

THE DESIGN AND SIMULATION OF THE HOT STAMPING PROCESS FOR PRODUCING A NAIL-SKIN CUTICLE NIPPER

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ABSTRACT

This paper presents design and simulation of the hot stamping process for producing a nail-skin cuticle nipper. This tool belongs to a group of body care products, which have a high demand in society. So far, it has been manufactured by the use of conventional method. In this paper, 3D nipper model, die modelling and hot stamping simulation were performed successfully in the CAD/CAE program. Based on this, the optimal stamping parameters such as speed, force, temperature, etc. can be obtained. As a result of that, engineer can analyze all of steps in the design process of nipper, so that it is possible to predict a failure, to save cost of experimental test, to improve productivity. The obtained results are also valuable for producing of other useful product by mean of hot stamping process.

KEYWORDS: Block Stamping, Hot Stamping, CAD/CAE, Finite Element Method & Simulation

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INTRODUCTION

Today, hot stamping is one of the most important pressing methods, because it is possible to manufacture products with good mechanical properties and high reliability [1-2]. Apart from mechanical parts including gear, fork, coupling, etc. which are widely used in vehicle and defense industries, it also needs to mention nail-skin cuticle nippers. These tools belong to a group of body care products, which have a high demand in society. To manufacture them, most of companies in developing countries, especially Vietnam, employ conventional production process, which requires a plenty of trial-error experimental tests to determine a suitable machining approach. This often results in time-consuming and high expenditure in comparison with products made in developed countries, even though from the aesthetic point of view the former tools are even better [3-4].

Lately, cutting-edge technology such as numerical analysis in CAD/CAM programs has been employed in nipper-producing companies to improve the productivity. However, there still exist a series of drawbacks. For instance, it sometime takes a long time to build an intensive stamping model in the very well-known commercial software such as Ansys and Abaqus. The authors have intended to use the software Pamp-Stamp for simulation [5], but it is mostly suitable for sheet presswork rather than block stamping. While, the other software such as Transvalor Forge, Qform, Engin Soft are still not common. Although Deform-3D presents a user-friendly software, it is still difficult to build a model of complex configuration due to the fact that it requires the input data of chip and die form from another software. Moreover, in order to analyze the outcomes from simulation properly, which is the most essential process, the companies has to have high-qualified engineers on staff. Apart from cuticle

nippers, other products have also been machined by hot stamping such as screw [6] and/or cell phone case of magnesium alloys [7]. Besides, Misirli and Can [8] carried out the simulation and experiment of hot stamping using die of rectangular and leaf configuration in the condition with and without friction in order to analyze alteration rules of material properties. Simulation of gear hot stamping was studied by Khalilpourazary et al. [9], yet the outcome can be used for predicting separation between die surfaces and defining a suitable pressing forces.

From all of abovementioned works, it is observed that there is still a lack of a comprehensive procedure, which can be used for various types of product. Thus, it is difficult to use for hot stamping process of nail-skin cuticle nippers. As a result of that, this paper studies a standard design procedure of nipper and die, as well as hot stamping simulation, which are available to use easily in the commercial CAD/CAE program.

NIPPER DESIGN PROCEDURE

It is truly crucial to model the nipper in 3D in the CAD/CAE program. Since this tool presents a complex configuration, the model needs to be built in the form of projection from an object. The design procedure, included into Figure 1, presents following steps:

- a) Model a projection view of the nippers
- b) Model a vertical view of the nippers
- c) Combine projection and vertical views to create 3D curve in accordance with nipper boundary
- d) Model curved surfaces from 3D curves to create a grip of nipper
- e) Assign vertical surfaces and with the blade section to create contour profiles
- f) Cut off excess parts in the grip area
- g) Create curved surfaces according to the profile of the blade section
- h) Cut off the excess from the surface created in part (g)
- i) Cut off the excess of the grip to obtain a complete upper / lower grip.
- j) Repeat steps (a) to (i) to design the remaining lower / upper pincers and recombine them with a hinge axis

These are basic steps to model a nipper. In fact, the dimensions in the above rendering process (thickness, thinness, radius of curvature, etc.) are usually determined by the method of inheriting experience, then conducting testing and analysing safety (durability and hardness). At a higher level, it is possible to parameterize the dimensions in the construction steps from (a) ÷ (i) to build a mathematical model. Solve it and get the optimal or suitable size parameters in the optimal design problem.

DIE DESIGN PROCEDURE

In order to serve the stamping process, it needs to design stamping die. It is well-known that as the chip is pressed in the mold, the work piece will transform its shape and fill the die to get the grip details. Thus, the die cavity must have the same shape and size as the grip designed above. Derived from this idea, building a 3D model of the die should be done in a compensatory method, i.e. taking the geometric shape of the pliable object to enter the original die object, then separating it, Eliminate the intersection space according to the geometric profile to obtain the “concave” space, which is equal to

the convex part of the nipper. This procedure is illustrated in detail in Figure 2, as follows:

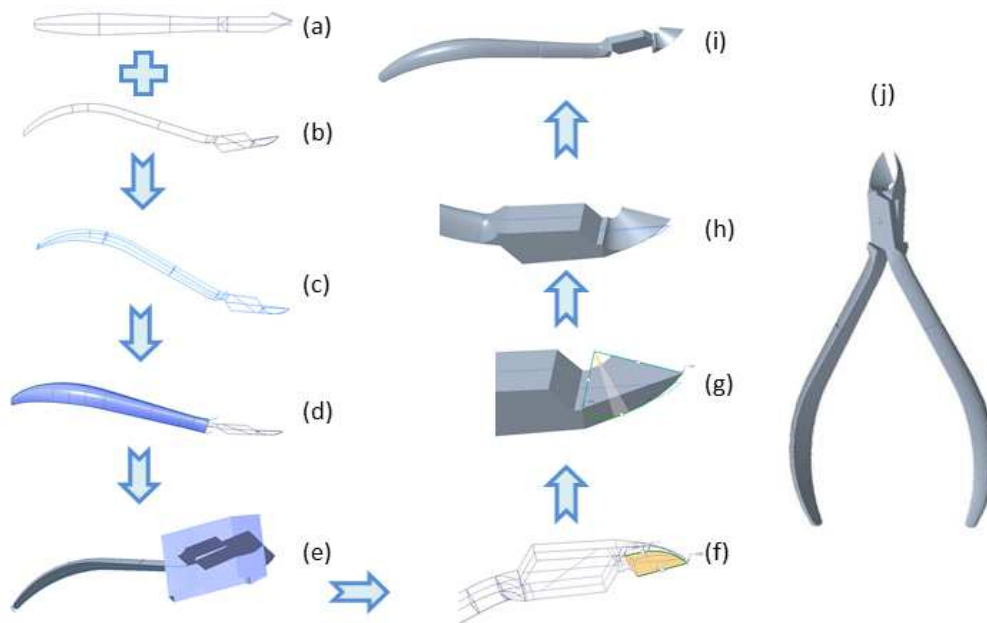


Figure 1: Design Procedure of Nail-Skin Nipper Carried Out in the Software CREO

- a) The lower surface profile is created from the design details
- b) The upper surface profile is made up of the base and the base of the lower die
- c) Combine top and bottom surfaces into the overall mass
- d) Separate the general block from the die surface under the lower die
- e) Separate the mass from the upper face on the upper mold

However, the stamping die needs to be designed as 2 halves: top and bottom, each half is concave designed the space of the nipper parts, so that when stamping and deformed chip is filled into the upper and lower dies at the same time. They are stuck together and shortened into nippers. After the design process (a) ÷ (e), it is possible to get two upper and lower halves of dies to prepare in the next main step.

HOT STAMPING RESULTS AND DISCUSSIONS

The mathematical model of hot stamping is based on finite element method, taking into account complex thermal phenomena [10, 11].

Thermo-Mechanical Formulation

- The mechanical and constitutive equations, such as The equilibrium equation, neglecting inertia and gravity forces, is written, using the Cauchy stress tensor; The material is assumed to be isotropic and incompressible with the condition on the velocity field; The Norton-Hoff law
- The mechanical boundary conditions, such as A friction law, consistent with the viscoplastic constitutive equation is built from a friction potential; The friction shear stress; the non-penetrability condition (of the material in the die)

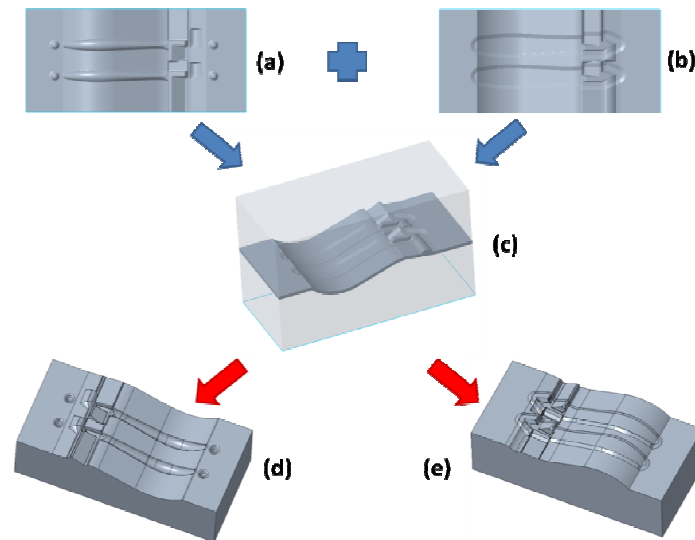


Figure 2: Die Design Procedure

- The heat transfer equation, such as the differential heat transfer equation; the viscoplastic deformation;
- Thermal boundary conditions

Numerical Resolution

- Resolution of the mechanical equation;
- Resolution of the thermal equation.

In order to simulate the hot stamping process of the nail-skin cuticle nipper, the die design procedure is shown in Figure 3. This is a general process and can be applied to many different software, for instance DEFORM 3D.

Looking into Figure 3, firstly it needs to introduce the 3D data of the nipper (a). The important parameter here is the diameter d . When the diameter is small, it is possible that as stamping the nipper will not fill the die and then there will be a shortage of materials, not the desired shape of grip. If the diameter is too large, the stamping force needs to be strong, causing energy losses and also generating many excess parts need to be removed after stamping. Hence, simulating the stamping is also an important tool to find the appropriate d -value. The next steps (b) - (c) are the input of the lower and upper die respectively. In the section 3, 3D model for 2 upper and lower dies is exported. The bottom die is placed in the appropriate position, as shown in Figure 3. Then, in step (d), it is possible to determine the coordinates of the relative position of the two dies, preparing for the correct stroke. After that, step (e) it needs to introduce data on firing temperature, stamping speed, number of simulation steps, friction coefficient, and material shrinkage. The last step (g) is simulation result, as shown in Figure 4.

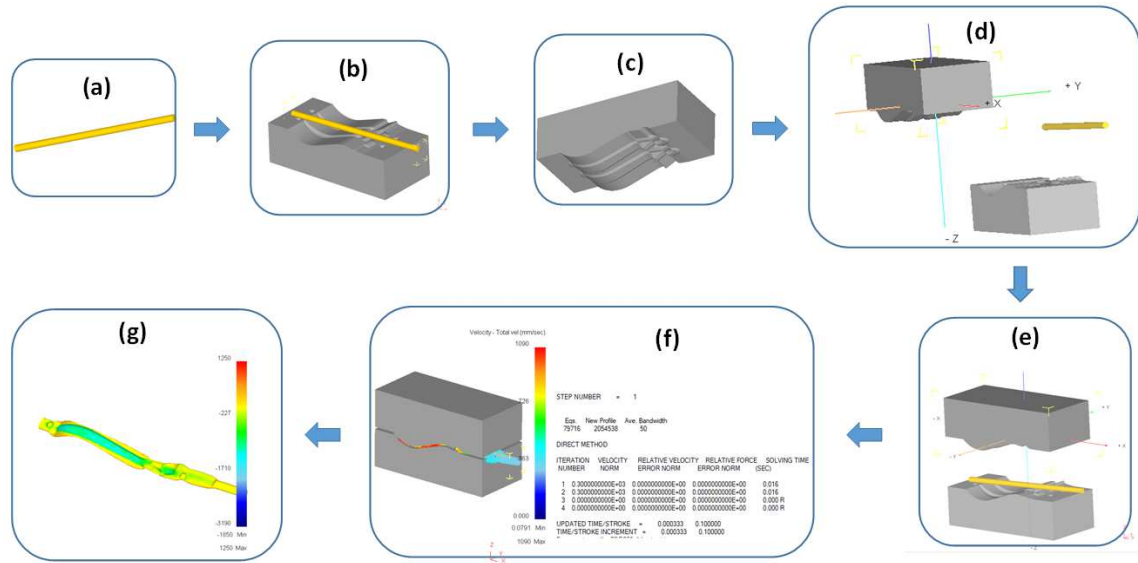
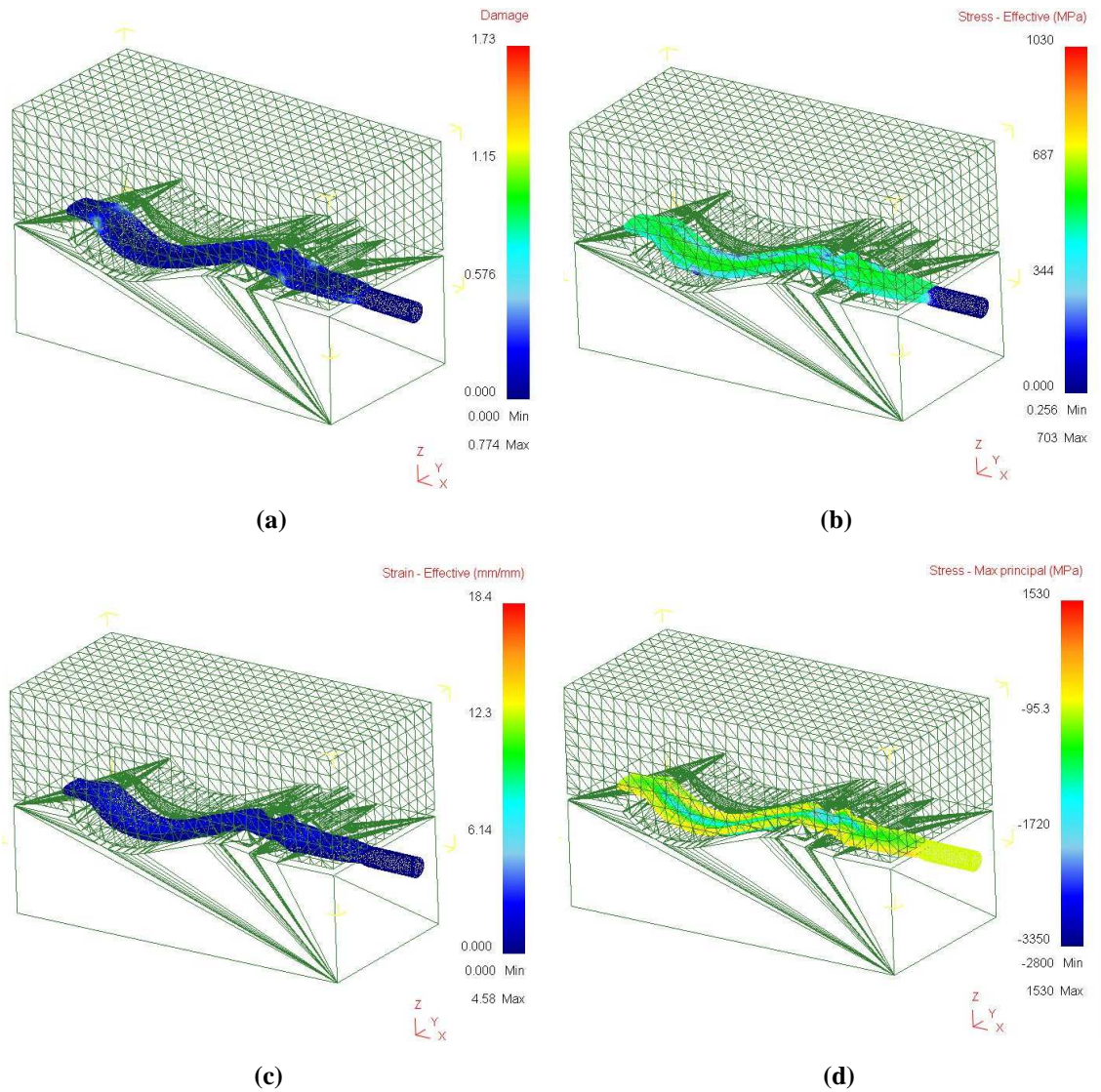


Figure 3: Hot Stamping Simulation Results of Nail-Skin Cuticle Nipper



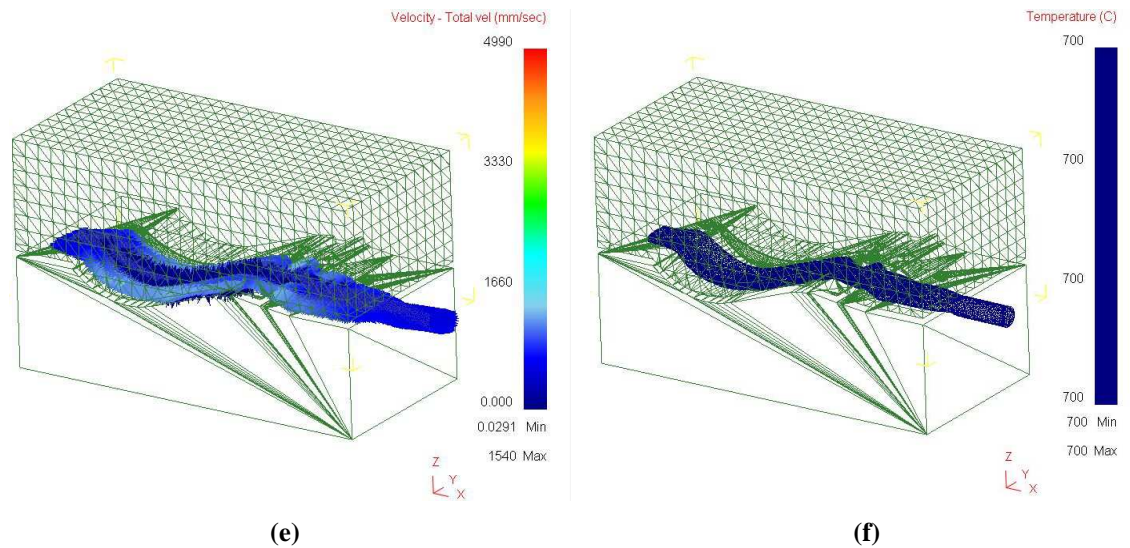


Figure 4: Simulation Results. (a) Failure; (b) Effective Stress in MPa; (c) Effective Strain in mm/mm; (d) Maximum Principal Stress in MPa; (e) Stamping Speed in mm/s; (f) – Temperature in °C

CONCLUSIONS

Nail-skin cuticle nipper is one of important body care products, which have a high demand in society. In this paper, design and hot stamping process for producing this tool was simulated properly. Indeed, three procedures, including nipper modelling, die modelling (both upper and lower parts) and hot stamping process simulation were carried out. All of these procedures were performed by mean of CAD/CAE systems such as CREO and DEFORM- 3D. These procedures can also be applied to other areas of pressure processing, in order to save the cost of experimental test. However, to produce the final product as same as the original design, it has to go through many other stages that need to be simulated, that is cutting edge, cold pressing, mechanical analysis and selection of methods.

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