CLINCHING OF HIGH STRENGTH SHEET STEELS

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Summary

Clinching nowadays is more and more widely applied forming process, which belongs to the pressing binding group in sheet metal forming. The substance of the process is that the binding occurs by pressing two or more sheets into each other with a special punch and die pair using any conventional or special pressing machine.

Keywords: sheet metal forming, clinching, high strength steels

1. Introduction

There is a big variety of sheet materials applied in the vehicle industry: manufacturers can choose the most suitable ones for the given application according to their needs. It is also often happens that two or more sheets are applied with different material quality or thickness even within a single part. However, in many cases, these different sheets have to be bonded with various methods to provide a suitable final product.

There is also a wide selection of possible joining processes: many different processes can be applied for joining sheet materials. One of the main groups is welding having a great amount of process variants including for example butt welding, resistance spot welding, laser welding, etc. There are also several further processes to join sheets as soldering, adhesive bonding and even different kinds of mechanical joining, or in many cases their combinations as well (e.g. adhesive bonding of spot welded sheets). The selection of the appropriate joining process is strongly affected by several factors, e.g. which process is the most suitable for preparing the proper joint between the sheets; what is the manufacturing cost – this question is particularly important if purchasing of new equipment required; what are the material and labour costs; and nowadays one of the most important issue is how far the automation can be applied to reduce the manufacturing time, the human resources, and how these parameters effect the overall economy of production. These points altogether determine the selection of the most appropriate process [1], [2], [3].

2. Clinching

Clinching is a mechanical joining method, which is nowadays more and more often applied in the vehicle industry for joining coated or uncoated thin sheets of different materials, and even with different thicknesses. This is a cold forming process that allows sheet metal and other materials to be bonded together without any bolts, rivets, or adhesives.
2.1. Main types of clinching

Round joint by clinching may be regarded as one of the basic types of clinching processes. In this process, two or more (usually up to three) sheets are placed overlapped each to others and the sheets are joined by stamping with a punch into a die cavity forming a permanent joint. The patented TOX®-Round Joint can be seen in Fig. 1. As it can be seen in this Figure, a simple round punch presses the materials into the die cavity. As the force increases, the punch side material is forced to spread outwards within the die side material. The process sequence and the material flow can be seen in Fig. 2. The result is an aesthetically good looking round button at the end of this clinching process: the sheets are mechanically joined, clearly without any burrs or sharp edges.

Due to its versatility and its manifold advantages (summarised later) there are many different types of joints made by clinching. The TOX®-Twin Point process (Fig. 3) provides two similar buttons with almost double strength of a single point. A special advantage of this process is that it prevents the rotation of two layers against each other.

It may happen that the button normally formed by a Round Joint clinching is not desirable: in this case the flat joint clinching may be applied (as shown in Fig.4.).
2.2. Characteristics of the clinch joints

The process has several versions, but among them the round clinching done in one step process is the most often used. In Fig.5, the main elements of a round clinching process is shown.

![Fig.5. Main elements in a clinching process](image)

2.2.1. The advantages of the clinching process

The process itself belongs to the innovative pressing-joining group. Clinching is used primarily in the automotive, as well as in the household and electronic industries for replacing resistance spot welding. One of the most prominent advantages of clinching is its capability to join coated and/or painted sheets that are widely used both in the automotive and in the household appliances industry. A further big advantage of clinching can be experienced in the automotive industry when aluminium panels are applied since the great difficulties of spot welding of aluminium. Among the advantages of clinching comparing to the resistance spot welding it also should be noted that it is more economical (up to 60% cost saving) and more environmental friendly, i.e. clinching is rather a so-called clean technology. Summarising the most important advantages of clinching the following main items should be listed:

- 30 – 60% cost saving comparing to point welding,
- the resistance ability of clinched joints against dynamic loading is larger than that of the resistance spot welding,
- the necessary preparation for clinching can be well automated,
- simple, non-destructive quality inspection is possible by using a simple measuring instrument to measure the remaining thickness at the bottom of the joint,
- during clinching there is no any heat generation thus no metallurgical changes occur,
- there are no damages at different surface protecting layers (e.g. galvanised, pre-painted, etc.) since the layer flows with the base material together,
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- parts joined by clinching have good electrical conductivity,
- since there is no high temperature effect, clinching can be applied together with adhesive bonding,
- sheet thickness can vary in large interval (usual range between 0.3 mm and 6 mm),
- intermediate layers (e.g. paper or glue) can also be used,
- the process can be excellently monitored,
- joints made by clinching may have long life duration,
- since there is no contamination during the process, it does not require supplementary work,
- the process itself is extraordinarily environment friendly,
- significantly cheaper than laser welding [6].

2.2.2. The disadvantages of the process

Besides the many advantages, obviously there are some disadvantages, too. As one of the few disadvantages, we have to mention that the mechanical properties of joints made by clinching usually are weaker than that of made by resistance spot welding, however, in many cases it is even not always necessary. We could also mention that the mechanical properties made by the new TOX technology already reach about 70% of the values of resistance spot welding. Furthermore, it is also worth mentioning that in spite of weaker mechanical properties, clinching is more and more often applied instead of the resistance spot welding, since the clinching process often better fits in the manufacturing processes.

2.3. Quality factors of clinching

In a general round joint clinching process, the strength of the joints is determined by the neck thickness and the under cutting: both parameters are affected by the tool formation, as the diameter of the punch and the die, as well as the die deepness. The main geometric parameters of a round joint clinching tool are shown in Fig. 6. [5].

![Fig. 6. Main technological and geometric parameters affecting the quality of clinching](image)

- $\phi d_0$: outside diameter
- $\phi d_i$: inside diameter
- $t_1$: top plate thickness
- $t_2$: lower plate thickness
- $t_t$: total thickness
- $t_b$: bottom thickness
- $t_n$: neck thickness
- $h$: point height
- $f$: under cutting
3. Investigation of clinched joints

To provide good quality clinched joints it is strongly advisable to perform experimental investigations to define the appropriate process parameters and to choose the proper tool set for a given application. It is also desirable to perform mechanical tests applying static and dynamic loads. The usually applied tests are the same as they are in case of spot welded joints, where the shearing and the pulling breakup tests are widely used (Fig. 7.). During these tests, the neck width is also measured to investigate the effect of the geometric parameters on the strength of the joints [4].

Fig. 7. Illustration of shearing-, neck- and head pulling tests with the main types of failures

3.1. Experimental investigations

A Tox tool pair was purchased for testing clinched joints. The tool was designed for producing round joints. DP 600 material quality of 1 mm thickness was used as test material. According to the tool manufacturer, the best properties of the joints can be reached for this material quality with 0.5 mm bottom thickness.

The tests were performed in the Material Testing Laboratory of the Institute of Materials Science and Technology. The testing machine was a MTS typed, electro-hydraulic, computer controlled, universal material testing equipment. The nominal force of this material testing system: $F_{\text{max}} = 250$ kN.

The testing equipment with the clinching tool mounted on the testing machine is shown in Fig. 8.
In Fig. 9., a closer view of the experimental clinching tool can be seen.

In order to analyse the forming process, first some preliminary clinching tests were performed with different punch displacements to produce different bottom thicknesses. After clinching, the parts are cut in the middle into two parts to create meridian sections as shown in Fig. 10.

On these cut sections, it is possible to measure the most important parameters of the joints as the bottom thickness, the under cutting, and the neck thickness. From these cut sections microscopic polished samples were also prepared to analyse the material flow and the soundness of the joints.

**Fig. 9. The experimental clinching tool**

![Fig. 9. The experimental clinching tool](image)

**Fig. 10. Sections of round joints made with different bottom thicknesses**

<table>
<thead>
<tr>
<th>t_bottom</th>
<th>t_bottom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.49 mm</td>
<td>1.05 mm</td>
</tr>
<tr>
<td>0.65 mm</td>
<td>0.55 mm</td>
</tr>
<tr>
<td>0.51 mm</td>
<td>0.46 mm</td>
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</table>
On the microscopic samples micro-hardness measurements (HVM 0.5) were also done. The micro-hardness values were measured in the neutral fibres of the sheets. Measurements started at the centre point of the joints, and the distance between the hardness measurement points was selected to 0.5 mm.

The measured micro-hardness values of the specimen with 0.5 mm bottom thickness are shown Fig. 11.

Then we investigated the effect of the bottom thickness (proposed by the tool manufacturer) on the bond strength properties.

Three different investigations (i.e. shearing-tensile tests, head pulling tests and neck pulling tests) were performed: the experimental specimen and the bonding process were designed accordingly.

The specimens for the experimental investigations were cut from sheet tables of 1000 x 2000 x 1 mm original dimensions. The cutting was done by laser cutting at the Industar Kft. in Felsőzsolca. The geometry of the cut specimen with the appropriate sizes is shown in Fig.12.
A special holder unit was prepared at the Department of Mechanical Technology for the experimental investigations. The holding device was suitable for performing the tensile and head pulling, as well as the neck pulling just by changing the various pins, to prepare the various joints. This unit is shown in the Fig. 9.

The experimental specimens for the different tests are shown in the Fig. 13.

![Experimental sheet samples for tensile, head pulling and neck pulling tests](image)

**Fig. 13. Experimental sheet samples for tensile, head pulling and neck pulling tests**

The results of the various pulling tests are summarised in Table 1.

**Table 1. The results of the pulling tests**

<table>
<thead>
<tr>
<th></th>
<th>t&lt;sub&gt;bottom&lt;/sub&gt; = 0.55 mm</th>
<th>t&lt;sub&gt;bottom&lt;/sub&gt; = 0.50 mm</th>
<th>t&lt;sub&gt;bottom&lt;/sub&gt; = 0.45 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>F [kN]</td>
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<tr>
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<tr>
<td>0,7</td>
<td>0,7</td>
<td>0,7</td>
<td>0,8</td>
</tr>
</tbody>
</table>

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On the basis of the experimental results, it can be stated that the best joints can be get at 0.45 mm bottom thickness, but the improvement of strength properties is not very significant, and taking into consideration the necessary forming force at creating the joints, as well as the deformation rate it can be also stated that the proposed 0.5 mm bottom thickness might be sufficient.

We plan to extend these investigations to create clinched joint applying different material qualities as shown in Table 2.

**Table 2. Different material combination for further experimental investigations**

<table>
<thead>
<tr>
<th>Punch side</th>
<th>Sheet thickness</th>
<th>Die side</th>
<th>Sheet thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP 600</td>
<td>1 mm</td>
<td>DP 600</td>
<td>1 mm</td>
</tr>
<tr>
<td>DP 600</td>
<td>1 mm</td>
<td>DP 800</td>
<td>1 mm</td>
</tr>
<tr>
<td>DP 800</td>
<td>1 mm</td>
<td>DP 600</td>
<td>1 mm</td>
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<td>1 mm</td>
<td>DP 1000</td>
<td>1 mm</td>
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<tr>
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<td>1 mm</td>
<td>DP 600</td>
<td>1 mm</td>
</tr>
<tr>
<td>DP 600</td>
<td>1 mm</td>
<td>DC 04</td>
<td>1 mm</td>
</tr>
<tr>
<td>DC 04</td>
<td>1 mm</td>
<td>DP 600</td>
<td>1 mm</td>
</tr>
</tbody>
</table>

**4. Summary**

In this paper, we shortly introduced the clinching as a new emerging joining process among the mechanical joining methods. Clinching becomes more and more widely applied mechanical joining of various parts in the industry, and particularly in the automotive sector, however, there are still many questions to be answered in serial production of a newly designed structure. Therefore, in this paper introduced some basic processes of clinching emphasizing their advantages and simultaneously describing some disadvantages, as well. Some preliminary results of experimental investigations were also shown.

The aim of both design and process engineers is to create the most suitable joints between materials: for this purpose among the mechanical joining methods clinching may be regarded as a promising solution, however it should be taken into consideration that the appropriate process parameters still are often unknown, and therefore, it is of utmost importance to perform a lot experimental investigations and to input a large amount of experimental effort. Obviously, it leads to increasing the costs but this will be repaid by getting more reliable joints with better properties.

Strength properties of clinched joints can be mainly assessed by applying destructive (mechanical) material tests, which are also inevitable at the beginning of the introduction of new processes into serial production. However, getting more theoretical and experimental
knowledge on this new joining process, we can also perform reliable simulations applying mainly finite element methods to reduce and hopefully mainly eliminate the time- and cost consuming experimental methods in the near future.

Application of Finite Element Simulations has great advantage not only by reducing experimental cost but also to reduce the lead time of new processes into everyday industrial practice and this is obviously valid for the new clinching processes, too [8].

5. Acknowledgement

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6. References