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NUMERICAL MODELLING OF CLINCHING PROCESS

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ABSTRACT

This paper deals with usage of explicit analysis modelling of clinching process. Clinching process is often used in mechanical engineering. In this paper process of connecting of profiles in civil engineering is analyzed. The aim of this paper is creation of appropriate numerical model in LS-DYNA, which would correspond to manufacturing process of clinching. The most important parameters for creation of clinch connection are specified by comparison of numerical model and physical experiment. This paper is part of a larger research, which deals with clinching method used in civil engineering.

Keywords: numerical modelling, clinching, LS-DYNA, material model, Johnson cook.

INTRODUCTION

This paper describes introduction to way of modelling of clinching process. These connections are easily characterized as a connection of two profiles without any connectors, with usage of two tools, punch and die [1-4]. A punch and a die are two tools placed in front of each other and between them connecting material is placed (see in Figure-1 and Figure-2). The punch is pressed into the die through wanted profiles. A connection, which is made by two pressed profiles together, can be made by tools with specific velocity and force. Advantages of these connections are quick production, absence of connectors and high potential for automation.

Modelling methodology, preparation of mesh and choices of suitable material models [4, 5] are emphasized in this part of the paper. The choice of suitable material model, which can clearly describe behavior of material, is the main part of this paper. A setting of boundary conditions, velocity of process and other parameters which influence final shape of clinch connection are other important aspects.

A representative tool for connecting of two profiles 2.67 mm thick was chosen as a first example for modelling. The numerical modelling was concentrated on restricted area which represented real behavior during production.

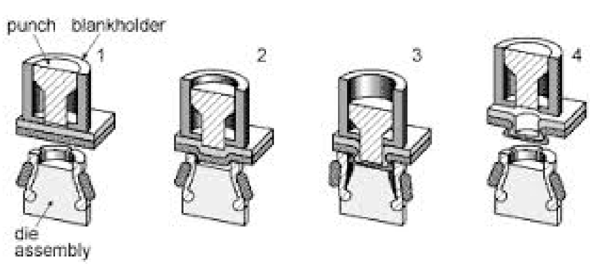

Figure-1. Process of clinching.

DESCRIPTION OF TECHNOLOGY

Choice of suitable tools for connecting of profiles used in civil engineering was a first step. Two profiles 2.67mm thick from steel with grade S390GD were chose as representative profiles [6]. These two profiles are connected by tools from Bollhöef Company. The tool is composed from two primary parts - punch and die. Punch is a simpler part of the tool which presses the material. Die is a more complicated part of the tool. Different modifications and types of die exist. The die, on which 3 moving parts in form an annulus are placed, is used in the experiment. Flexible spring ensures coherence of those parts and also returns the tool to its former position after the end of process.

Figure-2. Die, tools and numerical model in LS-DYNA.

METHODOLOGY

The process can be divided into several parts. Geometry was processed within preprocessing in ANSYS 16.0 [7, 8] which includes supporting functions for explicit analysis by LS-DYNA. Complete geometry of tools and connected profiles was processed in program ANSYS 16.0. K-file was an output from ANSYS program, which included geometry of all entities and basic settings [9], [10].

Next work took place in LS-PrePost-4.2 system. In this phase of preprocessing these important parts are defined, for example boundary conditions, contacts, displacement of punch, material model and material characteristics of profiles.

Description of numerical model

Numerical model consists of 9 parts. The die is composed from a counterpart and 3 separate parts,

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which create space for clinch connection. A ring is locked in a body of the tool, which encircles 3 parts. Counterpart for the die is the punch. Last part for creation of the connection is holding surface - blank holder. Next 2 parts are idealization of two profiles for connection.

All parts of the tool are modelled as rigid and therefore are all of them non-deformable. On the other hand, profiles used for connection are modelled using deformable volume elements. A great attention to adjusting to mesh is respected in a place of a contact of profiles with the tool. A size of an edge of one element of connecting profiles is 0.30 mm. A same size is taken for the contact surfaces.

Boundary condition

Boundary conditions can be divided into two parts. Into a movement of a punch and corresponding parts and external forces, which replace springs for connection of three segments?

The movement of the punch is set up as a movement of solid bodies and nodes. The movement itself can be defined by two approaches [11]. The first approach is to define a size of a force during process and to watch a response - force of the tested samples and tools. This approach is suitable if we know an exact size of a force from a specific process of creation of clinch connection. In the second approach, which showed as more suitable, is displacement of the punch given as a distance in a specific time. It is possible to read a size of a force during loading in the second approach. Disadvantage of this second approach is that the press for connection of the clinch connection always has a specific limit of a force which it can make. Therefore, it is needed to prove that this force was not exceeded during this process. During the movement of the punch it is needed to hold the sheet, which is on side of the first contact of the punch with the material. The holding is needed to prevent undesirable deformation in the first phase and lifting of the material in close proximity to the connection [12], [13]. Boundary condition for the blank holder is given as a constant force 30.00 kN, which holds the first material during whole time of the process.

Next boundary condition which was taken into account in this numerical model is idealization of a spring, which has an objective to simplify the numerical model. The force in the spring, which resists the opening of segment, is fixed to value of 1.00 kN. This force is distributed on individual segments and is given during whole process.

Contacts

Contacts are taken into account among all parts of the numerical model. Due to big deformations of connected profiles, mainly lower profile, defects of the structure of profile occur in the place of pressing the punch through lower profile. Contacts were chosen with so-called eroding elements. These contacts are usable only in combination with volume elements. In case of defect of the element in the contact place, new contact segments are generated. The defect occurs after exceeding the limit stress.

Material model

Two material models are used in the numerical model. Material model is defined as RIGID for parts which do not have deformability dealt with. This addresses all parts but profiles for connection which are handled. RIGID material is very useful from perspective of time saving. Johnson Cook model is used for profiles for connection. This model was developed in the 80´s for impact and is very often used for solving problems with high velocity, deformations and strains. Formulation of hardening of material model according to Johnson Cook:

$$\sigma_y = \left(A + B\bar{\varepsilon}^{p^n}\right)\left(1 + c\ln\varepsilon^{\bullet *}\right) \quad (1)$$

Where A, B and c are input constant, ε^{-p} is effective plastic strain and $\varepsilon^{\bullet *}$ is a normalized effective total strain rate.

Equation of state has to be defined while using solid element in combination with Johnson Cook model. An equation of state in form of linear polynomial was used in the numerical model. This in basic (general) is defined as (2).

$$P = C_0 + C_1\mu + C_2\mu^2 + C_3\mu^3 + (C_4 + C_5\mu + C_6\mu^2)E \quad (2)$$

Where μ [-] is the ratio of current density to reference density and E [MPa] is Young modulus.

Equation (2) is often solved only with definition of parameter C_1 for solid parts. Parameter C_1 in this case elastic bulk modulus for steel and his value is $1.750.10^5$ MPa. It can be defined according to equation (3)

$$K = \frac{E}{3(1 - 2\nu)} \quad (3)$$

Setup for numerical model and analysis of results

Numerical model consists of 9 parts and complete numbers of elements is approximately 120000. All parts of the model are modelled as a solid. Velocity of loading is set to 100 mm/s. Distance of loading is set to loading part and part where punch travels are set to 6.00 mm. Part where punch travels back is also part of the process to release the material and so it may result in potential relaxation. Maximal force during process of creation of the clinch connection was up to 70.00 kN. The so-called hourglass was prevented with use of Belytschko - Bindeman condition in model, which is useful for solid elements [14]. Young modulus E=210.10^3 MPa and Poisson ν=0.3 was taken into account for materials.

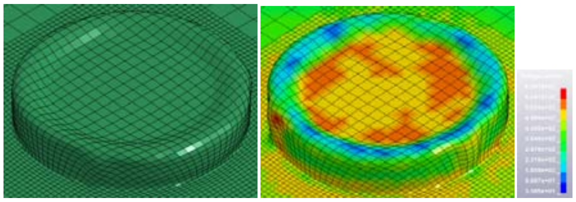

Figure-3. Shape of cut of connection, strain [-].

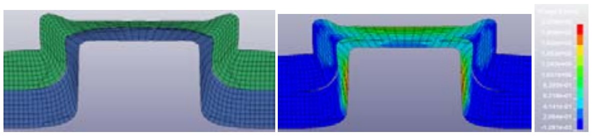

Figure-4. Upper sheet after completion of connections, stress von Mises [MPa].

Results of numerical analysis of clinching process can be seen in Figures 3 and 5, where illustration of a cross section and separated parts of chosen connection are shown. A cross section of center of clinch connection can be seen in the Figure-3, on the left final geometry of the connection can be seen and on the right the strain. In the Figure-4, a shape of an upper part of the connection, which was created on a side, where a die part of the tool was can be seen and von Mises stress after removal of the tool and partial relaxation can be seen on the right side of the picture. The same situation for the lower part of connection, where punching of material to upper part with use of the punch, is shown. In the Figure-5 on the left, geometry can be seen and on the right von Mises stress after removal of tool is shown.

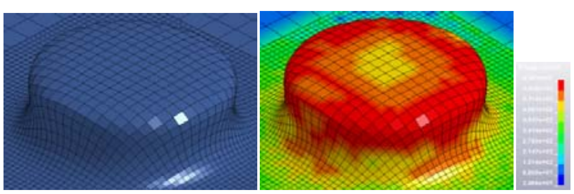

Figure-5. Lower sheet after completion of connections, stress von Mises [MPa].

CONCLUSIONS AND DISCUSSIONS

This paper describes general overview of one of possible clinch modelling process with the use of explicit solver LS-DYNA. Clinching method could be used for some specific connections in civil engineering, especially made from thin walled profiles. In this paper a general procedure of modelling and software tools used for a creation of numerical model were used. A general principle to assign boundary conditions, possibility of loading and suitable material model was shown. Johnson Cook material model in combination with equation of state in form of linear polynomial occurred as the most suitable.

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