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# Influence of Punch Coatings and Punch-Die Clearance on Blanking Force

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**-------------------------------------------------------*ABSTRACT*-------------------------------------------------------**
*Blanking electrical steel is a key manufacturing operation. The magnitude and evolution of the blanking force directly affect process stability, tool wear, and energy demand, and indirectly affect the integrity of the sheared edge. Punch–die clearance, tool–workpiece interfacial friction, and the geometry and condition of the cutting edge strongly shape local plastic deformation and the fracture mechanism, and thus the form and peak of the force–stroke response. The aim of the experiment was to quantify the effects of punch–die clearance and punch coatings on the blanking force. Three coatings applied to the punches were evaluated—C1: AlCrN, C2:$MoS_2$+AlCrN, and C3: $MoS_2$—at relative clearances of 1% and 7% of the sheet thickness. The highest forces were measured with uncoated punches. Among the coatings, C1 (AlCrN) produced the highest forces, C2 showed intermediate behavior, and C3 ($MoS_2$) yielded the lowest forces. At both clearances, coatings reduced the blanking force, implying potential gains in tool life, lower elastic deflection, and reduced energy demand.*
***KEYWORDS;-****Blanking,shearing, coating, blanking force, punch-die clearance*
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## I. INTRODUCTION

In recent years, sheet metal has been extensively used in industries such as electronics, automotive, and aerospace. Shearing, typically in the form of blanking and piercing, is commonly employed as the primary operation to shape flat-rolled sheet to a near-net shape. Secondary operations are then applied to achieve the final product geometry. In most cases, high dimensional accuracy and the shortest possible process chain are required, which favorably affect manufacturing costs and functionality. During shearing, burrs are generated on the sheared edges. Manufacturers therefore aim to produce semi-finished parts with minimal burr formation [1,2].

Shearing (blanking/piercing) is among the most economical sheet-metal separation processes, combining high production rates with low unit cost. The quality of the sheared edge depends on the workpiece material and thickness, punch–die clearance, cutting-edge radius, tool wear, and the selected shearing strategy [3].

The manufacturing industry continually seeks to reduce blanking costs and improve the quality of blanks. The development of materials for cutting and blanking tools has been driven by the growing need to increase productivity, process more complex materials, and achieve high quality at large production volumes [4]. Since the first tool material suitable for metal shearing was developed about a century ago, numerous shearing tools have been continuously developed [5].

The quality of the shearing (blanking) process is assessed by the quality of the blanks (edge integrity, burr height, burnish–fracture ratio) and by the tool life of the functional parts of the shearing tool. Shearing tools are typically produced from high-performance tool steels or cemented carbides. Tool performance can be enhanced by applying coatings to the working surfaces (punch, die land, cutting edges). Manufacturing productivity can be increased by accelerating the development of improved shearing tools that deliver superior tribological behavior and wear resistance [6].

Shearing (blanking) modifies the surface and subsurface of the workpiece in the shear affected zone near the cut edge. These modifications influence both geometric characteristics and the material state. Typical effects include microstructural changes, residual stress, strain hardening with corresponding increases in microhardness, the formation of cracks and microcracks, and changes in corrosion behavior. Taken together, these modifications constitute surface integrity. Surface integrity is a key quality attribute that is particularly critical for stator and rotor laminations in electric machines because the functional and reliability requirements are very stringent [7,8].

At the beginning of the 20th century, electrical (silicon) steel was developed and soon became the preferred core material for large transformers, generators, and motors. Today, soft magnetic materials are ubiquitous in electrical and electronic equipment. Silicon steels, used as soft magnetic materials in electrical devices, are evaluated primarily by their magnetic core losses under AC magnetization (alternating magnetic field) [9]. Their key properties include low specific core loss under AC magnetization, high permeability and high saturation flux density, and low magnetostriction [10].

Low specific core losses (hysteresis and eddy-current) reduce heat generation and improve efficiency; high permeability and high saturation flux density enable smaller core cross-sections and thus lower part mass and volume; low magnetostriction reduces magnetically induced acoustic noise (hum) in transformers and large electrical machines [10,11].

## II. MATERIAL AND METHODOLOGY OF EXPERIMENT

The experiments were conducted in the Mechanical Properties Testing Laboratory at the Institute of Technology and Materials Engineering. The test material was non-oriented (isotropic) electrical steel with a thickness of 0.50 mm. Table 1 summarizes the material properties of the steel used.

Mechanical property tests were performed in accordance with STN EN ISO 6892-1:2019 (room-temperature tensile testing), STN EN ISO 10113:2020 (determination of the plastic strain ratio, r-value, in sheet and strip), and STN EN ISO 10275:2020 (determination of the strain-hardening exponent in tension). Testing was carried out on a TIRAtest 2300 universal testing machine equipped with a force transducer, a longitudinal extensometer, and a width-measurement sensor for r-value assessment. Test pieces for tensile testing were prepared in accordance with STN EN ISO 6892-1:2019.

Table 1Average mechanical properties of the electrical steel under study (t = 0.50 mm)

| **Direction [˚]** | **$R_{p0.2}$ [MPa]** | **$R_m$ [MPa]** | **$A_{80}$ [%]** | **r** | **$r_m$** | **Δr** | **n** | **$n_m$** | **Δn** |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 366 | 492 | 24.1 | 0.741 | 1.067 | -0.386 | 0.186 | 0.179 | 0.002 |

The experimental investigation of the influence of punch coatings and punch–die clearance on the blanking force was carried out on a VEB ZD-40 hydraulic testing press equipped with a load-cell-based digital controller that recorded the force–stroke signal in real time. The press operated in single-stroke mode, and clearances were set to 1% and 7% of the sheet thickness (t). Force–stroke histories captured by the controller were exported to a PC and post-processed in Microsoft Excel. All tests were performed under laboratory ambient conditions.Figure 1 shows the shearing tool (punch and die set) used in the experiments.

Figure 1 Experimental punch–die set

The experimental blank is ring-shaped (washer-type) with an inner diameter (ID) of 15 mm and an outer diameter (OD) of 25 mm.

Experiment parameters:

- Tool stroke: 5.48 mm (to complete the cut after the blank-holder has seated),
- Springs used: blue; rated force F = 1.6 kN; quantity 4

In the experiment, three coating variants applied to the punches were compared:

- C1: AlCrN-based coating
- C2: combined coating ($MoS_2$ + AlCrN)
- C3: $MoS_2$-based coating

During the experiments, two blanking forces were recorded:

- for the smaller-diameter punch (D = 15 mm), the measured force was denoted F15,
- for the larger-diameter punch (D = 25 mm), the measured force was denoted F25.

## III. RESULTS AND DISCUSSION

To experimentally assess the effect of punch–die clearance on blanking force, uncoated punches were first used at relative clearances of 1% and 7% of the sheet thickness. The recorded blanking-force values are presented in Table 2, and the corresponding plot is shown in Figure 2.

Table 2 Blanking force with uncoated punches at punch–die clearances of 1% and 7%

| Coating | Thickness [mm] | Clearance [%] | F15 [kN] | F25 [kN] |
|---|---|---|---|---|
| - | 0.50 | 1 | 10.91 | 15.05 |
| - | 0.50 | 7 | 6.85 | 14.37 |

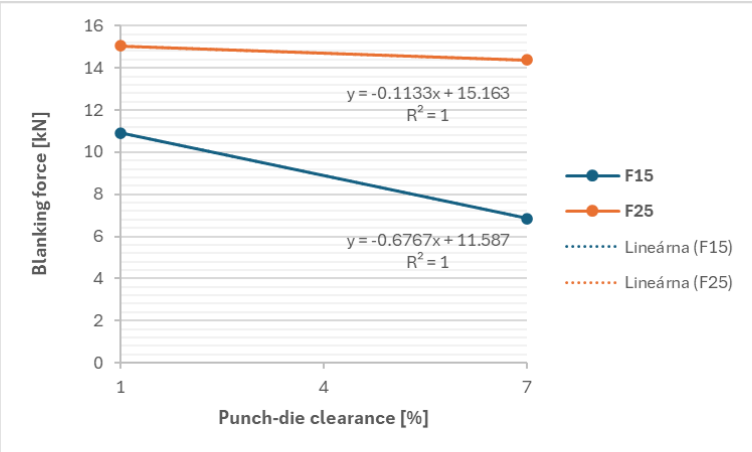


Figure 2 Blanking force with uncoated punches at punch–die clearances of 1% and 7%

At a 1% punch–die clearance for material (t = 0.50 mm), the blanking force on the Ø15 mm punch was 10.91 kN, and on the Ø25 mm punch it was 15.05 kN.At a 7% punch–die clearance for material (t = 0.50 mm), the blanking force on the Ø15 mm punch was 6.85 kN, and on the Ø25 mm punch it was 14.37kN.

The effect of the individual coatings (C1, C2, C3) on the blanking force at a punch–die clearance of 1% is presented in Table 3. The graphical representation of the measured blanking-force values is shown in Figure 3.

Table 3 Blanking-force values at a 1% punch–die clearance using coated punches

| Coating | Thickness [mm] | Clearance [%] | F15 [kN] | F25 [kN] |
|---|---|---|---|---|
| **C1 (1)** | 0.50 | 1 | 8.31 | 14.27 |
| **C2 (2)** | 0.50 | 1 | 7.76 | 13.12 |
| **C3 (3)** | 0.50 | 1 | 7.60 | 12.99 |

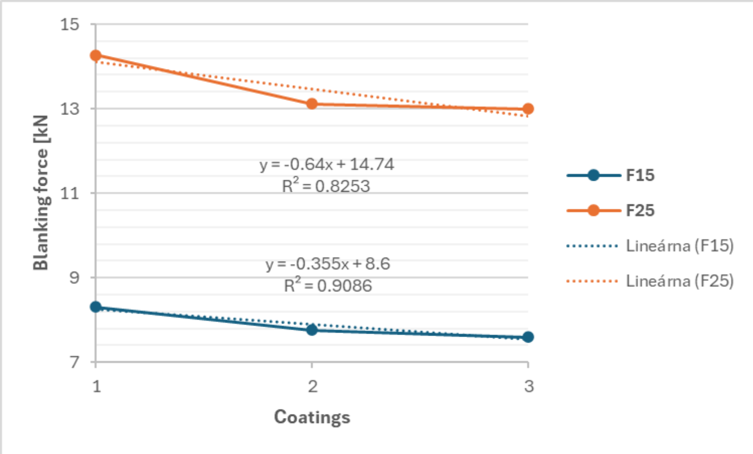


Figure 3 Blanking-force values at a 1% punch–die clearance using coated punches

The effect of the individual coatings (C1, C2, C3) on the blanking force at a punch–die clearance of 7% is presented in Table 4. The graphical representation of the measured blanking-force values is shown in Figure 4.

Table 4 Blanking-force values at a 7% punch–die clearance using coated punches

| Coating | Thickness [mm] | Clearance [%] | F15 [kN] | F25 [kN] |
|---|---|---|---|---|
| **C1 (1)** | 0.50 | 1 | 8.01 | 12.76 |
| **C2 (2)** | 0.50 | 1 | 7.65 | 13.03 |
| **C3 (3)** | 0.50 | 1 | 7.46 | 12.65 |

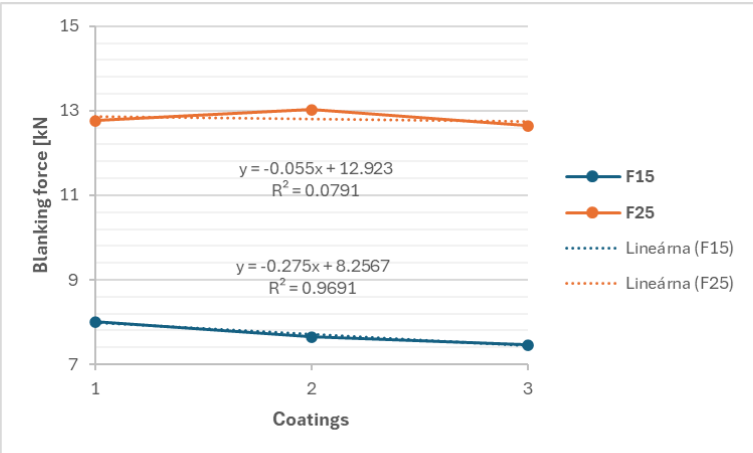


Figure 4 Blanking-force values at a 7% punch–die clearance using coated punches

The results indicate that increasing the punch–die clearance lowers the blanking force. Mechanistically, a larger clearance promotes earlier crack initiation and faster propagation along the shear plane during the stroke, reducing the load-bearing ligament and thus the peak force.

From the blanking-force results in Tables 3 and 4, the C3 coating shows the greatest reduction in blanking force. It can also be concluded that, at both punch–die clearances investigated, the coated punches produced lower blanking forces than the uncoated punches. The effect of the coatings was slightly greater at a 1% punch–die clearance than for blanks sheared with a 7% clearance.

## IV. CONCLUSION

To assess the effects of punch–die clearance and punch coating on blanking force, three coating types (C1, C2, C3) were evaluated at relative clearances of 1% and 7% of the sheet thickness. The highest blanking forces were recorded with uncoated punches. Among the coated variants, C2 yielded the highest measured forces at both 1% and 7% clearance, followed by the combined C1 + C2 coating, while C1 produced the lowest forces. Across the investigated clearances and sheet materials, coatings reduced the blanking force, indicating a potential increase in shearing tool service life.

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