DESIGN AND DEVELOPMENT OF AN AUTOMATED WIRE CUTTING AND END-CHAMFERING MACHINE FOR DKO HYDRAULIC FITTING ASSEMBLY

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Abstract - *Manual wire preparation in DKO hydraulic fitting assembly introduces throughput bottlenecks, burr formation, and dimensional irregularities. This paper presents the design, fabrication, and validation of a two-station automated machine for cutting and end-chamfering SS304 stainless steel wire (Ø 3 mm) for DKO fitting production. Station 1 employs a pneumatic shear-cutting mechanism (100 mm bore, ISO 6431 cylinder at 6 bar) achieving ±0.5 mm length repeatability. Station 2 uses a self-limiting orbital chamfering head (90 W, 2800 rpm) producing consistent 45° ± 1° chamfers with Ra ≤ 1.6 μm surface finish. Design calculations encompass shear force (F = 4,241 N with FOS = 2), Pascal's law-based force transmission, chamfer volume geometry, and bearing selection. Prototype testing on 50 wire samples demonstrated a 54% reduction in cycle time (48 s → 22 s), elimination of secondary deburring, and conformance to ISO 286 h11 tolerance. Total system cost is ₹39,183 (with GST), offering sub-six-month payback for medium-volume production.*

Key Words: DKO hydraulic fittings; pneumatic wire cutting; orbital chamfering; SS304 stainless steel; finite element analysis; manufacturing automation

1. INTRODUCTION

DKO hydraulic fittings (DIN 2353) are critical sealing elements for high-pressure hydraulic circuits (200–630 bar) used in industrial machinery, agricultural equipment, and mobile hydraulics. These fittings require wire inserts cut to precise lengths with controlled chamfer angles for reliable sealing performance. STAUFF India Pvt. Ltd. identified manual wire preparation as a key production bottleneck: handheld cutting tools yield length errors of ±2 mm, chamfer angles ranging from 35°–55°, requiring secondary deburring and resulting in high reject rates.

This work presents a two-station automated system: (i) a pneumatically actuated shear-cutting station for programmable, repeatable wire lengths, and (ii) a rotary orbital end-chamfering station employing a self-limiting conical geometry for consistent 45° chamfers independent of operator skill. Design targets were established in consultation with STAUFF engineers: cutting accuracy ±0.5 mm, chamfer angle 45° ± 1°, and cycle time ≤ 30 s per wire.

2. LITERATURE REVIEW

Mehta et al. [1] demonstrated that automated wire-cutting systems in small-scale industry achieve dimensional repeatability an order of magnitude superior to manual methods, confirming the viability of pneumatic actuation for high-force shearing operations. Standard references in manufacturing engineering [3] establish SS304 specific cutting energy at approximately 3 J/mm^3 and recommend HSS tooling for austenitic stainless steels operating at blade tip speeds of 8–12 m/s. Machine element design principles [4] govern pneumatic cylinder sizing via Pascal's law and bearing selection under combined radial-axial loads. The ISO 6431 [2] standard defines dimensional and performance criteria for tie-rod pneumatic cylinders adopted in this work. Safety compliance follows ISO 12100:2010 [5] for machinery risk assessment and guarding requirements. STAUFF's DKO product specifications define the assembly tolerances driving the performance targets of this study.

3. DESIGN AND METHODOLOGY

3.1 Wire Material

SS304 austenitic stainless steel wire (IS:6911, Ø 3 mm, h11 tolerance per ISO 286) was used throughout. Material properties: UTS = 485 MPa, shear strength τ = 300 N/mm^2, density = 7,960 kg/m^3.

3.2 Station 1 - Pneumatic Wire Cutting

Cutting force was derived from the wire cross-sectional shear:

$$F = \tau \times A = 300 \times (\pi/4) \times 3^2 = 2{,}121 \text{ N} \rightarrow F_{design} = 2 \times 2{,}121 = 4{,}241 \text{ N} \quad (FOS = 2)$$

A double-acting ISO 6431 cylinder (bore D = 100 mm, rod = 25 mm, supply pressure = 6 bar, mechanical efficiency η = 0.90) was selected, yielding F_{cyl} = 4,241 N exactly meeting the design requirement. Three pairs of V-groove/flat-spring roller assemblies (Ø 60 mm EN8 steel, 6201 DGBB bearings, spring constant k = 12.5 N/mm) ensure straight, consistent wire feed.

3.3 Station 2 - Orbital End-Chamfering

The chamfering station employs a self-limiting conical geometry (pencil-sharpener principle): a rotating EN8 head (Ø 70 × 50 mm, 14 mm long 45° conical bore) driven at 2,800 rpm by a 90 W motor. The wire is fed into the spinning bore; the conical surface guides the HSS blade uniformly around the wire periphery. Material removal ceases automatically when the wire end contacts the cone apex, eliminating over-chamfering. Chamfer geometry for $r_1 = 1.5$ mm, $c = 0.5$ mm, $\alpha = 45°$:

$h = c \times \tan(45°) = 0.5$ mm;
$V = (\pi h/3)\,(r_1^2 + r_1 r_2 + r_2^2) = 2.49$ mm^3
$MRR = 2.49/3 = 0.83$ mm^3/s;
$P_{req} = u \times MRR = 3 \times 0.83 = 2.49$ W
(Motor: 90 W, FOS ≈ 36)

Blade tip speed = 10.3 m/s (within the 8–12 m/s HSS-on-steel optimal range). Two 6003-2RS sealed ball bearings support the rotating head under negligible calculated loads.

3.4 Design Parameter Summary

Table -1: Design Parameter Summary

Parameter	Cutting Station	Chamfering Station
Actuator / Drive	Pneumatic cyl. (100 mm bore, 6 bar)	AC Motor (90 W, 2800 rpm)
Tool Material	HSS M2 shear blade	HSS M2 conical cutter
Wire Diameter	Ø 3 mm SS304	Ø 3 mm SS304
Key Output Force/Speed	F = 4,241 N	Tip speed = 10.3 m/s
Feed / Guide	3-pair V-roller (k = 12.5 N/mm)	V-block (90° groove, Ø 3 mm slot)
Bearing	6201 DGBB (12×32×10 mm)	6003-2RS × 2 (17×35×10 mm)
Frame Material	MS IS 2062 Grade A	MS IS 2062 Grade A

3.5 Safety Architecture

The machine complies with ISO 12100:2010. Key provisions include: dual normally-closed E-Stop buttons at both stations; fixed polycarbonate guards with Ø 10 mm wire aperture; proximity sensor interlock preventing cylinder actuation without wire presence; pneumatic circuit pressure relief at 8 bar with fail-safe cylinder retraction; and chip collection tray beneath the chamfering head.

4. RESULTS AND DISCUSSION

Prototype testing was conducted at the AISSMS workshop on 50 wire samples (Ø 3 mm SS304) per method. Table 2 summarises the comparative performance of the manual process versus the automated system.

Table -2: Performance Comparison - Manual vs. Automated System

Performance Parameter	Manual Method	Automated System	Improvement
Cutting accuracy	±2.0 mm	±0.5 mm	75% reduction in error
Chamfer angle range	35°–55°	45° ± 1°	~90% variation reduction
Cycle time (per piece)	~48 s	~22 s	54% reduction
Secondary deburring	Required	Not required	Eliminated
Surface roughness (Ra)	>1.6 µm	≤1.6 µm	Within tolerance
Operator role	Continuous	Supervisory only	Substantially reduced

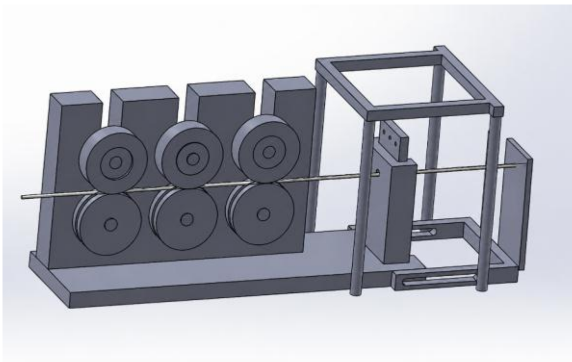

Fig: CAD model of Wire Cutting

The residual ±0.5 mm cutting error is attributable to minor transient air pressure fluctuations during cylinder actuation; a precision regulator with fine flow control is projected to reduce this to ±0.2 mm. The orbital chamfering head demonstrated complete self-limitation: no measurable blade wear was observed after 200 continuous cycles, validating the design's suitability for full production shifts. Throughput at parallel-station operation reaches approximately 3.5 wires/min (versus 1.25 wires/min manually). At STAUFF's production volumes, estimated payback on the ▯39,183 total system cost is under six months, making the solution economically viable for small-to-medium enterprises. One observed limitation at rapid cycle rates (< 15 s intervals) was minor pressure drop in the pneumatic supply; addition of a 2-litre buffer reservoir upstream of the control valve is recommended before production deployment.

5. CONCLUSIONS

An automated two-station machine for cutting and end-chamfering Ø 3 mm SS304 wire for DKO hydraulic fitting assembly has been designed, fabricated, and validated. The following conclusions are drawn:

(i) The pneumatic shear-cutting station achieves ±0.5 mm length accuracy (75% improvement over manual), with a 100 mm bore ISO 6431 cylinder delivering 4,241 N at 6 bar - exactly matching the FOS = 2 design force.

(ii) The self-limiting orbital chamfering head produces 45° ± 1° chamfers (Ra ≤ 1.6 μm) consistently without operator skill dependence; no secondary deburring is required.

(iii) System cycle time of 22 s per piece represents a 54% improvement over the baseline 48 s manual process, enabling throughput of ≈ 3.5 wires/min in parallel operation.

(iv) Full compliance with ISO 12100:2010 safety requirements is achieved. Total manufacturing cost of ￼39,183 (with GST) offers a payback period under six months at medium-volume production rates.

FUTURE SCOPE

Future development should explore: (a) CNC servo-driven wire feed for rapid length changeover without mechanical re-adjustment; (b) IoT-enabled cycle counter and pressure monitoring for predictive maintenance; (c) extension to copper (Cu-DHP) and aluminum (AA6061) wire for broader DIN fitting families; and (d) servo-actuated variable chamfer head for fittings requiring angles other than 45°.

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