Research progress of cold extrusion technology for light alloy internal thread

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Abstract. Light alloy materials are widely used in aerospace, automobile, shipbuilding and chemical industry, and the service life of aircraft, automobile and high-speed train is directly related to the thread connection performance of light alloy. The surface quality, dimensional accuracy, material utilization and mechanical properties of cold extruded internal threads are superior to those of traditional processing methods. The influence of processing conditions on the surface microstructure and mechanical properties of internal thread is described. In this paper, the development direction of the finite element simulation technique for metal plastic processing and the design of new extrusion tap structure and the optimization of extrusion process parameters are proposed.

1. Introduction
With the rapid development of transportation and aerospace industry in the 21st century, light alloy manufacturing technology has made great contributions to the development of aerospace, automobile, major equipment, energy, weapons, shipbuilding and information industries in China [1]. At present, light alloys mainly include aluminum alloy, magnesium alloy, titanium alloy and other high-performance light alloys. Light alloy is a good non-ferrous metal structural material. Because of its light weight and good recyclability, it has been widely used in aviation, aerospace, automobile, machinery manufacturing, shipping and chemical industry. Because of its low density and good casting and processing properties, light alloys offer a variety of application possibilities for manufacturing industry [2].

Thread connection not only meets the requirement of rapid and accurate assembly and disassembly, but also ensures that interconnected parts are not destroyed [3]. Due to the low hardness and high plasticity of Aluminium alloy materials, Aluminium chips will be produced during tapping. Chips sticking to the inner wall of threads are difficult to clean, which affects the cleanliness of products and the reliability of threads. In recent years, with the improvement of processing environment and the concept of "green manufacturing", cold extrusion threads have been widely used in industry [4]. In recent years, with the improvement of processing environment and the concept of "green manufacturing", cold extrusion threads have been widely used in industry. Cold extrusion of internal threads can prolong tool life, improve thread processing accuracy, surface roughness, mechanical strength and reliability, improve process cleanliness and reduce production costs.
In this paper, the cold extrusion processing technology of light alloy internal threads is summarized, and the research status of cold extrusion processing technology of light alloy internal threads is analyzed. Based on the actual demand of cold extrusion processing technology of light alloy internal threads, the deficiencies of current research are expounded, and the development prospect of cold extrusion processing technology of light alloy internal threads is prospected.

2. Research Status of Cold Extrusion Internal Thread Processing Technology

Due to the particularity of materials and extrusion forming process, extrusion of internal threads often causes many problems, such as rough or material depression on the top of small-diameter threads, crista in the thread profile, chips in processing, tap fracture, material protrusion around the external face after extrusion processing, etc. Therefore, in order to obtain high quality internal thread profile, it is necessary to study the influence of processing parameters on extrusion forming. At present, the research of light alloy cold extrusion internal threads mainly focuses on the influence of processing technology on the structure and properties of the threads after forming. Through on-line monitoring system, the thrust, torque, temperature and other indicators in the process of internal thread processing are obtained. The micro-structure and profile of internal thread after processing are observed, and the relevant processing parameters (hole diameter, forming speed, tool type and lubricant) are optimized.

2.1. Hole Diameter

Most scholars believe that the change of hole diameter has the greatest influence on thread profile, and hole diameter is the key parameter of extrusion thread. Too large hole diameter and less amount of base metal result in incomplete tooth shape, which leads to larger thread diameter and lower thread profile height, which can not meet the requirement of small diameter tolerance of thread, and leads to lower thread strength. If hole diameter is too small, and the closed metal moves nowhere, resulting in excessive extrusion torque, faster wear and tear of the tap, and increasing the risk of tap breakage. Carvalho [5] believes that the filling rate of the material depends directly on hole diameter in the processing of internal threads. Within a certain range, the smaller the diameter of the hole, the better the filling rate of the threaded material. This is because the small diameter extruded tap provides better closure and smaller cristae at the top of the thread.

The diameter of the hole has a great influence on the extrusion forming process, thread profile, thread surface quality and thread connection strength [6]. Most of the hole diameters come from the sellers' recommendation and empirical formulas. Zhang Yi [7] deduced the diameter of the hole of the thread by simplifying the helix into a series of circles 2 mm apart, and carried out experimental verification. Liu Zhaohong [8] deduced the theoretical formula for calculating the hole size of internal thread based on the cold extrusion forming mechanism, studied the influence of the hole size on extrusion torque and thread tooth height, and revised the theoretical formula. However, most of the formulas for calculating the diameter of hole do not take into account the structural form and tooth size of tap, the mechanical properties of materials, and the tolerance range of hole diameter is not determined. Therefore, it is necessary to determine the ultimate value of the diameter of hole of workpiece through theoretical calculation, simulation analysis and processing test.

2.2. Forming Speed

In the process of cold extrusion of internal thread, the forming speed affects the quality of cold extrusion of internal thread [9]. High forming speed can reduce the extrusion force and torque, reduce friction force and generate heat, help to relieve the pressure of materials, improve the plastic strain of materials, and help to tighten the thread profile. On the basis of definite tool material, choosing proper forming speed can improve the durability of tap and obtain stable thread accuracy and surface quality.

The explanations of forming speed are different in most literatures, and there is a big difference [10]. Sérgio [11] believes that the surface quality of threads will deteriorate when the forming speed reaches 150 m/min. This is due to the rapid displacement of the extrusion tap, which does not have
enough time to soften the material in a limited area, and can not provide perfect material strain, so that a good thread profile can not be formed.

2.3. Tool Structure
Extrusion tap is the main tool for cold extrusion of internal threads. Its structure directly affects the quality of internal threads. The optimum design of extrusion tap is the key to solve the problem of high precision and high strength internal thread processing [12]. Wang Zhuolin [13] obtained the concept of pitch error of edge ridge theory in transition zone by analyzing the grinding process of extrusion tap threads, and put forward the dislocation grinding method and double precision grinding method to eliminate the error, so as to improve the design and manufacturing level of extrusion tap. Mu Jixiang [14] used VB to get the optimum value of extrusion angle and eccentric relief amount for the main factors affecting the service life of extrusion tap, which improved the service life of extrusion tap. Miao [15] proposed to use genetic algorithm to optimize the structure design of extrusion tap, and the optimization results effectively reduced the extrusion torque. At present, the structure design of extrusion tap still relies on experience, and then improves continuously through experiments. Therefore, the design cycle is long and wasteful. On the basis of collecting design data widely, Zeng Jie [16] applied case-based reasoning technology to the computer-aided design of extrusion taps. The structure model of extruded tap and the influencing factors model of tap design are analyzed and established. According to the information of the internal thread to be extruded, the automatic matching and selection of the extruded tap are realized, the reuse rate of the design knowledge of the tap is improved, and the problems of tedious and inefficient design process of the tap are solved. The extrusion tap is not only troublesome, complex in structure and complicated in calculation, but also must be customized according to the thread parameters and performance. Therefore, the design calculation and manufacturing technology of extruded tap structure has always been an important research direction of cold extrusion processing technology for internal threads.

2.4. Cutting Tool Materials
The main tap materials are alloy tool steel, high speed steel and cemented carbide [17]. Alloy tool steels, such as 9CrSi and Cr12MoV, can be used as tap materials for extruding internal threads of non-ferrous metals. High speed steel has high toughness, red hardness and wear resistance, such as W18Cr4V, W9Mo3Cr4V, etc. The extrusion force of high-speed steel tap is large, and the surface roughness of the processed thread is not high. Tungsten-cobalt YG series materials are often used in cemented carbides with good toughness. Coelho [18] studies that cemented carbide taps can work at higher extrusion speed, with smaller extrusion force and longer tool wear life, but they need to be processed by diamond grinding wheels on thread grinders.

In recent years, extrusion Taps coated with metal TiN have been used more and more, which have long service life and high production efficiency. Carvalho [5] considers that the filling rate and surface roughness of internal threads are affected by the coating on the tool surface during extrusion of magnesium alloy threads. The filling rate of materials processed by coated tools is significantly higher than that of uncoated tools. By visual analysis of thread surface roughness, the value of surface roughness of inner thread machined by uncoated tool is lower. According to Nedic [19], coated cutting tools have superior friction, help to increase the thrust of the tap forward, and are easier to adhere to materials. Therefore, the material of extrusion tap should be selected according to the material of the workpiece to be processed and the working conditions during processing.

2.5. Lubricating Fluid
In the process of extrusion threading, plastic deformation occurs between extrusion tap and light alloy material, and strong friction occurs, which causes temperature rise. Choosing suitable cooling lubricant can not only reduce the friction between tap and light alloy material, but also significantly reduce the extrusion force, and improve the working life of tap. If the lubrication effect is not good, when the tap contacts the metal surface directly, it will produce metal bonding and bonding wear,
which will lead to surface tearing, scratching and other defects, leading to taper wear, or even breakage. Brownmick [20] research shows that lubricant can make thrust and torque more stable during extrusion of magnesium alloy internal threads, and the contour quality of processed threads is better. Hu Niansun [21] found that when Aluminium alloy thread was extruded by processing center, better thread quality could be obtained by using emulsifier with 6%~7% concentration. Fromentin [22] studied the effect of extruding threads with different kinds of oil lubrication under high pressure, and also studied the effect of additives on the temperature of forming threads. It was found that the performance of lubricating oil was determined by the molecular structure and thermal properties of additives. In summary, the selection of suitable lubricant for forming threads is a necessary condition for success.

3. Conclusion And Prospect
As we know, cold extrusion forming is one of the best performance technologies in near net forming. The cold extrusion forming parts have stable quality and high precision, and are suitable for mass production. There is no theoretical system for the research of cold extrusion processing technology of light alloy internal threads. According to the research status and existing problems of cold extrusion processing technology of light alloy internal threads, the following aspects can be studied in depth.

3.1. Study on The Relationship between Deformation And Extrusion Force in Different Stages of Extrusion Thread
The rule of metal flow during extrusion of internal threads should be explored. Because extrusion thread is a very complicated process, the displacement and velocity fields of particles in alloy can be obtained by studying the relationship between deformation and extrusion force in different stages of thread forming and combining with slip line method, which can explain the movement law of particles in alloy material to a certain extent. Then, according to the relationship between strain and displacement, the strain field in the alloy and the change of the final thread shape are determined.

3.2. Finite Element Simulation of Metal Plastic Processing Aided Analysis of Extrusion Internal Thread Forming Process of Light Alloy
Finite element simulation technology has been widely used in extrusion of internal threads, but the material is limited to ferrous metals. Combining the theory of metal plastic forming with simulation, the flow rule, extrusion velocity field and stress-strain state of light alloy metal are obtained. The optimum process parameters during extrusion of light alloy internal threads are analyzed. The influence of microstructure evolution, residual stress in light alloy and the change of lubrication mode on plastic forming can also be analyzed.

3.3. Design of New Extrusion Tap Structure And Optimization of Extrusion Process Parameters
Bratan [23] designed a new type of composite tap based on cutting-extrusion compound theory and applied it to Aluminium alloy. However, the deformation characteristics of the alloy material and the friction between the material and the tool are not taken into account in the design process. Based on the new cutting-extrusion compound theory, the computer simulation and extrusion process are combined to optimize the structure of extrusion tap and the extrusion process parameters, taking into account the deformation characteristics of light alloy materials.

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