to the formation of an undesirable two-step groove on the screw. Additionally, due to the protrusion of the groove area within the die, it experienced high stress concentration during cold heading, which significantly reduced the tool life, especially through fracture of the groove profile.

In response, the R&D team at KKS proposed a new approach: forming the entire relief groove using only one die. This eliminated the mismatch issue between the two dies, and by removing the stress concentration from the second die, its service life increased by approximately 45%.

However, the success of this improvement was heavily dependent on the selection of an appropriate tungsten carbide grade for the third die. Since the second die was no longer responsible for forming the groove, all the forming stress for this feature was now concentrated on the third die. Without proper carbide material selection, the gain in durability for the second die could be offset by premature wear or failure of the third die.

To address this, the R&D and engineering teams at KKS launched a new research initiative and simultaneously began designing an optimized third die capable of withstanding the concentrated stress while ensuring high dimensional accuracy. A brief overview of tungsten carbide material characteristics is presented in the next section.

Material Selection Process for the New Die in Hose Clamp Screw Manufacturing

As previously discussed in section (), following the redesign of the second die and the elimination of the relief groove formation operation, the entire forming stress required to create the under-head groove was transferred to the third die. This significant shift in load prompted the R&D team at KKS to initiate a new investigation focused on selecting an appropriate grade of tungsten carbide for manufacturing the third die.

This objective required a comprehensive analysis of the mechanical and dynamic parameters governing the operation of the third die. The process began with the calculation of the hammer's striking velocity, determined by analyzing motor speed, pulley dimensions, and the mechanical efficiency of the power transmission system from the motor to the hammer ram.

In the next stage, the impact stress exerted on the die during each forming strike was calculated using mechanical deformation equations, as indicated in Equation

$$E = \frac{1}{2}mv^2 = w = Fd\cos\theta$$

$$\underline{\theta = 0 \rightarrow \cos\theta = 1} \; F = \frac{mv^2}{2d}$$

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

In Equation (), the symbol E represents the kinetic energy, which in this case corresponds to the impact energy transferred to the die during forming. The parameters are defined as follows:

m: mass of the hammer ram

v: striking velocity

F: impact force

d: displacement during impact

A: contact area at the die surface

Given that all the variables are measurable, both the impact force and the resulting stress on the die can be calculated using the following relationships:

$$E = \frac{1}{2}mv^2 = F \cdot d \Rightarrow F = \frac{1}{2}mv^2 \div d$$

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

Where:

\sigma: stress applied to the die surface.

Once the applied stress is determined, the required stress resistance range for the die material can be identified. Considering this range, as well as environmental factors such as ambient atmosphere, presence of corrosive agents, and operational temperature, the appropriate tungsten carbide grade was selected.

Based on this comprehensive evaluation, Grade G40 tungsten carbide was chosen for manufacturing the new third die. This grade was selected due to its:

- High impact resistance
- Excellent toughness
- Proven suitability for stamping and cold forming dies

Therefore, G40 was found to be a highly appropriate choice for the third die used in hose clamp screw manufacturing.

Thread Rolling Operation

Initially, KKS Co. utilized standard thread rolling dies in the production of hose clamp screws. However, due to frequent issues such as limited service life, surface wear, and corrosion of the thread grooves, the company identified the need for a fundamental redesign of the rolling die components.

To address these challenges, the R&D team at KKS combined technical expertise with engineering experience to pioneer a new die design. Through precise engineering calculations, the team developed a novel die groove profile that led to the transformation of conventional die structures into next-generation four-segment rolling dies.

This innovative shift addressed several key problems in the previous designs:

- Reduction in localized stress concentration
- Enhanced thread formation accuracy
- Longer die service life
- Increased resistance to wear and corrosion

Given that thread rolling die technology is underdeveloped domestically due to the lack of infrastructure and know-how, KKS reached out to one of the global leaders in rolling die technology:

TAIYA – Taiwan Rolling Die Plate (RDP).

Following the successful in-house design of the new four-segment rolling die, the company initiated technical consultations with TAIYA to evaluate and benchmark their design under international quality and performance standards.

Following an extensive six-month evaluation period, including the manufacture of a sample pair of rolling dies by the Taiwanese company, and the successful completion of all related performance and engineering tests, RDP (Taiwan Rolling Die Plate – TAIYA) officially validated the technical and engineering integrity of the design developed by KKS Co.

As a result of this achievement, and for the first time globally, RDP issued an official Innovation Design Certificate under the name of KKS, recognizing the novel four-segment thread rolling die structure as an original and globally pioneering invention.

This international recognition marks a significant milestone in the localization and advancement of high-precision tool design in Iran's manufacturing sector.

Evaluation and Analysis of the New Generation Four-Sided Thread Rolling Dies Design at KKS

As mentioned in previous sections, a novel design was developed for the thread rolling dies used in the production of hose clamp screws, which is unique in its kind. The original design of the die was single-sided (fig11 and fig12), requiring the use of plates during die setup on the thread rolling machine to create the upper thread clearance and ensure the proper positioning of the die on the machine.

Initially, the technical engineering team at KKS decided to integrate the plate directly onto the die, eliminating the negative effects associated with using a separate plate, such as slippage and deformation of the plate assembly (fig13 and fig14).

Subsequently, the engineering team took a further step by mirroring two complete die-and-plate assemblies on one side of the die, and in the final stage, a total of four complete die-and-plate assemblies were designed and manufactured on both sides of the die.

The following figures illustrate the design evolution and the engineering drawings of the new generation four-sided rolling dies.

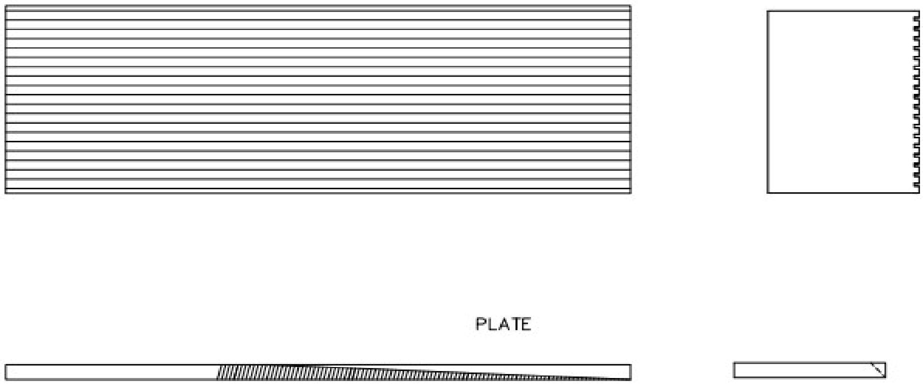


Fig 11) Stage One: One-Piece Die with Separate Plate

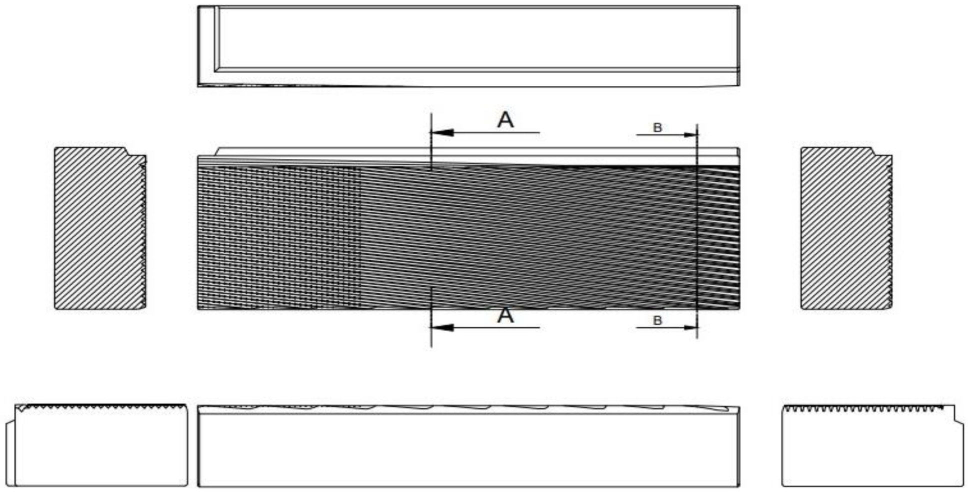


Fig 12) Stage Two: Integrated Die and Plate (One-Piece Assembly)

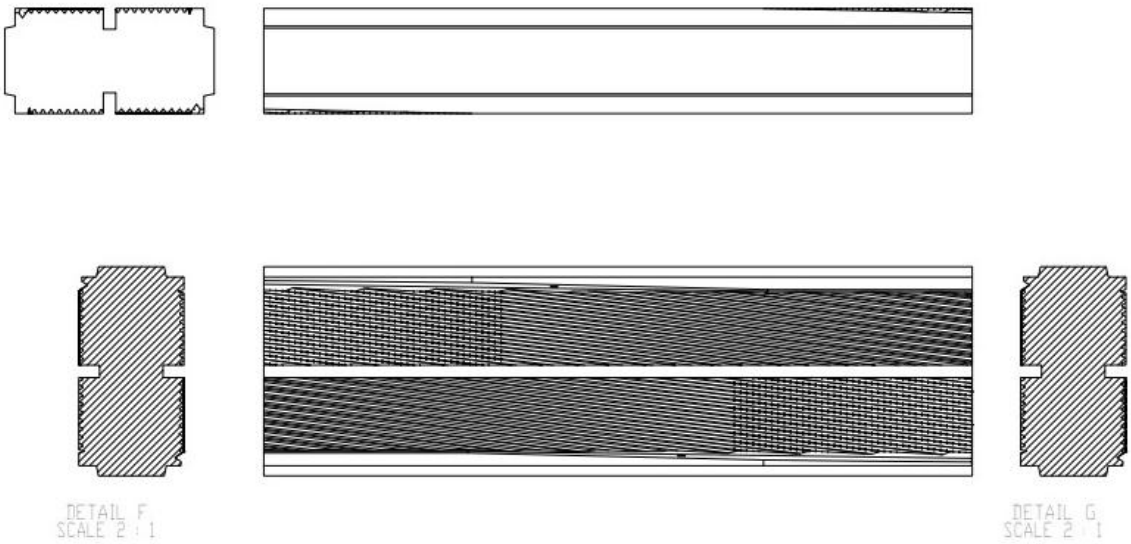


Fig 13) Stage Three: Full Four-Sided Die-Plate Assembly

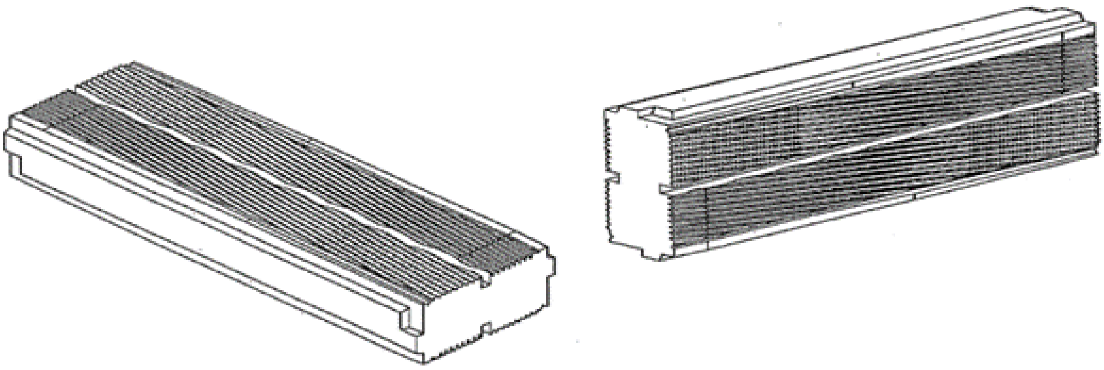


Fig 14) 3D Model of the Final Four-Sided Die Design

Advantages of the Four-Sided Thread Rolling Die Designed KKS Co.

1.Reduction in Thread Rolling Cost per Piece:

Thread rolling cost is influenced by variables such as die wear, blank quality, setup precision, and machine performance. The newly designed four-sided die significantly reduces die wear through enhanced longevity and the integration of a precision-engineered groove. This innovation eliminates excessive wear and corrosion commonly found in conventional dies, minimizing the depreciation factor. As a result, the cost per threaded piece is substantially reduced.

2.Easy Installation Due to High Dimensional Precision:

The dies were designed and manufactured with exceptional geometric accuracy—achieving parallelism and squareness within 0.01 mm per 25 mm. This precision allows the die to rest fully on a perfectly flat surface, ensuring uniform contact between the die and the screw blank throughout the thread rolling process. This leads to the formation of precise, square-profile threads, improving both product quality and mechanical properties.

3.Reduced Setup Time and Vibration; Smoother Startup:

Thanks to its square geometry, the die ensures better alignment during setup, minimizes machine vibrations, eliminates impulse shocks during startup, and extends die life. Unlike traditional dies where the screw must align with a helical groove, here the screw rotates parallel to the die surface. This allows for a gentler engagement, preventing blank deflection and ensuring smoother initiation of the rolling process.

4.Prevention of Die Cracking:

Die tooth cracking can result from mismatch between fixed and moving dies, improper blank shape, poor material quality, inaccurate die design, or machine setup errors. The precision design and tight dimensional tolerances achieved by KKS's quality control team minimize these risks. Each die is manufactured under strict tolerance control to limit angular and dimensional deviations, significantly reducing crack initiation and promoting smoother thread profiles (fig15).

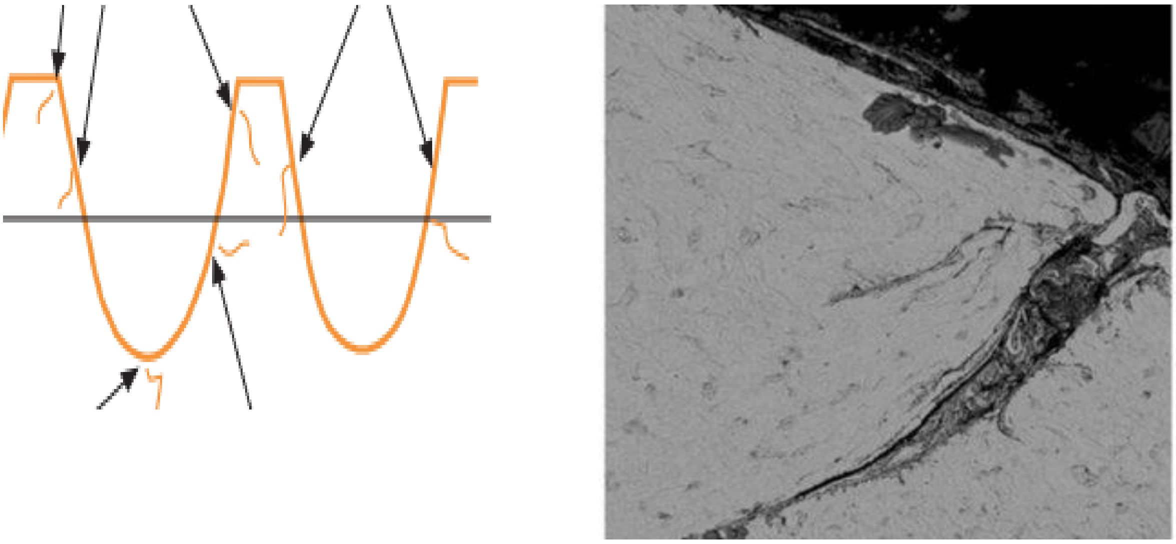


Fig 15) Prevention of Die Cracking

5. Comparison Between the KKS Die and Conventional Market-Available Dies

In the field of flat thread rolling dies, particularly for hose clamp screw production, two common types of dies are widely used in the global market: Single-Sided Dies, and Double-Sided Dies.

typical single-sided die. In this traditional generation, threading is performed on only one side of the die. The setup process is single-phase and suitable for basic rolling operations with low risk of cracking or hard thread start

double-sided die, which can form threads on both sides. It supports dual or quad-side setups and is often used in cost-effective thread rolling machines. These dies offer extended usability compared to single-sided types but still face limitations in terms of alignment precision, wear resistance, and thread uniformity.

In contrast, the four-sided die developed by KKS represents a significant technological advancement and the pinnacle of modern die design. This new generation of thread rolling dies not only incorporates all the functional and structural advantages mentioned earlier but also greatly enhances rotational alignment and thread precision. It is compatible with all types of thread rolling machines, with no restrictions on setup configurations or operational modes (fig16).

This innovation provides a new benchmark in die performance, combining maximum efficiency with versatility and durability across high-volume production environments.

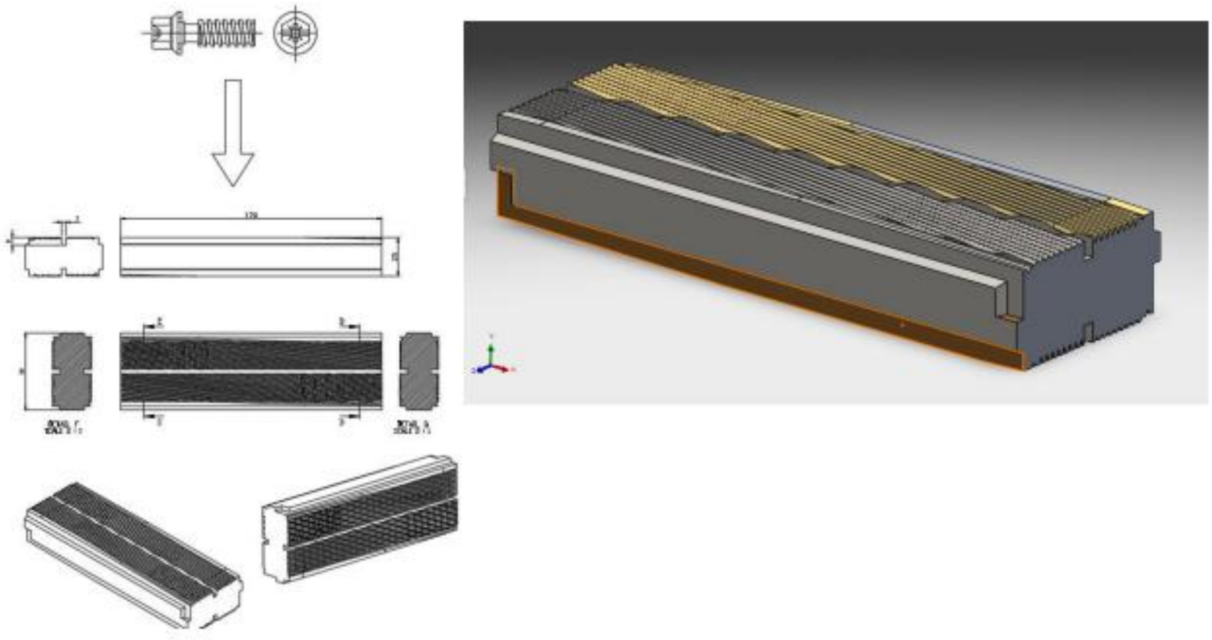


Fig 16) Four-Sided Thread Rolling Die Designed KKS Co

Conclusion

This study comprehensively examined the multi-stage manufacturing process of hose clamp bolts at KKS Company, emphasizing continuous improvements in design and production techniques. Key process optimizations, including the refinement of the secondary hammer and pear-shaped blank formation, the transition to a segmented third hammer mechanism, and the redesign of the mandrel (nafie) mold, significantly enhanced product quality while reducing production costs.

The strategic selection of tungsten carbide grades, combined with precise machining and polishing methods, extended tool life by approximately 20% to 45% and substantially decreased manufacturing scrap rates. Moreover, the innovative design of the four-segment rolling dies considerably improved die longevity, threading accuracy, setup time, and crack resistance, thereby boosting overall manufacturing efficiency and product performance.

Comparative analysis between single-sided, double-sided, and the newly developed four-sided rolling dies revealed that the latter offers superior precision and adaptability, making it the optimal solution for various bolt threading machines.

Overall, the technical advancements and extensive R&D efforts at KKS have proven instrumental in enhancing hose clamp bolt quality and reducing production expenses, solidifying the company's competitive position in both domestic and international markets.

Acknowledgments

KKS Company is a leading Iranian manufacturer specializing in the production of custom-designed industrial fasteners, including bolts, nuts, pins, and rivets. Established in 2002 in the East Industrial Park of Semnan Province, the company was founded with the aim of enhancing the national economy and meeting the domestic demand for specialized fastening components. With a commitment to quality and innovation, KKS has developed a comprehensive manufacturing infrastructure, including state-of-the-art laboratories and mold-making facilities. The company adheres to international quality standards, including IATF, and has implemented a robust organizational framework to ensure consistent product excellence. Through continuous research and development efforts, KKS has pioneered advancements in the design and production of hose clamp bolts, introducing innovative solutions that have set new benchmarks in the industry. The company's dedication to technical excellence and customer satisfaction has solidified its position as a trusted partner in the industrial fastener sector.

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