Superhard carbon coatings with the potential for dry aluminum sheet forming

Task

The forming of aluminum sheets into readily usable parts demands high quality surfaces on the employed tooling. These tools are typically complex in shape and very expensive. Refining these surfaces with special coatings aims at improving the wear resistance of the tool, at reducing the sticking of material on the tool surface and at reducing the friction between tool surface and sheet. Despite all these efforts it is typically still necessary to use a lubricant during the process, which requires a subsequent expensive cleaning step to remove the lubrication residue from the parts.

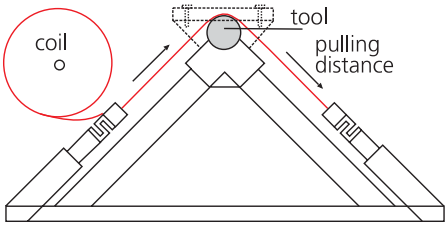

Fig. 1: Schematic representation of the strip drawing test (sheet marked in red)

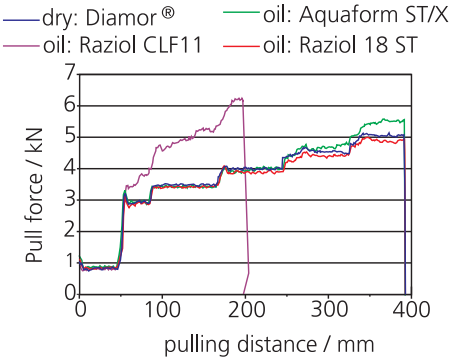

Fig. 2: Force progressions during the strip drawing test with AlMg5Mn sheets. Compared are uncoated tools with oils and a dry running Diamor® coated tool

Diamor® dry | Oil: Raziol CLF 11 | Oil: Aquaform ST / X | Oil: Raziol 18 ST

Fig. 3: Tools after drawing tests with AlMg5Mn strips (compare Fig. 2)

Solution

A solution to this problem is to apply diamond-like carbon (DLC) coatings to the tool surface. The covalent bonding between the carbon atoms in such coatings shows little tendency to adhere to metals and causes low friction between the coated tool surface and the metal sheet. Under dry contact conditions the coefficient of friction is only about 0.1.

Of particular importance for this application are ta-C coatings. They offer a hardness of about 5000 HV and thus a markedly increased wear resistance if compared to classic DLC coatings (ta-C = tetrahedrally bonded amorphous carbon). At the Fraunhofer IWS we produce these coatings under industrial conditions. They are marketed as Diamor® coatings and have proven their performance in numerous wear applications.

Recent investigations into the processing of aluminum showed that these coatings are not only beneficial from the standpoint of wear; they also demonstrated advantages over classic DLC coatings in terms of reducing the material's sticking and cold welding tendency.

These investigations were performed at the institute for manufacturing technology at the TU Dresden in form of metal strip drawing tests (Fig. 1). The materials used were the aluminum alloy AlMg5Mn as well as the particularly stick-prone alloy Al99.5. Compared were uncoated tools in combination with three typical lubricants and Diamor® coated tools without lubricant.

Results

The graph in Fig. 2 shows the pull force as a function of the pulled distance. Diamor® coated forming tools perform dry as well as uncoated tools in combination with high value drawing oils. Comparing the contact areas on the tools in Fig. 3 clearly shows cold welds on the surfaces of the uncoated material even tough they were wetted by drawing oil.

The dry running Diamor® coating does not show any cold welds. These investigations demonstrate that Diamor® coating provides the tool surface conditions for lubricant free aluminum sheet forming. These results were confirmed in industry based on coated rolls for the manufacturing of aluminum cables.

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