Claims

1. Devolatilisation apparatus comprising at least one extruder which has:

- a barrel and n barrel holes B_n having the associated hole diameters D_n where n is an integer, preferably an integer from 1 to 16, particularly preferably from 1 to 12, very particularly preferably from 2 to 8 and even more preferably 2, and the barrel holes in the case of n being greater than 1 preferably pass through opposite one another and are likewise preferably arranged parallel to one another,
- one or more screws W_n which can be driven so as to rotate and are in each case arranged concentrically in one of the barrel holes B_n, have an axis of rotation A_n and are equipped with treatment elements whose cross-sectional profile in the circumferential direction has
  - m relative maxima $R^m_{max\ n}$ in respect of the radial dimension of the cross-sectional profile to the axis of rotation A_n of the screw W_n, where m is an integer from 1 to 8, preferably from 1 to 4, particularly preferably 1, 2 or 3, very particularly preferably 1 or 2 and even more preferably 2,
  - a maximum value $R_{max\ n}$ in respect of the radial dimension of the cross-sectional profile to the axis of rotation A_n of the screw W_n, where $R_{max\ n}$ fulfils:

    $R_{max\ n} <= (D_n/2)$

- at least one feed zone,
- one or more devolatilisation zones comprising in each case at least one devolatilisation opening which is suitable for discharge of volatile constituents from a polymer-containing medium from the extruder,
- at least one discharge zone,

where the extruder has screw elements SE having a pitch t as treatment elements, which are configured so that at least two of the following three conditions are met:

S1) the cross-sectional profile has at least one relative maximum $R^m_{max\ n}$ based on the radial dimension of the profile curve, for which:

$0.420\ D_n < R^m_{max\ n} < 0.490\ D_n$, preferably $0.430\ D_n >= R^m_{max\ n} < 0.485\ D_n$, particularly preferably $0.440\ D_n < R^m_{max\ n} < 0.482\ D_n$ and particularly preferably $0.450\ D_n < R^m_{max\ n} < 0.480\ D_n$,

S2) $1.38\ D_n < t < 5.00\ D_n$, preferably $1.60\ D_n < t < 3.00\ D_n$, particularly preferably $1.80\ D_n < t < 2.50\ D_n$ and very particularly preferably $1.90\ D_n < t < 2.40\ D_n$,

S3) the cross-sectional profile of the respective screw element has no tangential angle β greater than 30°, preferably greater than 25°, particularly preferably 22°, very particularly preferably 15° and very particularly preferably 10°, on the active flanks located at the front in the direction of rotation in the range of the radial dimension from 0.95 R_{max} to R_{max}, preferably from 0.90 R_{max} to R_{max}, particularly preferably from 0.80 R_{max} to R_{max}, very particularly preferably from 0.50 R_{max} to R_{max} and even more preferably in the entire range from 0 to R_{max}, where the tangential angle β is defined as

- the smaller of the two angles formed on drawing the tangents at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile cannot be continually differentiated
- and is 0° at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile can always be differentiated.

2. Devolatilisation apparatus according to Claim 1, characterized in that the screw elements SE have a modular construction and consist of a core shaft and screw elements which have an accommodation opening for the core shafts or are configured as screws having a solid construction or as screws consisting of individual subsegments and produced in solid construction.

3. Devolatilisation apparatus according to Claim 1 or 2, characterized in that the extruder has a barrel and n = 1 to 16, particularly preferably n = 1 to 12, very particularly preferably n = 2 to 8 and even more preferably n = 2, barrel holes B_n.

4. Devolatilisation apparatus according to any of Claims 1 to 3, characterized in that when n is greater than 1, the barrel holes B_n pass through and are preferably arranged parallel to one another.

5. Devolatilisation apparatus according to any of Claims 1 to 4, characterized in that single-screw and multiscrew extruders, in particular twin-screw extruders or ring extruders, are used as extruders.

6. Devolatilisation apparatus according to any of Claims 1 to 5, characterized in that the extruder of the devolatilisation apparatus has at least one dispersing zone.

7. Devolatilisation apparatus according to any of Claims 1 to 5, characterized in that the screw elements SE satisfy the features S1) and S2) or S2) and S3) or S1) and S3) or all three features S1), S2) and S3).

8. Devolatilisation apparatus according to any of Claims 1 to 7, characterized in that the last devolatilisation zone of the extruder in the transport direction of the extruder (14), preferably all devolatilisation zones, is/are equipped with screw elements SE.

9. Devolatilisation apparatus according to any of Claims 1 to 8, characterized in that the number of devolatilisation zones is from 1 to 20, preferably from 1 to 10 and particularly preferably from 2 to 8.

10. Devolatilisation apparatus according to any of Claims 1 to 9, characterized in that at least one devolatilisation zone is located upstream of the feed zone (4) of the extruder (14).

11. Devolatilisation apparatus according to any of Claims 1 to 10, characterized in that the devolatilisation openings (16) and the devolatilisation domes (17) are configured so that they effectively prevent or reduce exit of polymer-containing medium and in particular have single-screw or multiscrew, in particular twin-screw, stopping screws which are mounted at the devolatilisation openings and are operated so as to convey into the extruder or have rollers or belts which are arranged on the inside of the devolatilisation openings in order to push polymer-containing medium or product back into the extruder.

12. Devolatilisation apparatus according to any of Claims 1 to 11, characterized in that coatings which reduce or prevent adhesion of the material to the surface are used at the devolatilisation openings (15).

13. Devolatilisation apparatus according to any of Claims 1 to 12, characterized in that the extruder has at least one dispersing zone.

14. Devolatilisation apparatus according to any of Claims 1 to 13, characterized in that at least some depressurisation elements, in particular rotating or fixed perforated plates, are located upstream of the devolatilisation zones of the extruder.

15. Devolatilisation apparatus according to Claim 14, characterized in that the perforated plates are made up of a plurality of parts, preferably two parts, so that they can be taken from the barrel (21) without removal of the screws.

16. Devolatilisation apparatus according to any of Claims 1 to 15, characterized in that the extruder comprises one or more feed openings for the introduction of additives.

17. Devolatilisation apparatus according to any of Claims 1 to 16, characterized in that the screw elements SE have a cross-sectional profile which can be represented completely by a profile curve which can be continually differentiated.

18. Devolatilisation apparatus according to Claim 17, characterized in that the screw elements SE are two-flighted or three-flighted.

19. Devolatilisation apparatus according to Claims 17 or 18, characterized in that the screw elements SE are characterized in that

- the generating screw profile and the screw profile generated lie in one plane,
- the axis of rotation of the generating screw profile and the axis of rotation of the screw profile generated are at a spacing a (axial spacing) in each case perpendicularly on said plane of the screw profiles, where the intersection of the axis of rotation of the generating screw profile with said plane is referred to as point of rotation of the generating screw profile and the intersection of the axis of rotation of the screw profile generated with said plane is referred to as point of rotation of the screw profile generated,
- the number of circular arcs of the total generating screw profile n is greater than or equal to four ($n > 4$),
- the outer radius ra of the generating screw profile is greater than zero ($ra>0$) and less than the axial spacing ($ra<a$),
- the core radius ri of the generating screw profile is greater than zero ($ri>0$) and less than or equal to ra ($ri \leq ra$),
- all circular arcs of the generating screw profile go into one another tangentially,
- the circular arcs form a closed screw profile, i.e. the sum of the angles a_j of all circular arcs j is equal to 2p; where p is the number pi,
- the circular arcs form a convex screw profile,

- each of the circular arcs of the generating screw profile is within or on the boundaries of an annulus which has the outer radius ra and the core radius ri and whose midpoint is on the point of rotation of the generating screw profile,

- at least one of the circular arcs of the generating screw profile contacts the outer radius ra of the generating screw profile at a point P_A,

- at least one of the circular arcs of the generating screw profile contacts the core radius ri of the generating screw profile at a point P_I and the number of circular arcs n' of the screw profile generated is equal to the number of circular arcs n of the generating screw profile,

- the outer radius ra' of the screw profile generated is equal to the difference between the axial spacing and core radius ri of the generating screw profile (ra' = a-ri),

- the core radius ri' of the screw profile generated is equal to the difference between the axial spacing and outer radius ra of the generating screw profile (ri' = a-ra),

- the angle a_j' of the j'-th circular arc of the screw profile generated is equal to the angle a_j of the j-th circular arc of the generating screw profile, where j and j' are integers which together go through all values in the range from 1 to the number of circular arcs n or n',

- the sum of the radius r of the j'-th circular arc of the screw profile generated and the radius j of the j-th circular arc of the generating screw profile is equal to the axial spacing a, where j and j' are integers which together run through all values in the range from 1 to the number of circular arcs n or n',

- the midpoint of the j'-th circular arc of the screw profile generated is at a spacing from the midpoint of the j-th circular arc of the generating screw profile which is equal to the axial spacing a and the midpoint of the j'-th circular arc of the screw profile generated is at a spacing from the point of rotation of the screw profile generated which is equal to the spacing of the midpoint of the j-th circular arc of the generating screw profile from the point of rotation of the generating screw profile and the connecting line between the midpoint of the j'-th circular arc of the screw profile generated and the midpoint of the j-th circular arc of the generating screw profile is parallel to a connecting line between the point of rotation of the screw profile generated and the point of rotation of the generating screw profile, where j and j' are integers which together run through all values in the range from 1 to the number of circular arcs n or n',

- a starting point of the j'-th circular arc of the screw profile generated is in a direction based on the midpoint of the j'-th circular arc of the screw profile generated which is opposite to the direction which has a starting point of the j-th circular arc of the generating screw profile based on the midpoint of the j-th circular arc of the generating screw profile, where j and j' are integers which together run through all values in the range from 1 to the number of circular arcs n or n'.

20. Devolatilisation apparatus according to Claims 17, 18 or 19, characterized in that the screw elements SE are unsymmetrical or symmetrical.

21. Devolatilisation apparatus according to any of Claims 1 to 16, characterized in that the screw elements SE, whose cross-sectional profiles will be referred to as outer contour below, have

- a longitudinal axis M*,
- a core radius Rj and an outer radius R_a which each have the longitudinal axis M* as midpoint,
- an outer contour A(φ) running around the longitudinal axis M*, where φ is the angle around the longitudinal axis M* and
- $R_i < D_A((p) < R_a$ for a spacing $D_A((p)$ of the outer contour A(φ) from the longitudinal axis M,

and are further characterized in that

- the outer contour A(φ) has at least one outer contour section A(Δφ) which runs along an angular section Δφ and has a continually changing spacing $D_A(\Delta\varphi)$ from the longitudinal axis M*, where $Rj < D_A(\Delta\varphi) < R_a$, and
- has an associated evolute E,
- which is a number of n points P(i) where i = 1 to n and $n \geq 3$,
- where each of the points P(i) is located outside the longitudinal axis M* and within the outer radius R_a, and

each two adjacent points P(i) and P(i+1) have a spacing Δr(i) from one another which is less than $R_i/2$.

22. Devolatilisation apparatus according to any of Claims 1 to 21, characterized in that the screw elements SE are made of steels, in particular nitriding steels, chromium steels, tool steels and stainless steels or powder-metallurgically produced metallic composites based on iron, nickel or cobalt.

23. Devolatilisation apparatus according to any of Claims 1 to 22, characterized in that a preextruder (2) or a prekneader which are each configured as devolatilisation extruder or devolatilisation kneader are located upstream of the extruder (3).

24. Devolatilisation apparatus according to Claim 23, characterized in that the transfer zone (12) connecting the devolatilising preextruder or devolatilising prekneader and the extruder (3) has at least one, preferably precisely one, depressurisation element, such as, in particular, perforated plates.

25. Devolatilisation apparatus according to Claim 23 or 24, characterized in that at least one pressure regulating unit such as an orifice plate is present in the transfer zone (12).

26. Devolatilisation apparatus according to any of Claims 1 to 25, characterized in that one or more further concentrator units are located upstream.

27. Process for removing volatile compounds from a polymer-containing medium (PM) which contains at least one polymer and at least one volatile compound, which process comprises at least the following steps:

a) provision of a devolatilisation apparatus according to any of Claims 1 to 27,

b) introduction of the polymer-containing medium (PM) into the devolatilisation apparatus which is operated so that volatile compounds are given off from the polymer-containing medium (PM) through the devolatilisation openings of the devolatilisation unit and the polymer-containing medium (PM) is in this way depleted in volatile compounds and the polymer is isolated as product P from the polymer-containing medium on discharge from the devolatilisation apparatus and the product P then has a lower proportion of volatile compounds than the polymer-containing medium (PM) introduced into the devolatilisation apparatus and preferably has a total concentration of volatile compounds of less than 1% by weight, preferably less than 0.5% by weight, based on the mass of the polymer.

28. Process according to Claim 27, characterized in that the polymer-containing medium contains natural or synthetic polymers.

29. Process according to Claim 27 or 28, characterized in that the polymer-containing medium contains thermoplastic polymers such as polycarbonates, polyamides, polyesters, in particular polybutylene terephthalate and polyethylene terephthalate, polylactides, polyethers, thermoplastic polyurethanes, polyacetals, fluoro polymers, in particular polyvinylidene fluoride, polyether sulphones, polyolefins, in particular polyethylene and polypropylene, polyimides, polyacrylates, in particular poly(methyl) methacrylate, polyphenylene oxide, polyphenylene sulphide, polyether ketone, polyaryl ether ketone, styrene polymers, in particular polystyrene, styrene copolymers, in particular styrene-acrylonitrile copolymer, acrylonitrile-butadiene-styrene block copolymers, and polyvinyl chloride and also elastomers such as rubbers from the group consisting of styrene-butadiene rubbers, natural rubbers, butadiene rubbers, isoprene rubbers, ethylene-propylene-diene rubbers such as ethylene-propylene-diene (M class) rubbers (EPDM), ethylene-propylene rubbers, butadiene-acrylonitrile rubbers, hydrogenated nitrile rubbers, butyl rubbers, halobutyl rubbers, chloroprene rubbers, ethylene-vinyl acetate rubbers, polyurethane rubbers, guttapercha, fluoro rubbers, silicone rubbers, sulphide rubbers, chlorosulphonyl-polyethylene rubbers and also any mixtures of the abovementioned thermoplastic polymers and elastomers.

30. Process according to any of Claims 27 to 29, characterized in that the polymer-containing medium contains butyl rubber and/or halogenated butyl rubbers.

31. Process according to any of Claims 27 to 30, characterized in that the polymer-containing medium is in the form of suspensions, pastes, melts, solutions, particulate solid compositions or mixed forms of the abovementioned forms.

32. Process according to any of Claims 27 to 31, characterized in that the polymer-containing medium contains from 3 to 98% by weight of a polymer and from 2 to 97% by weight of volatile compounds, in particular an organic solvent or an organic solvent and water, where the abovementioned components make up up to 90-100% by weight, preferably from 95 to 100% by weight, of the total mass of the polymer-containing medium.

33. Process according to any of Claims 27 to 32, characterized in that the pressure in the devolatilisation openings (16) and devolatilisation domes (17) is in the range from 1 hPa to 2000 hPa.

34. Process according to any of Claims 27 to 33, characterized in that stripping agents are introduced into the extruder of the devolatilisation apparatus or the preextruder or prekneader.

35. Use of screw elements having a pitch t which are configured so that at least two of the three following conditions are satisfied:

S1) the cross-sectional profile has at least one relative maximum $R^m_{max\ n}$ based on the radial dimension of the profile curve, for which:

$0.420\ D_n < R^m_{max\ n} < 0.490\ D_n$, preferably $0.430\ D_n >= R^m_{max\ n} < 0.485\ D_n$, particularly preferably $0.440\ D_n < R^m_{max\ n} < 0.482\ D_n$ and particularly preferably $0.450\ D_n < R^m_{max\ n} < 0.480\ D_n$,

S2) $1.38\ D_n < t < 5.00\ D_n$, preferably $1.60\ D_n < t < 3.00\ D_n$, particularly preferably $1.80\ D_n < t < 2.50\ D_n$ and very particularly preferably $1.90\ D_n < t < 2.40\ D_n$,

S3) the cross-sectional profile of the respective screw element has no tangential angle β greater than 30°, preferably greater than 25°, particularly preferably 22°, very particularly preferably 15° and very particularly preferably 10°, on the active flanks located at the front in the direction of rotation in the range of the radial dimension from 0.95 R_{max} to R_{max}, preferably from 0.90 R_{max} to R_{max}, particularly preferably from 0.80 R_{max} to R_{max}, very particularly preferably from 0.50 R_{max} to R_{max} and even more preferably in the entire range from 0 to R_{max}, where the tangential angle β is defined as

- the smaller of the two angles formed on drawing the tangents at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile cannot be continually differentiated
- and is 0° at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile can always be differentiated,

in an extruder.

CLAIMS

1. Devolatilisation apparatus comprising at least one extruder which has:

- a barrel and n barrel holes B_n having the associated hole diameters D_n where n is an integer, and the barrel holes in the case of n being greater than 1 pass through opposite one another and are likewise arranged parallel to one another,

- one or more screws W_n which can be driven so as to rotate and are in each case arranged concentrically in one of the barrel holes B_n, have an axis of rotation A_n and are equipped with treatment elements whose cross-sectional profile in the circumferential direction has

  - m relative maxima $R^m_{max\ n}$ in respect of the radial dimension of the cross-sectional profile to the axis of rotation A_n of the screw W_n, where m is an integer from 1 to 8,

  - a maximum value $R_{max\ n}$ in respect of the radial dimension of the cross-sectional profile to the axis of rotation A_n of the screw W_n, where $R_{max\ n}$ fulfils:

    $R_{max\ n} <= (D_n/2)$

- at least one feed zone,

- one or more devolatilisation zones comprising in each case at least one devolatilisation opening which is suitable for discharge of volatile constituents from a polymer-containing medium from the extruder,

- at least one discharge zone,

where the extruder has screw elements SE having a pitch t as treatment elements, which are configured so that at least two of the following three conditions are met:

S1) the cross-sectional profile has at least one relative maximum $R^m_{max\ n}$ based on the radial dimension of the profile curve, for which:

$0.430\ D_n >= R^m_{max\ n} < 0.485\ D_n$,

S2) $1.60\ D_n < t < 3.00\ D_n$,

S3) the cross-sectional profile of the respective screw element has no tangential angle β greater than 25° on the active flanks located at the front in the direction of rotation in the range of the radial dimension from $0.90\ R_{max}$ to R_{max}whereby the tangential angle β is defined as

- the smaller of the two angles formed on drawing the tangents at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile cannot be continually differentiated
- and is 0° at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile can always be differentiated.

2. Devolatilisation apparatus according to Claim 1, characterized in that the screw elements SE have a modular construction and consist of a core shaft and screw elements which have an accommodation opening for the core shafts or are configured as screws having a solid construction or as screws consisting of individual subsegments and produced in solid construction.

3. Devolatilisation apparatus according to Claim 1 or 2, characterized in that the extruder has a barrel and n = 1 to 16 barrel holes B_n.

4. Devolatilisation apparatus according to any of Claims 1 to 3, characterized in that when n is greater than 1, the barrel holes B_n pass through and are arranged parallel to one another.

5. Devolatilisation apparatus according to any of Claims 1 to 4, characterized in that single-screw and multiscrew extruders are used as extruders.

6. Devolatilisation apparatus according to any of Claims 1 to 5, characterized in that the extruder of the devolatilisation apparatus has at least one dispersing zone.

7. Devolatilisation apparatus according to any of Claims 1 to 5, characterized in that the screw elements SE satisfy the features S1) and S2) or S2) and S3) or S1) and S3) or all three features S1), S2) and S3).

8. Devolatilisation apparatus according to any of Claims 1 to 7, characterized in that the last devolatilisation zone of the extruder in the transport direction of the extruder (14), is equipped with screw elements SE.

9. Devolatilisation apparatus according to any of Claims 1 to 8, characterized in that the number of devolatilisation zones is from 1 to 20.

10. Devolatilisation apparatus according to any of Claims 1 to 9, characterized in that at least one devolatilisation zone is located upstream of the feed zone (4) of the extruder (14).

11. Devolatilisation apparatus according to any of Claims 1 to 10, characterized in that the devolatilisation openings (16) and the devolatilisation domes (17) are configured so that they effectively prevent or reduce exit of polymer-containing medium and in particular have single-screw or multiscrew stopping screws which are mounted at the devolatilisation openings and are operated so as to convey into the extruder or have rollers or belts which are arranged on the inside of the devolatilisation openings in order to push polymer-containing medium or product back into the extruder.

12. Devolatilisation apparatus according to any of Claims 1 to 11, characterized in that coatings which reduce or prevent adhesion of the material to the surface are used at the devolatilisation openings (15).

13. Devolatilisation apparatus according to any of Claims 1 to 12, characterized in that the extruder has at least one dispersing zone.

14. Devolatilisation apparatus according to any of Claims 1 to 13, characterized in that at least some depressurisation elements are located upstream of the devolatilisation zones of the extruder.

15. Devolatilisation apparatus according to Claim 14, characterized in that the perforated plates are made up of a plurality of parts, preferably two parts, so that they can be taken from the barrel (21) without removal of the screws.

16. Devolatilisation apparatus according to any of Claims 1 to 15, characterized in that the extruder comprises one or more feed openings for the introduction of additives.

17. Devolatilisation apparatus according to any of Claims 1 to 16, characterized in that the screw elements SE have a cross-sectional profile which can be represented completely by a profile curve which can be continually differentiated.

18. Devolatilisation apparatus according to Claim 17, characterized in that the screw elements SE are two-flighted or three-flighted.

19. Devolatilisation apparatus according to Claims 17 or 18, characterized in that the screw elements SE are unsymmetrical or symmetrical.

20. Devolatilisation apparatus according to any of Claims 1 to 19, characterized in that the screw elements SE are made of steels or powder-metallurgically produced metallic composites based on iron, nickel or cobalt.

21. Devolatilisation apparatus according to any of Claims 1 to 20, characterized in that a preextruder (2) or a prekneader which are each configured as devolatilisation extruder or devolatilisation kneader are located upstream of the extruder (3).

22. Devolatilisation apparatus according to Claim 21, characterized in that the transfer zone (12) connecting the devolatilising preextruder or devolatilising prekneader and the extruder (3) has at least one depressurisation element.

23. Devolatilisation apparatus according to Claim 21 or 22, characterized in that at least one pressure regulating unit is present in the transfer zone (12).

24. Devolatilisation apparatus according to any of Claims 1 to 23, characterized in that one or more further concentrator units are located upstream.

25. Process for removing volatile compounds from a polymer-containing medium (PM) which contains at least one polymer and at least one volatile compound, which process comprises at least the following steps:

a) provision of a devolatilisation apparatus according to any of Claims 1 to 24,

b) introduction of the polymer-containing medium (PM) into the devolatilisation apparatus which is operated so that volatile compounds are given off from the polymer-containing medium (PM) through the devolatilisation openings of the devolatilisation unit and the polymer-containing medium (PM) is in this way depleted in volatile compounds and the polymer is isolated as product P from the polymer-containing medium on discharge from the devolatilisation apparatus and the product P then has a lower proportion of volatile compounds than the polymer-containing medium (PM) introduced into the devolatilisation apparatus and has a total concentration of volatile compounds of less than 1% by weight based on the mass of the polymer.

26. Process according to Claim 25, characterized in that the polymer-containing medium contains natural or synthetic polymers.

27. Process according to Claim 25 or 26, characterized in that the polymer-containing medium contains at least one elastomer.

28. Process according to any of Claims 25 to 27, characterized in that the polymer-containing medium contains butyl rubber and/or halogenated butyl rubbers.

29. Process according to any of Claims 25 to 28, characterized in that the polymer-containing medium is in the form of suspensions, pastes, melts, solutions, particulate solid compositions or mixed forms of the abovementioned forms.

30. Process according to any of Claims 25 to 29, characterized in that the polymer-containing medium contains from 3 to 98% by weight of a polymer and from 2 to 97% by weight of volatile compounds where the polymer and the volatile compounds make up up to 90-100% by weight of the total mass of the polymer-containing medium.

31. Process according to any of Claims 25 to 30, characterized in that the pressure in the devolatilisation openings (16) and devolatilisation domes (17) is in the range from 1 hPa to 2000 hPa.

32. Process according to any of Claims 25 to 31, characterized in that stripping agents are introduced into the extruder of the devolatilisation apparatus.

33. Use of screw elements having a pitch t which are configured so that at least two of the three following conditions are satisfied:

S1) the cross-sectional profile has at least one relative maximum $R^m_{max\ n}$ based on the radial dimension of the profile curve, for which:

$0.430\ D_n >= R^m_{max\ n} < 0.485\ D_n$

S2) $1.60\ D_n < t < 3.00\ D_n$

S3) the cross-sectional profile of the respective screw element has no tangential angle β greater than 25° on the active flanks located at the front in the direction of rotation in the range of the radial dimension from $0.90\ R_{max}$ to R_{max} whereby the tangential angle β is defined as

- the smaller of the two angles formed on drawing the tangents at any point on the cross-sectional profile of the treatment element at which the cross-sectional profile cannot be continually differentiated
- and is 0° at any point on the cross-sectional profile of the screw element at which the cross-sectional profile can always be differentiated,

in an extruder.