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Coco

Synthesis Report
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2. Abstract

The main goal of the project consists in increasing the performance of fine blanking tools by developing new hard coatings and adapting these to the tribological conditions of the fine blanking process as a central operation for stamping and cold forming processes.

Therefore a consortium consisting of a coating company (Hauzer, Venlo, NL), users of the fine blanking and cold forming technology (Algat, Torino, I and Fichtel & Sachs, Schweinfurt, D), a consultant for the fine blanking technology as well as for the tool heat treatment (Feintool, Lyss, CH) and a research institute (WZL, Aachen, D) was founded.

At the beginning of the project there was only information available based on trial and error. No systematic approach of knowledge about the interaction of the components of the tribological system "fine blanking" was done.

The economic viability of fine blanking depends essentially on the tool costs per workpiece. Furthermore the economically efficient production of the fine blanking parts with complex geometries and shapes has been made possible with coated tools which presents enhanced resistance mainly to abrasive or to frictional wear.

A modified Physical Vapor Deposition (PVD) coating technology had to be developed producing a good interface between the substrate material and the coating itself to ensure high coating-substrate adhesion.

The PVD coating technologies "unbalanced magnetron sputtering" and "arc ion-plating" were combined. This new technology is the so called "Arc Bond Sputtering (ABS) technology". The ABS coating technology is continuously in development.

The ABS coating technology can fulfil requirements from the market and is at this moment on an industrial production standard.

Industrial fine blanking tools have been coated according to the knowledge gained during this BRITE-EURAM project. The coated tools survived a considerable life-time improvement.

The adaption of the results for other cold” forming processes was investigated within the last project phase.

The close cooperation of coating company, tool *user* and research institute made it possible to further develop the PVD-process and coating systems significantly as well as understand the technical requirements of tool producer, coating company and tool user.

3. Introduction

PVD hard coatings extend the tool life by some 100 percent, enable lower production costs and down time, increase the reliability of production processes and enhance the quality of the components produced. Coating pays off especially on sophisticated and expensive tools as used in fine blanking and metal forming.

The economic viability of fine blanking depends essentially on the tool costs per workpiece. The service life of the tools can be extended by a coating of hard material (TiN) on average by a factor of 2 to 3. Furthermore the economically efficient production of parts with complex geometries and shapes has only been made possible at all with coated tools, since the generally good frictional properties of the layers of hard quality-criteria (smooth surfaces, sharp edges, no burr) are rectified on a trial and error base rather than a systematic approach. This is due to the lack of knowledge about the interaction of the components of the tribological system ‘fine blanking’.

Therefore a well balanced consortium was established to research into this complicated tribological system. The tribological system of fine blanking has to be seen in this context as a central operation for stamping and cold forming processes.

4. Technical description

The main goal of the project consists in increasing the performance of fine blanking tools by developing new hard coatings and adapting these to the tribological conditions of the fine blanking process as a central operation for stamping and cold forming processes.

All coatings are carried out by Hauzer Techno Coating Europe B.V. using the HTC ABS equipment. During the project phase various tools and samples from the partners have been coated.

In the beginning of the project phase five existing coatings were tested. This means that tools with different geometries were tested in production as well as laboratory tests. Various sheet materials were used in order to cause a mainly adhesive or a mainly frictional wear on the tool elements. The wear progress on the tools was determined on the one hand by indirect methods such as surface roughness and burr formation of the blanked parts as well as direct by measuring the roughness and the edge profile of the tools and taking SEM images.

With these tests it was found, that TiAlN coatings performed best concerning workpiece quality and tool life. Therefore it was decided to improve this film by adding Niobium,

Algat and the WZL were working very close together and exchanged tool sets. The production tests were carried out by Algat and the examination of the tools and workplaces as well as force measurement during the fine blanking process were done by the WZL.

TiAlNbN coating was used by Algat and the WZL on differently preprocessed tools and with various layer thicknesses. The 'test results gained with these tools were extremely good and especially compared to TiN coating much better.

Fichtel & Sachs tested their tools with two different sheet materials and tool geometries. They received similar results as Algat.

Since in the beginning of the project phase the geometry of the coated tools was more simple, the influence of a complex tool geometry was evaluated during the last project phase. These tools were tested with different sheet materials and two preprocessing variants were evaluated.

The adaption of the results for other cold forming processes was investigated within the last project phase too. Here a combined loading of the tools resulting from forming and blanking operation was investigated.

With coated tools the tool life can be significantly increased. Because of this the tools might wear due to low cycle fatigue. This was seen by the evaluation of punches which showed chipping at the front face. Therefore a fatigue test for fine blanking tools was designed and the influence of various preprocessing methods and hard coatings was evaluated. The specimens were loaded with both compressive and tensile stress. This can be explained by the fine blanking process. Due to the blanking operation the punches are loaded with high compressive stress. During the retraction phase the punches are clamped into the strip material causing a frictional force and resulting in a tensile stress of approximately 10 % of the blanking force.

The close cooperation of coating company, tool user and research institue made it possible to further develop the l?VD-process and coating systems significantly as well as understand the technical requirements of tool producer, coating company and tool user.

5. Results

In the beginning of the project five state of the art coatings, TiN, TiCN, TiAlN, TiNbN and CrAlN, were deposited on various tool sets. The results gained with the round “rosetta” will be described.

Experimental set up

At Algat they blanked five parts per stroke using five geometric identical tool sets whereas at the WZL only a single tool set is mounted in the press. Each tool set consists of a main and inner punch as well as die (Figure 1). The design of the tools is similar so that an exchange of the punches and dies is possible.
In order to reduce the influence of the tool material a powder metallurgical high speed steel is used for both punches and the die. In general PM-steels have an even microstructure. This leads on the one hand to rare micro and macro cracks at the cutting edge and a better basis for the hard coating. For the tests the complete tool set is coated with the same hard coating.

The parts blanked are washers of material grade 41 Cr 4 (1.7035) and C 16 B (1.5523) with a thickness of 7,5 mm. The two different materials are used in order to cause a mainly abrasive wear on the tools when blanking 41 Cr 4 and a mainly frictional wear with C 16 B respectively.

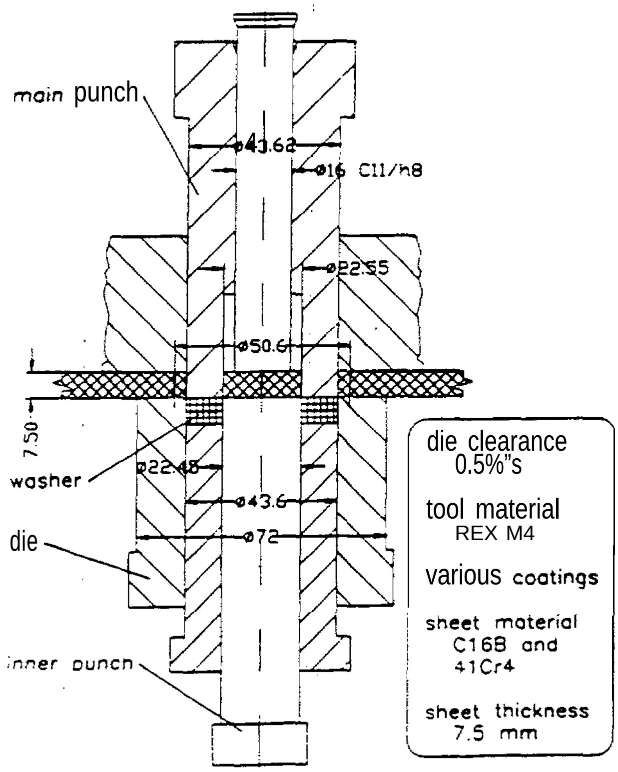


Figure 1: Tool set for fine blanking tests

The fine blanking tests are carried out at the WZL on a 400 t hydraulic fine blanking press in the beginning, approximately in the middle and at the end of the tool life. At these points blanking forces are measured and load-stroke curves are plotted. Furthermore SEM images are taken for the documentation of the outer appearance and the wear development of the tools. Sample parts are taken at the WZL as well as at the industrial partner every 1.000 strokes.

Machining of fine blanking tools

Fine blanking tools can be generally spoken manufactured in two ways:

the material can be heat treated and later the tools are cut out of the hard material using wire-EDM, or
the soft material can be machined; then heat treated and finally ground.

Therefore both ways are considered and five different preprocessing variants were examined:

EDM with a main and three finishing cuts ("superfinish"),
EDM with a main, three finishing and a subsequent sand blasting,

EDM with a main, a final cut and a subsequent polishing,
profile grinding and
coordinate grinding.

The imer surface of the dies are machined according to the above mentioned preprocessing methods and later coated with TiN or TiAlNbN.

Since the surface roughness of the tools strongly influences the workpiece roughness, the roughness was measured in two dircetions: perpendicular and parallel to the later blanking direction (Figure 2).

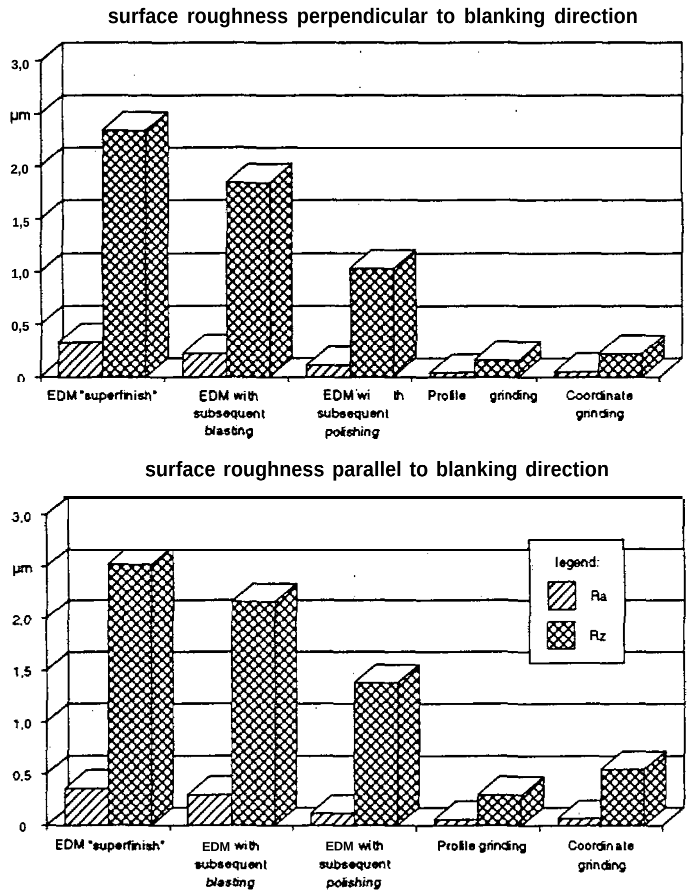


Figure 2: Surface roughness of uncoated dies perpendicular and parallel to the later blanking direction

Fine blanking tests

In the beginning these state of the art and newly developed coatings are compared by blanking the above mentioned washer of the two different material grades 41 Cr 4 ($R_m \approx 570$ N/mm2) and C 16 B ($R_m = 420$ N/mm^2).

The examination of the surface roughness of the workplaces (material grade 41 Cr 4) shows on the one hand that parts blanked with TiCN coated tools only have an increase of the R_a values from 0,48 µm to 0,6 pm and on the other hand that the TiN and TiAlN coated tools result in roughness values of R_a = 0,9 µm and R_a = 0,85pm for the latter after 10.000 strokes (Figure 3). The good performance of the TiCN is to be put to the fact that it reaches the highest microhardness values combined with a low surface roughness of the hard coating. The tests were stopped after 10.000 strokes although the workpiece quality was still sufficient.

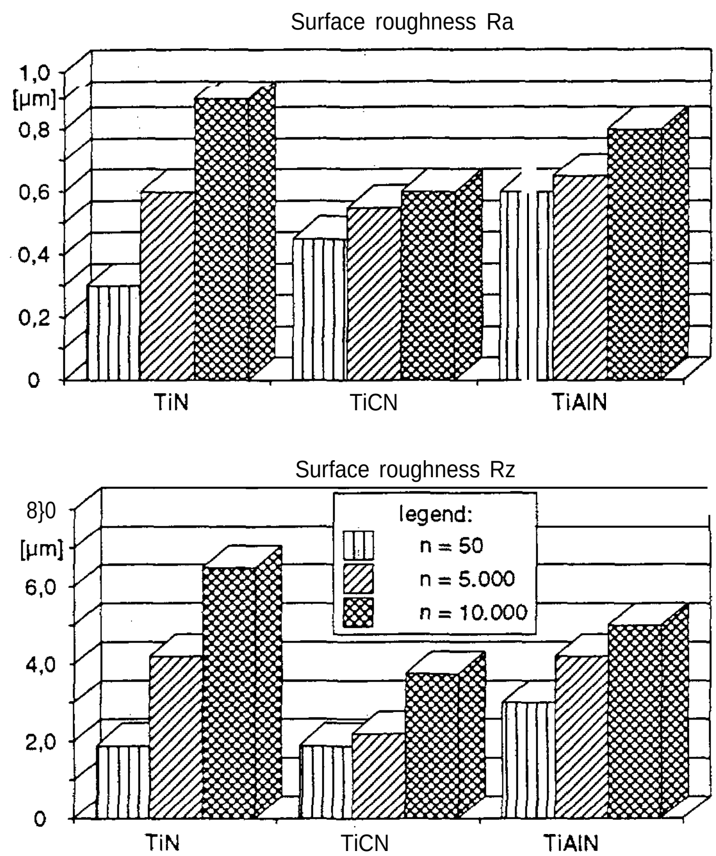
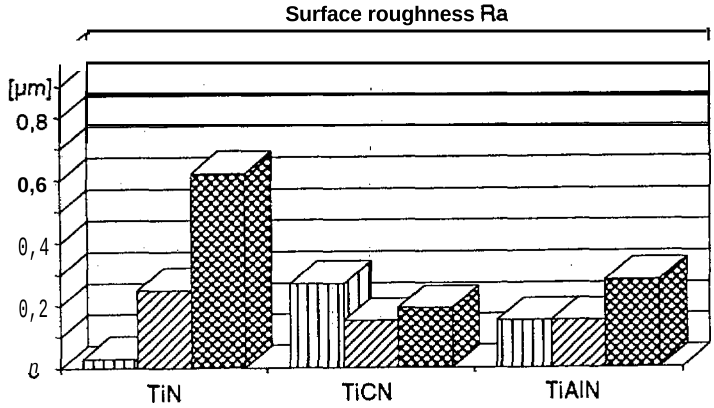


Figure 3: Roughness of workplaces at outer circumference; material grade 41 Cr 4 (1.7035)

The same test was carried out with blanking sheet material with material grade C 16 B. Again the TiCN coating performes good, but the results gained with TiAIN are very close (Figure 4). Especially in the beginning of the test series the TiN and the TiAIN coatings performed better. This fact can be explained by the initially lower roughness of the TiN coating.



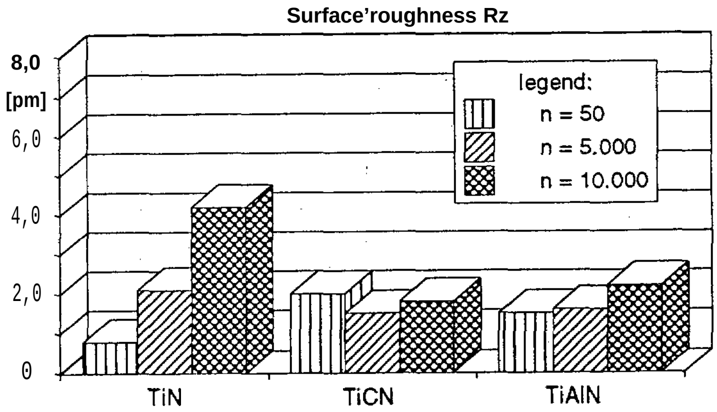


Figure 4: Roughness of workplaces at outer circumference; material grade C 16 B (1.5523)

6. Conclusions

Within this investigation various hard coatings and five different preprocessing methods for the machining of fine blanking tools were examined. The judgement of the performance of the various hard coatings and the premachining methods was based on the examination of the surface roughness of the blanked parts as well as SEM images and cross-section of the tools.

In the beginning of the project phase five existing hard materials (TiN, TiCN, TiAlN, TiNbN and CrAlN) were deposited on fine blanking tools by Hauzer. All films were deposited by the ABS method (Arc Bond Sputtering). This means that an arc process is involved in etching respectively pretreating the substrates (tools) prior to coating. As the arc process does not contribute to the actual growth of the various films, one can observe an enormous influence on the appearance and morphology of the coated surface. The film surfaces seem to be smoother and less droplets arise.

It was seen that the hard coatings TiCN and TiAlN are suitable for blanking sheet materials causing a mainly abrasive wear on the tools, whereas TiAIN performed best in blanking a sheet material causing a mainly frictional wear on the tools.

The two final users of fine blanking tools, Algat and Fichtel & Sachs were testing these tools in the production of various workplaces and therefore sheet materials. The different sheet materials were selected in order to cause a mainly abrasive and in the other case a mainly frictional wear on the tools.

The production tests have shown that in case of a more abrasive wear the TiN, TiAIN and the TiCN films performed best. This was evaluated by the roughness of the sheared surface as well as the burr height and width of the workplaces produced. Furthermore the condition of the tools was examined in the beginning of the production cycle, at approximately 50 % of the foreseen tool life and at the end of tool life.

In the second case, when blanking material causing a mainly frictional wear on the tools, the TiCN and the TiAlN films showed the best results.

The further investigations concerning the hard coatings were focused on the improvement of TiAlN films with the addition of Niobium. It was shown that the TiAlNbN coated tools performed the best. They resulted in a very low surface roughness of the fine blanked parts.

Another point of the research work carried out is the influence of the machining operation prior to coating. In general for the machining of fine blanking tools grinding and wire-EDM is used.

The tests of the differently machined tools showed that ground tools performed in general better than EDM'ed ones.

The well balanced consortium, which consisted of a coating company, two final users of the fine blanking technology, a company specialized in this technology and a research institute made it possible to investigate the specific demands of the cold forming processes on the PVD-hard coatings very systematical. With the improvement of the complete manufacturing sequence of the fine blanking tools a significant increase in quality of the parts and tool life was obtained.

7. Acknowledgements

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